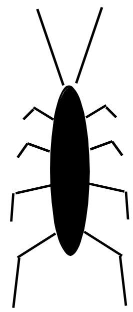

The Cockroach EV
(Electric Vehicle)

Vol. 1—Concept and Politics
- Circa 2014 -

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An Angry Old Novice Living in a Tyranny Advocates for a *Practical* Electric Vehicle Through New Model Production or Conversion of Existing Designs

Public-service commentary for the USA

Caution! Disclaimer
As is, Use at your own risk

Many EV enthusiasts set out to convert a car to electric. There are thousands cataloged on the Internet. They often learn what works as they go. Some make progress and some only bloody their noses. As a beginner, this writer set out to learn what works in the literature and may only then, if then, perhaps attempt a conversion. He hopes to develop a different, more detailed, perspective on the design and operation of electric vehicles than appears present in the common enthusiast literature today. This first book was assembled in a rush (about two years), like many a conversion, because progress delayed is progress denied. Besides, the writer is kinda old and writes in solitude, therefore do not expect scrupulous precision and error detection nor peer consensus. A background in physics and math does not necessarily automatically qualify one to do this kind of analysis.

Nonetheless, this first volume defines a specific concept and its political ramifications. It brings together numerous scattered data on electric vehicles and attempts to supplement it with critical technical and political opinion and speculation some of which does not appear to be addressed elsewhere in the literature (luckily some say there are no stupid questions) but also may therefore prove to be imperfect in part or in whole even to the point of being grievously wrong. A later volume may seek to examine a specific design of the concept. Knowing how fragile some material may be, there is no commercial aspect to this commentary. It is a public service. As a disenchanted conservative Republican whomsoever has no use whatever for the Democrat party (Die! Democrat Party, Die!), this material is offered only as political opinion in fulfillment of his civic responsibility. Conservatives are not necessarily anti-environment, and anti-conservation as Democrats have told you. And we are willing to seek compromises but are usually ignored.

The likelihood that anyone will actually read this manifesto is small, but if any error is identified and validated through further study or in comments from any reader, and if the text is repairable, later drafts or versions may seek to fix such indiscretions and fill in blanks, if within the writer's ability, but at least they can be flagged for readers with humblest apologies.

Therefore, Humblest Apologies

This writer has read many earnest, well-intentioned E-car activists and has met a few and been quite impressed with their dedication. The perspective, the approach, and/or the science and engineering herein is believed appropriate but might seem misguided or even offensive to some of the "old guard" and even to some actual trained scientists and engineers. However, we are in a real crisis and time is too short to spend seeking to verify every thought and speculation herein. Apologies are offered. Hopefully this can make some contribution with any valid collection of data and ideas it contains and won't do much damage with any errors that may also be present.

Justification

This justification for this political commentary is being written September 11, 2011. The tenth anniversary. Yesterday the ceremony for the dedication of the Shanksville Memorial to United Flight 93 was held. Much was said there. Today there will be many more speeches and many more fears of threatened new attacks.

George W. Bush was there to say that Flight 93 would never feel like history and to cite portions of the Gettysburg address that I myself would have cited. "...we can not hallow…"

William Clinton was there to compare the battle on Flight 93 to the battle of Thermopylae 2500 years earlier and to hope that Flight 93 would be remembered similarly 2500 years hence. He would claim singular importance, that while most heroism results from trained soldiers, like those at Thermopylae, this was from everyday people. People that he, himself, often discouraged and even thwarted from heroism, and on occasion, crushed. Of course the ordinary people on Flight 93 had nothing to lose.

Joseph Biden was there to say the passengers of Flight 93 fought the first battle in the soon-to-begin war on terror. That they had drawn the line, this far and no more.

They all went there to honor Flight 93. Honor it with speeches and marble slabs that are really headstones. In part, this book is also to honor Flight 93 and to follow its extraordinary inspiration.

Flight 93 was, indeed, inspirational even to the nonreligious. Even to me. On a day when everyone was getting it wrong (perhaps deliberately in some cases), they got it right. They were extraordinary in many ways some of which are covered in more detail later. But they were lucky, too.

They got it right and are revered because their outcome was good. Would they be as revered if they had been two seconds slower and that plane had impacted a hundred yards further on into the probably occupied school just beyond the crash site or any of a slew of other populated sites. That could have produced massive deaths of innocents on the ground. They would have been equally justified. They would have been equally heroic and the quality of their heroism would have been unsullied. They would have been equally right. But like other heroes, of interest later, they would have had a lot of collateral damage. Even though most revere them, some might criticize them and harshly. They broke a lot of rules. Committed crimes. But sometimes you must. Sometimes you are justified. The founding fathers taught us that same lesson.

They were everyday people who set up an ad hoc democracy to deal with a bad situation. To deal with what most (but by no means all) would consider an imminent peril. And they did deal with it. Boy, did they deal with it! In stark violation of the morality of so many of us, they were our law enforcement on that day. They were vigilantes. Dialing 911, instead of acting, would have been as futile as it so often is. Writing their Congressperson would have been as irrelevant as it apparently is. And the only vote that counted that day was whether to take the plane back. We have no idea how much participation was involved in their vote, how much unanimity was present, nor even how many voted. Most likely it was at least somewhat like the democracy here on the ground and imperfect by far. Given the choice I suspect none of them would have chosen to be there. But they had no choice of that kind. They only had choices of reaction to bullies, and they made a difference.

Flight 93 is a metaphor for the entire United States today. We are trapped here, there is no place better to go, and some of us sense imminent peril. Some bullies are taking us and have taken us and others against our will to places we don't want to go. To mortal places. Like on a metaphoric Flight 93, some of us here are aware of metaphors for the other September 11 Flights 11, 175 and 77. Our democratic republic here on the ground has become seriously flawed. Many of us do not get to participate in choosing our direction or the direction of the country despite our so-called votes. As a result, many of us don't vote and the message in our abstinence is ignored and mocked. Our only choices, our only chances to make a difference, like for those on Flight 93, are of reaction to bullies in both political parties. But like Flight 93, we are justified, even if along the way, we also break rules and laws, make errors like our opponents, and produce collateral damage.

This book is also a reaction to our bullies. That is more than enough justification.

Dedication

For several decades, I have been watching family and friends die, sometimes miserably, almost always unnecessarily and too soon while my government plays cubic money tyrant games under the deceit of protecting us and mockingly calling that their number one duty.

Therefore, this manifesto is dedicated to those two tyrant gangs of thugs: the Democrat and Republican parties. Our very own political Crips and Bloods. I make this dedication in hopes of offending them or their toadies sufficiently to gain some modicum of recognition for this effort. There are of course more graphic ways to propose new ideas or to make a difference. The current President from the worst of these gangs likes to say he is eager for new ideas and to send them along. But as will be covered in a later chapter, it is most likely that as for so many of my past efforts among the efforts of so many others, this humble effort will be *censored, marginalized and excluded*.

Any recognition is more likely to come in the form of excoriation and demonization for its shortcomings and flaws, of which there may be many. Do not hypocritically call upon me to work within the system, as I have done for decades: The System Does Not Work! Nothing new there. Therefore, this realist harbors no delusions as to whether these ideas will do any good here in this nation that can accomplish anything it sets its mind to. Or so some say.

Of course some also say that one man can change the world and should. Some individual men have done this in the past. Heroic men like George Washington, Thomas Jefferson, John Adams, John Brown, Timothy McVeigh, but also the other kind, Osama bin Laden, William Jefferson Clinton, George W. Bush, and Lee Harvey Oswald. I also dedicate this to all of them.

I honestly think that like them, I, too, could make a difference, and this book would be one of the less dramatic ways to try to do that, if the system worked. Like I said, it usually does not. And that is a big damn shame and the reason I expect and predict the worst. And this is but yet another warning in a long line of harbingers.

Contents

Introduction

This is *not* a mystery novel, despite certain mysterious elements in it and important last-minute discovery in Appendix A *[and even later discovery/corrections in Volume 2]*. Therefore, you do not have to read to the very end to find out who done it. This abstract tells you what I am going to tell you. And the rest of the book is a more detailed exposition.

Today, the *ideal* electric vehicle (EV) is being pursued as if it were a Holy Grail and the results so far are obnoxious at the very least. Something is seriously wrong. In the early 1960s, setting a goal of going to the moon in ten years was realistic—we knew how to do it, we just had to actually do it. Pursuit of the *ideal* EV in any time frame may never be possible at all. There are things we don't yet know how to do and some may *not* be possible.

This writing argues and defends an hypothesis that the electric vehicle may never again compete on equal terms with the internal combustion engine (ICE) vehicle. The EV may well be doomed to serve only very narrow niches, but narrow does not necessarily mean small. And it definitely does not mean unworthy. This writing defends one of the most important niches, a grail of a different kind, which is selected retiree transportation, and proposes a "Cockroach" EV as the niche's most worthy servant.

Unlike the cubic-money EVs that industry targets (for their profit potential) and that government foolishly finances and incentivizes (with my money no less), the Cockroach may well be realistic with only modest technological advances and a few clever, if Socialistic, political shadings. The Cockroach is much more like hobby EVs that are usually converted used cars, except that conversion cars typically fall short in range, convenience, reliability, ease of use, and even their cost is excessive. With a little standardization and innovation, new-manufacture Cockroach EVs might be possible that can superbly serve millions who fit this prescribed niche. And yes, some may even achieve the lofty status of a grail.

But as big as the technical obstacles are, the real barrier is politics. For eight years (2001-2008) we had a Republican-led government that couldn't shoot straight, and for the past five years we have had an un-American Democrat-led government that has done what may have seemed impossible — has shown that with its corrupt politics, it can make even those lousy Republicans look relatively good. But not nearly good enough.

Between them they have now entrenched themselves as a bipartisan tyranny in these United States that must not stand. Perhaps, Virginia State says it best: "Thus always to tyrants."

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Background

Acronyms and Initialisms:

AC—alternating current
AN—ammonium nitrate
ANFO—ammonium nitrate/fuel oil
BTU—British Thermal Unit
CATIA—Computer Aided Three Dimensional Interactive Application
C_d—coefficient of drag
c/d—converging/diverging
DC—direct current
E—electric
EV-1—GM 1996 electric vehicle
GNU—GNU's Not Unix
GPL—General Public License
HVAC—heating, ventilation, air conditioning
ICE —internal combustion engine
JDR—John D. Rockefeller
LAB—lead acid battery
LINUX—open source OS software
LiOH-–Lithium hydroxide
Li-ion—Lithium ion
MR-2—Toyota mid-engine car
NAFTA—North America Free Trade Act
NEV—neighborhood electric vehicle

In the early 1900s, Franz Kafka, a German-language writer from Bohemia and an anarchist wrote some really dark and bizarre literature (at least as it was translated to English) that could lead one to conclude Kafka was one really screwed up dude. His efforts led to our adoption of the term *Kafkaesque* to describe anything that defies reason and logic in a bizarre and dark way. One of his short stories was *Metamorphosis* about a character who undergoes an extreme change for the worse. It may have simply been autobiographical about his own change when he contracted tuberculosis back when it was a scourge and before penicillin had been discovered. It killed him young. However, here where we sometimes mistranslate, the main character's transformation was taken, correctly or not, in the quarters I frequent, to be literally a boy who went to bed and woke up as a cockroach, and Kafka examined how that change affected those around him. Cockroaches can affect you.

Today, the automobile industry is going through a metamorphosis, it is a-changing and that change is Kafkaesque, because the industry might as well change into a cockroach. Hence I want to defend as a patriotic duty a potential alternative fractional metamorphosis of the traditional automobile paradigm from internal combustion engine (ICE) power into the much ballyhooed electric (E) power and specifically the design of some cars into something akin to "cockroaches".

I would like to buy an electric vehicle but not because of the ballyhoo. Hell, I would even be happy to buy a new gas car. But there is nothing being made that I want. Nothing even real close. Not the cubic money Volt nor Leaf nor less obnoxious Prius nor the rest of the conventional stuff. Maybe I should just build my own?

After I retired in 1999, I went looking for a new car. Nothing suited like the decade-old car I already had that was really very nice and which I will detail later. The car industry was clearly not interested in meeting *my* expectations and needs. Nor was it interested in participating in that part of the American marketplace that I and others like me represent. They wanted to let us eat "Detroit" cake. So I would rate them zero by modern quality terms based on conformance to this customer's expectations. And as one might expect, the government (our tyranny) was not helping one bit, in fact it seems they are trying to not only tax me to death but to actually indirectly kill me not too unlike the way they killed bin Laden[1].

A few years later, when there was talk of GM ending the EV1 electric car experiment and destroying their product, and with September eleven magnifying the tyranny of the cowards in charge of our government, I got to thinking, maybe I should buy one of those things on the cheap (not realizing how coveted they were and how impossible that would be). And an electric car in my situation started to make a lot of sense to me. Since then I have followed the reality and politics of electric cars, the ballyhoo, the arrival of the current economic depression (call it a banana if you prefer) and the related technology.

Along the way, the possibility of building my own car or of just converting an existing vehicle to electric often recurred. And that led to much more study. But it did not lead to me converting an actual car, at least *not just yet*.

Today, circa 2014, a decade since my interest surfaced there is still no suitable electric or gas vehicle being made new nor being converted. Nor is one being forecast among many forecasts out there. Nor do the common conversion tactics for existing vehicles seem sufficient that I might build one myself. But electric still holds promise. Not as much as some enthusiastic advocates say nor as little as some die hard opponents deny (both have had too much of the Kool Aid to drink). I have spent a decade looking both in a range of reference materials and in the lab for tutorial and answers to questions not so easily found (if they exist). But I am not badmouthing the available reference materials. The information they contain is useful, but much of the information I, myself, would want and need to launch a conversion is absent or is too obscure. I may not be the optimum commentator with the best

[1]The pseudo-dramatic killing of Osama bin Laden was great political theater. Here was a man who could not be found for a decade, because he was so skillful at hiding in Pakistan's remote caves. A man that some would have loved to "torture" like we have "tortured" some of his associates in order to learn critical intelligence on what his plans were, while others would have loved to apply less terrifying tactics that they claim work better. Then when he is found and killed, it turns out he was hiding in plain sight where he would have been easy to find except, shucks, no one in the new and improved United States intelligence network was looking there. Really? A big Rick Perry: Oops! Yes, easy to find, just like the September eleven attacks, themselves, which would have also been easy to find and to prevent (even without the PATRIOT Act) but no one was looking. Really? Oops! Clearly in this opinion, bin Laden was enjoying a tacit or real quid pro quo relationship with our government in which he provided them with a super-villain that was used to justify hundreds of billions of dollars of war expenditures and the loss of lives not unlike my own, and they allowed him to live until he was no longer useful. And then he was dispatched (if he was in fact dispatched), and without so much as a thank you, shot in the face (they say) with either no concern for what he might know, or perhaps too much concern for what he might reveal. What amateur wrote that script? And some of us cheered in the streets. Shame!

skill set to address this issue, apologies for that, but I want to try to close that information gap at least a little with this writing.

Nor am I badmouthing the well intentioned activists and enthusiasts who have been diddling with and promoting electric cars for at least two decades or so. The energy they have expended and the personal expense they have incurred is mind boggling. However their success so far is impressive in many ways. If only they could have coordinated better with each other some way. They have not been very successful at promoting E-Cars, despite the recent introduction of several high profile examples that I consider ill-conceived. Why? Are these enthusiasts too few? Do they also lack critical skills? Are they up against too-powerful contrary interests? Do they just need to turn a corner? Will the collection of information and speculation in this book help?

Hence I am writing this to compile the overall situation as I see it, including the damnable politics and tyranny, the technology, and the future promise in my limited view as of 2014. There may be significant flaws in any parts or in the manuscript as a whole. Flaws notwithstanding, I want to speculate on potential answers to as many questions as I was able to obtain, or surmise, and to build upon existing historical wisdom in hopes of aiding those earnest enthusiasts who seek an honest electric solution, and to speculate (perhaps to even just guess) more widely on tactics and technological approaches that might be useful or need to be ruled in or ruled out, despite any flaws due to my inadequacies. After all, where would science be today if Albert Einstein hadn't dared to propose his ridiculous theories of relativity to a world that thought the book on nature was closed by Newton. Luckily he wasn't trying today to oppose the gospel of global cooling, I mean global warming, I mean climate change, that so many assert is not just gospel but absolute truth these days. Hopefully my humble ramblings will receive less hostility. Some research, devices, and approaches that may well be original are possibly being reported here for the first time. Hence some of them may even seem to be hare-brained. Some, in fact, may *be* hare-brained.

I may then try my hand at applying these data to the detailed design of a conversion, a car I classify herein as The Cockroach, as a demonstration, especially if this contribution appears to be beneficial. That is to say, if it gains any acceptance by the enthusiasts or others and is validated to any significant extent. However, in these United States today, censorship, marginalization and exclusion is to be expected, because they are rampant. Today only the bullies are heard.

A hand-built Cockroach could prove way too much work and expense to serve me as an actual *practical* solution to my needs, nor might even *its* possible embodiments meet my wants. But if anyone is listening, a prototype might contribute to incremental progress (without me being a so-called "Progressive") and point the way to better solutions for others. However unlikely, along the way, maybe I could influence a number of these aspiring enthusiasts, to form an ad-hoc democracy, to test some speculation and to launch businesses to provide needed equipment for conversion cars and maybe later for production vehicles. And perhaps they can offer their own solutions to some of the problems still being faced as I see them. So if conversions can be facilitated sufficiently, it might encourage, nay force, the big car manufacturers, including those that have been Socialized, to build a Cockroach of their own, you think? Not too likely! I bet not, and I will explain why later. Then again maybe there may be another way worth considering and broaching to manufacture *practical* cockroaches, and I will certainly suggest it.

This text should be considered a first-draft, first-edition, Version 1.00, circa 2014, status and may be revised or followed up depending upon its reception, depending on the scale of any flaws that need correcting. It is not intended to duplicate existing materials on conversion that are published by E-Car promoters such as Leitman and Brant [**1**][2], Brown and Prange [**2**], Wagner [**3**], Boxwell [**4**], Leitman [**5**], Shacket [**6**] and others, which are all frequently referenced and relied upon herein rather than being restated or rephrased in detail. But it and any sequel volume two that may follow will seek to simplify, elaborate and explain key portions of the material in those references in the spirit of bringing the information and a better perspective to a wider audience of non engineers like I represented when my own interest began.

Many books tend to be either theoretical with lots of math, science and engineering while others seek to be practical in nuts and bolts terms. I hope to include some of each, and to challenge some of the material out there, to suggest alternative and supplemental and even obvious tactics, and to update and elaborate on the technology from the perspective of a physicist and mathematician. But I will try to put some separation between the politics and the nuts and bolts and the worst of the math, science and engineering (some to be relegated to a Volume 2). I want to debunk myths on all three counts. This means saying some things that some who lie to themselves (and to us) will consider to be nasty or worse.[3] But it is my duty to comment honestly on our Emperor's new clothes, even if no one is listening.

Selected History of E-Cars and Lessons Learned

Many references note that electric cars predate those with internal combustion engines (ICEs). Many were very popular. One can read these histories elsewhere, including a very optimistic version in Leitman and Brant [**1**]. The ICE-Car was not an instant winner. It

[2] Numbers in square brackets refer to the references listed at the end of the text.

[3] The writer has recently gone through a nationwide intervention in which he learned that he is just no damn good, because he is a jack-booted storm trooper in the war on women and women's health. Damn! He didn't know that. However, because he does not want to pay for contraceptives for women in general, including Warren Buffet's secretary (if she/he uses them). His misogyny has apparently revealed him for what he is. This is patently clear, because dozens of analyses of this have been seen on various shows, many of them on the Democrat Infomercial Channel (MSNBC) and indeed, the prominent head of the Democrat National Committee, one Congresswoman: Debbie Wasserman-Schultz, has given her assurances in several interviews. He feels such shame. He wishes he could reform, but he is hopeless. He never thought of himself as such a low-down scumbag, but, Alas! Give me the name and I'll play the game. The situation is far worse than even that. For you see, he can't help himself. Although he is not opposed to healthy women nor to their contraception, and even supports free contraceptives for those who can not afford them (because the real pollution on this planet is not carbon dioxide, it is people), that apparently does not matter. He must also confess, he does not want to pay for Ms. Wasserman-Schultz's toilet paper either, despite wishing her backside could be as healthy and as fresh as a spring rose. Perhaps, Ms. Wasserman-Shultz and our President could check their several thousand page long ObamaCare Act and/or lead an effort to ensure it also includes a couple things that benefit men's health. Namely it needs to cover hand guns for personal protection and prostitute services (think of it as aiding women's contraception). Then it might seem more reasonable, because that would at least help show that they, too, are not storm troopers in a war on men's health—misandronists. And so that in the same way as for contraceptives, these items can also be gotten for free with no expense to employers by making sure the insurance companies have to pay for them and offset the costs with saving on lower men's health bills in the future. How Win/Win is that?

had to evolve and many think to cheat in order to prevail. It is also a given that the E-Car is in many, many ways superior to the ICE-Car. Far less complex, therefore way-far more reliable in *most* ways and cheaper. Indeed one could, and many do, argue that the original ICE cars had to compete for a time as niche vehicles that offered advantages for some, but that the advantages had to offset significant disadvantages and that many of those disadvantages still obtain to this day. In fact in a heads up comparison, apparently even today a good E-Car fails to surpass the ICE-Car in only two albeit crucial ways: (1) range and (2) reliability of one central component: the batteries.

Both of these criticisms are valid and although there are those who say the early E-Car died because of corrupt industrial intrigue, and the writer accepts that there was a lot of that involved, nonetheless today no E-Car can meet as wide a range of requirements for as many people as does the sometimes more expensive ICE-Car. At present it is the E-Car that has to compete as a niche vehicle, and *it may never again be anything else*.

Today, no *practical* E-Car can take off and drive for hundreds of miles then fill-up with fuel in minutes and drive for hundreds of more miles. Even the latest and greatest cubic money machines can not, and even when there is an infrastructure of charging stations or battery exchange stations made available, there will still be an edge to the ICE-Car.

But there are those niches where the E-Car can more than compete today and in which the E-Car is apparently so superior that were *practical* E-Cars available, the thought of buying an ICE-Car to serve the niche would be unthinkable in any sensible mind. Indeed, for the writer's niche, there is an optimum range and an E-Car with greater range than necessary (with too much range) can also be at a disadvantage. Electric vehicles dominate the golf cart and related industries right now (golf carts are also an example of where too much range is wasteful). And for many people, including me, my own niche needs are for a glorified, a very much glorified, golf cart.

If such glorified golf carts were available, they would provide a viable niche competition for ICE-Cars. In time, perhaps, they could move into wider markets.

When ICE-Cars were taking over they were not perfect (as they still aren't) and they still suffer terrible shortcomings, but over time many of their ills were resolved and adapted to. At one time, around 1910, when Einstein was formulating the bizarre theory of relativity, electric cars were very popular with women who had a hard time with ICE-Cars. A favorite story involves an important threshold in the ICE-Car transition to practicality, some say the biggest threshold ever crossed.

Early ICE-Cars had to be crank-started by hand. Women often did not have the strength. And on one occasion a good friend and coworker of Henry Leland (Founder and Head of the Cadillac division of General Motors), was driving along and saw a woman stranded, struggling to start her car. He stopped to help. Haven't we all been there? Now to start the hand-crank cars, you had to first position the crank handle the right way. *This was important*. You positioned it after six o'clock, typically between six o'clock and twelve o'clock so that when you cranked it, you were pulling up and if the engine backfired, it would just pull the handle out of your hand. But he made the serious, in this case grievous, mistake of positioning it between twelve o'clock and six o'clock, and so he had to push downward on it. It backfired and so it forced his arm upward (a scenario in which cranks often broke arms). But it did not break his arm. Instead it hit his face and gave him a nasty cut. And in 1910, some twenty years before the discovery of penicillin, a lacking Kafka was just beginning to face at the time, cuts could be serious. He developed an infection and, Leland's good friend died within a week.

This loss was what inspired Leland in 1920 to approach the great and famous Charles Kettering to solve the problem.[4] Back then, *everyone* wanted to use electric motors to start gas engines, that was not great thinking. But the problem was that motors rated for the amount of power needed were as big or bigger than the ICE engines. Kettering's subtle but crucial contribution was in realizing that a "starting" motor is exclusively a low duty-cycle device. You could undersize it and then just overload the hell out of it for the few seconds it took to start the engine. And that was how the first *practical* (meaning small and inexpensive) electrical starter came to be. The later GM patent was apparently not based on something new, it was based on an unobvious use of existing technology, something I hope to dwell on a bit later. Then as now however the driver had to be aware that if his car is hard starting that he must not lay on the starter for long periods lest he burn it out and/or damage the battery, as well. Still true, how many people know this today?

Today, this same thinking underpins the design of electric motors for E-Cars. They are sized for low power continuous cruise conditions and are just temporarily overloaded for brief periods of high load conditions. But again, in many cases, one might not want to climb the entire Rocky Mountains, or say Pike's Peak, with one.[5]

Although there are several "cubic money" electric cars, and numerous modest golf carts, and neighborhood cars and commercial and hobby conversion cars (all of them already being referred to as niche cars) that are serving their drivers well, there are also many issues that need refinement, need the insightful touch of a Charles Kettering to make them truly op-

[4] Back in 1920, it apparently took a body, the death of a valued friend, to inspire this very significant corporate progress. Although costly and grievous losses are oftentimes ignored with no qualms, sometimes progress in corporations or nations only results *because* of costly or grievous losses. Costly and grievous losses must therefore be viewed as a key part of, a motivation within, our system. Almost a century later, Richard Clarke noted in his now famous testimony before the 9/11 Commission [2004] that in these United States: ".. unfortunately, this country takes body bags and requires body bags sometimes to make really tough decisions about money and about governmental arrangements." Afterwards, his questioner, Jaime Gorelick, apparently commented "Well that's a very sobering statement, particularly from someone whose reputation is as aggressive as your reputation is. And it makes me think that individuals who are less of a pile driver — to use Sandy Berger's words — must feel even less able to push for change." Apparently, Gorelick was a key player in the 1995 Clinton justice department during the trial of Timothy McVeigh, another pile driver who found it very difficult to push for change and whose trial was conducted to make that push as hard as possible. She was apparently also a central figure in establishing the so-called 'wall' between the FBI and CIA that supposedly made it so much easier for the 9/11 attack to occur. Did she or anyone else learn anything from either? Nonetheless, she was right, as will be explored later. Although I have lost no friends nor family in the 9/11 attack, I myself *have* lost numerous valued friends and relatives grievously and unjustifiably to assorted cancers, Alzheimers, diabetes, and other scourges, and I must agree that, as I will rant upon later in the appropriate place, that I have found it is very difficult to "push for change" and consider this book just a tiny small effort at "pile driving" that predicts a much larger equally unpleasant pile driving that may be needed.

[5] Indeed, EVs have not only successfully climbed Pike's Peak but have done so at great speeds. As of this writing, Internet reports, circa 2011, indicate a Nissan Leaf made it to the top in 14 minutes and 33 seconds while a purpose-built vehicle from Team Yokahama set An EV record at 12 minutes and 20 seconds. In 2011 the record for all kinds of vehicles was only slightly under ten minutes.

timum for even those prime-time services for which they would be most competitive.

To me, the General Motors EV1 of the mid 1990s is the best exemplar thus far of a niche E-Car regardless of whether that was how GM saw it. GM sales hand picked their customers and defined the niche by excluding those customers who were too bad a fit. The EV1 was optimized in many new ways. It used the latest batteries for greatest range along with low friction tires, streamlining (a drag coefficient of only about 1.9) and small size, had electric (actually, electro-hydraulic) steering and electric brakes and a heat pump for HVAC, and high tech materials for weight reduction. It even included the ability to program the car so it would warm or cool itself off of the grid just before it was used. The EV1 is reported to have achieved up to a round trip range of very roughly 70, 100 or 150 miles from the three generations of batteries it used.

Yes, with one exception an EV1 might appeal to me. That one exception, however, is critical. It is a deal breaker. The EV1 was way too expensive to build and sell. And although there was debate between proponents and GM over how large the demand for it was, its price would have kept it as a severe impractical niche-car, its niche being as a toy for the well to do. However, apparently every person who leased one and used it in its expensive niche scenario, loved it.

Today there are all kinds of electric prototypes being produced and promised for the future, but none of them (even a retro EV1) would be a good fit for the niche this writer is in. They all seem pretty much alike as a base and seem to be concentrating on looks more than purpose and many appear to be very appealing new toys for the wealthy, but that is a niche of a different kind, one limited by the number of wealthy people hunting toys to play with. But with obvious exception, cars like the Volt (that started at $43,000) and Leaf (that started at $37,000) and even Prius (at “only” $25,000) are not something I would take to the supermarket.

Neighborhood cars are limited variously and by regulations to about 25 mph, and although they seem to be popular in gated communities where there may be a private access road to a nearby mall, they are not anything I would want to take on the open road.

Hobbyists, however, are converting numerous cars to electric drive, and many *are* fit for the open road. Many are only delivering ranges of up to 35-40 miles or less (a little too low, falling to perhaps half that in three years) unless equipped with very numerous or very expensive batteries. Among the most successful are small truck conversions (heralded in the E-Car literature [**1-3**] often based with good reason on the Ford Ranger). These bring the cost down to where a niche short-range vehicle might serve a decent number of people, but the conversion, maintenance and compromises often made (manual steering, manual brakes, no heat nor air conditioning) make many of these conversions into E-Cars something only their highly motivated creators could love.

Current Flawed Paradigms

The cubic money E-Cars being touted are trying to compete with the ICE-Car on the ICE-Car’s turf (especially in price premium). E-Cars may never achieve that goal. And expecting customers to pay such premiums to be second rate is not a formula for success. In this mind, they are doomed to fail (and perhaps the Leaf and Volt were once again deliberately designed to fail as part of an intrigue).

The more often *practical* E-Cars are made and converted, the better the chance that there will be progress made in their basic designs. But the writer's view is that the E-car will not break through until there is a new commercial or a conversion paradigm found that makes them desirable as head-to-head competitors with ICE-Cars for people of normal income and for one group in particular soon to be studied, both of which would not want to give up the power features, nor would they want to pay $43,000 to pretend they were saving the planet. These people are not the damned millionaires or billionaires that the Democrat party loves to hate.

In the writer's mind a true commercial niche E-Car requires good performance, comfortable if not easy steering and brakes, heat and air conditioning, a round-trip range of at least 50-75 miles (preferably more but maybe not massively more) and *a purchase or conversion price a good bit lower than that of new compact ICE cars like the Corolla or Focus.* That is the niche paradigm this analysis pursues and advocates. That is the paradigm this commentator thinks can be successful.

The price issue is a big, really big, deal. All indications are that when you forego the massive amount of precision machined parts, and sensors and fuel system and exhaust system and pollution control system, and even transmission system of an ICE-Car, an E-Car heads-up (except for the limited range), new or converted, should cost significantly less. Hence the idea of "expensive E-Cars" like the Leaf or Focus Electric is oxymoronic. It is like paying extra for a "premium housecat".

I mentioned I am retired. In the last dozen years I have not driven my car a round trip distance more than about thirty miles. Not once. Most of the time I have driven only once a week. I have coordinated my errands (as a form of social consciousness gesture because I am a generally conservative, but atheistic, disenchanted Republican, yes there are such things) so that I can drive four miles to one "distant" supermarket where they have the largest variety and certain favorable prices. Then on my return leg, I pass a second specialty supermarket where I stop for their generally excellent produce and assorted specialty and refrigerated items. Then I continue the return to where I can stop in at a drugstore or two if needed, and using a traffic light to make the only cross traffic maneuver (as a safety tactic), can stop at a bank and a series of fast food shops to grab lunch. And I still make it home in time to get to my bathroom. Then my new ICE-Car stood for a week unused doing nothing but rusting its brake rotors and draining its battery.

This routine trip which has been about eighty percent of my driving (I have driven only 1200 miles a year consuming about 60 total gallons of gasoline for nearly a decade) has been accomplished with only eight miles of motion, just barely enough to thoroughly heat the IC engine. Therefore, because it is important not to turn off a cold engine (because moisture and acids can condense therein and lead to serious corrosion damage—the reason short trip driving of ICE cars is considered severe service), I sometimes have had to wait at the end of the trip and idle away a bit of gas to make sure the engine had reached operating temperature and that I am not polluting my oil (a well-designed E-Car does not have *this* concern among many more).

More recently, I have been taking trips on multiple days in the week and some have extended to the lofty round-trip distance of twenty-five miles. I may double my total driving for the next few years. Since I do not foresee any need for a long range trip (and can rent an ICE-Car if need be), an E-Car with any robust[6] range of fifty miles, or even up to a hundred miles, or more, has real appeal.

Not only that but when my ICE-Car was new and when I was driving ten thousand miles in eight years, I had to travel twice a year to the dealer for oil changes and safety inspections and pollution tests (the latter that were never performed because of my limited driving but at the behest of our tyrant politicians were nonetheless paid for). Curiously, nearly five percent of my gasoline consumed was in driving for routine maintenance service and mandated safety/pollution inspections, both of which were overkill even for an ICE Car. If my government wanted to save energy, they could have saved five percent of my consumption by making these unnecessary trips unnecessary.

I paid for a full complement of pollution controls on the car, controls mandated by tyranny, the manufacturing of which may have produced more pollution then they prevented in my case, at least for my yearly consumption of gasoline of about sixty gallons. Pollution controls are less effective until a car has warmed up, a point at which I was turning mine off. Similarly, I paid for a full complement of safety gear that is much less effective for me and much less needed for retiree driving and in some ways *increases* my risk. Clearly the ICE-Car was a poor fit for my needs, and therefore for my nation's niche needs. And I may not be exactly typical among retirees but am not nearly alone.

Massive safety regulations, and pollution regulations, and maintenance demands are counterproductive to me and, therefore, my planet. So, what's good for me, is good for earth.

We Need a "Model T" E-Car: "The Cockroach"

We have seen, the ICE-Car did not catch on right away even as a niche car, and there are people like myself today for which the ICE-Car is still clearly a bad fit *especially* as a niche car. It wasn't until Henry Ford introduced the *affordable therefore practical* [7] Model T that car sales of any kind really took off. Affordability was crucial (along with Ford's five dollar a day wage) to bring ICE-Cars to large numbers of customers. But even when it became affordable, it still had to offer enough to make it worth people's effort to buy.

We need an electric car to cross a similar threshold barrier today. We need a niche E-Car to provide enough performance (meaning more than just acceleration) to compete heads-up with ICE-Cars in niches like mine among others, and it has to be sufficiently affordable (including any sweat equity in conversions) to draw people away from ICE-Cars despite its lack of range. Today (2014) the importance of affordability is especially crucial, because tens of millions of families have lost or abandoned their homes in the National

[6] Remember, a current hobby EV conversion today with a basic range of 50 -100 miles will lose half (making it 25-50 miles) when its batteries are three years old and another half (making it 12.5-25 miles) in cold weather and when driven at higher speed will suffer even further loss of two-to-three fold in range. Hence a big factor in this effort is how to avoid a 100-mile E-Car acting like it is a ten-mile-or-less E-Car.

[7] Henry Ford's Model T was "affordable" in the old definition of the word which means to be able to buy without detriment *from your own wealth* (even though Ford gave many of his employee/customers pay raises to help them achieve the status). The current Democrat definition of "affordable" as used in "The National Home Ownership Strategy" and "Affordable Housing Quotas" and "Affordable Care Act (Obamacare)" meaning to be able to buy with borrowed or gifted money you will not be able to pay back does *not* imply practicality.

Home Ownership Strategy scam and have trashed their savings and credit. Our clueless tyrants often wonder why more people are not buying cars and improving the economy. Partly it is because *some people are not potential customers for $43,000 Volts*.

Manufacturers clearly want to build and sell cubic money machines, be they cars or personal computers. They always do. That is reasonable and human. That is capitalism and greed. That was even Henry Ford's ultimate dream also, but he had to put up with us riff-raff along the way. Hey! Even back then there were many who worshipped and may have invented the "Greed is Good" religion. GM later taught Ford and all of us in the world that you can build a fancy car and call it a Cadillac using duded up Chevrolet parts and sell it for a far bigger profit margin than you could ever hope to sell a measly Chevy. That is because you sell the Chevy to people with less money, people who are *practical*. This process is chronicled in Christiansens's *The Innovators Dilemma* [**7**]. Christiansen tells how to maximize profits and also how disruptive technology like I suggest here is called "progress".

Progress was not the only reason the Model T (R.I.P. 1910-1920) and its similar sibling, the Model A (R.I.P. 1920-1930), were killed with less infamy than the assassination of the EV1. Those cars had niche utility, beyond their demise, even when bigger and better was in the showrooms. A neighbor of mine found off-road use for his Model A often as I was growing up in the 1950s when cars were becoming crap and tailfins were the current big thing (don't get me wrong, I liked tail fins a whole lot and owned some of the very biggest of those things). Ever since, and with great toxicity recently, this quest for their next big score contributed to but did not cause the worst economic tragedy since the great depression: the 2009 real estate meltdown following yet another gas crisis (which was not due to the Republicans, despite their sharing lots of guilt, driving the car, even the E-Car, into a ditch).

Now one should not mind that we have visionaries, or even that we also have greedy bastards, chasing the dream of untold wealth. That is the American way. But when they start cheating and intriguing and assassination, they compare to the Evil Empire and need similar medication. Make your money, but not at my unwilling expense. Not through monopoly, not through oligopoly.

The "great" and famous John D. Rockefeller (JDR, one of those oil magnates that it is now not only acceptable but patriotic in some quarters to hate) taught us how to enforce a monopoly. And his rules are still in use today. His ethic established that you do not enforce a monopoly (or oligopoly) by keeping prices high. You enforce it by varying prices. First you raise them to gouge your customers which creates an incentive to draw in competition (because competition is good). Then when competition comes into the market and becomes a threat, you lower your prices to an artificially low level in which you and they both lose money until you kill them (like the were electric cars), and when they are gone you raise the prices up again to recoup your loses.

Oil producing nations know this. When there is no competition their prices rise, and when alternatives get close their prices drop and the competitors are dispatched. In my day there was much commentary about how lucky Ronald Reagan was in his presidency because the price of petroleum suddenly fell and so he quickly scrapped all plans to pursue energy sufficiency in the USA after a fortune had been spent to develop them. Reagan the former Democrat simply must have been ignorant of JDR's monopoly maxims and was played for a fool and duped (granting him the benefit of the doubt for a moment and assuming he had not sold out and was not in on a conspiracy to keep us dependent).

This process is to be expected even when there is a sham competition going on. Every business man has an incentive to raise prices and make more money. And even in fields where the allegation of an oligopoly would seem ridiculous, the mechanism still operates. Every business monitors its competitors prices and whenever one of them becomes a price leader, either up or down, the others have to decide whether to follow suit. The incentive to do so can at times be compelling. In the car industry it is much worse. As we shall see later the entry fee to make cars is so high that competitors are not quickly nor easily lured into market. So the few car makers can participate in a tacit conspiracy that could never be proven. Trade Unions work the same way.

When the little Henry J automobile was supposed to bring economic cars to the people, its biggest competition came from a Chevrolet model that was full sized, yet only a little bit more expensive. Coincidence?

Hence if a way can be found to overcome nascent greed, to introduce a competitive vehicle, like the Henry J, like the K-Car as we will consider later, you can bet there *will* be competition, some of which will be sham competition from the incumbents following JDR's prescripts. The ICE proponents will make their closest ICE-Cars competitive even if they have to lose massive amounts of money for a significant time selling them below cost. Losing money is not new for them. It has been reported that Ford's small car, the Escort, was manufactured in its first several configurations over a period of nearly two decades with Ford losing more than $500 on every one they ever made. But the losses are defended not on Ford trying to kill competition but on trying to be competitive in a required segment, a segment in which first time Ford buyers can later graduate to more profitable cars.

*The **Real** Beetle*

The VW Beetle was a car for the masses like the Model T. That was Adolph Hitler's intent for the car when he asked Ferdinand Porsche to design it in the 1930s. Hitler even went so far as to personally select its manufacturing site and patterned it after his hero's (Henry Ford's) thinking by locating it on the Aller river in the way that Ford placed his plant on the Rouge River. And it was named the people's car (or Volks-Wagen).

It was imported into the U.S.A from 1949 until 1979 as a *practical* vehicle. Over the years its manufacture was highly refined. Many are still viable vehicles on the road today. VW tried to move it upscale but its appeal was to a *practical* bunch. Finally in 1979 its sale in the USA was discontinued when, alas, it could no longer meet safety and pollution regulations. Bummer! Those regulations were put in place by a caring and doting government, a government I now consider a tyranny, to protect the citizens it served and so highly prized. No car company gets to place American lives at risk. Only the caring doting government gets to do that. And if that doting government harms or even kills some of those prized American citizens, well, there are plenty more where they came from.

As a small car, the Beetle could be dangerous in certain kinds of service. And it could "pollute" more than some others in some other kinds of service. However in some niches both of the concerns were trivial or even untrue. Nonetheless, Americans after that were allowed to enjoy only higher priced cars and I am sure it broke VW's heart having to upscale like that. In 1998, VW introduced the New Beetle into America but it was ungainly large and had a far more complex configuration and cost upwards of $20,000. And it was popular as a cult car, to people including some pretending to save the planet, but not among the core *practical* crowd.

However the original Beetle was still being made in Mexico until 2004, by which time [according to Wikipedia] it was equipped with fuel injection, catalytic converters and a bunch of other niceties that American Beetle fans would have loved and it cost just $7450. And used within a certain niche audience in the USA, it would have *reduced* pollution, *saved* energy, helped *practical* Americans (especially retirees) to save, improved the standard of living for many and it would not have even unduly corrupted their safety.

There is still a market for the old "real" Beetle today in the USA. It is not huge, but it is a market that goes wanting. Old Beetles actually sell for a premium (some for conversion to E-Cars). And in a display of strong support for free trade, free enterprise and capitalism, our doting government (what I refer to as our tyranny) has taken steps to prevent their being repaired and used indefinitely. Although massive numbers of cars come into the U.S. every year from Mexico, it is reported that Beetles from Mexico may not be brought into the country even to use as parts cars to repair existing legal Beetles. And if Americans try to enter the country from Mexico driving a Beetle, apparently it is seized at the border (so says Wikipedia). So strong is our commitment to free enterprise, including that NAFTA thingamajig, and capitalism. We may be the free-est people in the world but god-damn-it we will heel to our political correctness.

Of course if we had had $7450 Beetles available during the fuel crises of 2005-2008, it would have lessened, delayed, and who knows, maybe, just maybe, even prevented the depression/banana that resulted from the sub-prime housing scam for at least some people. And it would have resulted in less pollution and less global climate change (if that stuff is real).

Hence any successful "People's" E-Car (a Volks-E-Wagen), any successful Cockroach, must have a mechanism to sustain production even when sales fall off, when car companies are trying to kill it (in the spirit of free enterprise and capitalism) with phony underpriced competitors and its death is proclaimed.

The USA needs a car like the original real Beetle today. If only we could build them ourselves. Wouldn't that be great if a group of volunteer, public-spirited, possibly even Socialistic citizens got together and parsed the components of the Beetle for the good of all the masses and made them available as a kit car that people could build at home? Of course I am sure VW would never allow that. Only then would we learn what VW thought of the value of its original "inadequate, un-commercial" *Real* Beetle. Ah yes! If only there were another option... (Wait for it… It has now been forecast, and it *is* coming.)

Where Have you Gone, Henry Ford?

Apparently, there are no Henry Ford's around today, so a new production "Model T" E-Car does not seem likely. Yes, the neighborhood cars may evolve but they are not there today and they face humongous challenges. Conversion E-Cars suit a number of highly motivated enthusiasts but they have nothing sufficient to offer any large niche. They are not "People's cars" yet. But maybe the conversion cars can point the way to a "Model T" E-Car. Maybe we are within a breakthrough or two of achieving that. So let's examine conversions first as an interim solution with the ability to lead the way to a new production E-Car that is *practical*.

Incredibly, enthusiasts are sparing no energy in converting nearly everything into E-

Cars. Everything from bicycles to big trucks. None of them is what I would consider a close approximation to a Cockroach, a "Model T" E-Car. I have not seen one that I would buy as a conversion or as new manufactured product.

Currently there is strong advocacy for the small pickup truck [**1-3**] as the most favorable basis for a *practical* E-Car conversion whether by hobbyists or conversion companies. Namely the Ford Ranger is often cited for several specific advantages it offers. I have to agree with this assessment. Yes, in theory a compact (or subcompact) car seems the preferred platform of choice for new production when a number of problems have been resolved. In some cases, hobby converters go to Herculean efforts to convert compacts, and I will later suggest or even just speculate on possible solutions to some of those compact option problems. But for now, conversion, especially consumer conversion, of a compact car involves too much modification to the car, too much sweat equity, too much engineering (whether doing it yourself or paying someone to do it) and the results fall short of "Model T" E-Car status. But nonetheless, let us first explore the small pickup truck.

First one needs availability. The Edmunds.com website (2011) introduced its section on the Ford Ranger as follows:

> "They say that in the event of Armageddon, the only thing to survive will be cockroaches. Well, there is a good chance the Ford Ranger will stick around too."

They went on to say how little the Ranger has changed since 1983, even though it was still a competitive vehicle. And like the cockroach bug it has multiplied. In early 2010, the 7 millionth Ranger was made in 28 years of production. And although it is less sophisticated than some other pickup trucks, it has been way more than price competitive. So we will first consider specifically the conversion of the Ranger ala those Rangers that have been converted in the past and this is why I have decided to call the resulting E-Cars and future *practical* generic E-Cars that seek to satisfy this niche: *The Cockroach*.

Among the cited benefits of the Ranger for conversion to Cockroach duty are [**1-3**]:

- It is as small as current pickups go (but much bigger than compact cars and it has much more undesirable aerodynamic drag).
- It was price competitive when new and tends to be cheap when purchased used.
- It is popular and numerous (EBay is lousy with them and many are nearby)
- One can isolate the batteries from the passenger compartment easily (good to do but apparently not a requirement) by installing them with ease in the bed, or with some effort under the bed, under the hood, and some have even installed batteries under the cab.
- The pickup cargo rating is sufficient to carry large numbers of heavy batteries needed to achieve a 30 mile (or much greater) range.

To these, this writer would add:

- They are available in two seat (preferred for the most basic E-

Car), extended cab with some tiny rear seat room, or with a rear bench seat).

- They have a full frame so one seeking to do a conversion does not have to worry so much about body modifications that might weaken a monocoque (uni-) body compact car.
- They are rear-wheel drive which can be a benefit (or not) to be examined in more detail later.
- They have enough bed cargo space to be practical even if much of it is diverted for battery storage.
- Their cargo space can be used to carry temporarily or permanently (ala the Volt) a “range extender” gas powered generator.

But they also have downsides, to wit:

- They are heavy (more of a problem especially without regenerative braking or with manual steering and brakes)
- They have a large slab cross section (lots of air drag at speed)
- They have large tires (more air drag and rolling friction)
- They are tall (but can be lowered).
- And of course, like all conversions they have to deal with the imposing downside of politics
- They have an angled drive shaft, staggered rear shock absorbers and apparently narrow frame rails that complicate discreet battery installations under the bed.

Indeed, on the last point, the very similar Chevrolet S10 pickup truck (which was also made in pretty large numbers) and several other similar pickups have centered drive shafts, appear to have wider frame rails and therefore their own strong followings for use as conversion vehicles.

Good Alternatives to the Ranger

In the apparently simplest Ranger conversions, one removes the ICE and its related components of fuel tank, exhaust system, radiator, pollution controls, and in some cases transmission, bolts an electric motor to the transmission or drive shaft, bolts a large number of batteries into the bed, and adds control electronics connected to the accelerator. If the Ranger has manual brakes and steering and lacks air conditioning, the conversion is nearly complete. However those and other convenience options can multiply the effort, add a good bit of cost, and seriously affect range.

As already noted, similar small pickup trucks (S10, early Tacoma, etc.) share these virtues. However all of them are also tall and adding so much weight in the bed can raise their center of gravity a lot. Hence, many enthusiasts go to the trouble of fabricating battery boxes (of appreciable and undesirable weight) to contain the batteries under the bed between the frame rails. This is a significant amount of extra work and expense and often requires a bed that can be tipped up to get at the batteries (unless much more expensive maintenance-free batteries are used) .

There are some less common conversion prospects that solve both issues. The rear-wheel drive: Chevrolet El Camino and Ford Ranchero, and especially the front-wheel drive Dodge Rampage and identical Plymouth Scamp and (to lesser extent) the Subaru Brat and VW Rabbit Pickup are lighter and are smaller compact-passenger-car based trucks that are much less tall (or in the case of the Subarus might be lowered with standard parts) and have beds suitable for carrying easy-to-install batteries that result in more favorable centers of gravity with less weight and probably much less aerodynamic drag. These are all smaller and more car-like than the Ranger but are either much less available than the Ranger or could be much more costly. However, in the case of some, especially like the Rampage/Scamp, they exhibit small cross-section, aerodynamic shapes in the front, smaller wheels and tires, have low weights yet perhaps the highest cargo to weight ratios, were available with manual steering and brakes and can be outfitted easily with desirable equipment such as four-wheel disk brakes. One must also note, however, the Rampage/Scamp, and Rabbit Pickup as for many cars from the era, did not exhibit the best crashworthiness, but then many pickup trucks are not very crashworthy in barrier tests either.

Politics Sucks

Whatever the difficulty (or pleasure for some) to convert a Ranger or other alternative to a Cockroach, the politics adds a whole new dimension. Laws here in Pennsylvania (as in many states) require licensing, inspection, and insurance. And all of these are hurdles, especially the inspection.

If you convert a vehicle to electric use in Pennsylvania, it must be approved by something called an enhanced inspection station. The inspector must complete a Pennsylvania Bureau of Motor Vehicles Form MV-426B, Application for Reconstructed, Specially Constructed, Collectible, Modified, Flood, Recovered Theft Vehicles, and Street Rods. Fees and taxes must be paid, and a new title can be issued if all the terms and conditions are met. A copy of the MV-426B can be seen on-line with a Yahoo or Google search.

While the corrupt Federal government has given $7500 rebates ($50 more than a new Real VW Beetle cost in 2004) to encourage purchase of E-Cars nationally (and there are proposals to increase the incentives to $10,000), in Pennsylvania, and perhaps other places, the existing procedures discourage practical conversions by creating vague and obscure hurdles against them. Indeed, a $7,500-$10,000 incentive would pay for most of the cost to convert an existing car into a Cockroach.

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The Problems in a *Practical* E-Car

A *practical* new or conversion E-Car, a true paradigm for the Cockroach, needs to go beyond many current conversions (beyond those cited in [**1-3**]) in a number of ways, some needing innovation, some needing invention, some needing determination. They include:

- Good steering options (manual if possible) are needed
- Good braking options (manual if possible) are needed
- Good regenerative braking is desirable
- A good HVAC option is needed
- Good lighting options are needed.
- The right motor and controller are needed
- Better economic batteries are needed
- Aerodynamic drag needs reduction
- Rolling friction needs reduction
- Range extenders need to be defined, refined and standardized
- The pardigm needs smarts—microprocessor intelligence is crucial.

To a large extent, the ways in which ICE cars cope with many of these issues are antithetical to the needs of a Cockroach. Indeed, many of the ways these issues were dealt with in bygone eras that have been abandoned are more applicable and should be reconsidered. Fortunately in most cases technology patents that may have prevented the use of some technology would all be expired (but design patents would still be an issue to be discussed later), or would soon expire, and they would not pose an obstacle. Who knows what other useful, or ignored, patents that have expired or soon will expire, might serve or be “good enough” to serve. So the following several sections will drill down into each of these issues and hopefully inspire worthwhile discussion.

Steering Drill Down

Power steering is not just a luxury on today’s cars. And the predominant hydraulic systems available on ICE-Cars today work just fine. But they are poor solutions for a Cockroach. Most draw continuous and significant parasitic power from the idling engine with its copious energy reservoir. Lacking a similar reservoir, the Cockroach needs more efficiency.

The EV1 and Toyota MR2 (the latter with a mid engine too far from the front wheel steering to plumb hydraulic lines) used electro-hydraulic steering in which an electric motor spins a hydraulic pump when assist is needed. Probably not as responsive as the full-time idling hydraulic system, but workable. No wasted energy when the car is not being steered but not real efficient when it is. And it is presently expensive.

Fully electric steering has great appeal because it could be turned on and off and would only draw power in the highest effort situations. Furthermore, unlike hydraulic systems, it would not add frictional drag due to hydraulic seals on the drive piston and fluid flow caused by piston motion while steering when the effort is below the threshold where assist is needed. Any electric steering technology patents dating to 1997 or before would be expired, and there may have been several. Fully electric power steering was being planned for the mid-engine Pontiac Fiero (which had the same mid-engine problem as the previously mentioned MR2) in the 1990s, but the car was killed before the steering was ready, nonetheless, full electric systems have now been refined and have been used in various GM, Toyota, VW and other cars also.

In a Cockroach, electric steering would efficiently draw power from the batteries only when the car was being steered. Data for electric steering energy demands were not found but could be easily measured. But, even if very efficient, electric steering systems are nonetheless an electric drain and do add complexity, weight and cost. Therefore, can a more efficient manual or other system possibly serve?

Manual steering effort is less when vehicle weight is reduced (but some E-Cars tend to weigh more), and effort is less when tires are narrower (and narrow tires are practical at most E-Car weight levels, and provide better traction in many snow and rain conditions); wide tires are popular for looks and use in high performance driving, but their benefits for Cockroachs are minimal.

Indeed, variable ratio steering has been available at many times dating back to the 1970s or before in cars with either power steering or manual steering. It can reduce on-center effort and improve precision and road feel when the vehicle is in motion but can increase effort in hard turns. Still it would reduce the amount of power steering that must be automatically supplemented for hard turns and parking.

Steering effort can also be reduced with simple gearing, but this slows response time. Historically, manually steered cars had about five turns lock-to-lock while power-steered cars were as little as three turns or less. Reduced effort is important for parking but not nearly so much on the highway. Hence, one could simply place a two speed planetary gear set[8] with no "neutral" in the column of a Cockroach system. It could be shifted to a lower gear (numerically higher) ratio for parking and shifted back (perhaps automatically) for normal steering.

[8]BMW introduced something they call active steering in the early 2000s which incorporates a planetary gearset into the steering column, however not as a two-speed transmission but as a differential. A differential has three rotating inputs (just as the rear-axle differential has a drive shaft and two wheel inputs), and each input is mathematically either the sum or difference of the other two inputs. The BMW system decides what the steering ratio should be based on speed and things like whether the car is turning hard and it adjusts one input to either add or subtract from the steering wheel rotation linearly or variably providing continuously adjustable ratios. This approach is more sophisticated than required for a Cockroach but demonstrates the viability of adjustable steering ratios and planetary gears.

In some designs, this could change the steering wheel “center” position with every shift. Hence this might work best if the steering wheel had no “center”, that is, was fully cylindrically symmetrical and had no visible spokes (for example had either a clear plastic rim-support instead of spokes, or if the rim support were fully solid so that the wheel would not have to be re-centered before shifting gears back). Indeed, dash instruments could be rear-projected onto a semi-clear rim-support or front projected on a solid support or moved.

So at present there may be no really good existing mechanism, with electric steering as the best second choice, but at least its electric draw can be tailored so that little assist is present at speeds where it is not as necessary. And it can be turned on and off or adjusted.

However, since many manual steering systems especially variable ratio systems work very well and are even preferred in a moving car (for their superb “road feel”), perhaps developers should consider adding a transmission in the steering column.

Brakes Drill Down

Recent Rangers, as for most vehicles, use either a vacuum servo or electric four-wheel antilock brakes. Newer cars with four wheel antilock brakes should be easy to power up but they run from 12 volts and so may require a dedicated accessory battery supply. As for electric steering, data for the amount of energy they draw are scant. Older vehicle conversions with vacuum-assisted power brakes often deploy an electric vacuum pump, but that consumes precious battery capacity and reduces already marginal range. ICE-Car power brakes use a vacuum- or hydraulic-fluid-pressure reservoir that provide for several stops in case the engine stalls or electrical power fails, and with “smart” designs, E-Cars could incorporate much larger vacuum reservoirs that could be evacuated from the grid to allow for dozens of stops before battery drain begins.

On the EV1, the rear brakes were operated electrically [**8**] and there may be a use for electric operation in future E-cars. But they are still power drains better avoided if possible.

Today, many hobby conversion vehicles revert to manual brakes which are highly efficient but can be very unpleasant to use. Nonetheless there appear to be *very* good manual options possible, though few conversions seem to be using them.

Today and in the reasonable past, cars have tended to use either drum brakes, disk brakes, or most often mixtures of the two. The two kinds have different issues. Some present disk brakes may not be good choices for an electric vehicle. For one, they rely on small brake pad areas, tending to require large forces to operate, a reason why many disk brake systems almost always have power-assisted actuation. Second, the disk pads do not retract. When hydraulic pressure is released, the pads just lay where they are next to the rotor, perhaps pushed back a little from any run-out of the disk or resilience in the cylinders. This is why disk brakes do not need adjusting. As they wear they automatically continue to lay right next to the rotors.

That is both good and bad. If the pads are in close proximity to the rotors, then actuation does not require a large displacement of hydraulic fluid from the master cylinder. Hence one could use a master cylinder with a smaller bore and this would provide a mechanical advantage that would make manual brake use *much* easier. However, since the pads do not retract, any continuous contact is a source of rubbing friction loss that must be overcome with power from the battery stores. This appears to be negligible but again, data are scant.

In comparison, typical rear drum brakes as for both front and rear drum brakes in the old days employ two brake shoes. A hydraulic cylinder forces the shoes to rotate apart and press against the inside of the drum. Springs retract the shoes fully against an adjustable stop, whenever pressure is relaxed. Hence, a comparatively larger amount of fluid than for disk brakes is pushed back into the master cylinder when the brakes are released. As the lining wears, the travel of the shoes increases and the amount of fluid displacement required to activate the brakes increases. In the old days, as lining wore, a progressively longer stroke of the master cylinder piston was required to lift the brake shoes to the drums. One could tell when brake shoes needed adjustment or replacement by how close the brake peddle came to the floor board before braking began. At least as far back as the 1950s, assorted automatic adjusters were used. However sometimes the adjusters over-adjusted and sometime they under-adjusted. Hence, one needed to be sure enough fluid could be displaced by the master cylinder to ensure the brakes would work.

For a number of reasons, the forces required to activate drum brakes are significantly less than for disk brakes, and hence as manual brakes, they are significantly easier to operate. Drum brakes are also less expensive than disks, and that is a big reason why they are still in use for the rear brakes on many cars today. Drum brakes have also been easier than disk brakes to equip for emergency brake use and many disk brake cars use small drum brakes for the emergency brake function.

Which of these or others makes sense for new production E-Cars or for a Cockroach conversion?

Because range is so crucial in an E-Car any use of battery power for brake activation is counter productive. The vaunted GM EV1 broke this rule. However, if regulations were to impose antilock or even stability control brakes on all new cars, or if such regulations are already in place, then the decision is largely a done (foreclosed) deal. At present, electric power would have to be diverted and then either type or combination of them can serve. However, manual brakes are potentially desirable in any other scenario, especially if they can be improved and they probably can. In fact the idea of "mechanical" low effort brakes is worth exploring.

Disk Brakes

Where all four wheels have disk brakes, the prospect of scaling down the master cylinder diameter to gain mechanical advantage is both realistic and highly *practical*. If the master cylinder diameter were to be reduced to half its diameter, it would produce a four-fold magnification of the applied pedal force. Since disk brake pads sit almost in contact, if not in partial contact with the rotor, the amount of brake fluid that must be "pumped" is negligible and this would enable a four fold ease in operation of the manual disks.

Current car manufacturing regulations requires dual braking circuits (a "good" regulation the writer attests to as someone who lost braking more than once on old single circuit cars). Most cars have placed front brakes on one circuit, rear brakes on another. However most braking perhaps upwards of 60% is accomplished by the front wheels due to weight transfer in hard stops, and so some cars put duplicate circuits on the front wheels and then tie one rear wheel brake into each circuit. This increases the fluid displacement needed to activate the brakes.

In these cases, the two circuits are equalized. And when one circuit fails, the remaining circuit has to have capacity, enough stroke, to compensate for the abrupt increase in extra master cylinder travel. This can be difficult to achieve with worn drum brakes which can require a larger stroke to activate the brakes plus the reserve stroke necessary to cope with failure of either circuit. Hence small pistons with drum brakes are marginal and four-wheel disk brakes offer serious benefits for all manually braked Cockroaches.

With a manual four-wheel disk brake system, the next largest cause of unnecessary pedal travel is likely due to elasticity in the flex hose at each wheel. This ballooning of the flex hose is small, but can be minimized with steel-braided lines that should reduce pumped brake fluid during stops to near zero.

Drum Brakes

Many E-Cars do not face the braking demands of modern high-speed, high-performance ICE cars. Hence, although four-wheel disk bakes offer the advantages cited above, less expensive drum brakes might, nonetheless, actually be a very workable choice for many an E-Car. The most common design for drum brakes (two semicircular shoes that are pushed apart by a single wheel cylinder) incorporates a "primary" shoe and a "secondary" shoe. In service the primary shoe wears much faster than the secondary, because it does a greater portion of the braking. This is because the primary shoe is "self-energizing". In a forward moving wheel, when the primary shoe is rotated out to contact the drum, the friction tries to drag the shoe in the direction of rotation, acting to help actuate the friction. This tends to wedge the shoe against the anchor and force it against the drum with added force. In the secondary shoe, when the shoe is rotated out to contact the drum, the friction tries to drag it away from its anchor and therefore unloads some of the force. The self-energizing effect can be designed to provide any desired amount of supplemental braking force to the primary shoe.

Even so when front disk brakes first came into widespread service with drum rear brakes, much less hydraulic pressure was needed for the rear brakes and so an equalization valve was used to send less pressure to the rear drums than went to the front disks. With a return to four wheel drum brakes a reduced pressure level would be sufficient in both front and rear brake circuits.

Furthermore in the 1950's Chrysler cars used a design referred to as center plane front brakes (Reference [**9**], page 207) which in some cases made both brake shoes be self energizing, therefore were both primaries. And of course on new-manufacture cars center-plane brakes could be incorporated in the rear brake designs also. And if a precise self adjusting mechanism can be incorporated, a reduced diameter master cylinder piston would further reduce the pedal force necessary with manual brakes.

Although disk brake systems are generally felt to be more effective and less fade prone, drum brakes should be more than adequate in a limited range E-Car, a Cockroach, with a modest top speed.

Antilock and Stability-Control Brakes

Antilock brakes and stability-control brakes were both introduced with much ballyhoo. Antilock brakes however soon were associated with a number of safety concerns. They were less effective than manual brakes in the hands of highly skilled drivers and often caused erratic braking if traditional driving methods were used (specifically if antilock brakes were pumped in skid conditions). More recently, problems of this kind have been less frequent (or are mentioned less), and antilocks are quite handy when they work well.

Stability control has gone into service much more smoothly and the claims for its benefits are impressive with some claims of reducing fatalities in accidents by hundreds each year.

For Cockroach service neither is nearly as desirable as for general service. For one, a typical Cockroach driver would drive little in total, much less in slick conditions, would drive at much lower speeds in general, so manual brakes might be perfectly adequate. However, there is a prospect for the incorporation of antilock brakes that conform to both the economic and performance conditions for Cockroach service.

In 1991, GM introduced the Delco Moraine ABS VI antilock brake system [**10**] for the 1992 model year and in 1993 modified it to also provide a traction control function in some models. Hence, any patent encumbrances on either system probably expired in or before 2010. ABS VI was much different than most other ABS systems. Many systems were elctrohydraulic in that they drew electrical power to operate a pump that pressurized a spring loaded hydraulic fluid reservoir and then used that pressure source (in the way that older power brakes used a vacuum tank) to operate the brakes under emergency conditions. They were expensive, complicated, and many, perhaps most, were dangerous to service with the high pressure fluid[9] often at more than a thousand pounds per square inch.

The ABS VI system was an add-on, nonintegral system that used a conventional master cylinder and indeed, operated conventionally except in emergencies when pressure had to be reduced on wheels that were at incipient lockup. To accomplish this they sealed off the circuit that was locking and relaxed a piston in the circuit to release the wheel, and then re-activated the piston and brought pressure back up towards the system pressure. This resulted in a system that pumped no high pressure fluid and was therefore comparatively efficient, stored no high pressure hydraulic fluid, relied mostly on standard braking power indeed using power bakes in most but maybe not all standard applications (but might be used with manual brakes with adjustments, and especially with drum brakes) and was therefore much less expensive.

ABS VI was likely used on millions of GM cars in the 1990s, until it was succeeded by the more complex, high pressure design. Apparently, the higher pressure kinds were marginally more effective, perhaps more easily adapted to stability control (because it could apply as well as release braking), and certainly was much more expensive and profitable.

[9] Historically, an occupational hazard for Diesel engine mechanics has been a tendency to test the high pressure injectors by operating them and putting one's hand in front of them to "feel" the spray. Unfortunately, they were not at all unlike and operated at pressures much like those injectors used for mass inoculations of people against disease, having so small a jet that it passed right through the skin. In the case of Diesel mechanics they wound up injecting fuel oil into their blood stream with potential fatal consequences. At up to three thousand pounds per square inch, antilock bake fluid reservoirs pose a similar risk to any who might attempt to disassemble a pressurized system and whomsoever might spray brake fluid onto painted surfaces and *into* themselves.

HVAC Drill Down

Both heating and cooling are major issues for E-Cars, because both are real energy hogs. Joule (resistive/hot-wire) heaters are used in a lot of conversion EVs. Easy, and cheap but a bad solution. The writer has seen cases where up to three kilowatt electrical heaters are installed in converted cars. Bear in mind that there are 746 watts to a horsepower, so that a three kilowatt heater is consuming the equivalent of about four horsepower of battery capacity. In some cases the traction motor itself draws less.

Therefore, in slow traffic on a cold day Joule heating can drain a majority of the battery energy in no time. Similarly, cooling can also waste energy on a massive scale on a hot day in slow traffic. In ICE-Cars, gas mileage drops when air conditioning is used, but at least the massive heat rejection from the ICE provides plenty of rejected heat to warm the interior for “free” on a cold day.

In the EV1 (and perhaps now in the Leaf, and Volt), the HVAC function was performed by an electrically driven heat pump. Heat pumps are at least highly efficient in some scenarios. In a heat pump, mechanical energy is used to transfer heat from a lower temperature to a higher temperature and the mechanical parts generate frictional heat along the way. So for every unit of energy you send to the heat pump you push some quantity of heat from a low temperature to a higher temperature. If the scenario is optimum (if the difference in temperatures is small) the amount pumped can be several times greater than the amount of energy doing the pumping.

In cooling the interior of an E-Car, a heat pump will have the exact same behavior as an air conditioner (because it is operating the exact same way). When heating the interior of an E-Car, a heat pump will provide the heat energy withdrawn from the batteries plus a free multiple thereof. So the heat pump beats the Joule heater going away.

This can be a really great advantage in states that do not get severe temperatures. But if you are driving in zero-degree weather, it is so hard to push heat up to 70°F that the heat pump defaults to approximately the same efficiency as a Joule heater, and these are the conditions where the demand for energy is most extreme. Shnayerson [**8**] indicates the EV1 people considered the advantages of the heat pump pretty nonexistent below ambient temperatures of 30°F, perhaps another reason why the EV1 was designed for southern California and pretty much restricted to niche users who did not go great distances.

Minimizing HVAC Demands

Clearly, E-Cars are at a major disadvantage compared to ICE-Cars in the deep winter. And although both E-Cars and ICE-Cars face the same challenge in the peak of summer, the ICE-Car has way more energy stores available to do air conditioning chores. And in most cases the heating/cooling requirements for many a car can approach those for a whole normal house. Therefore, E-Cars, especially for some regions, should minimize the heating/ cooling demands of their vehicles. This might include:

- Minimizing the interior volume to heat/cool (choosing two seaters like a regular cab pickups rather than cavernous station wagons, SUVs and hatchbacks, or by closing off the rear vehicle areas, which would also isolate vapors from any batteries installed therein).

- Superior insulation, such as polyurethane foam on the inside of all exterior surfaces.
- Thermo-pane windows perhaps with low "e" glass and argon filling ala good-quality home windows. For side windows that open and close, the designs used on the Delorean and Subaru SVX (small operable window within a bigger fixed window) are desirable, with the fixed portion as thermo-pane.
- Ala Henry Ford, a smart E-Car will be painted any color as long as it is white to reduce radiation-absorption effects. Now one might argue that a black car would be preferred in winter, but, in general, warming solar radiation absorption in winter is of much less value than solar reflection is in summer. So, if form is to follow function, white is the engineering pick for most cases.

This insulation is needed not so much to save money but to preserve precious range.

Alternative Heating and Cooling

A preheated Cockroach EV with super-insulation may not require any further heating at all in the winter, because the driver and passengers provide body heat (horses help heat barns, don't they?). A well-insulated vehicle is like a parka. But in the summer that body heat must be rejected.

There are a couple tactics that are well founded and have been reported. When an E-Car is awaiting duty, one can, of course, use the grid to pre-warm/pre-cool the car interior (as the EV1 did [**8**]). One could similarly pre-warm the batteries (beneficial to provide full range in the winter, but also a thousand pounds of batteries are an excellent heat sink from which one might draw energy to warm the interior in winter).

However, one would probably not want to pre-cool the batteries in summer (though this may warrant study), but since a Cockroach is an E-Car of very limited range by definition, one might pre-warm or pre-cool/freeze a well-insulated reservoir of water (actually in summer a water/antifreeze mixture might be preferred to form a pump-able slurry of ice and liquid), from which cooling might be drawn as a range preservation device.

An EV with a one hundred mile "range", that is driven hard (say an average 60 mph cruise) might drain its battery pack in as little as a half hour, yet even driven very timidly (say a 30 mph average) will drain its battery pack in only 3 hours. Allowing for an additional hour to stand in traffic, a Cockroach EV might typically require a maximum of four hours of air conditioning.

If a Cockroach has been super-insulated so that instead of acting like a whole house, it requires the refrigeration of a small room, then even on a severe day, a 5000 BTU air conditioner would service its need. Operating continuously that would mean a range of refrigeration from 2500 BTU to a maximum of 20,000 BTU.

Water has a latent heat of fusion of about 80 calories (0.32 BTU) per gram, or 2.4 million calories (10,000 BTU) per cubic foot. Hence in addition to its lesser sensible heat, one could provide 20,000 BTU cooling from a ten-gallon (130 pound) mass of frozen water to an E-car interior before drawing energy from the batteries would be required. This amount of cooling might well allow for up to four hours of cooling with little loss to range (in case one gets stuck in traffic).

Indeed, the Internet contains reports from people who have installed crude picnic coolers that they fill with ice and then heat exchange against it to cool their E-Car interiors and there are some commercial devices that work similarly but are not cheap in the most favorable embodiments. It can be inexpensive but rather than manual addition of ice, one would prefer to install a small electric refrigeration unit akin to those in one to two cubic foot mini-freezers. These have been developed to a high state of reliability, having sealed compressors that often will last for decades (unlike current automotive air conditioner refrigerant compressors that often spring leaks at sliding seals. And they are inexpensive, often costing ten percent of what an automotive A/C system costs. And these systems can cool or heat the working fluid over night and so do not have to have the size and weight of central air conditioning.

Lighting Drill Down

There are dozens of lights in every car. Traditional incandescent lights are energy hogs, especially headlights. Luckily there are good alternative lighting options available for most of these in the form of light emitting diodes (LEDs) which use comparatively negligible amounts of energy yet also last far longer. Indeed, they last so long (tens of thousands of hours) as to be removed from the list of normal wear items that oftentimes justify periodic safety inspections. In fact, the way they are designed with multiple diodes (light sources) ganged to provide adequate light levels, even if one or two should fail, it is still no safety issue because of the redundancy.

LEDs have been expensive but their prices are coming down and because they impact range, as many lights in a Cockroach EV as possible, especially those used most often or having safety functions, should be converted to LEDs.

Motor Drill Down

Today most hobby conversion E-cars use direct current (DC) motors for cost reasons. Like the EV1, most cubic-money machines use alternating current (AC) motors.

- The DC motors are simpler and cheaper. They employ brushes that are wear items but numerous reports indicate they have modest cost and 80,000 mile life-spans that are plenty ample for cockroach service. They are apparently stunning in their performance at low speeds but run out of steam at highway speeds with many having top speeds below the legal speed limit.
- The AC motors are more powerful and simplify regenerative braking, but they are several-fold more expensive and much higher in voltage and have that additional safety risk.

For hobby conversions, the cost and complexity of alternating current motors is a big downside. However for newly manufactured E-Cars more study and analysis is needed on whether their additional cost is justified.

Nonetheless, the users of E-Cars with either DC or AC motors seem very happy with their performance, although they can be limited for driving up hills and often have limited top speeds. These are not grave shortcomings for Cockroach service or for parents who would prefer their children did not have the ability to venture upwards of 100 mph.

Regardless of how old and mature motor technology is, it seems there is still room for invention and innovation. Indeed, at present to this commentator, greater horsepower ratings and the use of expensive electronic controllers are both topics ripe for detailed study in a second volume of this book. But for now only superficial consideration is possible.

At present, motor efficiency needs improvement not merely as a means to increase range but as a means to increase peak continuous-service horsepower, therefore top speed, and hill climbing ability. Today, the careless application of too much throttle for too long (too much Kettering "Effect") can overload and damage the motor, the batteries and the controller. Whereas, ICE power plants are often either self limiting or relatively unlimited in their normal ability, current hobby E-Cars require their drivers to be ever vigilant to the possibility of overdoing occasional overloads. Hence, *practical* Cockroach E-Car motors may need intelligent monitoring of status and consequential control by a computer to prevent inadvertent abusive failures. Many current conversion E-Cars seem to be hovering on this edge of disaster.

Curiously, better performance from E-Car power-plants seems to hinge on better cooling. Further study for future publication suggests:

- Use the highest motor voltages possible for best efficiency, top speed and acceleration.
- Operate the motor at the highest speeds that do not exceed the best efficiency point.
- Optimize aerodynamics, and minimize weight and parasitic drains.
- Seek improved lead-acid battery designs and controller designs.

Hobby conversions seem adequate for many vigilant users and yet most do not appear to optimize any of these and that suggests there is still much promise for DC motors to realize even in newly manufactured Cockroaches to meet the goals of the Cockroach EV hypothesis.

Lead-Acid (or Other) Battery Drill Down

Batteries are where the rubber meets the road, so to speak. Battery shortcomings are the biggest single reason why there is no flood of new E-Cars hitting showroom floors, and why the current trickle has been limited even with incentives. Batteries tend to fall into one of two major categories. Those of low capacity and those that carry a God-awful price (and have a short history of use).

Common deep-draw lead acid batteries are much like starting batteries in ICE-Cars (but different in very important ways). They are relatively low in cost but for a car like the Ranger Cockroach, currently about twenty to thirty lead-acid batteries (weighing perhaps 1200-1800 pounds and costing about $3000-$5000) are used for conversion cars to drive 30-50 miles, or so, at a time and they yield only something like 600-800 full-charge cycles before they are ready to scrap. However much better lead acid batteries appear to be possible.

TABLE 1—*Battery performance comparison.*[a]

Parameter	Lead Acid	NiMH	Li –Ion
Specific energy - Wh/kg	30-50	60-120	150-190, 100-135,90-120
Energy density - Wh/Liter	100	300	230
Internal R - mΩ/cell	<17	<40-60	75-15, 25-75, 25-50
Cycle Life - 80% DoD	200-300	300-500	500-1k, 500-1k, 1k-2k
Fast Charge time	8-16 hr	204 hr	2-4, <1, <1 hr
Overcharge tolerance	High	Low	Low, no trickle

[a]Most data from Reference [**17**], page 37, Specific energy density data from www.allabout.batteries.com

The other most often cited batteries are the Nickel Metal Hydride (used in the final version of the EV1, the current Prius, and several other hybrids, and in some factory electric vehicles like the Ford factory Rangers made in 1997-2000), and finally the Lithium based batteries (which are in the Tesla, and most personal Computers and cell phones and the Leaf and Volt and the Ford Focus Electric).

Yes there are still others (sodium, zinc, etc.) and someday one may emerge a winner but for now there are only marginally adequate data available to cover only the leading candidates here.

Table 1 exhibits key properties of these three types based on internet data. Notice that lead-based batteries are up to four times heavier than nickel based batteries and up to a whopping six or seven times heavier than lithium based batteries. Lead is well known to be extremely dense, while the much less common lithium metal is so light that it would float on water. This is why there is so much interest in lithium batteries even though they are so expensive.

However, although the energy per pound of lithium batteries is spectacular compared to NiMH and LAB, notice that the energy per unit volume is much more comparable. A lithium car would seem to be limited to a range of only up to about four times that of a LAB car, but would be lighter. However, there are efforts to extend the range of lithium cars (Toyota boasting of breakthroughs[10] as much as anyone). But then, as this writer suspects, there may also be ways to increase LAB or NiMH capacity also (see Appendix A).

In this humble opinion, battery discussions in the literature are wanting. Efforts to simplify often convey a less than precise, or at least convoluted, description of how they work. Indeed, the writer finds that older textbooks [**11-15**] are more rewarding to read than newer texts [**16-18**], and if you want to understand battery operation, I suggest reading the

[10] For years, Toyota has publicized breakthroughs: a many fold increases in Lithium battery energy capacity while using NiMH in their hybrid cars. News releases today (2013) talk of magnesium and sodium as well as lithium batteries with ranges over 600 miles. Only time will tell if they can pull any of these off.

older texts, Vinal [**14**] from 1955 is particularly good, but even the oldest that were written when batteries were first being invented and developed are excellent. They are still remarkably valid and much less obscure in their writing. I recommend those from the 1910-1930 era [**11,12,15**]. And those books are much less expensive since some have run out of copyright and are being reprinted as public-domain print-on-demand texts. They often contain simpler explanations and often contain gems of wisdom not disputed in current literature (because they are not mentioned or perhaps one should wonder if they are censored) and if they are true, they suggest the LAB may even have a bright future—if they can only be exploited more effectively. Back then LABs were cutting edge and expensive. Batteries were serviceable items. If a plate failed, the battery was opened and a new plate was installed, and so there was more incentive to understand their workings.

Old is not necessarily bad. Not old cars. Not old books. Not old technology. Not old batteries. Not even old people. But old may need some accommodation that it may not always get. This writing seeks to champion old stuff, especially including old batteries, in many ways.

The Problems With Nickel (NiMH)

The writer rejects NiMH. They have a good cycle life and a better range than current Lead acid, but they fail the critical cost test. They contain nickel, an extremely useful and therefore valuable metal. In WWII, there was a period in which the nickel coins, called nickels, because they were made of nickel, were made of a silver alloy, so that the nickel reserves could be used for strategic military purpose. Today silver is more valuable than nickel by far but nickel is still very expensive for battery use. Nickel is widely used in some stainless steels, and in fire-resistant metals and has great magnetic properties. It has been chasing the costs of many industrial hardware items up forever. Nickel batteries would doubtless be the most expensive component in an E-Car and are therefore well worth stealing (remember when early catalytic converters were being stolen because of the platinum and palladium in them) and the chances of NiMH battery packs coming down in cost as demand goes up is highly unlikely. If demand went way up, the supply of nickel might be strained and the battery cost might go from five or ten thousand dollars to ten or twenty thousand dollars. They also have been around for a fairly brief time, their long term service and recyclability may yet yield surprises.

The Problems With Lithium

The writer rejects lithium. Lithium is the current top choice in many cognoscente quarters. It is in the Leaf and Volt and Tesla and personal computer batteries and cell phones. Lithium based batteries come in a wide range of variations. But like nickel, lithium has even greater cubic costs. It is even more worth stealing than nickel. Will you come out of work to find someone has stolen your battery pack? Like nickel, lithium is very useful and can also be used to reduce the density of aluminum for aircraft structures. It appears to lessen the flammability in alloy with aluminum for use in some oxidant systems. But lithium is also scarce at present, the reason it is so expensive. As with nickel and even more so today, the lithium battery pack will be not only the most expensive component in an E-Car (even as the engine or paint job have been the most expensive components of a ICE-Car in the past), it may actually be a *majority* of the cost of an E-Car. Some lithium packs today cost more than some entire ICE-Cars and more than several ICE cars in some cases.

Can available lithium supplies in only a few countries meet the potential need? And can lithium avoid therefore becoming a strategic material? Will we someday be fighting wars over lithium the way we fight them now over petroleum?

But some present lithium batteries in common systems, like my cell phone, lose capacity at a high rate whether they are used a little or a lot or not at all. I know that each year I have to recharge my cell phone more often whether I have used it or not. I know some who bought PCs with eight hour runtime, only to find the run time per charge was down to four hours after a year and dropping fast.

And lithium batteries in PCs have at times exhibited a fire risk. With their light weight, there is much less heat capacity to absorb the energy in a LiOH battery should it short-circuit than is present in a lead-acid battery. In comparison the LAB has much more heat capacity thanks to that greater weight of the lead. A hundred and fifty years of widespread experience says we know a lot more about lead-acid batteries.

But the biggest question mark to the writer is not about fire threats but about explosion prospects. A two-hundred-mile capacity Lithium battery pack is comparable to the range one would get from a ten gallon gas tank in a 20 mpg car. Now some say batteries are 90% efficiency compared to maybe 30% for gasoline in ICE cars, so the bulk energy in a lithium pack would be comparable to maybe three gallons of gas. If all that energy could be released quickly it would be equivalent to the energy release in several pounds of TNT. What happens if the pack is crushed in an impact, to yield a massive short circuit? Would it "go critical" and yield a near instantaneous discharge? Do the two reactants quickly combine upon mixture? And if some can explode, can any resulting shock wave trigger a reaction of a whole pack. I have never read whether any of the lithium candidates have been drop weight tested in a system such as the Army Ballistic Missile Agency (ABMA) drop weight apparatuses. These testers are in common use within NASA (which has probably drop weight tested lithium with liquid oxygen, but what about actual lithium batteries) and at many air separation research facilities and explosives testing facilities and at Charpy-metal-test facilities. If lithium cells can detonate, sooner or later there will be such an event along with real bad publicity for every E-Car. Programs like *60 Minutes* would have a field day.

One would hope process hazard reviews have examined these risks thoroughly and mitigated or safe-guarded them. But if they have been accepted on the basis of a low FAR (fatal accident rate) or consequence, one would hope that possibility would be publicized so there is no panic when the rare and accepted events occur.

The world would have been better off if our leaders had the uncommon sense to realize before (and even after) September eleven, that bad things are predictable, can happen and should have been expected and dealt with without resorting to a multi-trillion dollar war. We should not be surprised if someday there is a dramatic lithium E-Car event but news organizations often censor, marginalize and exclude important *a-priori* information from us.

However, even the best process hazard reviews can be flawed, especially when dealing with new technology, and the bottom line is: neither lithium nor Nickel-Metal Hydride enjoy the hundred and fifty years of successful service like lead acid. LABs have been involved in thousands of collisions when installed right behind the front bumpers, and so we can rule out bad events upon impact, but we are not in the same boat with regard to lithium, NiMH and all the remaining battery chemistries.

Furthermore, lithium has become political. Our government has bet on lithium by investing massive amounts of money to make the U.S.A. the world leader in lithium battery production (unlikely as that is unless we control the lithium supply). Just as climate change has become political with both opponents and proponents locked in and willing to ignore data in order to save face, if lithium batteries were to become uncompetitive in comparison to say lead batteries, do not be surprised if suddenly politicians and capitalists do not abruptly seek to discredit the competition for political reasons. Suddenly we might see a great hypocritical concern well up in them for the toxicity of lead in batteries and otherwise discredited agencies such as the EPA might be called upon to outlaw the LAB, *for the good and safety of the people*. That is how JDR would compete. So be prepared.

The Promise and Problems of Antiquated Lead Acid Batteries

The writer is inclined to support Lead Acid Batteries (LABs) for any Cockroach EV conversion and for new production for a number of reasons:

- Common LABs have established a long safety record and may even have inherent safety against large-scale fire and explosion and are therefore well-known safe quantities so long as you do not eat them.
- Common LABs can hold charges well if done well, without extreme degradation of capacity, like for even up to a year or more. Honest! Appendix A is much more specific.
- LABs have a massive infrastructure for production and recycling.
- LABs are comparatively inexpensive, therefore affordable in the truest sense that the Model T was affordable [see earlier footnote 7].
- Public-domain technology appears to be available to produce high-performance LABs that can provide high reliability, low deterioration rates, long cycle life, low maintenance, and even increased capacity.

The last point is important. Whereas there are a number of LAB conversion cars and NEVs in use, current commercial LABs serve only marginally well for all of these services. With even just a little improvement, all of these would be much more desirable, more competitive, options. And yet a quantum leap in improvement may be possible.

Today there is an inter-industry group, the Advanced Lead Acid Battery Consortium working to upgrade these *old but not yet obsolete* devices. And they are claiming some interesting progress, but they work under a curious antitrust exception that may hinder their ability to pursue some developments and to reduce them to practice. And their efforts are apparently not common knowledge and so can not be examined here.

Table 2 lists currently accepted (at least in some quarters) properties of one commercial LAB of the flooded acid type (the cheapest kind commonly available today but with best capacity, though shortest life and most maintenance) versus one commercial latest-and-greatest AGM VRLA battery (much more expensive, less capacity, less maintenance, and longer life). However, this analysis still believes the original flooded acid type (for its crucial greater capacity and lower price) is still the best option, especially if upgraded. And this

TABLE 2—*Flooded Acid Versus Absorptive Glass Mat (AGM) Batteries.*

Parameter	Flooded Acid –12v	AGM-12v
Weight – lbs	61	60
Price $	~$165-200	~250
C-20 Capacity—Amp Hr	115	66
Cold Cranking Amps	Not Rated	1025
Size—in. LxWxH	13x7x10	12x7x9

analysis suggests it can be upgraded through fairly routine redesign. Appendix A goes into more detail than you may want in defending and explaining this surmise. However if valid, it points the way to potentially very *practical* lead acid battery options for Cockroach service that may yield two to three times more *in-situ* range, and life.

However always keep in mind that LABs are cheap and that by itself massively undercuts the incentive to improve them and creates an incentive to push the higher-priced alternatives. As reviewed earlier, GM would always rather sell you a Cadillac rather than a Chevy. If there is any way to cajole, induce, persuade, coddle the customer to pay the premium prices for NiMH or Li-options, the disciples of corrupt forms of crony capitalism will pursue it. But customers should not be cornered into going along.

The writer believes there is much value to hope for in LAB devices. Indeed, even with their weight penalty (but perhaps a much smaller penalty than is currently claimed) the LAB may be the overall best performer for Cockroach service notwithstanding cost. As a result, Appendix A presents a fairly detailed rather technical examination of LABs. It seeks to provide a more detailed, more accurate, more rigorous, and hopefully simpler, description than is found in the consumer press. It covers the operation of LABS, their key failure mechanisms, and speculation on apparently commercially untapped technology that is described in patents that have expired (meaning they can be deployed without license fees). It examines battery designs that flow from a clear analysis of the failure modes, Finally, similar progress that might come from this more detailed model analysis is examined (such revelation is intended to create a statutory bar against further patents and make sure a greedy capitalist does not attempt to monopolize such progress in a desire to *prevent* its use.).

As a result, the writer believes E-Cars are currently possible with much better LAB performance than is now being achieved. To wit, LABs may be possible to design with significantly:

- greater "apparent" capacity (up to several times the apparent capacity per volume and per pound *in the most demanding services*)
- greater numbers of deep-discharge life cycles (up to 2000 and maybe far beyond) and term life beyond ten years, maybe to twenty years.
- better cold weather adaptability (more low temperature current, less

freezing risk)

- less loss in performance per cycle and per year (less shedding and unhealthy sulfation) and far less loss of capacity during heavy discharge.
- Greatly reduced or eliminated maintenance needs

In other words, upgraded LAB batteries may be near-ideal for Cockroach service. Of course, who would spend funds to develop a better alternative that is cheaper and has smaller profit margins. So even if this surmise is valid, there is no incentive at present to pursue it. But if these surmises and a new commercial LAB can be realized, it can serve the old-tech, low- tech Cockroach EV and its old-tech, low-tech users extremely well.

In case some of the technology explored in these approaches are novel or unanticipated, be reminded again that publication establishes a statutory bar against their being patented later. This does not mean that related or supporting patents are not possible that would enable the old guard to maintain dominance in the market or might make exploitation difficult, just that they can not monopolize the market as a way to force customers upscale.

Regenerative Braking Drill Down

Regenerative braking is the use of an energy recovery means to slow a car in a fashion in which the energy recovered is stored or used to either re-propel the car or substitute for other energy support needs (radio, HVAC, etc.). In theory, a good regen braking system will help an ICE-Car to improve range more when driven in the city (where air drag losses are low and braking losses are high) than when it is driven on the highway. One of the recent Prius hybrids had a 50 mpg city rating exceeding its 45 mpg highway rating when for most cars, the city rating might be as low as half the highway rating. Was regen the entire reason?

Those Prii have a NiMH battery pack and although it is too small to save much money by charging it off the grid and using that base charge for the first four miles driven, it is large enough to store the energy recovered when the Prius is slowed from highway speed. Then when the Prius accelerates, it can use the recovered energy to help return to highway speed. However, regen energy is *not* the principal reason for the Prius city performance. Since city driving tends to be at lower average speeds, aerodynamic drag losses are much less, but engine efficiency can also be much much (yes, $much^2$, much squared) less due to greatly increased engine pumping losses. The Prius has a lot of attention paid to improving its engine's city efficiency (with use of an Atkinson cycle and more nearly optimum operating speeds), and has a rather low coefficient of drag, and its city mileage is so impressive because the reduction in drag *plus* the regen energy can exceed the much smaller than usual decrease in engine efficiency to yield the overall benefit.

Therefore, although the benefits of regen braking may seem miraculous, that benefit is largely illusory. There is a real, and significant, benefit but experience and physics both argue it is much smaller than might seem the case, and not too economic, and the benefits of regen for a Cockroach EV are still smaller.

Regen braking obtains in two ways. One is to recover kinetic energy when the car is brought to a stop, and the other is to recover gravitational energy when the car coasts down hills. The two have significant differences.

When recovering kinetic energy, the brake (frictional) horsepower that can be developed is substantial. Some cars can brake from 60 mph in as little as about 100 feet. For a 3000 pound vehicle this equates to an average brake horsepower approaching 300 hp or way in excess of an EVs traction motor's continuous rating. Furthermore, you would not want to recharge a battery at this rate. However when coasting down hills, especially in an EV that coasts well, one can siphon off any energy above that required to maintain speed. Hence a much more tolerable several horsepower can be recovered.

Electric Regen

An electric car driven from batteries, in principle merely has to reverse the operation of the traction motor and operate it as a generator or alternator. It will then charge the battery as it drags the car towards a stop. However, every time the brakes are applied the recharge cycle consumes part of the battery cycle life (and in some E-Cars, anytime the motor is backed off, the regen braking starts and can also be disconcerting). Hence, a Prius may produce hundreds of small charge/discharge cycles on the batteries every time it is driven. These small cycles are less damaging than full charge and discharge cycles, but their accumulative effect nonetheless amounts to wear and tear on the batteries which are often the weakest link in the system especially in a lead-acid powered Cockroach (the reason the Prius uses a NiMH battery for its excellent cycle life).

Nonetheless battery/motor based regen braking is quite inefficient. Compressed gas regen braking is another option but has it issues as well. A significant loss occurs when converting the kinetic energy into electrical energy and a significant portion of that is lost in recharging the battery, a significant portion of the recharged energy is lost in converting the charge back into current to the motor, and a final slug is lost in the efficiency of the motor. This compounding of efficiencies takes its toll. Table 3 provides a rough accounting suggested by member D. J. Becker in the regenerative braking forum at Do It Yourself Electric Cars (www.diyelectriccar.com). Becker takes a slug of kinetic energy for one round-trip circuit of regeneration and estimates a maximum of only about 33% recovery which predicts perhaps no more than a 31% or less gain in range. These estimates may be flawed, however, since other factors can reduce even this estimate significantly.

However, although full-regen kinetic energy braking is a hassle to implement that could overstress the circuitry and add to battery wear in a Cockroach, it is apparently fairly easy to implement a partial regen system with a standard alternator driven by the traction motor of an EV or even more easily with common alternators. Common alternators can generate more than one hundred amperes in a twelve volt system would therefore be rated at slightly more than two horsepower, and to connect one to charge an accessories battery whenever the accelerator is lifted or the brake is applied is easy. This could provide free power for electric steering, HVAC, radio and lighting supplementation. BMW does something like this now[11] in their 3-Series by careful control of when the alternator operates and they claim up to a 3% improvement in mpg. It would require an accessories battery that

[11]BMW apparently uses an AGM lead acid battery for starting because of its charge cycle ratings and controls the alternator so that it only charges on braking, coasting (including down hills) and when the battery gets too low. This frees a few horsepower for traction use, while providing "free" energy to run numerous electrical devices: lighting, electric power steering, computer, navigation, high power audio systems and other things.

TABLE 3—*Energy accounting for typical regenerative braking cycle.*

Step	Efficiency	Energy
Initial slug of kinetic energy in the vehicle	-	100 units
Energy converted to electrical current	.85	85 units
Energy conveyed to the battery by the controller	.85	72 units
Energy converted to chemical energy in the battery	.70	50 units
Chemical energy from battery back to controller	.85	43 units
Electric energy from controller back to motor	.85	37 units
Mechanical energy from motor to car	.90	33 units
Range benefit of regen braking of kinetic energy		31%

The benefit would accrue only when the vehicle is accelerated to a low speed for which aero drag is negligible then driven only a short distance so that rolling friction was minimal also. Based on accelerating to 30 mph for a one/eighth mile city block, consuming $0.5mV^2$, or nearly 10^6 ft-lb, neglecting aero drag, and overcoming 70 pounds rolling friction force [**1**] times 660 feet of travel, for 46,200 ft-lb of energy consumed, at the end of which a stop and start recovers about 31% of the kinetic energy yields a best case energy (range) extension of 31%. At higher speed, the recovery would be less because aero drag would increase and efficiencies might decrease.

could accommodate partial discharge conditions and frequent charge cycles (BMW uses an AGM, but a gelled electrolyte lead acid, NIMH or Lithium are alternatives). However since an EV no longer requires high ICE engine starting draws many options are possible, including use of a deep-cycle battery. And it would be especially cost-effective in hobby conversion EVs which already have an alternator on the engine that is being removed that can be used rather than to buy expensive DC-DC converters to charge the accessories battery from the traction pack.

Compressed Gases Regen

However there are other alternatives for regen storage of braking energy. A reversible compressor/expander could be used to recover braking energy by compressing air or an alternative compressible working fluid into a pressure vessel and expanding it during acceleration. And in this case, the energy would be stored as compressed (or perhaps liquefied) fluid. This approach has some advantages over batteries. Pressure vessels and most gaseous fluids do not experience cycle wear like batteries do. You can compress and expand gases millions of times with no deterioration.

Indeed, there are compressed-air powered cars out there that can have appreciable ranges [12] but as with lead-acid battery power, they have a problem with weight. In order to incorporate a significant stored energy, high-pressure cylinders are needed and with today's technology this means thick-wall heavy steel vessels.

However, just as regen braking is desirable on E-cars where the vehicle already has batteries and motors/generators for storage, most cars can already accommodate the storage of a small amount of compressed fluid. Existing structural frame members can be boxed and sealed and are sturdy enough to store small but appreciable amounts of a significantly compressed gas. However, compressor/expanders for more than a few horsepower could prove too large and expensive to be efficient for a Cockroach. If you wish to save braking energy at ten horsepower, you may need a ten horsepower compressor.

Nonetheless, just as charging and discharging is not perfectly efficient, compression of working fluids also can tend to yield losses as adiabatic (isentropic) compression produces hot gases which can cool to lose some of their internal energy and then return much less energy when expanded than was required to compress them. The mathematics of this process is somewhat technical and so is relegated to future effort if at all.

Note that in order to store a lot of energy (and the energy to accelerate a 4000 pound vehicle to 60 mph is a lot), one must store the gas at highest pressure. And although air is a desirable and conveniently available gas, it can pose a safety (fire and explosion) risk. Air compressors that operate at pressures up to about a hundred (perhaps two hundred) pounds per square inch or so, have an enviable safety record, but at pressures above this level, they experience increased oxidant fire risks. Higher-pressure compressed-air systems that have not been kept scrupulously clean, or that have employed less than the most fire-resistant materials, and that perhaps have not been saturated with humidity[13], have on occasion experienced devastating explosions and fires as the contaminants and incompatible materials have ignited. As a result, compression and storage of alternative gases for regen use might be needed .

Nonetheless, to the extent that geometric structures on the existing vehicle can be adapted to provide pressure storage, fluid expansion and compression may provide a relatively simple and inexpensive form of regen braking, however, the benefits of even the best designs are likely to be small at best and unlikely to benefit a Cockroach EV.

Aerodynamic Drag Drill Down

Aerodynamic drag is a resultant differential force that air exerts on a vehicle that resist its motion and that must be overcome with a opposing force from the engine in an ICE-Car or the motor in an E-Car. At high yet legal speed limits, the force in current cars can range up to more than one-hundred pounds and far higher at speeds above the limits. In any car, the aero force can be *the* major consumer of energy especially on the highway, espe-

[12] Compressed gas cars have their own issues of range, performance and safety.

[13] Upon compression, humidity in air tends to condense on all surfaces and to provide a nonflammable heat absorbing mist that tends to prevent localized temperature increases that might serve as ignition energy and ignition temperature to any flammable contaminants present. This effect or a related diluent effect *may* (or may not) explain why lower pressure air compressors have better safety records. However, in cold dry winters and in dry desserts this effect is reduced.

cially at high speeds.

Leitman and Brant [**1**] indicate that on level roads, the typical aero force is half the force resisting motion at about 40 mph (literally without aero-drag an EV's range at 40 mph would double) and that by 70 mph the aero force becomes 70% of the force (literally without aero-drag, an EV's range at 70 mph would more than triple). Furthermore, at 70 mph, the battery and motor efficiency can fall off so much that the 10-20 mph range of an EV can be more than ten times less at 70 mph. A major fraction of the gasoline we burn, the money we spend on gas, goes to heating and pushing air out our way and driving away from it. Therefore any improvement, even a small improvement in aerodynamics (or high-speed battery and motor efficiency) can have a significant effect on the economics and high-speed range of a Cockroach EV. And since there is a real need in many cases to drive at speeds up to at least 60-70 mph, with current aero-drag strategies, electric vehicles are severely handicapped from being truly competitive, even in many Cockroach applications. Therefore the Cockroach EV needs to exploit every *practical* aerodynamic benefit possible, and this produces a motivation to examine every prospect even those with low probability of success and even the desperate wild speculation here. *Caveat emptor*.

Designs to improve aerodynamics of current cars have resulted at times in some bizarre looking cars. Hence, even exotic aero tactics are worth contemplating and suggesting here. Furthermore, a general overview of some aero theories will be given in this section and the more exotic and bizarre speculation will be detailed in Appendix B. This will simplify several issues with less advanced math. Appendix B will explore related issues in new ways and from perspectives not commonly used in textbooks, and therefore Appendix B is at risk of being flawed or politically and even scientifically incorrect. In other words, Appendix B will ask proverbially "stupid questions".

Aero tactics are difficult to analyze and understand and test (a major reason why aero design in the past has seldom been attempted without wind tunnel verification) and therefore some of the suggestions in this text may not only be flawed, they may be just plain wrong in whole or part. However, because they do not appear to be addressed (ruled in or ruled out) in any other resources consulted that are common to the E-Car crowd, they are most appropriate to broach in this particular effort to get on to the record even at the risk of being in error. My apologies for any that prove to be embarrassingly wrong.

Aero drag losses are in many ways complementary to braking friction loses. If braking friction losses are mitigated (such as with regen braking), then city mileage would leap up and perhaps surpass highway mileage, because city mileage is at low speeds where there is less aero drag loss. If aero drag could be mitigated at higher speeds, then embarrassingly low highway range would perhaps leap up to approach, perhaps match or even surpass normal city mileages (but that is not too likely), because normal city driving has more braking friction losses. Hence, since a third major loss factor, rolling friction, is said to be fairly constant with speed, if braking friction and aero drag could both be mitigated, one would have an E-Car that provided more nearly similar range regardless of how it was driven, and a lot of toxic uncertainty and driver range consciousness and anxiety would be alleviated.

Aero drag is treated theoretically as a differential (resultant) force that holds a vehicle back where the magnitude of the force, F, is proportional to the drag coefficient for the car, C_d, multiplied by the superficial, cross-sectional area, A, of the car and the square of the velocity, v. Hence, $F = C_d \times A \times v^2$. This much is covered in detail in Leitman and Brandt [**1**] and many other texts.

Therefore to date, efforts at aero drag mitigation have focused on the three terms of this equation:

- Reduce A by reducing the car's average height and/or average width (except that today cars are being made wider to try to improve side impact safety).
- Reduce v (drive slower).
- Reduce C_d by "streamlining" the shape of the car.

Reducing A. Reduction of height and width are exemplified in the GM EV1 E-Car which was extremely low and narrow and teardrop shaped. Trading width for increased length to reduce A is also an effective strategy. Trains benefit greatly from length because they only have to push the air aside once and the more cars that pass through that one hole the better the efficiency, and trains achieve some truly incredible energy efficiencies (CSX advertises 423 ton-miles per gallon compared to perhaps only a measly 75 ton-miles per gallon for a Prius at its very best). A VW concept car, the "1-liter-car" (rumored to be scheduled for production), illustrated this by placing its driver and one passenger in a row rather then side by side and with a tiny one-liter Diesel engine achieved more than 90 ton-miles per gallon (equivalent to nearly 300 mpg for its 740 pound weight). This allows for a large reduction in drag due to decreased cross-section but also allows for a more tapered (more streamlined) tail, both of which benefit drag reduction.

But this approach suffers. For one, today there is that previously cited incentive to make cars wider to improve side impact risks. Second, the Cockroach EV proposed here is primarily targeted for retiree use. The overwhelming fraction of niche retirees are older and exhibit, or will sooner or later exhibit, varying degree of lower back-pain problems, as well as knee and hip and other skeleton problems, and their ability to enter and exit super low, cramped vehicles like the EV1, 1-liter car, or similar sports cars would be an instant deal breaker.

Reducing v. Driving slowly is a proven method to improve the energy mileage of all machines. Here again it flies in the face of human nature. Nonetheless, many E-cars are driven slowly by highly devoted E-Car enthusiasts in order to extend their ranges to minimally acceptable levels, and indeed, many are designed with very low top speeds that both extend range and keep vehicle capital costs low. But whereas, the extreme responsiveness of EVs at the lowest speeds appears to win much envy, their sluggishness at highway speeds would be a more than an offsetting turn off to many (dare I say nearly all) drivers.

Reducing C_d. Streamlining typically involves rounding or pointing the front of cars to reduce the C_d factor in the differential force equation, avoiding any raised or blunt edges or surfaces, and often using "fastback" tapered or chopped-off Kamm-back rear shapes to reduce the other differential force term. With humblest apologies to fluid mechanics, everywhere, Figure 1 illustrates the differential nature of vehicle aerodynamics. A vehicle as in part A at rest is pressed on its front and its back equally by atmospheric pressure. The average force on the front cancels exactly the average force on the rear. In part B the vehicle has been very abruptly (near instantaneously) moved forward faster than the air can follow (meaning faster than the speed of sound). Since the air could not move of its own accord in this hypothetical example, the air that was in front of the car has been shown crammed into

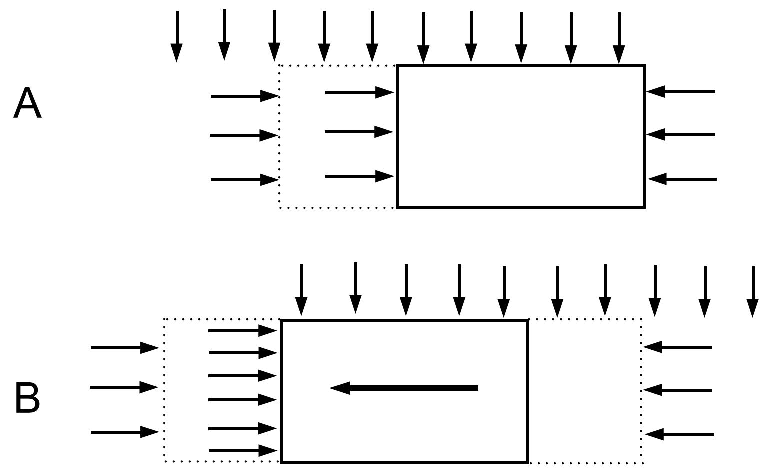

Figure 1—*Differential forces that produce aero drag.*

the air further to the front (left dotted region) compressing it in an arbitrary fashion and increasing the pressure above that of the atmosphere, and this creates an increased force towards the rear. Similarly, since the air behind the vehicle could not move, the vehicle has left it behind and opened a gap between it and the atmosphere (right dotted region), in which there is no air and hence the force of the atmosphere on the rear of the car has been decreased to zero. The difference between these two forces, the differential force, is the aerodynamic drag for this extreme and very approximate example.

When a car is moving at normal speeds, it does not approach the speed of sound and so as the front of the car pushes on the air, the air can move (can be pushed) away but it requires a slight increase in the pressure on the front of the car to do that. And similarly, air behind the vehicle can move fast enough to remain in contact with the car but it must also experience a force to do this and therefore it can not push quite as hard on the rear of the vehicle as it had before. This second effect is often discussed and analyzed as a vacuum which "pulls backwards" but air can not "pull" and so it is actually just a reduction of push (from slightly reduced rear pressure) rather than an actual "pull". In reality, the pressure on the front does not nearly double as in the hypothetical example and the force on the rear does not drop nearly to zero. Indeed, the pressure changes are very small, but they press on such a large area that the resultant differential force of up to several hundred pounds or more can obtain. Indeed, a hundred pounds of net resistant force (aero drag) spread over 20 square feet (about 3,000 square inches) is a differential pressure of only 0.03 pounds per square inch.

Like this one, many of the analyses that apply to aero effects are counterintuitive. If one takes steps to reduce the frontal force, they can wind up increasing the rear force *reduction* and in so doing, net drag can *increase*. In crude (but hopefully valid) intuitive experiments for this text, efforts to reduce C_d most often wound up increasing it.

Today most cars have C_ds in the range of 0.25 (for example, the Prius) to 0.7 (for example, the Hummer). Mercedes personnel [14] are quoted on the internet as saying that with the

[14] Daimler head of aerodynamics, Dr. Teddy Woll, as quoted in an interview at www.atzonline.com.

important contribution that tire cross-section makes to the mix, that a C_d of 0.2 may be a symbolic "sound barrier", a threshold below which it may be impossible to go in any *practical* vehicle. And to date only the extreme full-size vehicles such as the EV1 (C_d = 0.19) and the Aptera shaped like a airplane with wheels (like those on some small airplanes) in three pods (C_d = 0.16), and the exotic cars like the Ford Probe V (C_d = 0.137) [**19**] have broken that "barrier".

Nonetheless, this writer wants to question whether significant and maybe even substantial further reductions may be possible in C_d, especially in less aerodynamic traditionally shaped vehicles (Cockroaches) that are easier to get into and out of, by changing tactics and instead of trying to drive (to bull or slice or sneak our way) through the air, by instead trying to drive "around" it instead. By trying to be transparent to it and by then trying to recover some of the expended energy from that portion thrust aside. Perhaps punching holes through the vehicle and allowing the air to simply pass through the EV would help. This tenuous concept will be treated rather coarsely here and a little more carefully in Appendix B though almost certainly with much less precision and rigor than an engineer competent in fluid mechanics (and the writer knows a few of those) would wish.

However, crude (therefore potentially wrong) experimental work this writer has done, to date, if not too flawed, may, indeed, suggest that compact cars and even larger cars may just be able to either break the 0.2 C_d barrier by maybe even a significant amount, or that larger cars, especially Cockroaches, not previously considered aerodynamic might be able to fare much better than they have to date. As promised, this approach involves driving around the air, being transparent to it, and is based on the speculative (therefore risky and potentially totally wrong) suggestion cited above: being transparent by reducing the car's cross section (however, reducing its *subficial* rather than superficial cross section) through the use of holes that pass through the vehicle.

Recapturing energy. Since we apparently must expend energy pushing air out of the way, transferring that energy to the air, then we should also consider the ways to recapture that energy expended in creating this artificial "wind". Our present President (2012) likes windmills a whole lot and has spent lots of the writer's money to promote their use, and indeed active energy recovery might be a possibility worth considering (as energy loss reduction tactics rather than as perpetual motion machines which they definitely are *not*), but their chances of success are merest speculation here and, besides, passive devices are of greater interest for now.

With further apologies to fluid mechanics, Figure 2 exhibits an extreme view, but less extreme view than Figure 1, of how a moving body affects air. The increase of pressure in front of the body produces upward flow to displace the air. To lift it over the car. The faster the body is moving the greater the pressure developed (assuming the angle of the nose is not at or beyond a critical angle), then the faster the air is thrown upward. In this figure, the moving air has acquired kinetic energy and is acting to push on the atmosphere above it. It is locally compressing the atmosphere much like it were a spring. The faster the body moves, the faster the air is slung, the more local atmospheric compression occurs. After the body passes under, the upward push is eliminated and the atmosphere will overcome the deflected energy and push the air back down. If the (fast-backed) slope of the car is just right the air might be able to continue to push down on it and squeeze the car forward recovering a

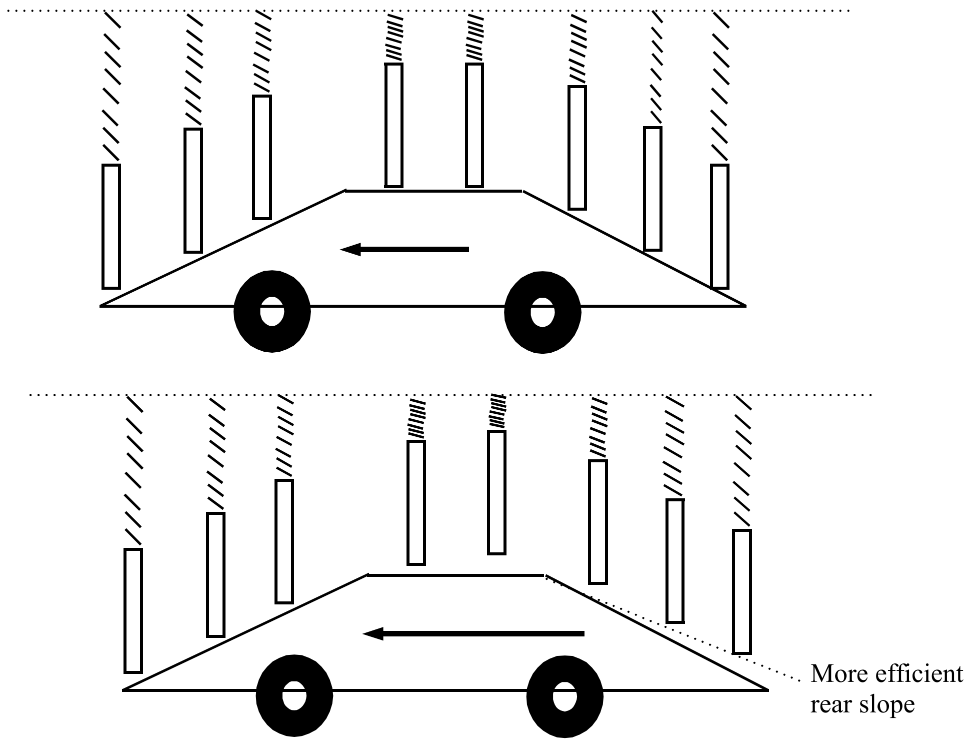

Figure 2—*Atmospheric compression and recovery.*

portion of the deflection energy. A greater slope will allow a greater fraction of the returning energy to be recovered, but if the slope is too great the air may not return quickly enough to push at all (and this is called "boundary layer separation"). However, in even the most optimistic cases, the tunnel of air that the car has bullied aside will come to rest after having been displaced some distance forward and therefore will have represented at least some resistance.

Nonetheless, one can think of the front of the car as a crude machine that introduces both pressure/volume (PV) energy as well as kinetic energy into the deflected stream, and if the upward flowing air stream can be deflected around the car, then perhaps the energy recovery ability of that fast back might be realized. In other words, the car expends energy to push the air upwards and sideways, and if that air is directed to a surface of just the right angle then it can recover some of that energy to propel the car forward the same as might happen in a rocket engine in which the burning gases are directed into a very carefully shaped diverging nozzle to help push the rocket upward. This is not at all unlike the concept of regenerative braking. Stored energy is expended to produce kinetic energy which is then recovered and converted, at least partially, back into stored energy.

Ideally in a theoretical sense, Figure 2 exhibits a highly efficient model. The oddly shaped wedge car deflects a section of air upwards, drives under it and then backfills in the air behind the car with the same air that was there originally. Alas!, if the air comes back down at a different location, either further forward or further rearward, this represents a net displacement, net work, and a loss of efficiency. In other words, if the car is going too fast, or if the air is too slow coming back down, then it will not push the car forward, and as the

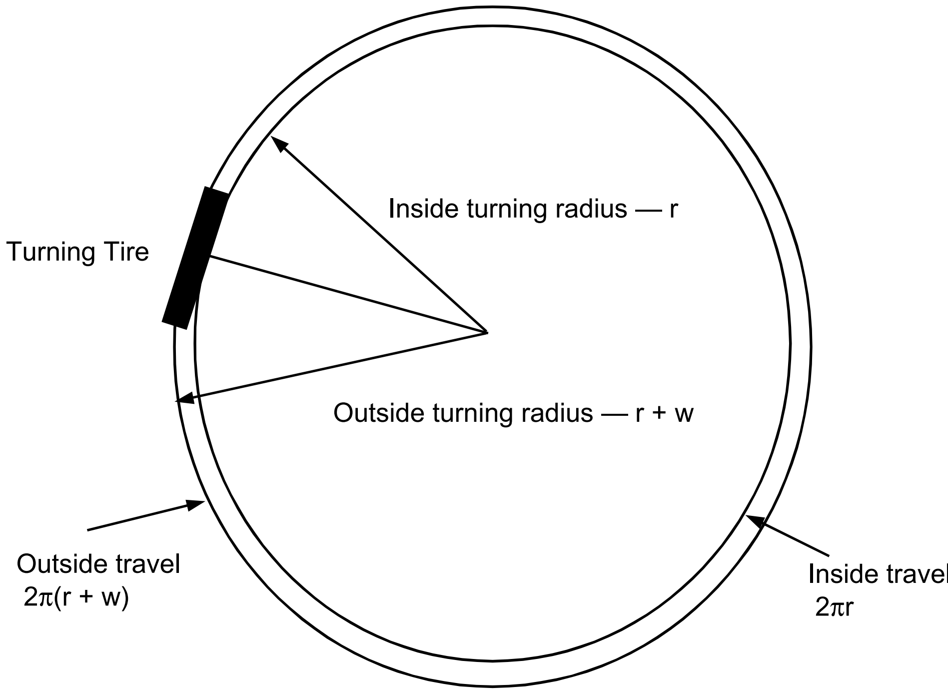

Figure 3—*Tire turning friction.*

lower portion of Figure 2 indicates a "faster" fast back (more gradual taper) is needed. Hence such energy recovery must be tuned to a specific set of conditions.

Some of these perspectives may prove wrong, but are worth considering. Apologies if along the way they wrongfully mislead any readers who may have some of the writer's same gullibility. However, if they are validated, the value is significant, even if the resulting devices wind up being manufactured in China.

Rolling Friction

Rolling friction is often relegated to a secondary importance. At high speeds it is much less than aero drag losses. Nonetheless, at low speeds it can sometimes dominate range far more than braking friction losses.

Friction results from rubbing throughout the drive train, but a very important rubbing take place in the tires. For example Figure 3 shows one type of tire friction as a car makes a tight turn. Notice that as a tire makes one full circle of travel the outside edge of the tire travels $2\pi(r + w) - 2\pi r = 2\pi w$ farther than the inside edge. So anytime a tire is turning it is dragging (scuffing) itself on its edges, and the drag will be less for narrow tires.

So, yes, to reduce tire friction, it is worthwhile and significant to use the most modern, *narrowest* tires, to keep tires pressurized to the maximum allowed level, and to align your tires carefully. However the general impression is that it will not make a major difference to the range of a current E-Car. And yet, rubber tires do not begin to approach the low rolling friction of steel wheels on steel rails that help CSX to achieve its 423 ton mile per gallon train efficiency.

But…! Suppose one uses all of the known range optimization techniques and further

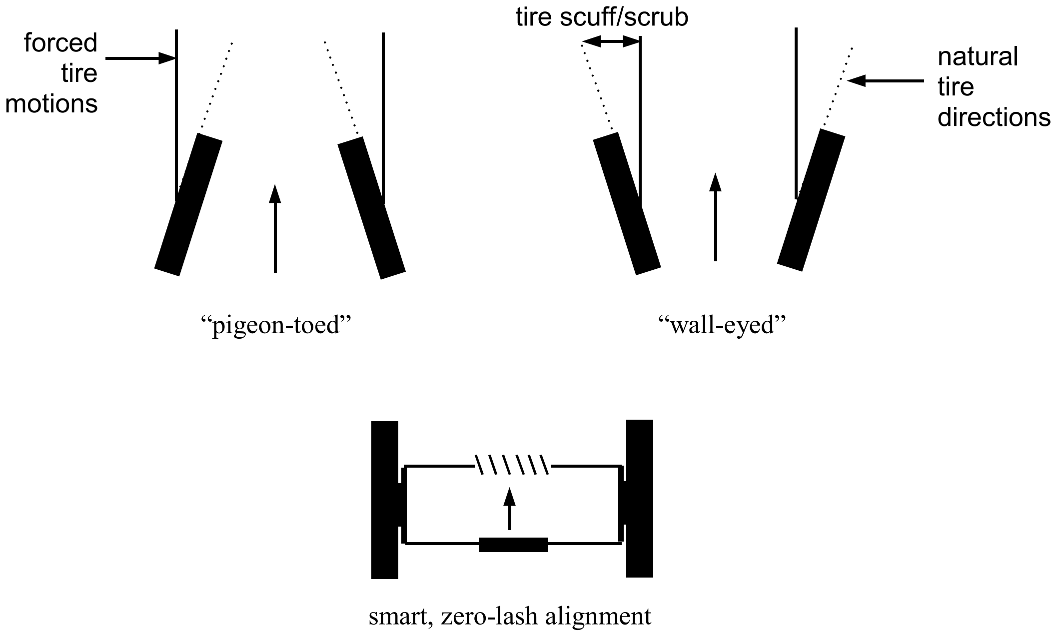

Figure 4—*Pigeon-toed, wall-eyed, and smart alignment.*

suppose the bizarre advanced aero drag mitigation strategies suggested here can actually extend the range of a *practical* E-Car. In this case, the rolling losses will become progressively and significantly more important, and they are possibly the next most important barrier to address.

This loss is not likely to be important to an ICE-Car unless gas prices go really extreme, but to an E-Car, the reduction of rolling friction might just translate into a significant extension of the car's range by acting like compound interest [15]: Any improvements of the battery magnifies the importance of the improvement in aero-drag and regen which in turn magnify the importance of the batteries and magnify the benefit of rolling friction reduction which increases the benefit of the batteries, aero drag, and regen improvements, and round and round.

Misalignment is particularly important. Today's cars use Ackerman steering principles which in combination with careful alignment establishes a geometry that governs the paths that wheels turn on. Any discrepancies from the optimum geometry means that tires are scuffing/scrubbing sideways on the road. For example, Figure 4 shows three sets of tires driving straight ahead and how with misalignment, the tires will try to move at angles to the forced motion. If misalignment aims the tires in either pigeon toed or wall-eyed directions, it means the tires will try to cram together or roll apart a distance of 2Tan(θ) miles (θ is the angle between the forced direction of travel and tire's aim) for every mile driven. For just one degree of misalignment in each tire, there is 184 feet (92 feet for each tire) of sideways

[15] Apologies to young readers who may not remember the halcyon days of yore, when taxes were the government's principle method of ravaging citizen's assets. Days when money invested in the bank actually paid interest which could then earn interest on itself (compounding) and validated the teaching of compound math functions in academia.

scuff/scrub predicted for each mile. But we know that the structure of the chassis disallows and constrains this lateral movement and so the tires scuff laterally by this distance every mile. And that is a whole lot of friction loss and tire wear.

A typical toe-in setting for a roughly 30-inch diameter tire is 0.125-inch, which corresponds to a tire deflection from straight ahead of roughly 0.119 degrees. By the preceding analysis, for every mile traveled each tire is dragged sideway about 11 feet.

Several basis for toe-in are cited:

- To improve stability steering
- So that when wheels deflect back during forward motion they come into perfect forward alignment.
- So that the wheels are pressed in one direction continuously so that they do not wobble back and forth through any lash present in the steering gear and wheel bearings.

Of course, can one ever be confident of the accuracy and permanence of wheel alignment under all driving conditions. To cope with this, smart dynamic alignment (either manual or automatic) can be developed. Figure 4 also illustrates a means to vary alignment while also eliminating lash in a front suspension. Normally, any play in the steering components allows wobble in the wheels and any resulting misalignment allows scuffing. Usually wheels are deliberately pigeon-toed (called toe-in) a small amount (typically the previously cited 0.125 inches out of perhaps a 30-inch diameter wheel), probably at least in part so that they do not oscillate (hum or vibrate) through the range of their play (their backlash). But ideally you also want the wheels to run as true as possible. In the smart system of Figure 4, a second set of suspension arms is included along with a spring to preload the lash and an adjustable link that can be adjusted dynamically. The adjustment can be manually or microprocessor controlled with a servo system.

The dynamic alignment can be surmised also from deflection of the tires or from LASER ranging between the tires. However, one really nice feature of an E-Car is that power expended in real time is the product of voltage and current, and meters to measure each are simple and inexpensive. So by multiplying the voltage and current (perhaps with a microprocessor as part of the cars "smarts") one knows the exact horsepower that is being expended in real time. Therefore, in the case of E-Cars, the horsepower being dissipated may be observed as a range of adjustments are varied, manually or automatically to empirically minimize rolling friction in real time.

Intelligence Drill Down

As just seen in the prior sections, microprocessor "smarts" are a way to mitigate several issues for the basic niche Cockroach promoted herein. In developing the GM EV1, Shnayerson [**8**] goes into detail how GM designers obsessed over many details especially those related to maximizing the car's range. One section describes a "mass Czar" appointed to keep a daily accounting of the design weight. The heavier the car, the shorter the range. So every bit of weight had to be examined and literally the Czar tracked the car's weight by the gram with each twenty-two gram addition being assigned as a one mile loss of range and every twenty-two grams shaved as a similar range increase. Similarly, "six counts" of aerodynamic drag, and every 34 watts of power [sic, he probably means watt-hours of energy] were also weighted as a mile each." Managing the details of range extension should be related closely to computerization in a Cockroach.

One way, besides weight loss, aero drag reduction or battery capacity, to improve the energy efficiency of a car is to gang trips. One burns the same gas going on one 20 mile trip with a 20 mpg car as one burns going on three twenty mile trips with a 60 mpg car. Programmed and remote electronic intelligence can simulate similar kinds of range management. For example, for the writer's history (supermarket shopping on Mondays, the car can be programmed to top off the battery charge that morning, the air conditioning or heat pump can be run in the summer to pre-cool the interior from the grid and in the winter it can be run to heat the interior from the grid for comfort and to warm the battery pack from the grid for maximum range again depending on temperature, and it can do a whole pre-flight checklist of range extending or personal comfort tasks as discussed herein. And even if not programmed specifically, a remote control can allow the driver to signal the car to do a standard "pre-flight" prep before unscheduled departure times. This may seem onerous, but currently, remote controls are starting cars, opening windows to ventilate heat, and starting and heaters and air conditioning on Yuppie machines and so ICE-Car drivers are already being trained to think these capabilities are cool fun rather than work or wretched excess.

Microprocessor monitoring and logging of all driving can intelligently tailor recharging for optimum reliability and service life. Indeed, with electric cars, the use of volt and ammeter gages provides a convenient dynamometer so one can see where their power is going and integration of the power draw provides data to aid in optimum recharging as well as verifying battery condition, *in-situ*.

Microprocessors can and should also monitor the loads on the batteries and motors. One can damage batteries greatly by drawing too much power from them and using it to overload a motor. This is a subject dealt with insufficiently in most of the references consulted in preparing this manuscript.

At present, hobby conversion cars do not seem to enjoy this advantage, they have enough problems dealing with the computer that was used to run the IC engines and peripherals like antilock brakes. Converters are struggling to get electronic dashes to merely work at all. But working out these electronics and testing them would serve every converter and any future new Cockroach manufacturing well.

Is a Brand New Cockroach Realistic?

Many hobby converted E-Cars are marginally *practical* (meaning within economic reach) if their owners are highly motivated (meaning willing to concentrate on range continuously while eschewing power steering, air conditioning and other niceties), but in the writer's view hobby E-Cars are too much work and expense to yield something less than desirable. Still they might become a lot better (much more capable *and* economic) if the preceding sections prove to be correct, and yet not everything cited here is realistic for inclusion in a hobby converted car. Current new E-Cars, like the Leaf, from the major manufacturers that have all the niceties are impractical in this view (mostly because of price). But the previous sections have indicated that there is a market here and perhaps in places like Mexico where there are people for whom the Real Beetle is still a preferred choice. This market might welcome a less costly design more nearly like hobby conversions, a brand new Cockroach, that does not try so hard to compete with ICE-Cars and that could nonetheless efficiently incorporate as many of the old and low tech and speculative suggestions herein as prove to be valid. Of course, current manufacturers will have no interest in this possibility.

Clearly the prospects for a very desirable, practical and economic Cockroach are best realized in a newly mass-produced vehicle. However, new car manufacturing is a really tough nut to crack. Well established new car marques have failed many times in the writer's life: Kaiser, Frazer, Studebaker, Packard, Nash, Hudson, Rambler, Willys and many, many more have taken leave. Some of these were key players in the industry from the very earliest days of the automobile's invention. Efforts to launch new startup car lines have failed also and often, among them: Excaliber, Muntz, Tucker, Bricklin, and most famously, Delorean. Some are legendary and were launched with large caches of money in an industry in which huge caches of money are merely ante. Even some new-model cars from current successful car companies have become miserable failures, among them: Edsel, Corvair, and yes even the GM EV1. Many have tried and virtually none have succeeded. This same fate is far too likely for Tesla, Fisker (both of which are receiving economic help from the government), and all the rest.

In *The Car That Could*, Shnayerson [**8**] recounts the history of the EV1 development from 1989 through its introduction in 1996. Nearly 300 pages review the way money (by the hundreds of millions) was poured in while the concept was largely on life support amidst strenuous efforts, until it launched in 1996. The conclusion describes the EV1, *The Car That*

Could as a “dream come true”. It was GM Chairman Roger Smith’s dream but it was also a nightmare. The happy ending, nay call it a passage, occurred in 1996 that was severely tarnished in subsequent years, recounted in the movie: *“Who Killed the Electric Car”*. The end of the EV1 was ignominious in that despite the cadre of people who loved them, hey we’re such ants in the afterbirth, they were destroyed. As were similar EV ventures from Honda, and who knows about certain of the Fords and Toyotas and others.

And the EV1 development costs were not near the records. In 1984 GM advertised that its all-new Corvette was developed with a budget greater than NASA had when they went to the moon. Billions of dollars. This is what causes old-guard car companies and start-ups alike to fail so often. Maybe keeping a more *practical* car like the original (real) VW Beetle alive is worthwhile.

But the 1984 Corvette (and to some extent, the later EV1) happened before software like CATIA (Computer Aided Three Dimensional Interactive Application) came into use—but only just before. By 1995, Chrysler set out to scoop the industry. They had purchased, well probably licensed, the CATIA software and set out to create the United States’ industries first profitable small car—The Neon. Before the Neon, Chrysler’s recent marques were most often upscale efforts (think Dodge Viper, think Plymouth Prowler, Think Chrysler PT Cruiser [16]) with premium prices used to both defray development costs and provide profits.

CATIA allowed Chrysler (having one of the industry’s first supercomputers) to design the car, to test the fits and clearance of all the parts (in software), to estimate crash test performance, and even to make prototype parts using triaxial LASERS that force-cure epoxy resins (today called 3D printing). They started from scratch and were able to introduce a new car in record time that wound up selling for almost exactly the price of the bigger (and in my opinion better) K-car derivatives it replaced. Even with the latest efficiencies, some sleazy politics[17] and the resulting cheap Mexican labor, the best they could do was to hold the line on price. However, even that was quite an accomplishment, however null it ultimately proved to be.

One would have to conclude, there is only little or no chance that a *practical* brand new-model E-Car is realistic. The Leaf, Volt and even the Prius are all way expensive and

[16] In the 1990s, Chrysler set out to succeed the famous Citreon 2CV with a *practical* ICE car for developing countries. The 2CV was much like the real VW Beetle, a people’s car but even more so. It was made from 1948 until 1990 and was as stark as possible. The Chrysler “successor”, called the CCV, was to be injection molded of plastic in two sides which were then to be glued together and the parts, including a two-cylinder engine were to be bolted to the plastic. Its styling resembled both cars of the thirties and forties including the 2CV. It proved very popular and soon prototypes for the USA were being produced. Before long (after Chrysler’s acquisition by Mercedes) the very similar looking PT Cruiser was seen as prototypes and then in production but not as a practical vehicle, rather as another upscale fad car, and it was very successful.

[17] In the early 1990s, there was a clamor from Detroit for the North American Free Trade Act (NAFTA). Some said it was because car companies wanted protection for the factories they were to build in Mexico, but there were also some who claimed they did not want to build factories in Mexico but had to in order to avoid tariffs that were preventing them from selling cars in Mexico that were made in the U.S.A NAFTA was passed but they built in Mexico anyhow and exported virtually all of the production to the U.S.A. But they claimed that exports to Mexico were increased by the Act and yet the “exports” being shipped to Mexico were *not* cars, but rather were parts to be assembled into cars to be returned to the USA. However, we can be grateful that because there were good jobs created in Mexico, there were fewer Mexicans who illegally went to the USA to get jobs. Believe that and you are more gullible than I am with my preposterous aero-drag speculation.

are not likely to sell well to *practical* people unless gas prices become truly astronomical.

We have seen the Ford Ranger (and probably to lesser extent, other pickups) has many virtues as either new or used conversion Cockroaches. Indeed, from 1997-2000 Ford, itself, sold electric Rangers in California having NiMH batteries having a 70 mile "range", and these occasionally appear used on E-Bay for sale at surprisingly high prices. However, when regulations forcing E-Car production for California were abandoned (whether it was really a sell-out, or due to intrigue, or other behind the scenes tacit or deliberate conspiracy), Ford E-Cars like those from Toyota, Honda, and most infamously GM with the EV1, were quickly ended. And even today, the Volt and Leaf and Tesla and many other future prototypes that are being diddled with really have little chance for success after the wealthy hobbyists are tapped out.

Indeed, there was talk on the internet of Ford making "glider" Rangers (Rangers without engines) available to select manufacturers, and they apparently did. This approach was not new and apparently Chrysler had also sold gliders as far back as 1980 to a Texas company (Jet Industries) for early E-Car conversions [**6**] in a cooperative program with the Department of Energy. Then new equipment was installed in the gliders to produce new-car EV conversions, but such conversions are not near optimal for cost. Chrysler, itself, used factory conversions of ICE cars for years in the 1980s and 1990s, but in their case they were converting standard cars into convertibles (the Chrysler LeBaron convertibles being their most successful star). Convertibles were so scare, they could charge a premium to offset the inefficiency. But this approach is interesting. This is sort of the way that Shelby made his Mustang modifications, and perhaps Yenko and few others too, who modified standard-fare products as a niche. But few lasted and none were *practical* (namely none were affordable). None threatened the principals. Maybe with some upgrades this might seem a good way to launch a very limited production new Cockroach version of the Ranger conversion, a step or maybe just an experiment on the way to defining a true niche vehicle. However, since Ford was building the "gliders" and since Ford has been victim of the same forces that plague every other car company and has no skin in the game, it in fact has incentive to sabotage any success made if there is too much of it. This approach holds no real long-term promise.

A newly manufactured E-Car needs to fit a paradigm and not be a tear-down or incompletely remanufactured example of existing fare (however much better than any chosen base production vehicle it might be when compared to other current options). New production might, and probably should, shift from the small pickup truck to a compact or smaller car configuration which is more suited to the spirit of an E-Car than is a pickup truck. Then with optimization, and new technology, a true *practical* E-Car paradigm might emerge.

Who could and who would ante the huge investment, often billions, required these days to launch a new car from scratch into the Cockroach paradigm, whether that "new" car was of a totally new design or just an existing design from newly manufactured parts. Is there some other way? Perhaps so.

A totally new design from scratch is far too much cubic money, but new manufacture from an existing design (like the original VW Beetle) might be much more do-able. Still, where can one get rights to an existing design. Since the optimum configuration seems to be the compact car, I have a few in particular in mind: namely, the 1990s Dodge Daytonas and to only a slightly lesser degree its K-Car derived siblings (Lebaron coupe and convertible, Sundance, and Shadow), and the earlier original K-Cars themselves (the Aires, Reliant, and original Lebaron) resulting from Chrysler Corporation's first bail-out.

Is a *Practical* E-Car From an Existing-Model Remix Realistic?

Even if one could somehow gain rights to modify and manufacture an existing car design, thereby avoiding the bulk of the cubic-money design, debugging and launch costs, there are still a host of costs, many resulting from damned regulations, that stand in the way. They can sink a fledgling effort also. But maybe some of those remix problems and costs can be mitigated if the vehicle serves the right niche.

Regulations often serve two purposes: primarily and most importantly to provide cash flow for the government, and secondarily as justification, to serve some lofty if flimsy purpose like safety, pollution control, energy savings, security, etc. If the niche Cockroach audience can obviate the second, it has a better chance of avoiding the primary cost. So the niche needs to be large and, therefore, politically powerful and relevant.

The niche I propose is populated by people like me, a class who are wrongfully and unfairly over-burdened by the government pursuing Quixotic pseudo-noble goals that are bogus. I argue here, the strongest case for a remix Cockroach, can be made by retirees who are on fixed incomes, because we number in the millions and our numbers are expected to grow like locusts as the baby boomers retire. This group has our corrupt government scared to death fearing we will suck Medicare and Social Security dry (so scared that they are hurrying to loot as much from us as they can first) and reveal these programs for the evil Ponzi schemes[18] that they have become.

For this reason, a remix retiree's Cockroach may consequently just have the best chance of success. Yes, it would serve nearly equally well as a starter car for teenagers and young adults that parents wish to limit in range and speed (both limits of which are inherent

[18] Many of our tyrant Democrats take severe umbrage at any suggestion that their Medicare (passed by Lyndon Johnson and a majority Democrat Congress in 1965) and Social Security (passed by FDR and a massively Democrat Congress in 1935) are Ponzi schemes. Both of these programs are based on forcing people to pay in for "insurance" they might not otherwise buy, especially in hard times (even though Democrats have no official clue what "insurance" is). Then these "investors" (Democrats are big on "investing") will get pay-back later when they desperately need it. Over the years, the insurance aspect that was used to sell the legislation has been corrupted. In the 1960s Johnson decided to treat payments into Social Security as just any other tax for the governments use (specifically for his Viet Nam war) and then in 1965 also created Medicare but also decided to treat its premiums as ordinary taxes to also spend on his Viet Nam war, and not as fees that are "earmarked" for future expenses. Democrats also praise Slick William Clinton for his years of "balanced" budgets in which nonetheless the national debt rose every damn year because Social Security and Medicare payments were counted as income while the treasury bonds that were "placed" into the Trust Fund were not counted as expenses. And today we hear some of them say that Social Security and Medicare are "pay as you go" welfare and lament how in past years there were fifty to one hundred people paying in for every one receiving benefits, while soon there will be only two paying for every one taking benefits. And so both programs are now treated by some who do not really consider them to be "insurance" as plans in which earlier investors (like me) are paid off with money from later investors in order to encourage more and bigger risks (think ObamaCare). But this is precisely the definition of a Ponzi Scheme (skeptics are referred to the Dictionary). And in 2012 with a "compromise" from the Republicans, Democrat leadership, proposed and got a year long waiver of the cleverly called "payroll" taxes, which are really the Medicare and Social Security premiums as a way to "stimulate" the economy. Curiously, when passing Social Security in 1935, even FDR did not have the balls to waive the premiums for people who were going through an even more severe depression. But this is how tyranny grows.

in the Cockroach) or that are cash strapped and for a smattering of folks in between who are range limited and even as a second or third car of limited use. And these ancillary categories should not be ignored, but it is the lower-income retirees who form the core, the kernel of the niche. The justification.

Is the K-Car a Potential New-Production Cockroach EV?

Key K-Car History

Chrysler Corporation has a long history of major contributions to the auto industry. Its cars were always famous for the soundness of their engineering and sturdiness. The writer has been told there was actually a period in drag racing history when other makes were allowed to install Chrysler drive trains (transmissions and rear axles) because they were the only kind that would hold up under harsh drag racing stresses.

But like Henry Ford when he was building the Models T and A, Chrysler wanted to chase the rainbow, to play the lottery (and that is both a right and a real twelve-step style problem). This proved a particular problem of fatal proportion at least twice: in the late 1970s and the late 2000s. For the latter portion of the 1970s, I was there. Chrysler had been scaling up the size of their cars like everyone else. I, myself, drove two used 1960 Chrysler New Yorker coupes and, believe me, they were big and so were their tailfins. But as the decade was ending, the Chrysler lineup had become truly humongous, truly bloated. When the gas crisis hit in 1973 Chrysler was hurt in having only huge cars to sell when fuel efficient cars were needed (and those huge cars did *not* sell). My New Yorkers were giving me about ten miles to a gallon. All Chrysler could do was import small cars from Mitsubishi which Chrysler had invested in when times were better. By the later 1970s, they introduced a subcompact front-wheel drive car (the Omni/Horizon) but it was not enough. And soon Chrysler faced bankruptcy and was strapped for cash and even they could not afford to launch any further small fuel-efficient cars for manufacture here in the USA. Even Chrysler, number three of the Big Three, could not launch a new design.

Chrysler appealed to the Government for a loan to finish engineering and launch a new line of fuel-efficient compact cars: The K-Cars. And the Government agreed when Chrysler showed prototypes of the new cars it would sell if it could get the capital to survive. Chrysler was loaned the funds on the basis of the national need for their new car line, and was saved.

It was not a new or unique situation. In 1949, Henry J. Kaiser approached the government similarly for funds to save the Kaiser-Frazer Corporation [**20**]. He borrowed 44 million dollars from the post war Reconstruction Finance Corporation on the condition he produce a new small car that any American could afford. And Kaiser turned out the somewhat less expensive “Henry J”. My brother drove one and it was quite a nice car. It was small for its time, but when I see them at classic car events today, they seem much larger than they were back then. They must be growing.

The K-Car saved Chrysler and allowed them to pay off their loan early. The first two K-Cars were the Plymouth Reliant and Dodge Aries. But over the years the basic K-car platform was stretched, prodded, poked, and given plastic surgery to produce the mechanically identical Daytona, Lazer, Shadow, Sundance, LeBaron, and other variants. It even gave birth to the Chrysler minivan which was stunningly successful and still is even to this day when most K-Car genetics have likely been bred from it.

By the early 1990s Chrysler was not selling as many K-Cars as previously, markets do saturate, and they wanted to follow the time honored GM strategy to upscale their cars and make more money. Frankly at the time, there were customers aplenty for buying old-technology-warmed-over in the form of big trucks and SUVs, many of which could be made with push-rod engines, and straight rear axles held with leaf springs, not at all unlike trucks of the 1940s. And in some cases the profit margins for the very biggest (the "Texas Cadillac" Chevrolet Suburbans yielded a huge profit in the neighborhood of ten thousand dollars per car). There were still loyal customers for the K-Car siblings but there were not enough to warrant paying large management bonuses, and capitalism demands you chase the rainbow, you survive by growing until you smash into something that bloodies your nose and quite possibly kills you. Then you hurt bad. Over a period of years, the K-Cars went away while Chrysler once again introduced new and bigger and more expensive cars. Cars that delivered much less gas mileage but bigger bonuses because they had higher price tags. They also consumed huge development costs. Sound familiar?

Now don't think the K-Car had become the death of Chrysler. Through the 1980s, Chrysler thrived on K-car sales and was out buying all kinds of goodies. They bought Maserati. They bought Lamborghini, and at one point were planning to put some "Lambo" engines in select K-Cars. The K-Car served them really well.

If it is true that Ford's most recent financial problem began well before the crash of 2008 (when they were also bloated with all kinds of goodies such as Jaguar, Mazda, and Volvo that they had bought during the good times), so too it is true with Chrysler. Chrysler already tottered on the edge of bankruptcy even earlier in 1991 and was selling off all of the goodies it had bought in the 80s. Despite the vehicles available to them, they were gambling on a new series of bigger more expensive cars, the "cab-forward" LH-Cars.

With much trepidation, I bought a new K-Car sibling, the Dodge Daytona in 1991 during the Chrysler tottering. I did not buy the service contract at the same time. That was just too much of a gamble, because there was a chance Chrysler would not be around to even honor the warranty, much less its service contracts. And Chrysler cars were not highly rated for reliability. Nor did the press like them. The reviewer cognoscenti bad mouthed them regularly for not being the latest and greatest in all ways. And my Daytona was not as reliable for me as most cars being made then would have been, but it was vastly superior in all ways to a new Camaro that I had bought in 1977 (GM new-car junk it was) that I had been milking along for fourteen years. If my Daytona was not as good as some contemporaries, it nonetheless was a really *really* good car. I still have it and wish I could buy a new one exactly like it. I later bought a 2004 Subaru Impreza (very highly rated in some consumer quality surveys) and very high tech in comparison, and the Subaru has had good reliability, but for shear fun to own and drive, the Daytona creams it (and was way cheaper, and cheap is something I consider very attractive in a new car).

Because the Daytona was a K-Car derivative made in nearly the same configuration for about a decade it delivered great value. It cost only a little more then some of its K-Car siblings and they were the lowest priced American-made cars at the time. Base price on the mechanically identical Plymouth Sundance and Dodge Shadow were in the high $7,000s and the Daytona with more standard gear and style started in the high $8000s. Mine had several cool packages for the time and went for a little over $11,000 when a stripped competing

Toyota Celica went for a fictitious $12,500 (most were loaded with mandatory pricey options and a comparably equipped Celica hatchback was upwards of the $16,000s). I have never regretted buying the Daytona.

The Chrysler gamble paid off. The new "cab-forward" LH-Cars were stunning successes, and Chrysler's Chairman, Lee Iacocca, commented at the time that it was good to retire after hitting a home run in his last at bat. Back in clover, they soon won the bid for the highly prized Jeep among other failed AMC cars.

Many years later, in the later 2000s, Chrysler had worked its way, full circle, back to where it was in 1979, again making big expensive cars, SUVs and trucks when there began another (*SURPRISE!*) upward spiraling of gas prices. And Chrysler, like a deer caught in the headlights, had learned nothing and had no *practical* cars like the K-car to sell (they had discontinued their last small car, the CATIA-designed Neon in 2007—talk about bad timing). This time they were not so much alone. Everybody was hurting but Ford was stable while Chrysler (again) and GM also went terminal.

However, this time a new government (one often accused of being Socialist leaning) took a different tack. Instead of again loaning Chrysler money in exchange for a commitment to build what was needed, or to go back and build some more K-cars, Chrysler, and GM, were pushed into bankruptcy, the creditors (even the secured creditors) were ripped off, and big chunks of the companies were given to the unions with the government also holding large chunks. Nothing Socialistic there! Chrysler was also merged with Fiat of Italy and has begun selling Fiat cars and selling them as "fuel-efficient economy" cars (for about twice what a K-car should cost). It was like a mini-step to a mini-new-world-order.

The K-Cars were not the most prestigious of cars ever made (more likely they were among the least prestigious) but they had many unheralded virtues. Chrysler took safety seriously and the K-Car derivatives were all quite frontally crash worthy (even without air bags), among the best being made. Indeed, the K-Car sibling, the Daytona, that I bought turned in frontal crash test results that were spectacular in its day and are still excellent by today's standard, and there was no passenger air bag in the 1991 model (nor was the driver's air bag the principal reason for the excellent driver results). I would choose a new Daytona over any car being made today. The physics of its crash behavior were just superb, an aspect of great value to older retired car occupants. [19]

K-Car Customer Loyalty

There were and still are, as I have already noted, many critics of the K-Cars exercising their right to free speech in condemning them, just as I exercise mine when I damn many

[19] The Daytona in 1989 [**21**] recorded a 399 head injury for the driver and 297 head injury for the passenger, both among the lowest ever and lower than many new cars achieve today, 20 years later. The Chest decelerations were 39gs and 32gs, respectively, both again excellent. Earlier and later tests of K-car variants including the Daytona many of which were without air bags were also relatively good even by today's standards. Theoretically, the K-cars performances would improve with later inexpensive devices like pretensioning and load limiting safety belt retractors. However, active safety features are not as valuable for retirees. Older folks are more brittle and injure more easily, and that leads to fatality stats that are worse than for younger people.

of the cubic money cars they love. But there were and still are also K-Car loyalists like me. Yes, there are even K-Car fan clubs.

As recently as in 2011, one critical blogger, Perry Sainati, hearkened back and described the K-Car as an ultra affordable car (which it was) "held together by some combination of glue staples and bailing wire" which it was most certainly not, not even metaphorically.

Certainly comments like that from many did not help K-Car sales, but as a K-Car owner, I regret I did not get the chance to buy a second one because the quality and design of the one I had was so good I did not want to let go of it (trade it in) at only two years when the last Daytonas were phased out. I should have bought and stored one for later use.

So as happened to the original VW Beetle loyalists, a car I really liked went away and was replaced by much less desirable but much more expensive replacements. Those replacements are gone now also.

The K-Car family as either an E-Car or even an ICE-Car makes sense, uncommon sense, for the niche audience I am defining here.

Really? The "Daytona" as an E-Car?

The Daytona as for its siblings and many two door hatchback coupes, has a lot to offer as an E-Car. The Daytona is a little bigger than many (more volume for batteries and more protection around them. Its frontal crashworthiness is superb. And it's a design that has good aero and would take well to the advanced aero drag reduction methods suggested here, if valid. A two-seat version would welcome a divider between the passenger compartment and the hatch And if the divider were made structural, it would improve the usually weak lateral buttressing of hatchbacks and might allow for a larger hatch or a drop-down tailgate in the rear for better hatch access, something that would appeal to older retirees.

With pricing like it had back then, (meaning near the very bottom of the then-current range) and with an electric drive-train that is lower in cost than an ICE power-plant it replaces, I am here to argue a new Daytona Cockroach could conceivably come in below the current price-range for current vehicles, that is to say near $10,000 new, maybe less[20]. With all the additional benefits yet to be discussed in this section, that is the car I want. But it is not a car Chrysler would want to build (not unless it could be priced at $43,000, like the original Volt). And there are ways to establish a National Affordable Cockroach Ownership Strategy that would be absent all of the pitfalls of the Clinton National Affordable Home Ownership Strategy, because Cockroaches could in fact be...affordable.

The Daytona as Either Gas or Electric Cockroach

Since the creation of a new car design is so God-awful expensive and time consum-

[20] Keep in mind, that as of this writing, a number of cars which all incurred full development costs that have to be amortized in their price, are being sold for this approximate amount. Hyundai sells an Accent at times for less than $10,000. A basic Nissan Versa is under $11,000. And since water based paints have been introduced, the biggest single cost in all of these is the ICE engine, although many cars still have hydraulic power steering, exhaust systems with catalytic converters, up to six air bags, shipping from the other side of the planet that are all also expensive. For a Cockroach, a ten thousand dollar price tag is not only realistic, it may even be significantly conservative.

ing, what if an existing design, for example, the K-Car siblings were in the public domain, open for anyone or any consortium to compete to produce as niche ICE-Cars or E-Cars? All of the K-Car siblings are proven designs. They require none of the hassle, the monstrous hassle, to get them to market that demands cubic-money investments on scratch-built new-car designs. All of the nastiest bugs have been worked out. The doors all open and close without hitting. There is an infrastructure that can service them. They have been crash tested many times. They have been proven for two decades in actual service. They incorporate little or no technology for which technology patents still apply (the last sibling cited here was made in 1995, and 1995 plus 17 probably means most technology patents expire(d) in or before 2012).

Hence, the case is being made here that the Daytona is an excellent K-Car platform on which to base a new Cockroach E-Car, and many of the same arguments apply equally to a slightly lesser extent to manufacture of the Daytona as a limited-use ICE-car for the niche retiree audience or other niche audiences, identified herein.

The Daytona or its siblings could be manufactured with a new name (e.g., "Cockroach") as niche ICE-Cars as soon as the parts could be ordered. But some obstacles below would have to be resolved before they could be sold. Cockroach E-Car versions would require some additional work, but both ICE versions and E versions would have issues related to:

-Moving K-Car designs into the public domain
-Poaching and Intrigues by opposition bully capitalists
-Electrical System Engineering
-Pollution, safety, and other tyrannical regulations
-Insurance issues

Are any of these fatal flaws? Or are there reasons why these should not be allowed to thwart a practical cockroach-niche E-Car or even ICE-Car.

Moving K-Cars into the Public Domain

Chrysler has abandoned the K-car variants, despite their perhaps small but loyal following. Now normally, that is Chrysler's business and none of our own. But in this case it is different. The people paid to develop the K-Cars, saving Chrysler's ass in 1979, and then again in 2009 saved (if you call it "saving") NewChrysler's ass a second, if socialistic, time. And we have a President with Socialist leanings who had no qualms firing CEOs (well perhaps he rather "convinced" the GM CEO to leave—he made him an offer he could not refuse).

Chrysler marketed the K-Cars as America's cars, even going so far as placing an "America" logo on some of them. These designs are not something to throw away or withhold as an un-American means to prevent competition and a free market, to force Cockroach Americans to pay higher prices for the later crapier higher-margin stuff.

It would be a wonderful gesture for Chrysler to release the K-Car designs. I call upon them to do so as a patriotic gesture. The call may be met with a surprising protest as to the critical value of the K-Car design to the NewChrysler Corporation, and I would not be surprised if GM and Ford and all the other manufacturers (whomsoever would also prefer to sell more expensive cars) were not similarly opposed to their release. We might well see the downtrodden K-Car suddenly experience a unexpected surge, a renaissance, in the level of its prestige.

However if Chrysler is not so inclined, then if they want to do business in the U.S., we should convince them to place the K-Car and its siblings in the pubic domain. The market can speak if it wants to with boycotts. If Chrysler still doesn't want to, then we should convince Congress to place them in the public domain through legislation or the President should ask the management of Chrysler if they would like to keep their jobs. And if all of those fail, American patriots should make America an unfriendly place for Chrysler to do any business otherwise. Good-by and good riddance.

At a famous candidates debate once upon a time, a bold candidate whom they were trying to shut up, to marginalize and exclude and censor, grabbed a microphone and proclaimed: "I paid for this microphone". Well with regard to the K-Cars: "I paid for these K-Cars." And so did many others.

With the K-Car siblings in the public domain, the cost of producing the Cockroach or other new E-Cars would become quite realistic.[21]

Avoiding Poaching and Intrigues (ala John D. Rockefeller)

Keep in mind that if new-manufacture Cockroach K-Cars or ICE K-Cars came into being, greedy capitalists who do not really want to compete will try to use bogus-competition to kill them off ala good old John D. Rockefeller. Immediately, the cost of the nearest competing cars will come down, possibly even down below the cost of making them, perhaps down to less than the cost of making new Cockroaches. This would be in an effort to bankrupt any who dares try to compete. JDR apparently invented it and did it a lot. Once the Cockroaches had been killed, then prices for cars that serve the Cockroach's niche would be pushed back up.

But there is a second mechanism that could be fatal. Just as Chrysler was happy to build the K-car in bad times, when things picked up they immediately addictively wanted to go back to high margin cars to maximize profits again. It is human nature. It is inherent in the free-trade capitalistic system (no offense intended, I am a Republican that supports capitalism). If a Cockroach manufacturer following traditional business practices were to incur any success, its management would immediately seek to broaden the market, to move it up scale—and they would betray the niche. They would try to increase the value of their stock and the size of their bonuses. That is what addiction is all about, and it is an addiction they are taught to surrender to in business school. Therefore, regular corporations to build Cockroaches are not the way to go.

So the question is, how can the viability of any Cockroach be preserved, so that there is always honest competition possible with the major car makers and their oligopoly?

[21] Yes NewGM was also "saved" (meaning was ripped off like it was a half trillion dollars in Medicare funds), and parsed out to the UAW, and a similar argument can be made for placing some of their past designs into the public domain also. Indeed, its Saturn Division was killed like the EV1. And the Ion was a potential strong candidate for Cockroach service. It was a small light compact, had electric steering (perhaps still under patent). The writer has had no experience with it but has heard good things. And it might be worthwhile to consider the Saturn vehicles among other older GM vehicles and technologies for possible public-domain designs.

Clearly, the public-domain design is important, as would be any loyal core of support. But perhaps this is a case where the damn Socialists can actually do something good for their country. If they care.

The Story of GNU/Linux

Free enterprise and capitalism are great and as a system have done much for America and can and should do much more. But they are not quite perfect. They have a seedy side. We have seen that they can force competition to get too intense at times and that some of their practitioners are willing to lie, cheat and steal in the pursuit of profit. And in those cases where they do not do the right thing, alternative competition, even Socialistic competition, should be allowed. The computer operating system, Linux is a good example. When personal computers began to flourish in the 1980s, Bill Gates (America's successor to John D. Rockefeller's legacy) manipulated our capitalistic system to his greedy advantage claiming all the while he just wanted to "innovate". Software I wanted to use was off limits because of arrangements between my employer and Microsoft. Ultimately there was an antitrust suit that the Clinton Administration copped out on, and I agree with the theory that it was because they did not want to hurt Microsoft's ability to export at a time when U.S. exports were few. By the mid nineties, Gates had become the richest man in the world with a series of tactics that outraged even many Capitalistic Republican Americans, like me, who otherwise believe in and support capitalism.

Gates' success was achieved in the way he controlled and excluded competition for his Windows Operating System. Windows, itself, was and always has been crap. Why? What are the bases for this opinion? Every version was shot full of bugs and every succeeding version promised to fix all of the bugs of the preceding version but often did not and usually introduced more. Recently (in 2011) there are reports that a new version allowed "Cookie-jacking" that aided identity theft. But there are other reasons too.

Windows has inspired a host of wrongful computer practices. Identity theft has made huge leaps and bounds through vulnerabilities in the Windows software. And there are viruses galore. Some say there are 10,000 new viruses a day written for Windows (3 million a year). The harm Mr. Gates has done is massive. No wonder he seeks redemption these days through claimed charitable efforts.

Then in the mid-nineties a couple of noncompetitive, none-capitalistic events surfaced. One might even compare them to Socialism, with no intent to offend. A fellow at MIT named Richard Stallman started something that one might call "programs for the people". He started writing first-class software that he made available for anyone to use and to modify under what he called a GNU-GPL (standing for **G**NUs **N**ot **U**nix **G**eneral **P**ublic **L**icense). Anyone could use his software and have the source code to modify it so long as any changes they made were also under the GPL. The second important event was when a Finnish computer student decided to write a kernel that replicates the command structure of Unix (an early and rock-solid operating system written at the regulated old public utility research department in Bell Telephone Laboratories). And it came to be called LINUX.

And over time a core of "public service" programmers calling themselves proponents of open-source software (plus some donations from capitalistic firms like IBM) developed Linux and its GPL libraries into the most stable, most capable operating system out there.

And it is free to use and revise. Although, I write this text on an old IBM PC (which I think of as a VW Beetle of PCs) using a Windows 98 OS that I would never dare to connect to the Internet (having lost a similar PC that exact way a long time ago), today when I go on the Net, I am running a Live CDRom (actually converted into a Live USB key) GPL version of GPL Knoppix, which is a version of GPL Debian, which is a version of GPL Linux. I just got tired of the viruses, and bugs and Blue Screens of Death that come with Windows. Since then no virus, no bug, has significantly damaged me, nor could one. It is not technologically possible. And it did not cost me a premium. I have lost files but no more whole computers.

I repeat I am not against capitalism and support it, but not 100.00%. In some cases supposedly capitalist products like Windows can suck like they are the Communist Yugo car. In the case of operating systems, some Socialistic things may make sense. Capitalists should not be cowards in competing with them.

Today many capitalistic companies use only Windows Software in support of their brethren Microsoft, but are forced to pay for staff and antivirus software to cope with viruses, often unsuccessfully, and yet when they go onto the internet and connect to servers that manage a much more challenging task, the software they are being served by is often LINUX. Indeed LINUX has been used in some of the world's fastest supercomputers.

Someday LINUX may send Windows to the junkyard where it belongs. But for now Linux serves the needs of a niche of people and those people serve LINUX often with voluntary programming and debugging and donations. And because there are so many of them when Linux gets a bug, it is often solved and fixed within days, and not within years when the next version of Windows will be marketed with a new batch of empty sales promises.

GNU-Linux has achieved this because its patriarchs Stallman and Torvalds hold fast to their vision. At present, Stallman Lives! Torvalds lives! When they die, what will happen to GNU-Linux? And therefore, by analogy what would happen long term to any similarly produced Cockroach EV?

So I am suggesting that something would need to be done to preserve and protect the public-domain Cockroach E-Car (and any ICE-Car versions of it, too). The Cockroach needs to be configured so that like LINUX it has a core of loyalists who can allow it to expand and thrive when times are good yet, and then, in a way in which capitalism can not, contract and endure when times are bad, so that it does not have to always chase the ever bigger profit margins and larger market shares. So that it can be a floor that supports the industry. How to do that?

This may be possible by also patterning any Cockroach after Stallman's and Torvalds' efforts. Indeed the writer considered calling the Cockroach a GNU in homage to Stallman's software but that's not sporting and might not be appreciated. Instead, I will later call for and defend an umbrella Cockroach organization to be chartered and given a chance at immortality as a "charity-like" public service operation akin to the Red Cross or Meals on Wheels.

Engineering, Upgrades, and Volunteers

Many of today's retirees are unique. They are among the most educated ever. They are the people who executed Kennedy's moon landing fantasy. Recall that in recent decades, many in their intellectual primes were incentivized to leave companies as cost-saving gestures. Many willingly left, but many were simply being pushed out. Some of these retirees were brilliant contributors to the companies they served, tops in there fields. Some of them may have designed the original K-Cars among others.

A retiree's social group I belong to often solicits members to perform volunteer public services in the community. And many do. Many are among those top historical contributors to the company I worked for. A good friend welcomed an incentive to retire. He was a model American. He was a Nisei (second generation Japanese ancestry born here of Issei (first generation parents who immigrated here from Japan) who spent a chunk of his teenage years in one of FDR's concentration camps in Arizona, who never had a kind word to say about FDR, yet who never displayed a bit if bitterness (I could not have been so magnanimous, I am more bitter over the tyranny of his treatment than he is). His family had to have sponsors to get out of the camp after the war and then they broke his family up and scattered them. He came to Pennsylvania to live with a Quaker (or was it Amish) family sponsor. Ultimately, he got an engineering degree and distinguished himself as a superb engineer. I have seen pictures of him in the retiree's newsletter volunteering to help his peers by stuffing those same newsletters into envelopes so that we could read about other retirees. A Cockroach project could make much better use of his skills and volunteerism.

This man had more than a passing interest in cars as an engineer and could and probably would have contributed help to engineer a Cockroach to benefit himself and his fellow retirees. He is that kind of human. I could cite stories of many other top engineer volunteers also. As will be examined later, such an effort could help save Social Security. And there are any of a series of similar projects that could save Social Security by improving the lot of its present and future beneficiaries based on voluntary efforts from those same beneficiaries. In fact, I would bet that the availability and scale of talent out there would make the design departments in the major manufacturers look like pathetic amateurs. It would make them look as bad as Microsoft's programmers look when compared to the GNU-LINUX crowd.

The question may not be whether there would be sufficient talent, the question may be how to effectively manage all of the talent that might surface for such a worthwhile public-service undertaking.

Pesky Pollution, Safety and Energy Regulations

Okay, so say we move the K-Car and its sibling designs into the public domain, and say we find there is a cadre of volunteers ready to modify its design and help manufacture it for Cockroach E-Car service, and maybe limited-use ICE-Car service too. What about the tyranny in all those safety and pollution and energy and other regulations out there? Clearly they must thwart this noble undertaking. Not so! Not if we don't let them.

America is screwed up just now. It is a tyranny. And it needs some unscrewing. And that can only happen and Americans can only be saved by kicking politician's asses (even adopting capital punishment for some of their most grievous betrayals). We can no longer continue to allow politicians to act as though they are merely greedy, corrupt, stupid and vile over-paid underachievers.

Safety

The K-car siblings were all excellent for frontal crashworthiness. Upgraded seat belts and conversion into heavier E-Cars use would make them even better. But they do not require air bags for cockroach service. Any regulation that imposes that is more corrupt, more tyrannical, than the King's tea tax. For retirees, whomsoever are typically old and often frail, neither seat belts nor air bags are nearly as effective as they are for more robust younger people, and many older people have conditions that contraindicate getting smacked with a bag or even restrained with a belt. Indeed, in many, many cases the regulatory agency, the tyrant National Highway Transportation Safety Administration (NHTSA), operates as a "Death Panel" and has made the calculated judgment to trade the increased risk of death that some devices cause in old people because they can save greater numbers of younger people. To them: "Kill an old fart, and save two young farts" is an approved ethical calculus. NHTSA has done this often in the past, for example when they mandated air bags that proved fatal for small children, babies and short women, then later encouraged strategies to lessen the hazard for all of these, like moving babies and children to the back seat, shifting seating positions away from the steering wheel for small women, de-powering air bags and blaming the victims. Clearly there were trades made among those for whom air bags were more beneficial and those for whom air bags were much less beneficial or even outright harmful.

Retirees need to, can, and many do, reduce risk by concentrating on such things as driving locally on familiar streets, avoiding cross traffic driving, driving at low risk times and in clear weather, etc, rather than relying on mechanical systems to save them. These are much preferable routes to achieving safety for retirees, and for these reasons such more recent regulations as side impact air bags (more shock for fragile skeletons) are less effective and in some cases are counterproductive. Indeed, a report in 2001 [**22**] found that although older drivers tend to be involved in more fatal accidents than younger drivers, it is due to their fragility. They can not take a hit as well. Indeed if an analogous study were conducted, I would bet it would also show that older *passengers* who can bear no guilt for the accident happening are involved in fatal accidents at a greater rate than younger *passengers* [22].

As a result proactive methods can be very effective and argue that a Cockroach would benefit little if at all from so many mandated expensive safety systems.

Much more important for retirees whose short term memories may be flagging, would be things like warning alarms that monitor seat belt use for all seating positions, that sound alarms when turn signals have been on for too long a distance (the writer's Daytona already does this, his newer Subaru does not).

Automobile safety regulations have been grievously mismanaged by NHTSA for years. NHTSA saves lives, yes, and they beat their chests when they do (their arrogant motto was and maybe still is "People saving people"), but they also kill people including babies ("People killing people"), and they are in denial about the importance of that when they trade lives like they were securities at the stock exchange. Let them eat cake, let them use air bags.

Cars for retiree Cockroach service, and most certainly those based on the extensively

[22] In the 1990s, crash instrumentation was placed on Indianapolis-style race cars for the first time. Initial results first discovered that Indy-car drivers were routinely surviving crashes at deceleration rates far above what was considered lethal. One of the most important "talents" for Indy drivers is ability to take a really bad hit. Bad hits that would kill ordinary people, just as hits that ordinary people would survive can kill old people.

tested and successful K-Car platform, deserve a waiver from compliance with most new crashworthiness safety regulations. A panel of retirees, including engineers with long histories of hazard review studies, who may have helped develop hazard methodologies such as fault tree analysis, HAZOPs, etc., could better address their own safety needs than NHTSA.

For example, when crash worthiness testing first began in the late 1970s, many of the most highly rated cars for safety (specifically the Volvo) were building a very strong but also rigid car. The rigidity produced some terrible results and so soon (with Volvo in the lead) crush zones were designed into cars to serve as a cushion. The Chrysler products and specifically the Daytona (had some of the largest crush zones and therefore some of the lowest deceleration rates recorded (making them among the most gentle). In the mid-1990s to produce better handling the rigidity of many vehicles was again increased massively and instead good crash-test results were obtained with very carefully calibrated and timed air bag deployment. But the vehicle deceleration rates in many cases increased dramatically. So if you could take an air bag hit and if your were sitting in the front seat of cars that only had airbags there, you recorded similar injury data, but if you were in the back seat, you were in for a collision worse than you might have seen in the 1980s. Older folks would be best off in a heavy car with large crush zones than in anything else made today.

Indeed current individual state safety inspections unreasonably burden retirees who might buy Cockroach E-cars, and who would drive them at low annual rates. A new Cockroach as proposed here should be exempt from annual safety inspections for at least ten year periods or 30,000–50,000 miles (though mandatory maintenance in the way of owner certification for periodic wiper blade replacements and bulb checks “might” be worthwhile). A team of volunteer retirees could propose a mechanism to achieve both safety and economy.

Pollution

Clearly E-Car Cockroaches are largely pollution compliant (even on the basis of miles driven) and should be exempted from all pollution regulations. However, if new ICE-Car K-cars were desired by retirees with greater range needs, they too should be exempt from most recent pollution regulations (i.e. those since the early 1990s) provided they are restrained as to total mileage driven. The retiree Cockroach E-Car paradigm is based on retirees who drive seldom and usually for only short distances but necessarily for only small annual total amounts. I burned 60 gallons of gas a year in my Subaru for nearly a decade. I am not a factor in pollution regardless of whether I get inspected or not. Regardless of whether I have massive antipollution hardware or not. Requiring most current pollution controls on Cockroaches, including ICE Cockroaches hurts rather than helps clear the air.

In fact to control pollution, a maximum annual mileage limit can be designated for ICE-based pseudo-Cockroaches subject to a, dare I say, tax penalty (I can hear Democrats cheering) if exceeded. Indeed, in Pennsylvania (as perhaps other states) this is already recognized in that cars that were driven less than 5000 miles in the past year currently do not have to be tested for pollution (but they still have to pay for the testing/tax—they just do not have to face any repair cost if they are spewing above the common limits).

Energy

Energy regulations (CAFEs: Corporate Average Fuel Economy) are similarly moot for Cockroaches be they ICE-Cars or E-Cars. CAFE regulations have little or no benefit when total annual driving is small, and they can make things worse. In the writer's case in which as little as 1200 miles were driven a year, only about 60 gallons of gas were consumed, therefore improving mileage by 50% (at large scale cost and energy use) would save only 20 gallons of gas, potentially less than the added technology would consume to produce the improved mileage. In the 1970s gas crisis, when great efforts were being made to reduce vehicle weights, one study found that the potential fuel saving that resulted from changing a dash panel from steel to plastic was so small that it took more fuel to produce the plastic part than the part saved unless the vehicle was driven far more than 100,000 miles. Every car that was recycled before it got to 100,000 miles, and there were many in those days, wasted energy and wasted it all up front.

And E-cars are so much more energy efficient that any Cockroach should be exempt from onerous energy regulations. Similarly, ICE Cockroaches should be forgiven these regulations (Democrats can think of this combined waiver as a form of their beloved Cap and Trade), the mileage limit being the cap, and the combined E-car and Ice-car results being the trade.

Vehicle Insurance Issues

Insurance of Cockroaches is another bone of contention. Many who might buy Cockroaches, especially as a second vehicle, especially among lower-income retirees, might find them too costly to insure. Currently I have a K-car which I seldom drive and a Subaru that I drive about 1200 miles a year (60 gallons of gas). My K-Car which I have driven as little as 50 miles or less in a year costs 80% of the premium for my primary Subaru.

The insurance companies pricing argues that the risk of a claim against the K-Car is virtually the same as for the Subaru. Is this reasonable? Hell no! If our Socialist President wants to damn insurance companies as he so often does, this a valid place to do it.

What is insurance? Today too many people, especially too many politicians, even too many insurance companies, seem to have no clue. The politicians want to make rules about insurance, want to ram programs like The "Affordable (not) Care Act (Obamacare)" down our throats, but they want to do it with the divine right of kings not as servants of the democracy. The insurance companies want to operate as financial organizations anymore, investing premiums and getting big bonuses for it.

But what is insurance? Do you know? An insurance expert once offered the following definition: "Insurance is not someone to *pay* your bills for you, it is someone to *finance* your bills for you". This should be taught in our currently incompetent public schools. A model can help make this point. Insurance is a "group" (the reason the word group is so important in insurance) of people who preferably are all at ostensibly the same risk (a risk pool) and who wish to cope with that common risk. The risk may be inevitable but of uncertain timing, and it may be like a lottery and more likely to affect you only if you live for a period of several lifetimes.

If a hundred people are all thought likely to face a bad outcome (a disease, an accident, a hurricane) but just don't know when, but do know it will on average be in the next ten years, then over a period of ten years each one will experience the event. Hence the group will be paid one hundred expenses, and so the insurance company will have to charge them as a group for one hundred expenses, so the average cost over the ten years will be one expense each. Each will have paid for his own claim. But each will have paid for that claim over a ten year period. The insurance company has not paid for their claim, it has financed it.

Among the more obnoxious features of ObamaCare is that it punishes people who have been responsible in financing their own health expenses through insurance and it simply pads their groups with people whose risks are in many cases far higher, and then expects the low risk people to pay for the high risk people, in many cases forgiving premium payments from some groups entirely. This is why ObamaCare is not health insurance at all but rather is a form of socialistic welfare (income redistribution). Calling it health insurance is a bigger lie than saying "If you like your plan/doctor/hospital, you can keep them, period, end of story, no matter what".

In the case of more nearly lottery-like events, an "honest" insurance group may face a need for some heart transplants, but some will die before they get to that point. So if one of them is going to get to that point over an average life span of several decades, then they will all pay a small amount each year and those who don't need the transplant win the lottery because they don't have to have it, and the one who needs the heart transplant wins because he does not have to pay for the whole thing himself. When so-called preexisting conditions are forced into insurance groups, it is a particularly blatant socialism, but it bears no relation to real insurance.

If the risk is not spread over a significant period of time (if everyone faces the risk at a high rate rather than over your lifespan or over several life spans) then it is also not insurance (someone financing your risks for you) then it is a credit card that you pay for in advance. Bread insurance is never insurance because if a hundred people eat a loaf of bread a day then at the end of the each year the insurance company would have paid for 36,500 loaves and when divided up, your daily "insurance" premium would be the cost of your daily loaf of bread *plus* administrative expenses (unless your insurance group has been loaded up by your government with parasitic members who pay little or nothing).

In the case of Cockroaches, the risk level is likely to be so small that insurance should be highly economic and even retirees with primary ICE-cars may want a Cockroach for errands.

Capitalization and Organization

If the K-Car designs could be coaxed, cajoled, leveraged or bullied into the public domain, who could, who would, chance producing and perpetuating and perhaps enduring new-production runs of them? They would be much less expensive to launch than a brand new marquee, but the front capital would not be small. There would be some engineering needed as a minimum, as well as, capital injection. And a lot of volunteers as well as conventional labor would be needed to mirror the LINUX model. Frankly the government has a stake in this, even though it is clueless. So do many others. And if there are to be any parallels between this and LINUX, then there needs to be public-spirited volunteers to be found to play a vital leadership role? Where can you get such volunteers?

Remember the Cockroach is a niche car. It typically serves only those who drive infrequently and/or for shorter distances. People, especially those like the writer (who is retired). Many retirees today have seen their "entitlements", their Medicare and Social Security ripped off, curtailed or reduced by a government that has mismanaged and looted their trust funds and they face more of the same.

In the past years, since 2008 when the latest depression/banana started the writer has witnessed one of the most blatant rip-offs ever when our wannabe Socialist President and Congress launched ObamaCare by promising to reduce Waste, Fraud and Abuse *in Medicare* by $500,000,000,000 (that's half a trillion dollars, repeat 0.5 trillion, roughly the initial cost of either the Iraq or Afghanistan wars) and then deciding somehow that that *entitles them* to take that budgeting out of the Medicare trust fund,[23] as an entitlement of their own, to loot it, and spend it on none-Medicare special interests. And their party cheered them. In earlier times both Medicare and Social Security, as well as other money pools, have been looted frequently, but at least the looters had the decency to pretend they were only borrowing the money. And yet that same looting party had no problem in damning (as I also did) the previous president for using two wars that fattened the coffers of Halliburton as literally a sole-source war vendor (Hey! Not any company can feed troops—it takes a lot of skill to make sandwiches). Some even think of that earlier president and that company as war profiteers. I know I do, and I am a Republican for the time being.

But we should not be surprised at the flagrant way both parties rip us off. There is a *Far Side* cartoon in which a pride of lions sits on a hill looking down at some antelope. One of the antelopes is up on his hind legs and has a cast on one of them and he is walking with crutches, and the caption has him musing tragically: " I just know they are looking at me". That is known as "The Law of the Jungle", and "Survival of the Fittest". It was always thus. A World War two flying ace was once asked what made him so successful, and he was candid in admitting that he looked at the flying skills of the pilots in the German aircraft, and then he tried to shoot down any that looked new or inexperienced. Less skill makes them easier targets. The predator always goes after the very young or very old, the sick, the infirm, the dumb. It makes them easier. So too it is with our government. Social Security and Medicare have been easy targets for predation. But I can only hope not as easy as an antelope with a cast and a crutch.

Why is it that we have two parties that agree something has to be done about the Medicare and Social Security Ponzi schemes, but neither of them wants to simply pay their God-damn debts. Today you hear of only three strategies: cut benefits, raise premiums or run them dry. They would like to walk away from them like they are homes with mortgages that are under water. How is it we have come to be burdened with such a dead-beat government? In 1774, King George III was less tyrannical with his stamp tax on tea.

[23] In an effort to stress the importance of this protest, which wells up in me as much as tax anger wells in any TEA partier, I considered including a political cartoon here which showed a storefront with a smashed window and on the remaining shards at the top of which is lettered "Medicare" and a President caricature perhaps also with a woman caricature to represent the former Speaker of the House and a milquetoast male figure to represent the former and present Senate leader all three of which are stepping out of the broken window with overstuffed satchels from which are projecting bills of US currency, the satchels being labeled $0.5 trillion. In the fore ground running away from them are three men leaving the storefront carrying TVs, the pictures tubes of which are displaying "Waste", "Fraud" and "Abuse" and the caption presents the President saying: "Don't worry we are going to put a stop to *their* looting." And just because it would please their party so much, I would have had Hitler-staches on all three of them (perhaps to make people think of Kristalnacht). The title of the cartoon would be the date the ObamaCare Bill was passed. Cartoonists are free to borrow this theme.

I would have been supportive if our dead-beat (number 44 not caliber 44) President and (number 111) Congress had said they would try to reduce Medicare waste, fraud and abuse by up to a half a trillion, if they had then said they were going to "borrow" that same amount to launch a Kennedy-esque research effort to keep us safe on behalf of the Medicare beneficiaries, seeking to reduce medical costs by finding *practical* cures for the current scourges of cancer, diabetes, Alzheimer's, Parkinsons, and other God-awful expensive maladies that threaten and destroy Americans in ways that Osama bin Laden could have only dreamed of when he was murdering those piddling three thousand people in the World Trade Center. Hell! If it had been placed on a referendum, which I still encourage, I would have voted for it. Instead they looted, why am I not surprised?

Practical cures would reduce the need for medical care and costs[24]. And would serve *all* of Medicare's beneficiaries *and everyone else*. Instead, these scourges are largely ignored while they kill Americans as if they are an army of Osamas.

Similarly, a *practical* Cockroach would serve the needs of some retirees especially those of lesser means for which transportation cost is especially burdensome and for whom a nice new highly reliable ten-thousand dollar Cockroach, (perhaps less a government $7500 incentive?), would be warmly welcomed. And so the Cockroach could help save Social Security by helping save its beneficiaries. Launching a *practical* Cockroach, would lessen the financial burden and other burdens on massive numbers of retirees, making them less dependent on Social Security and its COLAs. Therefore, I find it reasonable for the government to provide funds for facilitating a K-Car based Cockroach effort even if it means *borrowing* (rather than looting) those funds from the Social Security Trust Fund (to be repaid perhaps with the same low interest that is being paid on the Trust Fund's poorly managed treasury bonds) in an effort to help retirees cope economically. And I assure you, and will prove to you, that many retirees would rather pay $10,000 (less an incentive plus super-low interest to Social Security) for a Cockroach rather than $43,000 for a Volt.[25]

Indeed, if a Cockroach proved to be as desirable as it would for the writer, it might provide a fourth alternative to saving the Social Security and Medicare Trust Funds besides cutting benefits, raising premiums or running them dry. The Cockroach would allow for ***nonmonetary*** benefit payments. Namely since Cockroaches offer so many benefits, retirees like me might welcome reduced Social Security payments in exchange for the many advantages (the *non-monetary* compensation) the Cockroach gives. Freedom from safety, pollution and energy regulations, maintenance, ridiculous insurance burdens that serve no useful pur-

[24] Although practical cures can reduce the *need* for medical care and costs, never forget that the United States' medical industry has been taught to apportion its costs over its prices. And if the number of patients entering their megalithic industry is halved, they will react by doubling those remaining prices. Their industry would have to be halved but today they are busy expanding at breakneck speed. Saving Medicare would put them in a need of a bailout. In the writer's area, the big employers were traditionally: Bethlehem Steel (that made the steel for the Golden Gate Bridge), Mack Trucks, Union Pacific Railroad, and an Electrical Power utility: Pennsylvania Power and Light. Today, at least four out of the five largest employers are hospitals.

[25] In 1996 William Clinton launched a "National Home Ownership Strategy" which began with changing the Community Reinvestment Act quotas which ultimately forced banks to make 50% of their loans to risky (meaning less than optimum) borrowers, and in 1999 he changed the quotas for Affordable Housing Loans by Fannie Mae and Freddie Mac so that half their loans were risky also. The writer is among those who blame the 2008 real estate and consequential depression/banana on *this* scheme.

pose. In other words, freedom from imposed tyranny.

A Public Service (Socialist) Organization

Although there are many Americans who despise the American Red Cross, the Red Cross does not appear to be at risk of suddenly announcing it is going to upscale it services to increase their cost so as to increase its profit margins and therefore the value of its stock and the bonuses for its top managers (although some may feel the Red Cross overpays, over solicits, and under-serves). When times are good they do not spend like crazy and when times are bad they do not go out of business. Those are all elements needed in the business plan for a survivable public-service Cockroach producer.

No one, not even conservatives, questions the non-capitalist, non-free enterprise, need for public service organizations such as the Red Cross, which solicits contributions of money and labor for at least some benefit of those in need. Today retirees face the abridgment (oh Hell, call it theft) of healthcare and retirement they have paid for. Some face potential devastation much as if a hurricane or flood or tornado had destroyed their homes.

Today a public service organization chartered somewhat like the Red Cross could promote the production of, or could actually produce, Cockroach cars. These cars could serve to the benefit of their owners, the nation, the Social Security and Medicare trust funds, the retirees, and the environment. In 2009/10, we saw one political party brazenly loot the Medicare Trust Fund budget in order to divert funds to their pet projects. In 2010/11 both parties looted the Medicare and Social Security Trust Funds by canceling payroll taxes, and try to guess which one them tried to extend the payroll deductions even further as a "jobs" bill. One party now wants to give citizenship to a dozen-million (or two or three dozen million) of largely low income illegal immigrants, which will place them into the Social Security and Medicare systems, which are "progressive entitlements" [meaning "graduated" and *not* something yielding "progress"]. As a result these systems would suffer grievously when their rolls are flooded with low income contributors who will someday seek disproportionately high benefits that skew the funding base and make its shortfall worse rather than better. They want to do this, because these new members might help pay for today while making tomorrow much worse (more "Ponzi", and they might also vote for one party in particular). This is what politicians refer to as kicking the can down the road. It seems scurrilous but is much worse, and yet if they want to give Social Security coverage to these dozen millions, then why shouldn't they give it to everyone. To all the people of England, France, Germany, Spain, so long as they pay a pittance to help out now. Citizenship for everyone!

However, a public service organization that relies heavily on volunteer effort from motivated supporters and donations and with the ability to borrow funds from the Social Security Trust Fund in those cases where it serves the fund's beneficiaries makes uncommon sense. I should not have to tell the story of the squirrel and the grasshopper and its modern antigovernment version (you can look it up on the Web). Of course, squirrels are a lot smarter than most politicians.

And if retirees can save on energy and pollution and perfect the Cockroach as a new paradigm that can serve other niches as well, the whole nation can benefit. And perhaps most importantly it could be a public service organization dependent on retired volunteers and beneficiaries who have no incentive to fatten stock values or management bonuses, might (let's hope) monitor itself scrupulously for efficiency and effectiveness for the benefit of the "least" among us.

Problem Solved, …..Not

This book, perhaps the first of two, makes the case that a new manufacture Cockroach EV is viable and that as a bare minimum with some luck and some astute engineering and a slew of ingenuity, it can be a breakthrough that can really benefit some retirees, especially lower-income retirees. In the process, it can even help lessen the pressure on the Social Security Trust Fund. Win, Win. This writer is convinced of that but also of much more. This writer is of the opinion that many breakthroughs have already been made that can make the Cockroach a vehicle that most families might want to own, if not as a primary vehicle, then as a secondary vehicle. Add another win to the equation.

So what would a final Cockroach actually look like? Like a K-Car or its derivatives? If there is a second volume of this series, it will elaborate on the writer's own detailed design and analysis of a Cockroach that could be easily manufactured. That volume was originally intended to be a massive appendix to this volume but when contradictory data were found that made it impossible to perform a complete analysis of the internal resistance of lead acid batteries, it was deferred until some serious testing can be accomplished.

However, despite both the strong case and the strong conviction, is there any chance of the Cockroach gaining any traction at all? So many like to say "we need to have a serious conversation as a nation". And indeed, we need to have a serious conversation about the Cockroach. However, there are far too many people who do not want their own apple carts upset, especially including those in government whose special interests want to ignore "the People". They do not want to compete on fair terms.

As a nation, our problems are almost always caused by our politicians who spend the greatest of their energies controlling us rather than serving us. I am of no doubt that there are solutions available to many, maybe all, of the problems facing the USA. Maybe the Cockroach EV is one of them. But those in power who have done their damnedest to thwart Democracy (one party for its reasons and the other party for its different reasons) really just want to control us so that they might exploit their divine rights over us as our lords and masters. And so the next chapter deals with the biggest over-riding obstacle to the Cockroach and perhaps every other progress: the politics of the USA. For at the present, no matter how good a solution is defined for *any* current problem, there is no reason whatsoever to expect that solution will get a fair consideration or prevail based on merit. And that is a far bigger problem than the science and engineering.

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Warning!

Our System is Blinking Red—*Again*!

The United States is beset with problems, some really big, some small, and among the small ones is economic transportation such as the Cockroach EV for lower-income retirees. Pretty damn small. Many of these problems, big and small, are solvable, some quite easily, just as the Cockroach EV might perhaps easily solve economic transportation for some retirees. But the odds the Cockroach EV will ever solve anything may be slim at best.

The United States is also beset with talent that is being misused and wasted. Talent that is oftentimes directed to prevent "solvation", to dominate and control and curtail the freedom and liberty upon which the nation was established, and often the purpose is to merely gain an unfair economic advantage over one's peers. In other words, Representative Democracy has been overthrown [26]. That be bad.

[26] A quick, if faulty, history lesson about democracies and republics. Hundreds of years B.C. Greece invented the Democracy in which its City-States were run by majority rule of the people. It was a huge success. However it was slow taking all the necessary votes. Later Rome invented the Republic in which the leaders (Caesars and Senators) were elected to fulfill the will of the people. These leaders were charged with making the decisions the people wanted made without having to take all of those votes. Although mistakes could be made, the republic had great advantages: efficiency and speed. So when Rome attacked Greece, it was a little like Hitler's Blitzkrieg, while Greece was voting Rome was winning. In the USA today the government is a Democratic Republic, but a sinister corruption has been promoted to the effect that officials try to claim they are elected *to follow their own conscience*. That is a bald-faced lie. Politicians are elected to determine and effect the will "of, by and for" the people, not to substitute their own opinion. This leads to horrible corruptions. Supreme Courts that decide rather than interpret the Constitution and think that is okay. Politicians who tell any lies they can to get elected and then like Presidents as far back as the writer can remember do whatever the Hell they want instead on the basis that they are following their consciences.

However, while we need powerful leaders who can make tough decisions quickly when going to war, (like in the days when the Soviet Union might have launched its missiles against us), we do not need such leadership on many of the great issues of the day that have dragged on for decades. There is plenty of time to take a vote on abortion, and yes even on most wars. By allowing the two parties to limit us to the election of only the cronies they put up, we allow them to effect a coup d'etat. And this is where our fellow citizens worst guilt comes from. Today voting for either party is un-American.

This is not to say full centralism can work, it can't, but in facing this fact, one can come to appreciate why diversity, why Federalism is crucial to allow states to be significantly different so that some states can allow abortion where they consider it a right worth fighting for and others can preclude it where they consider it a crime worth fighting against. Unless of course we want to square off in civil war over such issues.

Politicians including Presidents are hired hands, nothing more.

If you think you have a solution to a problem, as the writer recently did and will soon explain (and he is *not* referring to the Cockroach EV), you might think that the lore of the United States might obtain. "Build a better mouse trap and the world will beat a path to your door." You might think that your idea is entitled to a fair consideration. You might hope that the protestations of the current President that he is always looking for new ideas to solve the country's problems contain more truth than did his declarations you can keep your healthcare if you like it. Not so, not even close.

The United States is also about winning. Oftentimes winning at any cost. Some will go to any ends to win. Even when the incentives are surprisingly small, they will lie, they will cheat, they will murder, rape, and pillage, *and they do*. And among the very worst of these are our politicians. Unfortunately when politicians go too far bad, it can lead to a very dangerous condition: *tyranny*.

Tyranny is the greatest single obstacle to the Cockroach EV and to most other problem solutions. One can obsess over the technical issues examined in the first seventy-two pages of this book and its appendices, but tyranny dwarfs them all. And therefore tyranny deserves a careful examination here, for its consequences are often grave. Tyranny must always be dealt with or *it* will deal with *you*.

Now tyranny (the "T" word) is a word that should be used with a modicum of caution. Its use should not automatically offend anyone. But one should always remember that it was tyranny that ultimately and finally sparked the violent rebellion and revolution that overthrew our last government and which codified the conduct we expect from the current government. That code of which is currently being so massively ignored and violated.

The First Amendment to the Constitution declares Americans have an absolute right to talk and write openly as I am doing here about whether the government has again lapsed into tyranny, and the Second Amendment to the Constitution (somewhat more symbolically today) is intended to ensure that we, the people, have the firepower needed to deal with any tyranny that may take root, and to enjoy individual equality of power that ensures the majority *is* the dominant power. In other words, there are good reasons to listen to the electorate, because tyranny of them justifies rebellion and revolution. Tyranny can make rebellion/ revolution a duty. Tyranny, like dynamite, is very serious stuff not to be played with.

The United States today is once again a tyranny, and I shall soon prove it. My apologies if that conclusion upsets you, but you need to realize for your own good that I am not the only one who draws that conclusion, and that means you need to listen up. At present, many of our people appear willing to live under the current tyranny. They are free to make that choice. However, if even a few are not, then such tyranny is like a pressure cooker. It can take a long time before the pressure ruptures the cooker. But when it does, the resulting spontaneous explosion can be both abrupt and devastating.

If the current majority willingness to tolerate tyranny should abate, then rebellion and revolution are once again likely. I don't make this news, I just report it. The politicians, especially Democrats, that form our government tax at oppressive levels. They do not represent the people (taxation without representation being the first form of tyranny that led to the first revolution). And too many current politicians seek to overthrow the people.

Today, politicians of both major persuasions seek clever ways to thwart the first and second and fifth and other amendments. They pass insidious laws. They install cameras by the millions and seek to record every movement of everyone. Bank records are tracked scrupulously. Phone and email and other communications are read even if they are encrypted. They will torture. They will vocalize devotion to the Constitution and service to the people and will take vows to uphold both but they routinely betray them both [27].

Such tyranny might ultimately lead patriotic heroic Americans to conclude violent rebellion, indeed violent revolution, is once again justified in these United States. Indeed it has already done this (It has convinced me.) and the harbingers are obvious for anyone willing to see them. I do not advocate violence of either kind. In fact I oppose it and not only in part because to advocate otherwise might violate one or more of our tyrant's laws. Rather, I oppose it because the first revolution and even the later Civil War were stupid and wasted their violence. I conclude that, as an objective observer, both would have been better avoided and at least one could have been. Nonetheless, our government and the people that elect it, and those who abstain, are playing a very dangerous form of Russian Roulette these days with our well-being and even all of our lives.

These times are trying. The current depression/banana is real and threatens our well being and, yes, our very lives. The healthcare crisis is real and threatens our well being and, yes, our very lives. The immigration reform crisis is real and threatens both our well being and, yes, our very lives. The National Debt is real and threatens both our well being and, yes, our very lives. And these, as well as the potential, yet comparatively trivial, need for the Cockroach EV, are only a few of the problems confronting us.

Chapter eight of the 9/11 Commission Report [**23**] is titled: "The System was Blinking Red", and it details how in the days, weeks and months prior to the 9/11 attack, there were numerous grim and obvious harbingers. Numerous conspiracy theorists today suggest our own government knocked down and even imploded those buildings. Doubtless some of these conspiracy theorists may be government agents provocateur, offering bizarre explanations as a way to obscure and discredit the more plausible critics. However, few of the conspiracy theories make the government look as bad as its own commission report. And the report does not specifically cite, or at least it does not examine, a number of signals that were missed, or perhaps more likely were deliberately ignored, even by the Commission, that make the government look *really* bad. It was as if the "imminent" terrorists were just trying to get our attention, and our government, acting also as an agent provocateur, was convincing them the only way they could do that would be with an attack that our government actually wanted so that it could be exploited. It was not the first time that such a situation obtained (think Pearl Harbor, think Gulf of Tonkin) in which our government conscience wanted the country to be attacked.

[27] In the writer's opinion, betrayal was evident in the blatant aristocracy that the "Compassionate Conservative" George W. Bush exhibited during his bipartisan wars in Afghanistan and Iraq. Though claiming to bring American-style democracy to the region, neither country's Constitution includes a "Second" Amendment. Indeed, news coverage frequently exhibited American troops kicking down Iraqi and Afghani doors, searching of their homes and confiscation of any arms they might have, calling it something like "clear and control" and making them vulnerable to the armed Taliban and Al Qaeda forces. Bush often said, US troops will stand down when Iraqi troops stand up. And we often heard criticism of the Presidents in each country for not "taking control of his country". In other words, Bush's interpretation of democracy is when the government controls the people, namely tyranny, rather than when the people control the government. This was just one of the reasons I, as a conservative Republican, voted straight party tickets for the Democrats in 2006 and 2008. Those Democrats have now more than amply demonstrated their own brand of tyranny.

Today because of that “cowardly ignored surprise attack”, The PATRIOT Act imposes severe encroachment on our liberty that would have been unthinkable before the attack. So the attack served the wishes of the FBI well. I must and do assume the Homeland Security Department supposedly making our safety its number one priority spends more time tracking internal threats (from people who oppose tyranny) than it does on outside threats. All this because nearly three thousand people were allowed to die unnecessarily, September 11, 2001.

Today (2013) the Homeland Security Department has a sequestered budget of 50-100 billion dollars and the Defense Department has a budget of 700 billion dollars and who knows what the secret massive CIA budget is, while research into the cure for cancer is given maybe five billion dollars (to the National Institutes of Health). And yet our gravest threat by orders of magnitude comes from, likely-unnatural, health scourges like cancer that kill more than a million Americans every damn year and that receive less than one penny on the dollar in comparison. Cancer alone is killing more than one American every minute, 60 every hour, 1440 every day, 10,000+ every week, more than a half million every year..... And the Medicare trust fund is being ravaged to pay for expensive yet largely hopeless treatments with little chance of real success. Stupidity, yes. Tyranny, yes.

In this writer’s opinion (that it is admittedly unlikely anyone will pay attention to), our system is blinking red—again! Our pressure cooker is bulging at its seams. We are ripe for violent rebellion and revolution if the right trigger is pulled. So how does one promote the concept of the Cockroach EV in such a delicate climate. To do that this section seeks to:

1. Examine the current crisis and its harbingers and fully expose the tyranny.
2. Appeal for help in backing away from conflict and try to prove that every one, even just one, man can make a difference...and should.

Our Present Crisis/Tyranny

Tyranny in these United States needs nothing more than the current excessive taxation without real representation to define it, but it goes way beyond that. It is also defined by the current depression/banana, the healthcare crises, the health crisis, the immigration reform crisis, the National Debt Crisis, and the Second Amendment Crisis. The last of these examples may be one of the most important because of the un-American methods, like mini-genocide, and rights-suppression tactics that have been used as tools of the tyranny. These can easily serve to justify rebellion and even violent revolution in the minds of even reasonable patriots. It bears close exploration.

Mini-Genocide and Its Consequences

William Jefferson Clinton was elected President in 1992, in part because the Republican party turned its back on George H. W. Bush and his policies including his “Read My Lips No New Taxes” promise/lie. However a majority Democrat house and senate also were elected, which immediately launched a traditional Democrat tax and spend agenda (tyranny all by itself). But that was not all. In the very first months of Clinton’s Administration, they began an intense assault on the Second Amendment. Democrats like to claim their candidates are uniquely really intelligent [Oh! Wasn't that (Kennedy, Roosevelt, Clinton, Obama) so smart?]. However, Clinton's assault was as stupid as it gets. Democrats have a long standing obsession trying to overthrow the Second Amendment right to keep and bear arms. It is as irrational as any mental illness can be. They try to be both sophistic and clever in disguising their efforts. And they lie with abandon about their intents, but they fool no one even when they succeed in chipping away at it. This analysis will mince no words in demonstrating the stupidity and the evil of their sinister obsession.

In 1993 they began their new administration with a brutal assault on a apocalyptic religion group in Waco, Texas[28] and wound up making the group's prophesies come true by killing almost all of them in a siege and attack with parallels to both Masada[29] in 73 A.D and the World Trade Center attack on September 11, 2001. Over the following several years they would go on to pass a bogus "assault weapons ban" (which was not about real assault weapons at all), and the Brady background checks bill (which was not about real background checks either). Both were camels-nose-in-the-tent efforts to suppress the Second Amendment. And they had shameful help from some "moderate" Republicans that were more likely either Democrats acting as double agents or actual rebadged Democrat agents provocateur.

The assault on Waco was to enforce a much earlier Democrat assault on the Second Amendment from 1934: *The National Firearms Act* passed by a too-clever FDR and based on a sophisticated Supreme Court ruling that even if there is a Constitutional Right, the government can regulate that right if it also taxes it. And so in 1934 they placed a stamp tax ($200 or more than half the price of a new car then) on "automatic" firearms (which includes firearms that would later quality as real "assault" weapons[30]). Then they "cleverly" did not

[28] The term "Waco" is used here to apply to The Waco Tax Party, named for the city in which it occurred, it has come to symbolize what some think of as an American mini-Auschwitz. In 1993, The Bureau of Alcohol, Tobacco and Firearms (a tax collection agency) raided, in storm trooper style, a church in Waco, Texas, that was suspected of having guns on which (though potentially Constitutionally protected) the stamp taxes mandated in the Democrat National Firearms Act of 1934, may not have been paid. Often bullied, fearing for their lives, and feeling in imminent peril, the congregation attempted to defend themselves, and were ultimately destroyed. Democrats who ordered the raid attempted to defend the resulting mini-holocaust on the basis that the church leader was a child molester and hence they all had it coming. Makes the commentator wonder if among the three thousand that died in the World Trade Center, there may have been one or more child molesters and whether that could mean they all had it coming to them also.

[29] Apparently in 73 AD, Roman legions were seeking to capture Masada, a fortified mesa about a quarter mile high then held by less than a thousand of the last remaining free Jews. For two years they held siege and built a ramp to allow them to access the stronghold. Upon finally breaching its walls they found the Jews had killed each other rather than become slaves. Better free dead than "Roman slave".

[30] According to current (2013) Wikipedia, Adolf Hilter coined the name "sturmgewehr" or "storm rifle" to describe the "Maschinepistole 43, (later named the Sturmgewehr 44) in about 1944. It was intended for use by storm troopers. We now consider storm troopers (in the sense of troops that "storm" castles or churches as in Waco) to be assault troops and so the weapon name is translated as "assault weapon". Their main strength was the ability to auto fire. Today the name is being corrupted to make legislation against non-automatic weapons easier to justify, by wrongfully suggesting they are intended only for military use despite the fact that real military weapons like the M-16 are capable of auto fire while none of the banned firearms were.

print any stamps. How is that for sophistry? [31]

The apocalyptic conclave at Waco was not popular in the community nor with its neighbors and had been going through assorted harassments and harangues for a long time. Neighbors had been trying to chase them out. They were about as popular as a conclave of African Americans would be in some parts of the country, if they were to set up a gunsmith shop, and a shooting range, and made a lot of noise while using it.

So it appears the Bureau of Alcohol Tobacco and Firearms collected some weak information and jerry rigged it into a ludicrous search warrant, judge shopped for someone not too familiar with the law and set out to conduct a spectacular militaristic raid on the Branch Davidian Church (literally "storming" it) apparently intended to make the ATF look heroic and surely gain for them a handsome budget from the new antigun administration. It was a raid that would have made the Nazi's proud. It was a tyranny most foul.

When the Davidians defended themselves as was their right to do under law, a battle reminiscent of Lexington and Concord resulted. When the FBI was called in, instead of arresting the tyrant ATF operation, they laid siege to the church instead for more than fifty days, terrorizing them in numerous ways, depriving them of sleep and ultimately killing nearly every man, woman, child and baby inside. It was a tragedy worthy of Presidential tears but there were none. Instead within three years, the bogus assault weapons ban and background checks laws were passed.

This particular tyranny, as emblematic as it was of the shootout in Lexington and Concord (which happened on the same day of the year as the final siege of Waco), did not sit well with many patriotic Americans, most noteworthily: one Timothy James McVeigh.

This writer believes McVeigh is best described as a cold-dead-hand defender [32] of the Second Amendment. He could not tolerate such genocidal tyranny from his own government, the government of the country he loved and had served brilliantly in war, and had both sworn to defend and had killed his fellow men to defend. Waco was, and still is, in the hearts of many Second Amendment Americans, like the church bombing and killing of four little girls in Birmingham, like the case of Emmit Till, and like the march across the bridge in Selma are in the minds of many African Americans. So when that tyrant government began whitewashing its tyranny, its mini-genocide, and there was no justice for the victims of Waco delivered (as there has not been to this day yet), it was a clear call to action.

McVeigh (1968-2001) was a decent, talented and capable mainstream American. He had both a highly developed patriotism and love of country. He believed in heroism and was a demonstrated, recognized, and decorated hero. He believed in the Constitution and accepted his personal duty to preserve, protect and defend it. And he did not appear to appreciate bullies nor bullying. His threshold for violence was not low, but he clearly understood and accepted a legitimate role for violence. Perhaps growing up as the child of a long-term member of the autoworkers union helped inform his philosophy.

He would have known the autoworkers union is a group forged in the domestic (and

[31] The Bureau of Alcohol Tobacco and Firearms website currently (December 2013) comments on the National Firearms Act (NFA) of 1934 saying: "While the NFA was enacted by Congress as an exercise of its authority to tax, the NFA had an underlying purpose unrelated to revenue collection. As the legislative history of the law discloses, its underlying purpose was to curtail, if not prohibit, transactions in NFA firearms."

[32] From the popular gun culture saying: "You can take my gun when you pry it from my cold dead hand."

illegal) violence of the twenties that it believed was justified violence, and as a group still has used intimidation and the potential threat of violence to operate its union as a sword rather than a shield to this day. In many regions, like the one the writer grew up in, union members were feared and represented a well-to-do class, paid often extorted wages beyond their skill-levels while feigning humbleness. As for most of the large unions, the autoworkers have been a darling of the Democrat party, praised for what it is and does, wooed for its political power, and was callously rewarded in 2009 when a Democrat president who prides himself on having saved General Motors and Chrysler from bankruptcy, in fact bankrupted them both and then gave big chunks of both to that union. Yes, McVeigh would have known that power one is not afraid to use can be very effective.

He had many potent options available to him. He had worked within the system and had done everything that could be reasonably expected of him. None of it was of any consequence. Hence, he only learned, as many citizens including this writer also knew, the system was not working. He was censored, marginalized and excluded, but knew one man can make a difference. Like the founding fathers of this nation, he narrowed his choice to an act of rebellion (and retaliation) much like theirs. The destruction he was capable of delivering was awesome. However he chose a limited attack on a Federal Building in Oklahoma City that was about twice as deadly (including some similar collateral damage) as the attack on Waco. It was intended as a measured but important response, as a message, as a statement. It was an act most Americans could have and should have recognized for the heroism it displayed.

Afterwards, the response from the government and its toady press was outrageous. President Clinton (killer of equal numbers of babies at that time), like Inspector Renault in *Casa Blanca*, was absolutely shocked. To him, "It was an act of cowardice. And it was evil."

McVeigh had worked within the system in the finest tradition of his forebears, and notwithstanding his discretion, he was treated as a common criminal, given a kangaroo court trial, in which he was denied the correct defense he was entitled to in law, was convicted and sentenced to death under the very same law that incorporated the bogus assault weapons ban. He was executed exactly three months (June 11, 2001) before the World Trade Center attack and gave his life for his country with the same bravery as when he had taken life for his country. To some of us, it was as if Lincoln had summarily had Robert E. Lee hanged.

The system had failed McVeigh and all of us. The system did not work.

The System is Still Not Working

In a sequence eerily similar to that in 1992, Barack Hussein Obama was elected President in 2008, this time because the Republican party turned its back on the son of George H. W. Bush and his policies including his "weapons of mass destruction in Iraq" promise/lie. However a majority Democrat House and Senate also were again elected, which immediately launched another traditional Democrat agenda (more tyranny all by itself).

Obama was again held out as one of those Super-Smart Democrats. Indeed, he managed to restrain his antigun agenda until the shooting in Newtown Connecticut on 14 December 2012[33]. And then all Hell broke loose. Any residual Government of by and for the peo-

[33] The President called it the worst day of his presidency in a crocodile-tearful speech in which he vowed to seek new gun "safety" [meaning Second Amendment thwarting] laws. He had no problem with the children he was killing with bombs he rained on them from drones, nor for the reelection help he had just received from for-

ple went missing that day.

Four months later a series of familiar sounding laws were voted upon in the Senate, including ludicrously expanded versions of the Clinton-era laws on the earlier bogus assault weapons ban that had lapsed and that was drafted by the same Senator (Dianne Feinstein, Super-Smart Democrat or Super-Bimbo Extraordinaire?) that had drafted the previous bogus law in 1994, and also sought an extremist bogus "Universal Background Checks" law. This time their majorities were not quite great enough. One-by-one the bills went down in ignominious defeat, ending with the Democrats vowing they (their tyranny) will rise again.

As always Democrat promises/lies played a major role. Their bogus assault weapons ban was especially pernicious and sent a harrowing message to all supporters of the Second Amendment, namely that the arrogance, ignorance and tyranny of these Super-Smart Democrats was virtually without limit.

However, nearly as bad and just as educational in this effort was the tyranny in their bill to adopt bogus "Universal Background Checks".

The push for "Universal Background Checks" was a galactic scale lie in that it had nothing to do with its principal stated goals. However, it allows one to infer whether Democrat politicians, Super-Smart or not, measure up to minimum standards for honesty and decency, or whether they pose an imminent peril to us all. They fail the former almost en masse and as to latter, they do.

With the same fake sincerity the President had employed when he was promising everyone who liked their health insurance plan, or their doctor, or their hospital, that they would be able to keep them, *period*, no matter what, Democrats launched their subterfuge to just keep guns out of the hands of people who should not have them referring to them as: "dangerous criminals and the severely mentally ill". Surely *everyone* wanted *that*! And this lie proved appealing to many who had no more clue what was in the proposed law than what was in Obamacare. Some polls claimed as many as 80% agreed with their bill when more likely what they agreed with was keeping guns out of the hands of criminals and the insane. Of course that was only the sales pitch and not the intent of their law at all. Nonetheless, it was as if Hitler had promoted his "final solution" as a safe streets act, something that surely *every* German would want. Democrat intent was not about serving any such noble goal. Like the Brady Bill before that it extended, like the National Firearms Act that was used to execute the Waco mini-genocide, it was about "suppressing gun ownership", about thwarting the Second Amendment, therefore the very Constitution itself. Some might call that treason.

Could it possibly be these poor Super-Smart Democrats did not realize suppression was their real consequence? Not very likely. For this was in the wake of the 2012 Presidential elections in which they had politicked massively and complained and gone to court to try to prevent what they called Republican Voter Suppression in an series of laws in numerous states that merely sought to prevent "people who should not be voting from voting". Surely *everyone* should want *that*! These voter laws varied but generally included the requirement to display a valid form of photo identification prior to being allowed to vote. Yet super-smart Democrats were not fooled, they were shocked.

Democrat commentators and politicians squealed unmercifully about how unfair and

mer-President Clinton (who had killed as many children at Waco) and within a year he would extort funding for his healthcare act by rejecting all other funding thereby interrupting the treatment of children with cancer. Super-smart and super-hypocrite.

racist that identification requirement is. The hypocrisy was insuperable. It was no big deal that they lied about allowing people to keep their healthcare plan, doctor or hospital in their Affordable [not] Care Act (Obamacare) then considered the lie irrelevant because only five percent or so of people would fall a victim to the lie. But for a few percent of the people who did not already have valid identification (drivers license, or alternative or passports, etc.) they felt that use of a non-photo electric bill should be accepted as proof of voting rights.

Those like myself who thought that valid identification was a reasonable request (since similar identification is routinely required to cash checks, buy alcohol and cigarettes, and do almost all forms of legal transactions), again found ourselves being labeled racists and sexists by numerous Democrat Infomercial Media. One could watch media reports condemning the racist Republican Voter suppression laws back to back with reports that the racist Republicans were serving up children as practice targets by opposing the Democrat Universal Background Checks law.

Democrat infomercial reporters followed elderly minority women as they tried to get a state photo identification, and for some they claimed it could take several totally unreasonable hours. Damn those racist Republicans! Clearly this was proof of efforts to subvert Constitutional Rights by suppressing the vote.

And yet the Right to Vote is certainly no more a Constitutional Right than the Right to Keep and Bear Arms (the number two right). So perhaps the Democrat's own Brady Bill and proposed Universal Backgrounds Check law (2013 Senate Bill S.649) can teach us how those same poor minorities should be treated so as to not subject them to blatant Republican racism? If one of those exact same minority individuals who would be so abused by the Republicans when they wish to vote wishes to exercise their Second Amendment right, they have to (by Democrat decree) first go and *get that exact same valid photo identification* that was so onerous and racist and un-American to obtain for voting (as certified by their Democrat supporters). Then they have to go to their seller (and if not a Federally licensed dealer must subsequently go to such a dealer with the seller) and file an ATF Form 4473 for which if they provide false information can subject them to ten years in prison and a fine of up to $250,000. And the federally licensed dealer is required to accept the form and may not help them fill it in correctly. Do an Internet search on "ATF Form 4473" to see a copy. Surely, being required to file a form like this prior to voting would not deter anyone in a minority, right? Then they wait for a background check by phone which can take as little as minutes. However recent sworn testimony that was not challenged in hearings in Pennsylvania indicate that during busy times it can also take nearly an hour before the phone call for the check is answered, then can take up to three hours if there is any ambiguity, and they may be asked to come back up to several days later, and in the case of some ambiguities can result in having the approval (which would mean their Constitutional right) suspended in which case the person can hire a lawyer and go to court to have their record disambiguated (some say at a potential cost of up to ten thousand dollars), and finally they pay a nominal fee for the background check, *and they do this every time they buy a gun*.

If the voter identification laws are racist Republican abuses, then perhaps the Democrat Brady Bill and these Universal Background Check proposals are an obvious way to replace them with Democrat-approved alternatives, since these are not considered racist abuses by the Democrat party. Simply require a Universal Background Check *every time you vote*.

This hypocritical inconsistency can not stand. This is tyranny that justifies far more than civil disobedience. The rules that allow voting can either adopt the same procedures as the Brady Bill imposes or vice versa. Because at present the Brady Bill is racist, sexist, Democrat suppression of Constitutional Second Amendment Rights.

As the President might say, this is not something to negotiate, even if one has to kill children to prevail (as he did during the government shutdown and with his drones). I either get to buy my gun by flashing my electric bill as proof that I am allowed to, or those who want to vote have to get identification and go through a background check every time they vote, and they also get to pay a poll "fee" (but not a poll "tax", because a "tax" would be racist). What is sauce for the voting minority is sauce for the armed minority.

So is there any way that this Democrat racism and sexism can be resolved? There is indeed but it appears neither they nor shamefully the Republicans wants them resolved. Neither wants to compromise on reasonable alternatives. The writer knows this because he has tried at least as hard as McVeigh tried before McVeigh opted for justified rebellion.

Talking Sense to Politicians?

"What we have here is a failure of communication" says the prison warden famously in the movie: *Cool Hand Luke*. If the lying Democrat party could be taken at its word, that it just wants to keep guns out of the hands of "dangerous criminals and the severely mentally ill" then it would not be that hard to as the Republicans say "find common ground". Indeed this writer has done just that. He has worked within the system that does not work for decades always with the same results and achieved the same dismal results that Timothy McVeigh had. After attempting to "contact" more than sixty senators, a half dozen house members, the President, and both pro- and anti–gun activist groups and more, after slogging though their assorted email submission requirements that are clearly designed to suppress input from the electorate, what was the upshot? Nothing. Nada. Zip. Zilch. Bupkis. To put it another way: more censorship, marginalization and exclusion.

Both parties are so wrapped up running our lives, dictating to us, that they have no time for new ideas and solutions regardless of how much they say they want new ideas and solutions or how they claim to serve us. Almost all have forgotten whom they work for.

But in the game of "keeping guns out of the hands of dangerous criminals and the severely mentally ill" common ground is actually not that hard to find, *if you take these people at their words*. Therefore one can only conclude that noble goal is not their *real* goal. I myself conclude that the Brady Bill is actually intended to discourage (to encumber and suppress and punish) gun ownership and to document who has what (a too-cute Democrat sophistic alternative to a "registry"). In other words it is about Second Amendment Suppression (Thwartation]. And it *is* both racist and sexist. Even worse, it is like the British attempting to seize the colonist's arms at Lexington and Concord.

Here is why. The Universal Backgrounds Check bill is not about background checks. Background checks are currently legal. No one disputes that. Anyone can have a background check run on anyone (on baby sitters, on dates). Any time. So can the state or federal governments. And they do every damn day. They can simply run background checks on everyone, *at their own expense* the same as any background checks I request are at *my* expense, they can put the data on our driver's licenses and then require the courts to update the files anytime anyone loses their right to buy guns (seizing and revising the licenses or identifications of those newly convicted or newly committed). This approach can similarly be used to record the right to vote. Or the right to obtain an abortion, the permission to donate organs (as is already currently done in many states) and perhaps a slew of other useful things.

No more need for the sinister intrusive intimidating entrapment of Form 4473. No more need for the fee. Nor the waits. Nor the approval. One with such photo identification can then buy a gun as conveniently as they can vote (even in those states with long voting lines) by simply showing their "okay to buy" flag. And this flag and any "no buy" flag would not be scarlet letters either. Since tens of millions of conscientious objector Democrats will waive their rights to buy guns, even a "no-buy" flag will be more likely to mean the individual is protesting or making a statement than that they are a criminal or insane. And those who have moral objection to these flags can have them removed and perhaps can go through the background checks instead.

Hence the Democrats can easily have what they say they *just* want, unless they are *just* lying. The Republicans and Second Amendment defenders lose nothing and gain a lot in the bargain. And that could pretty nearly serve as a definition of common ground. Win-Win.

And so when the Democrats ignore this idea and instead opt for a complex, intimidating system, the malice, the evil, the tyranny of the Democrat party is stripped bare. And yet, these arrogant bastards, don't seem to give a damn. They are too busy doing what they do to be bothered. Indeed *both* parties are too busy ignoring unwanted solutions like this.

So what is one to do? How does one do their duty to both participate and control their government? Apparently at some point similar to this, Timothy McVeigh believed we were in imminent peril (and I agree) and concluded a violent rebellion/retaliation was necessary ala Lexington and Concord. And so he did his duty as he saw it.

With some degree of smugness, the writer claims to be a pretty honest citizen. Never been arrested. Paid all my taxes even the tyrannical ones. I believe in doing the right thing. But I have come to the conclusion that the right thing (as in 1773) can be violent. Therefore I must rule under my authority as a United States citizen with accountability for what my country does (in the same way the Supreme Court Rules) that McVeigh was justified and his action was at least as valid as the Clinton Administration decision to violently attack that church in Waco. Clinton was never tried, yet McVeigh was wrongly convicted. We all have duties to perform, and he was just doing his. And this should give pause to us all.

What if a basically honest individual like myself, can find my government to be criminal in its efforts at Waco and its efforts to suppress the Second Amendment among many other ills, *as I do*. What if I can conclude that I, among huge numbers of others, am excluded from participation in my own country, a country I am responsible for, *as I do*. What if I believe my country and its people are in imminent peril, *as I most certainly do*. What if I must rule that my government has become a tyranny, regardless of the party in office, *as I do*. What if I am unable to identify any alternative other than the "military option"? If so, then what are others with greater victim-hood (like McVeigh was) to think? And that is why we must be prepared to consider potential justified rebellious acts as patriotic efforts (Lanza at Newtown?, Ciancia at LAX?, Stack at the IRS, McVeigh in OKC). It is why we must not let our government use its ability to obscure, to claim even principled violent protest is merely ordinary criminal activity whose perpetrators must be given kangaroo court trials and near summary executions as they did with McVeigh.

McVeigh was a hero and deserves the Presidential Medal of Freedom and Congressional Medal of Honor for giving "the last full measure of his devotion" in defense of his country.

We must not let our own government make fools of us like this, because it might and very possibly should lead to bigger and more violent protests later. Remember that McVeigh was a statesman (as so many like him have been), and he made a very measured gesture. Yes it was *not* trivial, causing 168 fatalities and probably tens of millions of dollars of damage. However, it *was* responding to a tyranny, including a mini-genocide, that produced eighty fatalities, and much more was possible, and that could be where things might well be headed. What would McVeigh do today if he knew how his protest in OKC was going to be ignored, marginalized and excluded. Indeed, we saw on September 11, 2001, that a protest could involve 3000 fatalities and something in the neighborhood of ten billion dollars in damage, though that was admittedly with tacit and passive government assistance.

Although our tyrants are doing everything they can to restrict us and to control us, and although taking our guns away may be more symbolic than effective, despite all their records, all their cameras, all their income suppression, and their liberty restrictions, all their protestations that they claim is all to keep us safe, even from ourselves, they are not able to do that. I need to convince you of that and will do my best here in the service of democracy.

They cannot get control of patriots like those who rebelled in 1776, not even if they do find a way to outlaw and then confiscate firearms guaranteed by the Second Amendment. Indeed, one might argue that just as the British effort in 1773 to confiscate firearms at Lexington and Concord revealed the King's tyranny, the ham-handed efforts to thwart the Second Amendment today (especially the Waco mini-genocide) merely serve to reveal and confirm our present tyranny.

Our military is awesome. The most powerful, most feared, in the world. We may issue millions of personal firearms to our troops. And yet if they were taken away it would still be the most powerful military in the world.

When McVeigh decided to make his measured, yet symbolic, protest, he did not base it on firearms (though with his skill set he could have). When Stack decided to make his protest he did not base it on firearms. They were being statesmen and their message has been ignored. Every American has the duty to consider all the possible protest alternatives and their implications for a proper context. For any may be justified. Any may be prologue.

For example, Wikipedia reports that in 1990, an apparently drunken man was ejected from a nightclub in New York City. Apparently he sustained his drunken anger long enough to find a small plastic container, fill it with gasoline and toss it into the entrance to the barroom with a match, then go home to sleep it off. The next morning he was arrested after his crudely improvised protest had killed 87 people, or four times as many as Adam Lanza killed at Newtown with a semiautomatic rifle that made our President cry. This with an unplanned spur-of-the-moment action.

Our tyranny looms large, and since in a democracy the people are responsible for their government, it behooves each of us to consider what our government has wrought and what that can yield in response. We have seen what our government is capable of when it gets violent. We know of Sherman's March to the Sea. We know of the firebombing of Europe and Japan most especially Dresden. We know of the atom bombs in Hiroshima and Nagasaki, and we know of Waco. But we have also seen what one statesman was capable of achieving in Oklahoma City, and what one drunk was capable of achieving in New York

City. And it behooves us to consider what else might we face because our tyranny in government is intransigent to the people.

One Man Can Truly Make a Difference

We all respect power. And we all have power. Even the wimpiest among us has considerable power, and not merely because the Second Amendment makes it possible and standardizes it. We can use that power for good or for bad. After all Spiderman's Uncle taught us "with great power comes great responsibility."

One man, *any* one man (or wo-man) can therefore make a difference because of his/her power. That man could use his power to pursue the cure for cancer. That would be really good. Or that man could join our nation's military and be significant even definitive in battle, and he could try to defend his country at home and if censored, marginalized and excluded could assemble a protest Oklahoma City must never forget. McVeigh *did* all of those. And of course, he could try to solve the dilemma of background checks and define a Cockroach EV with the possibility of making a difference for large numbers of Americans. This writer has tried both of those, and, until proven fatally flawed, they could be good, too.

So when that man, or any of the millions of other Americans who have tried and tried and tried to make a difference, sees his power being ignored and his efforts being censored, marginalized and excluded by the very nation he is responsible for, he has a duty to do something. He can ignore his own responsibility for this land. He can defer to those who would control us and limit our freedom and liberty. But he can also protest and resist in the style of the Sons of Liberty and Timothy McVeigh, and we must consider the possibility that he may justifiably direct his power in these less passive, less submissive, ways.

Therefore we should consider objectively what one censored, marginalized and excluded man is capable of. That is what this section seeks to do next. To perform a one man analysis of protest options in the style of Timothy McVeigh's Oklahoma City Tax Protest.[34]

This exercise is provided here in the spirit of our colonial forebears. They had great respect for the rattlesnake. For it is a peaceful creature and yet when it feels under assault, it issues a warning before it strikes. It was so respected that it appeared on the early colonial Gadsden and Culpepper Brigade flags. Coiled with the words: "Don't tread on me". Flags that are again popular and are therefore a harbinger, a warning. Listen up.

Today the gold standard for one man making a difference is the McVeigh protest. In it he assembled several thousand pounds of ammonium nitrate fertilizer, several fifty-five gallon drums of nitro-methane liquid auto racing fuel, and a number of feet of primacord detonation primer. It is likely his bomb had a TNT equivalency (was similar in destructive power) to about 2500 to 3500 pounds of TNT. He apparently wanted to knock down a Federal building to emulate the way the Branch Davidian Church had been leveled.

After he had made that goal a reality, when he was imprisoned waiting for his wrongful execution, he changed his view. His effort at statesmanship had been lied about and therefore, ignored, censored, marginalized and excluded. Go figure. His message was *not* re-

[34] It would be very instructive if every American would conduct a one-day, one-person, exercise like that in this book of the protest options available to them. **Note:** It is important that this be a one-man/woman exercise. If more than one individual does this then our government tyranny might consider it to be a "conspiracy" and criminal kangaroo-court charges might result.

ceived. And he admitted that were he to do it over, he would have changed methods. For one instead of standing trial and being denied his right to defend himself on principle, he would have included a way to escape.

McVeigh was way skillful with a firearm. In the Gulf War he apparently single handedly won his group's first conflict when as a past winner of the Army's Top Gun contest he was in the lead Bradley fighting vehicle and attacking an Iraqi position, and when an Iraqi soldier stepped out from a distance of some miles or so, McVeigh shot him in the head. It was just the matter of calculating how to put a very big bullet in a particular place at a particular time. Suppose McVeigh, a man with aim far better than Lee Harvey Oswald, had positioned himself on the flight path of an airport where large jets line up for landing and that he had taken out the engines of two or three and then beaten a retreat. And we get all worked up over The Shoe Bomber and The Crotch Bomber.

Not everyone is a Top Gun shot. So what might some lesser "any man" talent like the humble writer be capable of? Let us explore that prospect.

Worst Case Scenarios

We have heard our leaders warn us often of our risks, such as the Bush fictitious fantasy WMDs. And it has desensitized us. What follows is a hypothetical exercise of a type I recommend for every American and will share with you now. There are millions of patriotic Americans, especially scientists and engineers, but really anyone in the technical fields that could match or exceed this humble effort. However with additional effort, anyone that can use a library (the reason, I am sure, the PATRIOT Act incorporated library surveillance) could work through a similar or even more consequential analysis that would also qualify. Many competent Islamist terrorists can also qualify (and many probably have and we must assume that), even though they have apparently also been trying to send messages (statesmanship) more so than do *real* damage. This is why our security forces have been forced to arrest pathetic people like Mr. Pineil —the alleged match-head bomber, who was allegedly stuffing match heads into pipes, and whomsoever was very lucky he did not blow his hands off, not meaning to belittle match head pipe bombs in comparison to fantasy WMDs.

The following data are not secret nor can they be. Many of them we already know in our hearts but pretend not to know in the same way we pretend not to know the Emperor has no new clothes. This is not something our Homeland Security Department is warning us about, but then remember that in today's corrupt tyranny they are not working for *us* but have been subverted into serving the leadership and purposes of the two parties instead (a great reason why we really ought to elect a president sometime that is not from either party). But I assure you they are worried about it, and that is why they seek and welcome all the controls they can gain over us at the same time they seek and gain controls over the so-called radical Islamists. That is why their code words for angry disgruntled U.S. citizens is "lone wolves".

Besides that, if they were not lying to us and betraying our country, then we would have to conclude, to actually deduce, these analyses I present below are so fatally flawed that they could not possibly work. Perhaps I am so incompetent, the Cockroach EV could not work either. Therefore anyone making such an analysis like that I am about to make is by definition harmless, despite any arguments I make here to the contrary. Perhaps I should apologize for my incompetence in advance (as I did). Hey! What can you expect from a Democrat-Certified Jack-Booted Storm Trooper in the War on Women and Their Health like me. So you decide which it is. These analyses are like arguing the Civil War was wrong and that the South was not nearly as evil as we treated them, when conventional wisdom *must* be that the South *was* pure evil because it is otherwise a tad difficult to justify 600,000 killings equivalent to two hundred World Trade Center attacks [but if so, then why did we patch things up with such evil people the minute we won? Had we been so skillful that we killed all the bad Southerners leaving only the good ones alive, like sort of a *good* genocide].

In considering the possibilities for a really big hypothetical protest, one might first think of potential targets (malls, crowds, cars, trucks, trains, buses, planes, schools), then tools (firearms, biologicals, explosives, fire, poison), then movie and novel plots (*Goldfinger*). As benchmark historical protests, there are the Waco Tax Party, Oklahoma City Tax Protest, the Stack Tax Protest Flight, and of course the crotch, shoe and match-head bombers and the WTC attacks. Actually, in my calculus, the World Trade Center was a lousy, but spectacular, protest. Osama bin Laden must have wanted to send a very specific message to pick that over other better prospects at the cost of nineteen of his compadres.

It would be easy to take a firearm to a crowd. Nidal Haasan was been arrested and accused of doing that and got lots of press and was quite thoroughly convicted and will probably soon be executed. But he did not bloody the bully's nose a lot. Similar efforts might "trigger' yet another opportunistic internal feud over gun control that some might think is useful. [35] Indeed, if a government effort to seize guns in America can be inspired it might trigger a bloody Civil War, and that would be a basis for Newtown-like school shootings, but by and large Haasan is being censored, marginalized, excluded, and demonized as per usual. His trial may have been a repeat of the McVeigh kangaroo court with an outcome as certain as if the President had ordered his prompt execution.

More effective use of firearms, and much easier to accomplish, would be to use them to bring down aircraft. Let's not pretend that by not talking about it, that no one will think to try. And while bin Laden managed to get us to spend fortunes to try to keep firearms and explosives off planes, a *60 Minutes* report years ago pointed out that since hunters can bring down Canadian geese on the wing, a plane is just that much bigger and easier a target. They suggested that only one special gun can do that, but indeed in the Vietnam war we lost a lot of faster more evasive military aircraft to peasants on the ground with rifles (we called it ground fire). Therefore, something like a "matrix" gun made with perhaps a dozen semiautomatic rifles with the triggers all tied together so they can be pulled at the same time and all pre-aimed to produce a pattern and locked in place could throw up a wall of lead in front of an approaching aircraft. Consider! A large plane, say 300 feet long, on landing approach or

[35] Democrats have never been discouraged by the killing of people. Not Clinton at Waco nor with his expansion of the death penalty (that was used to murder McVeigh). Agencies popular with Democrats like the NHTSA trade lives and take lives routinely and consider it a good thing, if they can argue they are offsetting the deaths (paying for them so to speak). There are death panels in Medicare. There were fire bombings, and numerous wars, and drones, etc. Therefore we must consider that events like that in Newtown could also be a Democrat agent provocateur effort that might easily assume that the taking of twenty children's lives and the loss of one Democrat servant might be an acceptable trade if it can produce strong gun control laws.

takeoff at say 200 mph is flying three hundred feet a second. Fully legal, semi-auto guns can fire at manual recycle rates equivalent to at least 500 rounds a minute or about ten rounds per second. A three hundred foot long plane flying laterally through a matrix gun pattern in about one second would pass through about ten cycles and each cycle should involve numerous hits. As easy as shooting quail-hunting lawyers in the face.

However, a great amount of money is spent to track and control guns and ammunition. It is un-Constitutional but (screw the Constitution) they do it anyhow using clever ruses like the Form 4473, and they pretend not to do that but in fact that is what they do. Nineteen people each buying one gun and a few boxes of ammo would not stand out. One man buying nineteen guns and sixty boxes of ammo might draw attention. Either way the cost might be about ten thousand dollars. A bit more than what McVeigh spent. Each plane down might exceed the scale of the Oklahoma City protest (up to 200 or more fatalities and hundreds of millions of dollars of damage).

A matrix gun could also be pointed at a stadium and other targets from more than a mile away and drop a dozen times fifty rounds (600 rounds) of bullets in a five-second interval. Automatic weapons would not be a lot faster. Indeed, there is an extensive discussion of automatic weapons and their firing rates related to the government's holocaust at the Waco Tax Party but would distract here and is being reserved for other publications.

It would also be easy to use biology. There are some really scary prospects that have incredible potential, and are not difficult to do, but are too complex to describe here. They are not secret and are known by many, and certainly by any who wish to know. But among the more easily implemented, the more easy to describe and understand (Keep It Simple, Stupid!), are blood-born pathogens. Remember when AIDS was that abstract disease that affected only a small group and terrified the rest of us. And then a small portion of that small group threatened to stick people with contaminated pins,——and some children in movie theaters got stuck with pins. Were they contaminated with AIDS blood? As I recall they were *not*, but in short order great progress was made, the message was received, and soon AIDs was no longer a death sentence. Coincidence? That statesmanship may have worked, and it was *very* terrifying. Today so-called LGBT people get a lot more respect than before.

It would be fairly easy to find someone with AIDS, or for some true-believer to acquire it, or even to identify someone with it to acquire the double threat of AIDS and even more (some say fifty times more) infectious Hepatitis B. Then to obtain a few blood donations, to place a small non-tempered glass bottle inside a bigger non-tempered bottle to create an annulus, and put the blood donation in the annulus. Then placing a few commercial firecrackers (say M60s) or some simple home-made explosives in the inner bottle. Then igniting the fireworks after taking the bottles to a crowd. The shock wave shatters the inner bottle sending the non-tempered shards (since it is non-tempered) through the annular blood and wetting them, then fragmenting the outer bottle contaminating its shards also, and all the shards spray out into the crowd in a pathogenic aerosol. Like sticking everyone with a contaminated pin? Right?

And although explosives have many shortcomings, for some of us only the drama of a big-bang will do. Only a big-bang makes a statement. So if one wanted to shock something (a train carrying industrial chemicals, a levee, a bus), there are the traditional options. However, commercial explosives are watched pretty carefully these days, and although so-called "fertilizer" bombs are much harder to restrict, it is likely much, much harder today to assemble a bomb like the often mischaracterized device [**24**] McVeigh used [36].

Still there are options far too numerous to examine here that are inexpensive, untraceable, using common materials that are simply awesome in their potential. However, one of them in this potentially explosive genre that is worth mentioning here (because it makes the important needed point) is the aluminum/water (AW) bomb. Aluminum is added to boost the bang of numerous commercial explosives. Aluminum as for most, if not all, light metals is a high explosive when correctly reacted with any of a range of oxidants. And if heated to a sufficiently high temperature, aluminum ignites spontaneously with water as though the water were an oxidant rather than the extinguishant it is often used as.

Water is available everywhere and aluminum is almost equally ubiquitous. And both are cheap. Neither can be tracked and neither can they be doped with tagants or neutralized. With the right aluminum heating source (perhaps iron oxide or an alternative metal oxide with aluminum in a simple thermite reaction to be considered later) AW explosions should produce anger (brisance) a good bit greater than that of many feared explosives such as ANFO, TNT, etc. And it makes no sense whatever to tax it and create a Bureau of Aluminum, Water and Rust (BAWR) to match the BATFE.

And there are other options my fellow Americans who have not thought about this realistically need to know about so that we can allocate our fears and votes and do our duty more effectively. But this is not intended as a comprehensive exposition in last-ditch protest. Still, it is vital to establish that each of us has power. It is not only firearms that can give us equality. One, even just one, of us can make a difference (McVeigh did, Lee Harvey Oswald did), and it is possible to feel it is a duty. So I will review one more protest prospect here that would be near to the top of my list in many ways were I to be more meaningfully protesting rather than publishing this damn little book instead, which is most likely destined for censorship, marginalization and exclusion, and possibly demonization, too. But which also can yield justification. While our nation tries to scare us with rumors of more crotch and atom bombs, this option is perhaps least secret, least preventable, yet maybe just possibly most ef-

[36] McVeigh's device, once called a "Rembrandt" (a somewhat politically incorrect but accurate description) is often referred to as an ANFO (Ammonium Nitrate Fuel Oil) explosive or "fertilizer" bomb. Both media appellations are sloppy. It had distinct differences that biased journalists have not paid attention to. It was not precisely an ANFO device because those devices employ commercially pure AN and literally fuel oil as used in a home heating system or diesel truck. The fertilizer grade AN he used contains some water which desensitizes AN and reduces its yield (but is easy to remove). The detonation of AN (as for many nitrated chemicals) results in its decomposition and internal combustion. As an oxidant, adding a little fuel oil or any other fuel such as: kerosene, gasoline, engine oil, or possibly aluminum, in the right amount allows the oxygen to be burned more easily and the yield to be boosted, and it makes AN more sensitive to detonation. However it takes only a few percent of oil to achieve this effect, any more tends to lower the bang for one's buck. McVeigh mixed his roughly 3000 pounds of fertilizer with as much as twelve hundred pounds of nitromethane (apparently three fifty-five gallon drums), which is not a fuel oil though often referred to and used as a racing car "fuel" but which is also a nitrated chemical in its own right and far, far more angry than even commercial-grade ANFO, but it is much more expensive. So literally, in this opinion, if anything, McVeigh was attempting to boost his nitromethane bomb by adding AN rather than vice-versa. And indeed, one wonders if he might have had much more destructive results if he had not dispersed and diluted the nitromethane in the AN but instead used it to blow the AN into the building. Hopefully this launches a myth they can someday test on Myth-Busters. Somehow, I doubt they will.

fective of all. Something that they are also not telling us about that is most worthy of our concern even as they waste our time trying to take our guns. Be forewarned! Or maybe as I have already acknowledged, I am just ignorant and totally wrong! You can decide for yourself, or you can listen to those who would and who do manipulate us.

And the Winner is!

As this section was begun, there was a record large forest fire spreading over Arizona, the 2011 Wallow fire, supposedly due to a few careless campers who left their campfire unattended. Bummer! Some have speculated that maybe it was caused by similarly careless illegal aliens or even Mexican drug cartel border jumpers, but that has been pretty much shouted down as being racist. Everyone knows that before Mexico allows any of its citizens or ne'er-do-well cartels to jump the border, it gives them intensive training in campfire safety practices ("learn not to burn") including tutorial on the extensive teachings of Smokey the Bear ("Only you can prevent forest fires"). So that proves it *must* have been caused by careless U.S. citizens. Nothing racist, or terrorist, there. That was as easy as proving that the slaughter of 600,000-plus Americans was fully justified over slavery.

But suppose, just suppose, that bin Laden's planning had ignored statesmanship, had been more like that of the casual hypothetical one-day exercise in this chapter. Suppose that on that beautiful dry Fall eleventh day of September 2001 we had experienced the simultaneous ignition of tens, hundreds, thousands or tens of thousands of forest fires. Would have, could have, a grand firestorm like that in Dresden, or even just localized mini-firestorms, say nineteen as a minimum, have resulted? Would fire have raced through regions of our forests, though entire small cities or even some large cities the way they once did though Dresden and the numerous other cities in Germany and Japan when we firebombed them? Could oxygen depletion and combustion products have led to asphyxiation or poisoning of some in even our largest cities?

It is easy to learn [**25**] that fire storming was apparently discovered on the night of 27-28 July 1943 (it was about the time when as a baby I was nearly dying of pneumonia), when about thirty minutes after massive nighttime bombing raids on Hamburg Germany a "storm of fire" raced though a large chunk of the city producing temperatures of up to 1000C (1832°F) over a region up to two miles in size and spiraling like a cyclone counterclockwise and generating winds of up to a hundred miles per hour. The body count (collateral damage) was up to thirty thousand (ten World Trade Center attack equivalents, or "WTCE"s as a unit of measure). Oklahoma City and the World Trade Center attacks were trivial in comparison. It was the whirlwind (first of many) that British RAF Bomber Command, Commander-in-Chief Sir Arthur Harris had promised in 1942 that Germany would be reaping. "They sowed the wind and now they are going to reap the whirlwind."

It is widely known that a hot fast fire requires a good draft. A thousand years ago, blacksmiths learned to force air into forges to achieve temperatures high enough to soften the steel so they could make horseshoes. Swords and knives were made similarly.

Simple combustion theory teaches that when a fire starts in gravity, the hot gases it produces are buoyed upward by their low density rising much as a helium-filled balloon might for the very same reason. This draws air into the fire at the bottom and produces its own self-draft. In some forest fires of large scale the upward draft is so great that high spires of twisting flame can be seen (possibly twisting under the Coriolis effect the way many think the effect makes the water in the drain to your sink spiral downward). If there is another fire nearby it also heats and thins air and sends it spiraling upward producing a self-draft of incoming air at ground level. And the artificial winds created amongst several fires enhances the draft so that all experience and create an artificial acceleration. This is how a firestorm operates. If enough points of fire are drawing air inward, then an artificial wind can behave like and exceed the effects of the Santa Ana winds which have on occasion produced natural draft to forest fires to yield sometimes small but always awesome firestorms in California, but nonetheless firestorms that often catch people off guard and race through whole housing developments sometimes before they can be evacuated.[37]

When a forest fire begins as the result of a single camp fire, apparently like the Wallow fire (of course), it burns out away from its source in all directions (a rough distorted circle) because the edge is where the unburned fuel is. A wind therefore would bring oxygen first to a fire boundary that is burning in the opposite direction, burning toward the wind, and then after blowing across the burned-out region would bring oxygen to a fire that is burning away from it. If the wind is at lower velocities, the second boundary moves faster because the wind blows heat and burning debris in the direction of the unburned fuel. But there is a combustion threshold that forms when the wind velocity is sufficiently high in which the faster you blow at a fire, the faster it will burn back at you. Hence a wind can accelerate fire at both boundaries it encounters. And with a fire-induced wind, the wind is blowing into the fire from all directions.

Furthermore, many normal forest fires burn so that often they consume only the tinder and surfaces of trees. The moisture in the core of the tree prevents complete combustion of the trunk, and many trees actually survive the fire and go on to thrive. This may be much less likely or less protective in a firestorm with its much higher temperatures to dry the trunk and potentially magnify the amount and duration of the combustion. And it would be less likely in drought conditions, too.

Also in the course of this writing, following (or perhaps as a result of) the Wallow fire, a fire (perhaps related to Wallow) was burning in New Mexico and there was fear one of the national atomic weapons labs may have to be evacuated. Suppose that, in that region, not one but twenty or one hundred fires had been started and a firestorm had resulted. In the future, I suspect forests around weapons labs will be removed to a good safe distance, ecology be damned. But if bin Laden had not been such a statesman, might he have considered this possibility and quite possibly rejected it as too likely to "awaken the sleeping bully". In the Spring of 2012, one year after bin Laden's assassination, CNN reported on records seized when he was killed that indicate he was, indeed, considering just such a possibility. We might want to consider whether his successors will be as diplomatic, as statesman-like

[37] Dried pine trees that ignite can impressively exhibit this effect. Every needle is surrounded by air and burns creating its own small updraft, the cumulative effect of which can appear like a firestorm, almost explosive combustion. This is the reason why Christmas (perhaps I should say "holiday") trees in December pose a terrible danger if allowed to dry out in one's home. This is why numerous Internet sites recommend keeping water in tree stands. Indeed, because of the many small high-surface-area needles, pine trees are very effective in evaporating water, although not mentioned in several web sites, room humidification would also help to reduce the hazard. The more moisture in the normally bone-dry heated winter air, the less moisture will be lost from the tree from its needles.

when they consider how his protest and others like it have been censored, marginalized, excluded. Yes, and demonized.

Could bin Laden or anyone else accomplish a massive firestorm like those in Dresden and Tokyo and dozens of other places with the help of nineteen men or even just one man alone? In the lowest-tech implementation, think of nineteen men armed with Bic lighters, nineteen who might think of themselves as what George H. W. Bush called Points of Light, strategically spread out over the country driving in assorted (perhaps strategic) directions one dark moonless night. Before daylight, having stopped while driving some 10,000 combined miles (55 mph x 10 hours x 19) to set fires or place timed igniters. If each one stopped five times an hour to set a fire or place a timed igniter and if only half of those roughly one thousand points of light were to become Wallow-scale fires, we would be looking at incredible destruction, whether true fire-storming were to obtain or not. The USA lower forty eight occupy roughly 4.5 million square miles (say 3000 by 1500 miles) of area. My calculus might argue it was possible to burn a major fraction of the nation. Think of all the carbon dioxide global-climate-change gas that would be produced. Hopefully that gets the attention of Democrats. Yet, bin Laden was an engineer. He could have spent a day on this if his goal was maximum destruction, if what some would call his "cowardice", had been more like that of Sherman's "cowardice" during Sherman's March to the Sea. Think of the prospect. Would even *this* scale of protest be heard today? Do any of us want to avoid rather than respond in blind anger to efforts like this? I wonder.

Maybe, just maybe, disparate and desperate ideas, even just tiny ideas like the humble Cockroach E-Car and similar much bigger ideas, similar protests, deserve a fair consideration and try-out after all. Maybe a return to a real democratic (as opposed to Democrat) republic is needed.

Indeed, timed igniters could be set over periods of months. They could be designed to spray ignition (say spray a reacting thermite slag)[38], to produce not merely a thousand, but tens, hundreds, even thousands of thousands of "points of light", all with atomic clock simultaneity.

And with precious little more thought, one can imagine a spectrum of alternative ways to effect this protest. One can imagine igniters attached to carrier pigeons. One could

[38] Thermite is a really interesting material. There are commercial versions of it and other similar exothermic material used in exotic welding operations. But the basic thermite of aluminum fines mixed with iron oxide has been used for a long time. In World War II it was placed on the railroad tracks of German trains to ignite and weld the wheels to the track (so I have been told). In traditional thermite, about one measure by weight of aluminum fines (powder or aluminum grindings) are mixed with three measures by weight of iron oxide (corrosion slag, or rusty steel, or a very nice superbly fine powder than can be produced by rusting steel wool pads to form red ferric [Fe_2O_3] oxide powder). Upon ignition, the aluminum strips the oxygen away from the iron oxide (even though iron oxide is normally considered to be inert) much the same way aluminum can strip the oxygen away from water, and there is a net heat release that is incandescent and intense achieving temperatures over 2000C. This is why such exothermic materials can be used to perform steel welding operations. Although thermite can be difficult to ignite, a layer of magnesium filings from survivalist igniters or other kindling methods can allow it to ignite easily with a match or electrical hot wires. Allowing it to melt and drip into a moist environment can cause it to "bump" and be sprayed in many directions at once. And for the really enterprising, one could use alternative light metals and more ready sources of oxygen such a copper oxides (also easy to obtain with no records). And so when our government is worrying so much about the destructive power of guns and nuclear bombs, that they think they can restrict, there are methods of protest or attack that that can not be thwarted and humble thermite may be one of the best.

attach a harness to trapped forest animals (the way we put trackers on them) and release of them into the forests. As igniters were ejected from their back packs to start a fire nearby the animals would run away from it, only a few minutes later to have another igniter ejected. And then another.

One can imagine incendiary bullets flying miles in assorted directions to produce a matrix of ignition and massive fire front in seconds. Or even just bows launching flaming arrows to box the compass.

And one can equally imagine large garbage bags being filled with helium or even hydrogen in the dead of a moonless night to float on the prevailing or jet stream winds from west to east to which are tied attached payloads that release periodically and lead to the dispensing of Hell. Students of history know that in WWII the Japanese used this same idea to release high altitude balloons in Japan that drifted on the prevailing winds over the Pacific ocean that were timed to drop incendiaries and cause forest fires in the U.S. And a few of them did.

And since trace-ability is important and since commercial helium might be watched, one can always produce hydrogen by themselves (it is not difficult and can be looked up), which yields a greater lift and payload capacity, or one can even use methane, an inexpensive untraceable, lighter than air, ubiquitous fuel-gas-of-the-future that is piped into millions of homes and is nearly impossible to track (but has less payload).

Yes our future is rife with possibilities that might justify some fear and so perhaps some respect is warranted for even the least of our fellow citizens. For no matter how big a bully one is, even a bully government like ours, they can always have their nose bloodied by even much smaller opponents, even opponents that lack guns. Fear and respect for all of us is more valid and worthwhile than only worrying whether the guy next to you on the plane is packing nitrated pentaerythritol in his crotch.

Sowing and Reaping Our Own Whirlwind

There have been no secrets revealed here. Nothing obscure. Any who might think that way need to get a real life (and they should request a refund of the money their education cost whether that was in public or private school). This is not sophisticated nor esoteric science beyond the grasp of all except the very most cognoscente. This is really basic stuff that any one with motivation can master. And perhaps the strongest reason forest attacks have not been tried (unless it *is* indeed the reason for the so-called accelerating rate and scale of billion-dollar-plus forest fires that are presently being blamed on climate change and global warming) is to avoid awakening the sleeping bully.

This last consideration is not to be minimized. In the movie *"von Helsing"* the title character wages an epic fight with Dracula's wives and kills one, yet the town does not consider it a victory. Why? Because Dracula used to only kill them to eat them. His hunger was limited, but von Helsing had suddenly given Dracula a reason to also kill them for revenge, as if von Helsing had awakened a sleeping bully.

The firestorm option and others of similar consequences was also available to McVeigh and others who were trying to make a political protest, to bloody a bully tyrant's nose. Thankfully, we are indebted to them for they chose lesser more statesmanlike protests (much like the original Tea Party), wrongly hoping they would suffice, again presumably out of diplomacy and/or statesmanship. But amazingly, they were ignored and demonized as their protests were censored, marginalized and excluded. Now their inadequate protests only provide calibration for any who follow next. Hopefully I can have some success trying to convince my fellow Americans (our real enemy that is "us"), especially those who have not been doing their duty, that there is both a way and incentive available to ratchet up the scale of protest. To make the next one, or the one after that, less excludable, even if it awakens, if that is what it takes to be heard today. I am not hopeful at all. Yet, to continue to ignore this is to sow our own whirlwind and to justify those whose current efforts to protest (like at OKC) may seem like background noise. It is how we are asking for it.

The fact is we rely on each other more than we know, or at least more than we want to admit. We need to respect each other, because of American birthright and tradition, but also because given the motivation, we are all capable of great things like this, good or bad. Even the least among us, but especially those like myself who try to bring protest and real solutions to our government, a government whose duty it is to hear us, but instead monolithically ignores us.

The Clinton Administration could have heard the protests and concerns of McVeigh and properly responded to them like a Representative Democracy. That was their job after all. Instead it was focused on covering up its own horrors. Instead they took the position that it was their right to exterminate any citizens whosoever got in its way (Branch Davidians, Civil rights groups?, or others?). Actually compared to Waco, the civil rights protesters in the sixties in Birmingham got off pretty easy facing only dogs and fire hoses. They could have been crushed with Army tanks and burned instead.

This is why I submit that this text proves that bin Laden, McVeigh, the Waco Tax Partiers, The Texas Tax Fight Protester were all statesmen. They were all sending Tea-Party-like messages when nothing less had worked. And now their efforts have also not worked. It is time to listen and learn from them, because right now we are sending the message that we are not only sleeping, we are also very hard of hearing and we need to be yelled at loudly.

I was listening. I heard. That is why I view Timothy McVeigh as a hero. But was anyone else listening? Anyone besides the disgruntled, censored, marginalized and excluded potential future protesters?

Some may dislike my analyses and worse. I am sure of it. Some may consider them evil. Some of the more ignorant among them may not want me to put ideas into people's heads, fragile heads that unlike their own might not have a day to spend thinking about protests to finally succeed where others have not. Heads that someday may become afflicted with the scourge of cancer that has been effectively ignored by our tyrants that takes away everything they have to lose. Some may hate that I say what we all should know, what we all may know but try to ignore, that our emperor, our tyrant emperor, has no new clothes. That he is telling us to eat cake, drive Volts, and drink his Kool-aid. But this analysis is not evil even if one adopts the most bizarre politician's definition of what the meaning of "is" *is* along with an alternative definition of "*definition*", and even a pondering of what "*what*" it *is* we are talking about.

And to any who might think that by acknowledging the emperor's nudity may lead some to try the things cited here, or may jinx us, might better spend their time pondering why they or anyone might think it is necessary. Today they would have us believe Timothy McVeigh who was a proven hero in wartime, was really merely a wacko neo-nazi racist who deserved to die, that the Waco Tax Partiers were merely un-American child molesters who also deserved to die, that John Stack was merely a born bad loser who deserved to die. That there was no trace of merit in anything any of them stood for.

In the case of forest fires, we are seeing events that supposedly are bigger and more numerous than ever, or so they say. Some fires are cited as causing more than a billion dollars in damage. But it is caused by global warming/climate change and damn those who don't listen to or accept the dogma on climate change. Why? Is it because these fires might actually be a protest, but to say *that* would be racist?

But I write this in an effort to present a potentially scientifically valid reasonable analysis of a serious grievous breach in the country that I have been enduring for decades. For virtually an entire life and that is long enough to prove my patience and discretion. In this time, I have watched people in my government which I, exercising my duty and authority, have now concluded are criminals, and tyrants. I judge them here to be criminals even worse than they themselves have judged McVeigh, The Waco Tax Party, and Joseph Stack. I have opposed them, I have worked against them, but I have not tried hard enough nor done enough to date. I have let them censor, marginalize and exclude me and huge numbers of my peers, and therefore have sowed a whirlwind myself.

Some of my more recent protests, like the protests of Lincoln, and Washington, and Jefferson, and Franklin, and Adams, and McVeigh and all the rest have already had bad results. I have already protested destructively within my authority to do so and people, fellow Americans, have died as a consequence, although I believe more have died because of my inaction (Some would calculate that by killing the smaller number, I was actually "saving" lives). So I, too, have reaped a whirlwind. I am become used to killing. We all have, but many of us do not admit it and maybe some may not realize it.

I confess with shame here, I voted for Clinton in 1992, and Obama and his Democrats in 2006 and 2008 in protest. They then betrayed me and their country. I helped them help the incumbents drive the car into the ditch. Even though I am a Democrat-certified racist, I wanted to vote for a black man. I had wanted to for some time. However the black man I would have much preferred to have voted for was Colin Powell in 1996 although he was having none of it.[39] Therefore, I guess my vote was racist. However, I was not merely trying to do the best for my country with those votes, I was sending a message. I suspected things would get worse before they got better. Besides, McCain, like so many Republicans, was just too much a war monger and many, but not all, Republicans needed to be taught a lesson for their own transgressions even if that decision resulted in the deaths of innocents. Collateral damage. And it has. And I hate that. But sometimes, as our government has taught us,

[39] Colin Powell is a major truly tragic figure in the truest sense of the Greek drama standards. Possibly the greatest tragedy ever, he was a great and powerful man who went through a great downfall visible for all to see, but that he himself failed to see until it was too late. Just think about it. In 1996 Colin Powell wins the Presidency. There is no National Home Ownership Strategy launched, no sudden increase in the quotas for banks through the Community Reinvestment Act that lead to bad loans to people whomsoever can not repay them. There is no Monica Levinsky affair that interferes with the then covert efforts to get Osama bin Laden,. There is no 1999 regulation change that forces Fannie Mae and Freddie Mac to massively buy bad mortgages and package them for sale to Europe. Maybe Osama bin Laden thinks twice and decides against the 9/11 attack, but even if not, the response to it is far more competent. Maybe the desire for war with Iraq is less and fantasy/fiction WMDs, and bogus wrongful retaliation and bogus drives for a bogus "democracy " in Iraq are

we as a nation and individually have to be willing to cause collateral damage. To kill. We have to bomb the restaurant killing everyone in it even if there is a chance Saddam Hussein is not there. We have to fire-bomb Dresden no matter how many innocent children and babies and fetus/clumps we know are there. So while I feared and even expected Obama's Democrat crew would make things worse, sometimes things have to get worse before they can get better. And Obama and his minions have not disappointed me. He has gone way beyond my worst expectations the way the WTC attack may have gone way beyond bin Laden's expectations.

As an American, like my peers, I have a number of very important duties, and I take them seriously. I am authorized to perform them. I must pay and am authorized to pay my taxes (or literally they might come and kill me, like at the Waco Tax Party). And I do. I must vote, regardless of how corrupt it has become. And I do. I may have to do jury duty again, though an old prostate may make that very difficult. And I must protest when it is needed, like herein even if it is marginalized and excluded. And my protest should start out by working civilly within the system as I have done patiently to no avail for decades, even when that system is corrupted and censors, marginalizes and excludes me. That is all on the record here. And at any time I may have to decide to defend myself or others the way McVeigh did. Like those heroes on Flight 93, I may someday find myself like millions each year, with nothing to lose and may need to help crash a plane. Like any of us, I may need to some day pilot a plane to a place like Hiroshima or Dresden and incinerate tens of thousands of live innocent civilians (not at all unlike the innocents in the Oklahoma City protest), and do it all in justified self-defense because of imminent peril (including peril ten years or more away). So it is for all my peers.

My Authority, Duty, Conclusions, and Rulings

The Constitution of the United States defines and issues explicit and implied authority and duty. Some go to the President, the Congress, the Supreme and other Courts. Some go to the citizens that are the real ultimate "boss".

This book has been prepared in an effort to address the scope of my duty and exercise the authority granted to me by the Constitution of the United States. I have concluded, I am ruling (just as do cute judges), we are in imminent peril from, of all things, our own government. I conclude and therefore *believe* that. And I *believe* the peril is imminent for the same reason our government felt the peril was imminent after September eleven. I believe it based upon the growing and ongoing body count due to such things as cancer and Parkinsons, Alzheimers, and diabetes (and cute bully judges are free to disagree). And that belief and that conclusion and that ruling justifies me (and anyone else) in taking any human life

←potentially averted. The real estate bubble never inflates nor bursts. There is no depression in 2008. Barack Obama is never elected, and there is no bogus "Affordable (Not) Healthcare Act" that loots a half trillion dollars from the Medicare budget. Obama never makes the foolish spending of George Bush seem prudent. Today we might live in a radically different world.

One man can make a difference and should, but seldom do men find themselves on a cusp of history facing this scale of greatness: A right man in a right place at the right time, and yet Powell, lacking only the audacity of Obama, decided not to run, and sealed his fate, his tragedy, and ours too.

that is believed to be responsible and in taking innocent lives also (like the collateral damage of those babies in Oklahoma City or Hiroshima) if I conclude that is necessary also. It is my duty. That does not mean that, if I were to do that, that criminals from my government, including cute judges won't break the law (again) and murder me as they did McVeigh (and they may even erroneously *believe* themselves to be similarly justified).

Therefore it is valid and prudent to fear me as an exemplar the same as you might and most probably do fear your government. At the moment we and our government are putting too much fear on shoe, crotch and match-head bombers. I have and have had a duty to speak out. I have tried but have been ignored and so have too many others. Just yesterday I heard our current President du jour speaking about his sick healthcare plan say that if there are any other ideas out there to bring them to him, to put them out there. He wants to hear them. It was yet another of his many lies. He is just being a typical politician, for he has been ignoring us.

And the opposing party has not been that much better.

My Rulings

On the basis of 70 years of observation and the materials in this book, I hereby rule:

- The United States government is in a technical state of tyranny and has been for some time. And it is worsening. It poses an imminent threat to us all. Its tyranny justifies even violent rebellion and revolution. I do not advocate such action and hope it can be avoided. However, when actions are taken by any whomsoever are exercising their own Constitutional duty and authority as was the case for Messrs: McVeigh, and Stack and Koresh, they are valid. They are justified.
- Our tyrant government is evil, and it is the responsibility of the citizens to do their duty in a representative Democracy. When the government goes bad, the citizens' duty is to throw them out. When the elections are corrupted or rigged, or the ballot boxes stuffed, the Second Amendment gives and standardizes and justifies and encourages the use of force, and that is why the voting process is preferred and must be exercised and pristine. Today, the use of force is justified against our criminal and corrupt government. At present more than half our eligible voters do not vote, and that is an extreme message to us.
- Our nation is therefore tinder. If our Founding Fathers were here today with their shorter fuses we would already be engaged in a revolutionary war. Instead for the most part we are sitting tight like the Germans were when Hitler came to power. That too is our choice to make, and it is a risky gamble.
- Regardless of how technically flawed, the concept of a Cockroach EV may be, it is not a fickle flimsy whim to be ignored. Large solutions are sometimes the summation of small solutions. It deserves the same fair appraisal that Democrats always beseech us to give to their often evil abominations like the "Affordable (Not) Healthcare Law". The chances it will receive that are slim to none, but it is my duty to pursue it regardless of futility, because it represents an object lesson. If nothing else it proves the tyranny.

- Our nation is sleeping and perhaps too gullible and is hereby forewarned. There is much to warn about. Today, sinister efforts to overthrow the Second Amendment, including the deceit of "Universal Background Checks" threaten to ignite justified reprisals. The "Affordable (Not) Care Act" turns poor people into mortal enemies to us all. And the arrogance of out-of-control government that ignores simple, yet significant, solutions perhaps like a Cockroach EV all too often epitomizes the prevailing oppression.

- As my fellow Americans live and plan their lives, decide to vote or not, whomsoever to vote for, whether to try to resolve problems or to create problems, peacefully or violently, the present tyranny must be a consideration as must be a plan for coping with the possibility of violent revolution and the choosing of sides. For based on our nation's history in war, and as one of the Bush doctrines asserted there is not likely to be a neutrality allowed. "You will be with either side or against that side."

Summary and Closure

Numerous resources indicate that many of those who retire in the USA must lower their standard of living. And when many do, Social Security, if they have it, will cover at most about 40% of their expenses. Private pensions are disappearing, and those that remain are often going bust and being lost or reduced. And not only have many of us not been saving at an adequate level to make up the disparity, but thanks to the tyranny of our two-party government, interest rates on safe insured savings accounts in banks have been deliberately reduced to near zero (or actually to zero) specifically to take (nay to usurp) income from retirees among others (without bothering to even call it taxes) and give it to banks to bail them out from the disastrous burst Democrat National Home Ownership Strategy bubble.

These retiree's health is also deteriorating while medical costs are skyrocketing and they are seeing a currently Socialist wannabe government ripping off a half trillion budget dollars they paid into Medicare to give health care welfare to those who are in even worse straights and perhaps doubtless many who are here illegally.

And at the same time, government has been borrowing from the Social Security and Medicare Trust Funds and at interest rates below the value of money and otherwise mismanaging these assets. The future obligations of both funds now far exceeds the assets they contain. Both have been operated like Ponzi schemes, paying the benefits of early investors with the money put up by later investors, and could legally qualify as bankrupt.

But this tyrant government claims to dote on its retirees and it thinks we retirees love these horribly botched programs. These tyrants also write regulations that requires many retirees to spend money on safety equipment and for safety inspections in automobiles that benefits neither them nor anyone else, that forces them to spend money on pollution equipment and inspections that similarly benefits neither them nor anyone else. And whom among the least of us has not worried that the next car inspection will not result in not only the minimally excessive expenses but also in large and potentially unnecessary repair bills as well. Because just as car companies like to inflate the price of cars to inflate profit margins, so does the car service industry like to inflate its prices to inflate its profit margins. Duh!

A patriotic citizen with uncommon sense who is living in the United States today sees a broken country. Free enterprise and capitalism have served it well but have become a little too much of a good thing. The U.S. does some things (namely the expensive, most profitable, things) really well. If you want really expensive health care, really expensive education, really expensive financial services, and have a lot of money this is the place to be.

But we can't all afford Volts, windmills or solar panels, and as we just spectacularly proved we can't all afford overpriced "affordable" housing. Therefore, as some of us have only recently learned, a lot of our "innocent" lives have been trashed or terminated as a result. Both parties are at fault. They often cite JFKs moon landing as an example of what is possible. But that was realistic. Today, the parties seek to lead us towards their respective goals that are *not* realistic. And perhaps some of us are too stupid to live because of the way we keep voting for the trivially differentiated scumbags they nominate to lead us. Luckily, the Cockroach EV is more realistic and affordable than windmills and solar panels, and a Hell of a lot more affordable than military equipment.

It has become a paradigm that more expensive is better ("not because it is expensive but because it costs more"). It has become the duty of even the uncommonly sensible among us to pay premium prices, because that is where corporate profits max out. And so those who would opt to drive *Real* Beetles can not because of the specious bases that they pollute too much (not true for some people) and are too unsafe (not true for some people) and because their double and triple priced versions are more profitable. It is easy to understand why a company would rather sell you a $25,000 complex New Beetle rather than a $7500 *Real* Beetle. But should government be using laws, tyranny actually, to aid and abet them. It is one thing to make a really expensive car available for those who want and can afford it, and quite another to make a really *practical* uncommonly sensible car *unavailable* to those who want or need them, instead.

This writing is a protest "working from within a corrupt system". It has made a case for a niche car: The Cockroach, principally (but not exclusively) a retiree's Cockroach. This Cockroach is most often an electric vehicle (but not necessarily only electric) that can serve retirees like me, and millions in my same boat, as well as any ICE-Car out there might serve me, but for which there is no ICE-Car out there nor likely currently possible that can come close to competing with *it*. But it is not adequately profitable. So how do we get them built?

The Cockroach was argued to be technically feasible, realistic and if every aspect panned out near its potential promise, it could be a monstrously effective benefit to those on Social Security without costing the government a cent. Therefore its introduction and promotion might be a non-monetary optional way for the government to compensate Social Security and Medicare beneficiaries. Alas, little and perhaps no real effort goes into developing better, lower priced lead batteries when lithium and nickel batteries are more profitable. Hence, the Cockroach is the antithesis of cubic-money cars like the Volt and Leaf and worse which the government has promoted in the past with $7500 subsidies, recently seeking increases in some places to $10,000 subsidies that are nearly enough to pay the potential full price of a Cockroach. Instead they are enticing buyers among what some derisively call the top several per centers (at the same time that some seek to raise their taxes in the spirit of "fairness"). Pretty nearly proof enough of a corrupt government, both parties of which always choose to tax and spend on their respective pet projects rather than to solve.

I have bothered to make this case because I have decades of experience with ICE-Cars and am a staunch member of the niche the Cockroach EV would serve best. I am retired and drive little. Many people in my class driving ICE cars pollute most of all on a per mile basis (because we do a maximal fraction of our driving with cold ICE engines) but we drive so little overall that it more than offsets our total harm. Nonetheless, if we were to shift to none-polluting Cockroaches, the gains in pollution reduction could be very substantial because even though our total miles are less, we would be eliminating ICE cold-starts.

I am a conservative American (in both definitions of the word) who has been getting ripped off by this corrupt government (even when it claims to be conservative) for decades to the tune of hundreds of thousands of dollars (on top of all the standard taxes for which I am *not* being represented) to the extent that, but for the rip-off, I (even with my largely sub-UAW, sub-USW career) should be a member of the despised top per-center millionaires/ billionaires club. Yet I am not.

These are *not* harmless games being played for therapy by defective politicians who are tragic genetically trashed victims of their birth. These are in many cases life and death decisions the government is consciously making that have gross collateral damage among innocents. These are in many cases worse than any Death Panels anyone has feared to date. Worse than any crime family selling dope to make money. Worse than any censored, marginalized and excluded patriotic protester with a much less harmful justified tax protest bomb in Oklahoma City.

We have considered how our current President in particular is busy sprinkling money like it were pixie dust to in theory help put windmills and solar panels around (so that we can pay for them). At the same time he is giving overly expensive healthcare (lying that it is "insurance") to people who can not pay for it[40] and wants to give citizenship to people who will vote for his party but will be disproportionately unjustified drains on Social Security and Medicare. However, he has not helped retirees cope with the mess he, like his predecessors, is making of things. Indeed, he and *his* party have looted *our* Medicare fund and have given an insane non-tax "tax" holiday to those who should be building Social Security and Medicare annuity credit. And if I hear him lament his poor mother's death one more time, after he has betrayed every similar sick and vulnerable human in this country, I am going to puke. Is this *Wonderland* we live in?

As a result, this thesis has focused on the dull, unexciting little subject of *practical* transportation for less-well-to-do retirees. It has tried to help produce a small, tiny, little victory in a sea of troubles by speaking truth to power. What is government doing to promote our general welfare with the transportation issue? Unlike its windmills and the damn Volt, the Cockroach might actually help. The Cockroach as proposed here holds the potential:

- To provide transportation that promises a stunning degree of practicality and reliability far beyond that of any ICE-Car to a niche audience (very important to large numbers of niche retirees).
- To reduce the cost of transportation by being substantially cheaper to buy

[40] During the Supreme Court arguments regarding Constitutionality of The "Affordable, (not)" Healthcare Act (ObamaCare), one of the President's appointees raised his favorite issue of fairness. Her question posited that it is unfair for people like me to have to pay for healthcare for people who use emergency rooms but do not have insurance often called "free-riders". However most of those people can not and are not required to pay for the bogus "insurance" (which means it is not insurance at all) that the Act creates. And so if sustained, I will not have to worry about having to pay for these free-rider people's treatment *after* they receive it and can not pay. Instead I will simply have to pay for it *before* they seek it, and yet that raises the question of whether having a bogus "insurance card" (a welfare card) will lead them to seek it much more often resulting in me again having to pay still more. Will this mindset lead to other fairness Acts? For example, women need to fear getting raped when they go out onto the streets, minorities have to fear getting shot. Perhaps it would be more fair to rape and shoot them in their homes *before* they go out onto the streets.

and maintain, and cheaper to operate than any compact or sub-compact ICE car being sold today (very important to *some* retirees). Retirees will not need a huge sub-prime loan to be inspired by a National Affordable Cockroach Strategy and Community Reinvestment Act quotas, or guaranteed by Fannie and Freddie Affordable EV Quotas to buy one.

- To favorably affect the environment and energy crises in a far more efficient way than windmills and solar panels (but while not kissing up to special commercial interests).
- To have negligible maintenance expenses and requirements (also very important to *some* retirees) such that for low mileage drivers, safety and pollution inspections are so unnecessary as to be asinine for an extended initial period and for any follow up repetitions. But this might reduce a government tax-revenue stream for which we are not being represented.
- To allow retirees to help themselves through their own collective volunteer efforts and then to help the Social Security Trust Fund through royalty fees (rather than corporate profits) or as non-monetary optional alternative benefits.
- To signal methods to launch additional similar strategies to help save Medicare (such as through financing of significant medical research) as well as further benefit Social Security through further additional prudent uses of the funds from both trusts in a revolutionary effort to actually benefit their beneficiaries rather than to build aircraft carriers or to bribe illegal aliens into voting for them when they are given their tacit quid pro quo citizenship.

We have examined how numerous E-Car hobby conversions have already proven useful to highly motivated users as practical but flawed vehicles, but that the flaws in these hobby conversions may just be technically and practically mitigated to a large extent, and especially so in newly manufactured vehicles. And the numerous tactics reviewed could yield a highly desirable and inexpensive newly mass-produced car. A car:

- That has efficient steering, braking, heating, ventilation and air conditioning, has low maintenance demands for its running gear and very possibly even for its lead acid batteries, and is safe and nonpolluting.
- That has a city/highway range behavior more nearly like those of ICE cars with a highway range perhaps half that in city instead of the enormous variations with range halving at low temperature, halving or more again due to power draw rate, halving yet again due to battery age.
- That has a little more top speed than current common EV conversions, but enough to make it a much more viable highway machine.

The Cockroach might continue to have perhaps only one legitimate major downside—its still somewhat limited and still somewhat variable range, which renders it unsuitable for many, perhaps most, people including many of the more-itinerant more well-to-do retirees. Yet for those whom it can serve, its benefits are potentially stunning. It is not like windmills and solar panels, both well worth researching, but both seldom ready for major prime time. Unlike those windmills and solar panels, it does not require subsidies to make it profitable and beneficial. This is America, it matters whether the Emperor really has new clothes or not

We have also examined the tyranny our government has again become. It tells us cop-killing drug pushers are often bad Americans and that, we are asked to accept, is why our government has decided to kill them. But they pose little if any threat to almost every last person in this country, including the police they kill. And there are so few of them. Still we kill them. Why? Killing must simply be good to do.

Similarly, ignored patriotic political protesters, like Timothy McVeigh and the protesters in Waco, were *not* bad men, and many fought and died for our freedoms. They are heroes. All are therefore justified. And there have been too few of them to pose any significant threat to nearly every last person in the country. Still our tyrants killed them, too. Why? The only possible explanation must be that killing *must* be good.

Therefore, perhaps we need to kill more, including some of our worst politicians who are responsible for so many of our deaths, and the approved and established way to do that would be with suitable punitive legislation like our government has taught us to use for good killings.

This has stressed how we have been exploited repeatedly, and still are, to bail out banks and savings and loans that were forced to fail by government pernice. We have had that half a trillion looted from our Medicare trust fund budget among earlier raids, and up to hundreds of thousands looted from our own potential personal retirement savings. And we are now faced with potentially unavoidable curtailment or abridgement of Social Security following grievous mismanagement including the raids on that trust fund. We face pernicious terrifying diseases some with probabilities approaching a perfect certainty that dwarf the risk of terrorists yet are comparably and virtually ignored.

Hence this thesis has suggested a humble small plan to help, but I have decades of experience to expect it will also be censored, marginalized and excluded despite my attempt at brutal candor. I know now how good Germans must have felt when they were ignored during Hitler's rise to power. And I would not be surprised if I am killed for my honesty and candor by some Stalinesque government wannabe. Timothy McVeigh has taught us that even spectacular statesmanlike protest (ala 1773, ala John Brown at Harper's Ferry) can be ignored, and we who form this democracy do nothing. I can not hope to succeed this time with this piddling effort, but I have made sure the truth can be known to all who seek it.

With this manifesto, anyone who wants to know the justification for the McVeigh Oklahoma City tax protest, the crushing of all those expendable babies that were used as a shield that upsets some of us so much for no good reason, can find it here without the lying government spin. Ditto the Waco Tax Party and other events.

The case has been made that it is unhealthy, it is terroristic, it is tyranny, to preside as our government does over a country claiming to be a democratic republic in which large numbers of people are being exploited, ripped off, censored, marginalized and excluded, who are losing their health and treasure and are being put in a place where they have nothing to lose, especially when they have the skill and ability *and power* to protest this tyranny in ways that would have shocked the original Sons of Liberty. That is asking, nay begging, for trouble, sowing a whirlwind. I certainly hope I have gotten *that* point across. As a presidential candidate once said "They won't tell you. I just did."

So will *this* message get through to anyone charged with the responsibility for this country? No, I am *not* referring to our government. It is my fellow citizens who are responsible for this country, whom among other obeisances are called upon to sit on juries for kangaroo courts and to kill their fellow Americans, heroes at times, at the behest of tyrants in our government. The tyranny we face has been growing like cancer for decades.

If they were to announce that the descendants of slaves were going to be returned to slavery, I think we would expect a bad reaction. During the surge in tyranny of the early nineties, the Waco and Ruby Ridge and Okalahoma City events and their protests occurred. One should not need a quality survey to know when things are getting this risky. Of course neither party cares what any of its constituents think of their tyranny. Both think they can lie to get elected and then exercise royal disdain, ignoring the population and just killing any heroes like McVeigh that dare to stand up to them. They have not learned the lesson we taught to King George III.

And I take no pleasure in declaring here that the country has degenerated to a place where revolutionary opinions and actions are justified. We are sitting on a bubble waiting for it to burst. How long will it be before a next Lexington-and-Concord-like event occurs.

And yet our government doesn't care if such opinions are forming, such conclusions are being drawn? Have our tyrants concluded that they have finally finagled enough control over us to exercise some narrow royal manifest destiny of their own, so that they can ignore our voices with their selective deafness.[41] They do nothing I can see. They have apparently concluded they can just kill off anyone like McVeigh. They can always cut off petroleum to Japan and sneak the aircraft carriers out of Pearl Harbor? They can gin up symbolic wars on women's health and minorities and illegal aliens? They can distract use.

[41] This point bears repeating and elaboration. *Never* underestimate the selective deafness of the United States government. As August 2, 2011 was approaching, there was a debt ceiling crises being touted by the Democrat party (which likes to call them selves the "Democratic" party even when they are being their most Socialistic). About a year earlier, they had control of the entire government (which the writer voted for as an act of violent protest), and they were about to adopt a healthcare plan now called ObamaCare which was supported by nearly the entire Democrat leadership. In polls, and in their town meetings the opposition was palpable. They were literally inciting violence. The Republican Party (what some Democrats would call the "Republicanic" Party) called upon them repeatedly to listen to the will of the people. But they assured us that the people didn't know what they wanted, only the Democrats knew that, and they knew what they were doing was right and that they would be exonerated and people would learn to love their ObamaCare once they had it. In the fall election of 2010 the Democrat party received what Obama described as a shellacking. Nonetheless, less than a year later, during the debt ceiling controversy, the Democrats still wanted to raise taxes and spend some more, perhaps hoping that yet another bribe will pull their fat out of the fire. And so they fought for "revenue increases" (taxes) as a way to reduce the deficit rather than to reduce their beloved spending. And so they once again spun their efforts as a "balanced" approach of future cuts in spending with current increases in taxes. And although most polls and most town meetings were still calling for reduced spending they managed to obtain a few poll results in which a scant majority of respondents were willing to support a "balanced" reduction in spending with some increase in taxes. And then like Inspector Renault, they were shocked, shocked that the Republicans would not listen to the will of the people and do what the people want, even as they were ignoring that other will the people wanted and using their ability to prevent what the people wanted even more: the repeal of Obamacare. Moral: Political parties will hear every word you say as long as you tell them what they want to hear, otherwise they are stone cold deaf.

Think about how the PATRIOT Act, the Gulag in Guantanimo and things like them take us ever so much closer to martial law without calling it by its real name.

So we know government does not listen. Has this provided a manifesto that will ring true in the hearts of patriots, warning them of what they must fear when tyrants that claim to represent them do the tyranny thing against free men instead? Will this alter the way anyone votes or if they vote at all? Will leashes ever be put on both of the corrupt out-of-control political parties? Certainly, this manifesto can be referenced as a legitimate basis should Constitutionally-protected free heroes protest as I, myself, did with my killer votes to make things worse (or perhaps go further as I predict with similar constitutionally justified self-defense, collateral damage or not).

Did I find a way to penetrate the so-called apathy, fear and loathing? Would I have been better off, would I have fulfilled my duty to my country better with scaled up protests of my own like those I have enumerated and predicted when so many at so many levels are innumerate tyrants? Will the next justified violent protest again bring forth pleas to an unlistening God? Why? Why? Oh! Why would anyone do something like that [when in fact it is obvious]? Never to receive an answer they really don't want. Will they continue their own selective deafness and ignore the justification revealed here? Will they and those in their government who were so outraged over Newtown, continue to tyrannize and to justify events like that in Oklahoma City, while ignoring the real threats of wrongful diseases that slaughter their constituents.

We shall see.

What Next?

This humble text may require defending or correction that the writer, himself, may or my not be up to or be around for. It can be otherwise expanded and revised in many ways to improve the science and politics or to correct unfortunate or ignorant errors. A detailed design for a Cockroach is in preparation for a Volume 2. A demonstration Cockroach EV of that design might then be worthwhile. But probably the most valuable next effort this commentator could seek would be to validate with historical data (and there may be a rich harvest of data surfacing in little cited but long-known electric-boat technology that should be adapted) or testing of the speculation and hypotheses in the Appendix A on any scale at all. For example, if the promise of circulating electrolyte with all the potential benefit thereto, benefit that would be so easy to incorporate might provide the anticipated and much needed increase in high-discharge-rate range and performance along with substantial potential gains in existing lead-acid battery reliability, then this would prove to be the biggest, if not best, game changer, whether anyone is listening or cares this time or not.

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Appendix A

Theory, Operation, Flaws and Potential for Lead-Acid Batteries (LABs)

Common Lead Acid Battery Failings

Among those hobbyists who use common LABs in E-Cars today there appears to be three principal handicaps:

- Deep-cycle lives of only 200-600 charge cycles, term lives of only one to five years with about half the capacity lost to age in three years.
- Loss of electrolyte (electrolysis/evaporation) requiring frequent maintenance (topping off).
- Limited maximum range of about 35-50 miles for typical conversions under the most optimum conditions, potentially much less otherwise.

If these three areas could be improved somewhat, the LAB could be a superb, possibly ideal, power source for E-cars that fit the Cockroach niche. Indeed, it appears that all three of these issues should not be *major* obstacles. So why after more than a hundred years of commercial service are they still "such" obstacles?

Today, the medical industry has a huge economic stake in *not* finding the cure for cancer. Politicians have a huge stake in *not* resolving the recession/banana we are in. And car makers have a huge stake in not finding the way to build a *practical* E-Car like the Cockroach. Maybe pursuit of profit is the main reason.

For over a hundred years, these three flaws have obtained. Yet when one seeks to understand these flaws, they do not seem so intractable. This appendix will try to explore and simplify how LABs appear to work and the apparent causes of these three flaws will be highlighted, and then both speculation and proven tactics for mitigating them will be presented.

How Does a Lead Acid Battery Work?

The two posts (electrodes) that protrude from a LAB case, one called negative, one called positive, are connected to a series of sandwiched plates alternately connected together in groups, and the plates are immersed in a sulfuric acid and water mixture. Each grouping of plates yields approximately two volts (about 1.9 to 2.1 volts) of electrical potential and in typical batteries three, four or six grouping yield an additive series total of six, eight or twelve nominal volts overall. During discharge, electrons flow from the negative electrode through equipment (e.g. a motor) and back into the positive electrode. During charging, electron flow is forced to go in the opposite direction, and act much like the winding of a spring.

Inside the case, the plates are typically made from lead grids (but there are other designs also) into which mixtures of lead oxides such as of red lead oxide (Pb_3O_4) and/or litharge (PbO) mixed with sulfuric acid and other items is spread and then allowed to "harden" (how hard it gets is not specified but one reference says plaster-hard). Then the plates are "formed" meaning they are put under charge (subjected to electric current) and each plate changes its chemistry.

Those plates which have a current drawn from them in use are called negative and receive electrons during forming and later during charging, and they convert the hardened paste into a porous lead. Those designated as positive and which receive electrons during use and have them extracted during formation and later charging convert the paste into lead peroxide (PbO_2). The formed plates are then sandwiched and installed into battery cases with wood or other spacers between them and the case is filled with fresh electrolyte (a 30% sulfuric acid and water mixture) and the battery is ready for use. Many practical assembly and construction details are found in the book: *The Battery Builders Guide* [**26**].

Figure A-1 shows how sandwiches of basic plates in their initial states separated by a wood or other porous material spacer can be combined (grouped in series) to yield a nominal six-volt battery. When a current is drawn, meaning when a device is connected to the electrodes, electrons leave the negative electrode and flow through the device then return to the positive electrode.

In mixture with water, sulfuric acid (H_2SO_4) is called a strong electrolyte because it is very ionic (specifically a strong acid) and that means it "hydrates". The two hydrogen (H) atoms are held tightly by the sulphate, SO_4, molecule (and that means their electrons are drawn with great force away from the hydrogen and towards the sulfate producing a molecule that is very positively charged in some regions near the hydrogens and negatively charged near the sulfates. Water molecules (which also have very positive and negative regions) surround each acid molecule (positive ends to negative ends and negative ends to positive ends) and by interfering with the electrostatic forces can break apart (dissociate) the two hydrogen atoms from the sulfate leaving their electrons behind to form positive ions (H^+) each attached to one or more available water molecules (H_2O) to form a hydrated hydrogen ion (H_3O^+or H^+:H_2O), also called hydronium which may be surrounded by additional water molecules. The remaining ionized sulfate ions (first $HSO_4^-$and later SO_4^{2-}) also attach to one or more water molecules to form singly or doubly charged negative ions (H_2O**:**HSO_4^- or H_2O**:**SO_4^{2-}) which also may attract additional water molecules. The electrolyte is initially neutral with equal numbers of positive and negative hydrated ions throughout. However because sulfuric acid is "strong" it tends to be extensively, even virtually fully, dissociated in

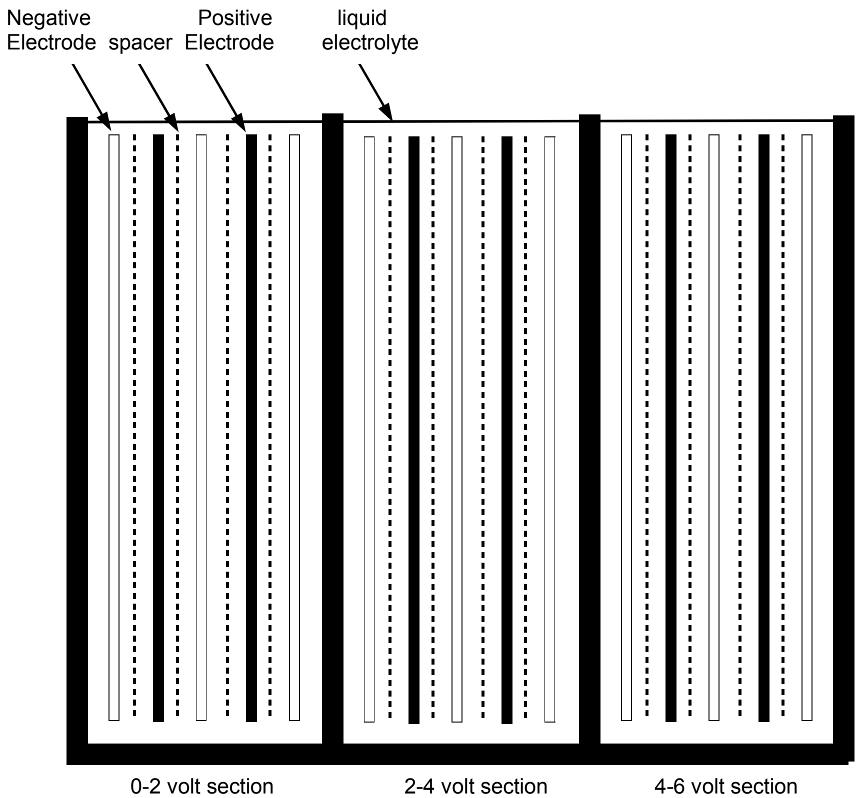

Figure A-1—*Parts of a six volt lead acid battery*

solution: apparently virtually every molecule is broken apart into at least the singly ionized state and most of those are further dissociated to the doubly ionized state. This attempt at simplification will treat every sulfate ion as being doubly ionized according to the following potentially flawed equation:

$$H_2SO_4 + 3H_2O \rightarrow 2(H^+\mathbf{:}H_2O) + SO_4^{2-}\mathbf{:}H_2O$$

These ions move around in the solution when the battery is being charged or discharged and can apparently pass easily through the wood spacer.

As described by Watson, the prevailing theory of the overall chemistry in a battery [**11**], is called the double sulfate reaction. At the surface of the negative plate, during discharge and recharge, the approximate equation below applies:

$$\begin{gathered}\text{Discharge} \rightarrow \\ Pb + SO_4^{2-}\mathbf{:}2H_2O \leftrightarrow PbSO_4 + 2H_2O + 2e^- \\ \leftarrow \text{Charge}\end{gathered}$$

In other words on discharge the left side of the equation indicates that a sulfate ion bearing two negative charges and perhaps at least two hydrated water molecules is drawn to the negative lead electrode where the sulfate ion reacts with the lead to produce lead sulfate which releases the two (or more) hydrated water molecules and the two liberated electrons flow out into the external circuit.

At the surface of the positive plate, during charge and discharge the following approximate equation applies:

$$\begin{array}{c} \text{Discharge} \rightarrow \\ PbO_2 + SO_4^{2-}\mathbf{:}2H_2O + 4H^+\mathbf{:}4H_2O \leftrightarrow PbSO_4 + 10H_2O - 2e^- \\ \leftarrow \text{Charge} \end{array}$$

In other words, during discharge, a doubly ionized sulfate ion combines with a lead peroxide molecule, forming lead sulfate and releasing two (perhaps negatively charged) oxygen atoms which along with two electrons from the external circuit combine with four positively charged hydronium atoms ($H^+\mathbf{:}H_2O$) to form four neutral water molecules. Notice that with the six (or more) hydrated water molecules, there is probably more water dilution at the surface of the positive plate than at the negative plate.

At both plates during discharge, the water that is released near the surface of the plates dilutes the acid near the surface and is less dense than the starting electrolyte and would tend to migrate (float, buoy) upwards to the top of the plate diluting (stratifying) the acid concentration there. Lead acid batteries in an EV that are discharged to any degree might stand for some period of time before being recharged (whereas in an ICE car the starting battery will tend to begin recharging as soon as the engine starts). However, usually lead acid batteries in electric vehicles fitting the Cockroach niche would be recharged fairly quickly (hopefully within hours) after use, so the stratification effects often will not have a lot of time to soak. Nonetheless over time any soaking effects can accumulate.

Table A-1 indicates the specific densities and volumes of the various solid materials present. Notice that the lead sulfate is much less dense than either the lead peroxide or the lead which are present in a battery. The expansion equations at the bottom of Table A-1 estimates how the plates might change size in use. For each cubic centimeter of litharge that makes up a negative plate, formation into spongy lead results in it shrinking to about 0.78cc, and then discharging changes it into lead sulfate and results in its growth to about 2.08cc. For the positive plate, one cubic centimeter of red lead, first shrinks slightly less than litharge on formation to about 0.89cc, then discharging it to lead sulfate, increases its volume up to about 1.95cc. Both of these materials have porosity so that the changes in their superficial dimensions may be different than these estimates suggest.

Figure A-2 depicts these estimated volume changes for "solid" paste that is contained in two directions and presumes all expansion/contraction occurs in one direction. These volume changes put stress on the hardened paste. The greater the degree of discharge, the more swollen these layers might become. Over time the layers apparently fatigue, crack and shed pieces that migrate to the bottom of the battery case. [*Vol. 2 has a better analysis*]

Numerous references report the shedding is predominantly, but not entirely, from the positive plates. However, the writer has seen no chemical analysis of the shed particles. If shedding occurs mostly under deep discharge (which seems to be the case) one would expect them to be lead sulfate. However if lead peroxide and pure lead particles were to shed, they could contact each other and convert into lead sulfate, also. Pagé [**13**], shows a badly worn plate for which numerous regions in the grid have lost all of the filler material. When too much shedding has occurred, the battery's cycle- and service-life is over. This can be due to

Table A-1
Densities of Battery Materials

Chemical	Specific Gravity[a]	Specific Volume[a]
Lead (Pb)	11.3	0.0885
Litharge (PbO)	9.53	0.1049
Red Lead (Pb_3O_4)	9.1	0.1099
Lead Sulfate ($PbSO_4$)	6.2	0.1613
Lead Peroxide (PbO_2)	9.375	0.1067

[a] specific gravity is the weight of the material compared to a similar volume of water. Specific volume is the volume of the material compared to a similar weight of water.

Expansion equations:

Negative Plates: Litharge (1.00 cc) $\rightarrow$ spongy lead (0.78 cc) $\rightarrow$ lead sulfate (2.08 cc)

Positive Plates: Red Lead (1.00 cc) $\rightarrow$ lead peroxide (0.89 cc) $\rightarrow$ lead sulfate (1.95 cc)

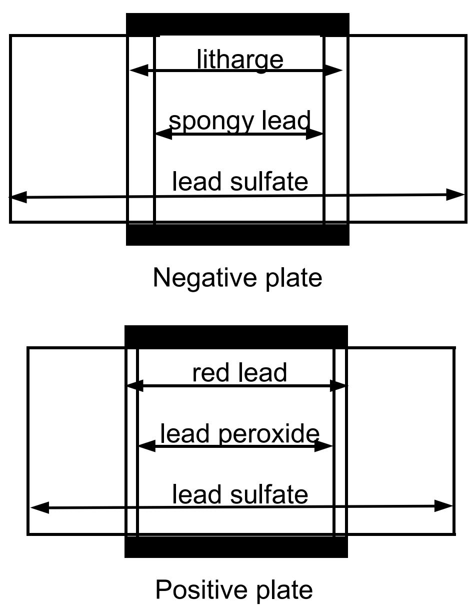

Figure A-2—*Estimated volume changes during formation and discharging/recharging.*

shorting of the plates (catastrophic failure) by accumulated debris (that is reported to be conductive) that builds up and contacts both plates, or because the sulfate remaining on the plates changes into a useless form (called sulfating to be covered next), or because the amount of active material left on the plate is reduced below a usable level. Often when the capacity has fallen to eighty percent of the original level, the battery is arbitrarily classed as failed. However, this amount of capacity might still be useful in some Cockroach EVs.

As a brand-new battery begins to discharge for the very first time, one would assume the lead sulfate that forms on either plate is pretty uniformly distributed, but as more forms it covers more and more of the plate and then gets thicker and thicker as the depth of discharge increases. The longer the sulfate remains on the plates and the thicker the sulfate, the more likely it will convert (apparently through growth of crystals) into a form that is hard to covert back into lead or lead peroxide and in this instance the majority of this form of sulfate apparently forms on the negative plates. [*Vol. 2 has a better analysis*]

Apparently, although the positive plates are most prone to shed a lot of particles, the negative plates are most prone to grow a lot of insulating sulfate.

These are apparently normal wear mechanisms for common historic battery designs. In normal use these basic-design batteries are often called "flooded" electrolyte which means they are submerged in liquid, but in general, there is more than enough hardened paste present than is needed to react away all of the sulfuric acid in the electrolyte. And a fully discharged battery can therefore have virtually pure water between the plates. This can lead to a risk if the weather is cold, because initial electrolyte has a low freezing temperature but as it converts to water its freezing point rises to approach 32°F, and it can freeze, expand, distort and damage the plates and even cause contact and shorting of the plates.

The formation and expansion of sulfate on the plates can also cause them to bend and distort, to bow, potentially to short, especially so for the end plates which do not form sulfate as fast on one side as the other (turning them into an analog of the bimetallic strip with sulfate expanding more on one side than the other.). This is another failure mechanism. End plates are usually (perhaps always) negative probably because they do not expand as much and so the force of distortion affects them less. Positive plates apparently always have negative plates on both side and that tends to balance the forces on them

A brand new battery will have a perfectly homogenous electrolyte having about one sulfate molecule for every three water molecules. During discharge, the homogenous initial electrolyte solution will be depleted of sulfuric acid molecules and the depletion is greatest near the surface of the plates. The uniformly mixed hydrated sulfate and hydronium ions in the new battery are being all driven to the surfaces of the plates where they are being removed from the solution.

When the plates have been partially discharged, the sulfate molecules near the plates are gone and the water formed or concentrated near the plates being less dense than the electrolyte farther away will tend to buoy upwards and reduce the acid concentration in the upper regions. This stratified condition should not be allowed to obtain for long before recharging.

When a new battery's plates are being recharged for the first time, the reactions are the reverse of the discharge reactions. In this case, the positive plates are now removing water from the electrolyte while forming hydronium ions and both plates are releasing sulfate (SO_4^{2-}) back into it. The released sulfate molecules are all near the plate surfaces and produce a more dense electrolyte than that farther way.

The dense sulfuric acid along the surfaces of both plates will now tend to migrate (percolate) down along the plates, through the existing electrolyte tending to puddle and increase the concentration of acid in the lower regions (just as the previously released water during discharge migrated upward to reduce the acid concentration in the higher regions). The concentration of acid in the lower regions of the battery is greater than the original homogenous initial charge. Each charge/discharge cycle increases the non-uniformity.

The sulfate presence is greatest at the bottom and least at the top. It is possible the battery in a recharged electric vehicle might then stand in this state for a protracted period (for days to weeks). Although this new battery may have been recharged to approximately the same extent as for its original new state things are *not* the same as when it was new. Even just one complete deep discharge/recharge cycle has produced two very undesirable consequences: (1) the electrolyte is significantly changed (it has begun to stratify) so that it is more concentrated near the plate surfaces and the acid near the plates being denser than the electrolyte, has migrated (sunk) to the bottom, and puddled near the lower regions of the plate and (2) possibly but not certainly, the increasing concentration at the lower levels may help promote the formation of a crystalline sulfate with any trace sulfate still remaining on the plates.

Here is where things get thorny. The voltage produced by any adjacent two plates depends on the concentration (the pH) of the acid between the plates and the temperature among other things. Table A-2 and Figure A-3 exhibit the way cell voltage varies with bulk acid concentration. The more concentrated the acid is, the higher is its specific gravity, and the higher the voltage produced. Before the first discharge, the plates were new and the electrolyte was thoroughly mixed, therefore uniform in concentration throughout. But after stratification, the acid concentration is progressively greater across the bottom of the cell compared to across the top. Therefore, if the battery were to be cut into two horizontal sections, treating the top section as one battery and the bottom section as a separate battery, the voltage measured across the top layer of the battery would be lower than the voltage measured across the bottom layer. Hence, any stratification in the original battery creates a scenario that is exactly like connecting batteries of differing charge levels across one another.

Since the voltage across the bottom of the stratified cell is greater, it will try to charge the upper portion of the cell, and in turn will slightly discharge itself. However the upper portion is fully charged and therefore any internal currents would tend to only electrolyze water in the upper levels releasing hydrogen and oxygen and causing water loss. However, the slight discharge that occurs in the bottom layers would form some small amount of discharge sulfate. This will happen even though the external charging was complete and even if there is nothing connected to the battery. This is an internal loss (discharge or leakage) mechanism. Most importantly, this stratified sulfate that is produced will soak in concentrated acid continuously and is apparently assured of converting sooner or later into a crystalline form mostly on the negative plates (which an older book [**12**] calls “unhealthy” sulfate) and it causes lost capacity. And although sulfation happens most rapidly in a discharged battery that is allowed to go uncharged for some time, this slower but nonetheless certain failure mechanism is present even in starting batteries and should be expected even in a deep discharge battery that is charged immediately after each use.

If the charging is stopped short of completion, the stratified acid and higher voltage of the bottom regions will try to even more fully charge the upper regions, effectively increasing the amount of sulfate on the lower regions and the amount of unhealthy sulfate

Table A-2
Cell Voltage Dependence on Acid Concentration [14][a]

Specific Gravity	Mean Voltage
1.020	1.855
1.030	1.877
1.040	1.892
1.050	1.905
1.100	1.960
1.150	2.005
1.200	2.048
1.250	2.095
1.280	2.125
1.300	2.144

[a] Vinal page 192.

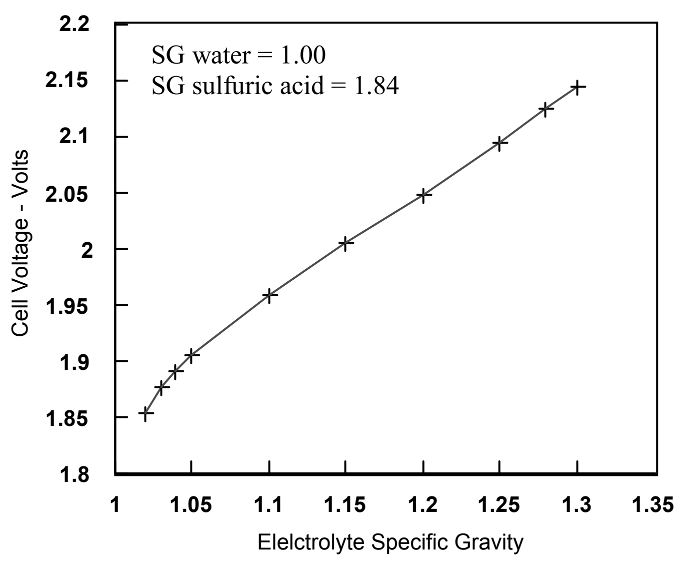

FIG. A-3—Cell Voltage Dependence on Acid Concentration Data of Table A-2

there. And this apparently happens in at least some real-world batteries in which unhealthy sulfation occurs more extensively on the lower regions of the plates.

Unhealthy sulfate causes lost capacity because normal recharging can not chemically convert it back to either lead or lead peroxide (but again recall some references indicate unhealthy sulfation occurs mostly on the negative plate per Watson [**11**], on his page 91). References for more than 100 years, have indicated that the unhealthy sulfate often grows to be quite large, covering and electrically insulating significant portions of the lower regions of the negative plate and preventing them from either charging or discharging again. On subsequent cycles, the full surface of the positive plate is reacting with only the upper portion of the negative plate (hence some ions must travel further to react the lower portion of the positive plate and maximum discharge currents that are possible are reduced). Pagé [**13**], on his page 54, exhibits a badly worn plate that as has been mentioned earlier shows complete loss of active material on its upper region (where over charging is likely) and white insulating sulfate on its lower regions has restricted their use. It is perhaps no accident that these opposite mechanisms (shedding at the top and sulfating at the bottom) would be consistent with the stratification mechanism.

Stratification can also cause an imbalance between cells of a battery and represents yet another failure mechanism. Specifically, its presence causes a disruption of the voltages available and the current flows possible from a series-connected battery pack, as is often used in most E-Cars. Some references (to wit, Buchman [**17**]), indicate this stratification mechanism is a, perhaps *the*, principal cause of battery failures in ICE cars. And in E-Cars the greater depths of discharge should magnify the amount and rate of stratification significantly. Stratification is a major evil.

The range of LAB cars is limited first by the local electrolyte inventory. Currently, every battery, and especially deep-draw batteries try to cope with sulfation and shedding from their surfaces by providing excess paste. Batteries are “dead” when the full quantity of sulfuric acid has been reacted away and the electrolyte has become nearly pure water, either locally or throughout the battery. At this point, the active paste in the plate has been incompletely but largely converted to lead sulfate, and an unknown amount is still present as lead peroxide and spongy lead. In many applications when a battery has permanently lost 20% of its capacity it is considered failed, although in E-Car applications a 20% loss of range from, say, forty to thirty-two miles might still be acceptable for use. Indeed, many hobbyist converters install used batteries (often available for free) at day one as a cost-saving measure.

As a result, virtually *all* references talk about the importance of recharging a traditional LAB as soon as possible after it is has been discharged (as opposed to new carbon-bearing LABs that supposedly handle partial-charge states better) to reduce stratification and sulphation. Furthermore because stratification is inherent in most current flooded LABs, it is recommended that an “equalization” charge (a charge to stir the electrolyte back towards a uniform mixture) is applied periodically (usually monthly). An equalization charge is performed by use of an intense, abusive, flow of current to cause bubbling (hydrogen and oxygen formation through hydrolysis) throughout the electrolyte so that the rising bubbles cause a mixing of the more concentrated acid at the bottom with the more dilute acid at the top. There are expensive chargers available to do just this, but clearly there are much better ways to mix electrolyte. For example, one could just shake or invert the battery [**17**] to remix the electrolyte except that in older batteries, all the shed particles would be thrown about and might cause shorts or other damage (however some batteries isolate each plate in its own “envelope” and might actually tolerate this approach well).

Methods such as pumping air into the bottom of a battery can provide mixing similar to what equalization charging provides (such "air lift pumps" have been patented and have been used in specialized applications). But perhaps even more effectively, a small electrically or mechanically driven pump could be installed to circulate the more concentrated electrolyte from the bottom of the cell and introduce it to the top where it would mix with the more dilute electrolyte there. This is entirely possible and should be a major way to both extend cell life and improve vehicle range and power. However, in a current E-Car with, say, twenty six-volt batteries (60 cells in all) it could mean having up to sixty of these little pumps running at a time. This option will be explored much more thoroughly later.

Though circulation would be less, passive inertial stirring would also be possible. Internal baffles could be arranged so that every time a car accelerated or stopped, the electrolyte inertia would cause it to pump some electrolyte from the bottom up into the top of the battery, and this could be better than much less frequent monthly equalization charging, but E-Cars would still be charged after each trip and would still stand and deteriorate until used again. Hence any inertial stirring would serve only to mix the previously stratified electrolyte, but that would, nonetheless, be a substantial improvement. Inertial stirring is not mentioned in any texts consulted and if this approach is novel, it is mentioned here specifically to serve as public disclosure and create a statutory bar to any future attempts to patent this.

Recently (meaning recent compared to one hundred and fifty years of LAB history) there have been batteries introduced to minimize stratification and any consequential unhealthy sulfation effects). One of these kinds is referred to as the gelled electrolyte battery and another is the absorbed glass mat battery, and what they do is to either mix the electrolyte with a gelling agent (for example ground glass) so that any concentrated acid that forms on surfaces of the plates is less able to move about. Alternatively, they use a porous compressed fiberglass spacer to similarly hold the acid in place. The improvement is apparently significant. However, both tend to reduce the capacity of the battery (by reducing the amount of electrolyte present) and they both add some weight. Such AGM (absorbed glass mat) cells are commercially available, but alas!, for one commercially available type, they yield about half the capacity of flooded cells at about twice the price and should yield consequently miserable EV ranges. A second, really important and quite elementary, yet apparently unobvious, (elementary does not mean easy) and apparently highly effective method is not currently commercially available for E-Cars and is the focus of the next section.

Improving Cycle and Term Life

When a simplified description of the stratification and paste shedding processes were presented to a chemical engineer friend (admittedly a very good engineer), his first reaction was the same as the writer's. Why not place the plates horizontally, so that on each layer any concentrated acid could fall only a fraction of an inch instead of nearly a foot, thereby cutting the maximum stratification by order(s) of magnitude? But since the stratification mechanism has been so clearly defined in texts going back to the early 1900s, it must have been thought of, perhaps tried, and been found undesirable way back then. Maybe not so, and the writer is at a loss to guess way. Maybe they were happy with what they had. They were making money, and so no one was trying to find a better LAB. Sometimes you don't need a better mousetrap. Capitalism is often very satisfied with the status quo. However this rather simple, yet apparently unobvious, remedy *was* discovered within eight decades later.

Sometime before September 20, 1983, The National Aeronautics and Space Administration issued a contract to the prestigious Cal Tech University to improve LABS and their Rowlette, John. J., [**27**] patented just such a horizontal plate battery (U.S. Patent #4,405,697 which can be downloaded from several patent search web sites) which they reported to have a far better cycle life. That patent expired on September 20, 2000, more than a dozen years ago, as of this writing, and at a time when great hordes of EV1s and other factory E-Cars roamed the highways of California, among much other E-Car activity. Although the EV1 used LABs in two of its three configurations, neither employed the NASA/Cal Tech design). And for all the writer knows, there may have been horizontal plate batteries patented even before 1983.

Indeed, when the writer searched the Internet for battery manufacturers selling this design including for either starting LABs or for the deep-draw LABs that are used in E-Cars, *or for any other use,* only two were found. One was in the US, one in India. Why is this? Indeed, only Storage Battery Systems (SBS) in the USA and Yelantra.com in India, were found to be using this design, and their literature lists it *only* for stationery power backup systems. Both of these were absorptive glass mat designs which by themselves are rated very highly for reliability and stratification avoidance, which in these cases results in ratings up to at least a stunning 2000 deep cycles and twenty-year service lives. Incredible reliability for a deep-draw battery. *But why only stationery applications?* They do not say. Perhaps the horizontal configuration is fragile with regard to hitting potholes and shaking the filler paste loose from the grids. But several simple fixes for that concern come to mind immediately. Is some capitalistic (monopoly, oligopoly, John D. Rockefeller, etc.) stuff getting in the way?

Indeed, in 1992, even before the NASA/Cal Tech patent expired, The Advanced Lead Acid Battery Consortium (ALABC, alabc.org) was formed to advance the technology in LABs in anticipation of the push to E-Cars. Do not confuse these folks with the United States Advanced Battery Consortium (formed in 1991) which is a part of the United States Council for Automotive Research, LLC. (uscar.org). Both are cooperative research groups formed largely of the lead-acid battery manufacturers (in the case of ALABC) and the three U.S. car manufacturers (Ford, Chrysler and GM in the case of USABC). Both groups avoid antitrust issues by working together on research that precedes commercialization and therefore can not in theory affect price fixing. Hence regardless of what these think-tanks feel about the expired NASA design (since it is already "developed" and commercial-ready perhaps their antitrust posture renders it untouchable). Clearly this important design has not found its way to EV consumers. But rest assured, hobbyist E-Car converters would be delighted, nay thrilled, to get their hands on a cheap 20 year, 2000 cycle LAB. I would too. This one commercial introduction (a "simple" technological breakthrough needing a commercial breakthrough) might be a several-fold improvement in the service life of practical hobbyist conversions and might mean even more to a mass-produced Cockroach EV.

At present, 2013, the ALABC is trying to come up with a LAB that will survive for long periods in a state of partial charge so that it can be used in hybrid electric vehicles in which the batteries are usually near half charged so that they can discharge to help acceleration or charge to store regen braking energy. The ALABC web site cites that the addition of carbon to the plates has made this possible. We shall see what comes of it in an industry that appears to have taken about one hundred and fifty years to make simple, if unobvious, progress on the acid stratification issue (if one may dare to suggest it has).

At present, the so-called AGM batteries are being sold for what seems to the writer to be an unjustified and extreme premium price (roughly half the capacity for twice the money) and would seem be a poor second choice to the NASA/Cal Tech design. But this design does not appear to be protected by patent or other monopoly. So there is no incentive (no extreme price premium) to manufacture it. Too bad we don't have a Socialistic-leaning President who has the welfare of the people at heart and could promote something like this as a way to create jobs. Bummer!

Temperature is a Problem too

The previous section explored how acid stratification and its effect on cell voltage can cause regions of the battery plates to fight each other, some regions at high acid levels attempting to overcharge other regions at lower acid concentrations. Temperature variations can trigger the same effect.

Heat is transferred inside a battery upon both discharging and even more so charging. The outside of the battery is immersed in an environment that may vary in temperature. And so the center of the battery may be at a different temperature than its outer edges. Here again battery voltage increases with temperature. If the center of a battery is insulated and heats more quickly, its voltage will increase and try to deliver a disproportionate amount of the current. Not good. On charging, if the center heats most (as is likely) it will try to overcharge the cooler regions much the same as occurs with stratification. A strong case can be made that a lead acid battery needs to be homogenous in both temperature and acid concentration.

Controlling temperature is difficult. Heat transfer is slow. Horizontal plate batteries should not offer any real advantage in this regard, however, circulating the electrolyte should be of significant benefit to improving LAB performance and life of either configuration.

Reducing Electrolyte Loss

Rather good progress has been made in near-sealing of LABs and preventing electrolyte loss. In current LABs, electrolyte vaporizes as a charging battery approaches full charge and sealed cases prevent loss, but also some water is electrolyzed (dissociated into hydrogen and oxygen gas under the influence of the charging current including during equalization charging) and that can pressurize the battery case. Two approaches to deal with the latter are in use today. In the simplest, there is a catalytic material (such as palladium installed in the battery caps so that as gas contacts them the hydrogen and oxygen are reacted back into water, and in other cases there is a more complicated "closed" reaction mechanism [**18**] that promotes movement of free oxygen that forms at the positive plate to the negative plate where it can recombine with hydrogen evolving there and reform into water. When the hydrogen and oxygen are sufficiently recombined, the battery can be sealed though in a recent development (early 1990s) a relief valve is placed on the case in case the pressure builds too fast to be recombined.

However, keep in mind that with a battery design that minimizes or prevents stratification effects (like that of Rowlette [**27**] or in one which circulates the electrolyte), that therefore there is less need to overcharge regions of the plates at low acid concentrations and the need for equalization charging could be eliminated entirely, and with still other improvements to be discussed below, there should be *much* less electrolysis of the electrolyte likely and electrolyte loss maintenance may become unnecessary, even in the most simple flooded-electrolyte-design batteries.

The horizontal plate LAB, does not necessarily eliminate all stratification, but it does ensure that any acid concentration near the surface of the plate is more nearly uniform over the entire surface, therefore that the plate will not try to both charge and discharge itself. Therefore, it should also experience much less electrolyte loss.

Unfortunately whenever stratification causes differing acid concentrations at different surface regions, regardless of battery design, one should expect it to interfere with operation. The higher acid concentration at the bottom of vertical plate batteries means the lower portion will not deplete the sulfuric acid as quickly as the top. Hence the top liquid will begin to electrolyze before the bottom, then you are forced to either stop charging at less than maximum capacity or to risk loss of water through electrolysis at the top. The horizontal plate battery should charge more uniformly over its entire surface. Nonetheless, some electrolysis is still a prospect, especially during wrongful aggressive charging or over-charging, and so a relief valve or vent is still a very good idea.

Improving Range Limitations

In many cases if you can improve a few things a little they may compound and improve each other a lot. So too here. In this analysis, the major criticisms of LABs may not be inherent, at least for Cockroach car use. Although current cars with short maximum ranges like the Cockroach can still be useful to many of us any additional range that could be obtained would be really welcomed by everyone. Is there a prospect for increasing the range, even just the apparent range, of LABs, even just a little? Even just of preserving it as the EV ages? This section explores (and suggests plausible yet unverified) conventional (and elementary) approaches, operational ways to increase apparent battery capacity.

It has been noted earlier that apparently the capacity of most LABs has been limited by the quantity of electrolyte present rather than the quantity of lead present (which has also led to the risk of "excess" discharge producing the low-temperature-freezing risk). And yet LAB design practices appear to be fairly rigid. Common LABs are pretty much the same.

In the early 1970s, the writer studied the physics of Charles Kettering's basic ICE ignition systems. Kettering's original design had been specified back around the time when electric starters were being introduced also. And it had been changed relatively little ever since. In the 1970s, his mechanical points were being phased out for transistors and optical timing was being introduced, but it appeared that there were still many original design premises upon which the system was based, that had been defined by Kettering when materials were much less capable than they had become in the 1960s/70s. Yet no one seemed to be questioning those premises.

The writer was driving a couple 1960 Chrysler New Yorkers, one of which he hoped to restore but at that time it had a really worn engine with poor oil rings. It used to foul the spark plugs in hundreds of miles, literally, filling the annulus between the insulator and case with an oily solid that prevented sparks from firing using Kettering's system. But there was research being done on capacitor discharge, fast rise-time systems that were of some benefit, yet it wasn't until the writer abandoned one of Kettering's original premises yielding a sys-

Table A-3—*Battery Stoichiometry*

Positive plate (Spongy lead per amp-hr)	3.866 g	0.0085 lbs		
Negative plate (Lead peroxide per amp-hr)	4.463 g	0.0098 lbs		
Electrolyte (Acid /water per amp hr)	18.35 g	0.040 lbs		
Total reaction per amp-hr	26.67 g	0.058 lbs		
250 amp-hr from 3 cells	20,002 g	44 lbs	C-100 rate, 2.5 amps	71% of total weight
225 amp-hr from 3 cells	18,002 g	39.7 lbs	C-20 rate, 11.25 amps	64% of total weight
186 amp-hr from 3 cells	14,882 g	32.8 lbs	C-7.5 rate, 25 amps	53% of total weight
143 amp-hr from 3 cells	11,441 g	25.2 lbs	C-1.92 rate, 75 amps	41% of total weight
Weight of typical battery	28,148 g	62 lbs		

tem unlike any other on the road that the car could be driven ten thousand miles between spark plug cleanings. Maybe a similar reexamination of apparent LAB design premises is worthwhile here.

In Watson, ([**11**], page 95), Vinal ([**14**], pages 209-212), and elsewhere, the basic stoichiometry (proportions of materials) for lead-acid batteries are cited as shown in Table A-3. One ampere hour requires a total of about 0.06 pounds of reactive materials per cell. So in the typical six-volt deep-cycle battery that weighs maybe 62 pounds (like the Trojan T-105), its four advertised ratings for ampere-hour capacity (ranging from discharge times from 1.92 hours to 100 hours) account for up to seventy percent of the entire weight of the battery.

If currents were drawn in this 2.5 to 75 ampere range, the battery would operate for from 100 to 1.92 hours, respectively, and accounting for non reactive materials in the battery (case, grids, spacers), up to 71% of the active materials would be exploited. Hence there would not appear to be a lot of “fat” in this design. EVs typically will require a minimum of perhaps one or two horsepower even to move at five or ten mph. Two horsepower is about 1500 watts and at six volts and even at a 100% efficiency, minimum current to move a vehicle is at least 248 amperes from a single battery, 24.8 amperes from a ten battery pack, 12.4 amperes from a twenty battery pack and 8.3 amps from a thirty battery pack. In addition, efficiency under high draw is often 50% or less and so for *practical* purposes, current draw rates of several hundred or more amps are common and yet there are no data advertised for this battery at more than a 75-amp draw rate. Battery capacity at high draw rates has been estimated for the last hundred plus years using the method of Peukert (see Vinal [**14**]), but that method appears to be quite flawed (and will be covered in detail in a next volume if there is any demand for one, and if this volume is not pilloried).

Nonetheless, if this example battery is capable of producing something slightly in excess of 250 amp-hours at low impractical draw rates, then the apparent capacity of its chemistry will be approximately halved at draw rates of 75 amps and is much less (perhaps fourfold or more) at still higher draw rates more typical of E-Car operation. As a result, current battery designs are capable of reacting a high fraction of their "fuel" but current methods of using batteries in EVs are often not capable of realizing this limit. This analysis must assume that lead acid batteries in hobby conversions may deliver perhaps only twenty to fifty percent of the capacity and range that would be possible at efficient low draw rates.

First semester college chemistry teaches Le Chatelier's Principle for chemical equilibrium. ICE technology applies this principle in its own quest for performance. Maximum power does not result from an ICE when its reactive materials (air, gas) are reacted in stoichiometric amounts. Le Chatelier's Principle asserts that a greater degree of reaction results when there is somewhat more fuel than needed for the amount of air. This is because the fuel being liquid and energy dense occupies much less volume and so a small excess of fuel can be added without significantly reducing the amount of air and so thereby "pushing" the reaction to greater air consumption can produce more power (but at less fuel economy). For best fuel economy, Le Chatelier's Principle is applied for IC engines in an analysis that allows greater reaction of the fuel with excess air that simultaneously reduces engine pumping losses.

Hence by analogy, one should wonder if shifting the ratio of reactants or the methods of reaction in a lead-acid cell at high draw rates might allow for a greater extent of reaction and better power or better efficiency. And the literature reviewed allows for a few observations in that vein.

Increasing the *concentration* of sulfuric acid in the electrolyte increases it resistivity (which exhibits a minimum and increases when the acid is either increased or decreased from a concentration of about thirty-five percent) per Vinal [**14**], page 110. In addition, the higher concentration may promote increased crystallization of sulfate (conversion to the "unhealthy" form) on the plates. Not good.

Increasing the *inventory* at current concentrations might help, but if the plates are moved further apart the battery internal resistance increases and its efficiency is reduced. And if the increased inventory is outside the plates it will still make the battery larger and the acid will not have good access to the active materials anyhow.

Clearly adding volume for more electrolyte or using a more concentrated electrolyte would allow a greater portion of the lead to be used. However today, it seems excess positive plate material is used to compensate for shedding (perhaps more for structural reasons than for electrical capacity).

Still it appears there may be some benefits from increase in the electrolyte inventory if that inventory can be exploited, and the good news is that modern LABs may just be able to offer up a tidy, perhaps robust, increase in *practical* range, even if the maximum range at optimum conditions is peaked out. These might improve their effective energy/weight ratio a bit and therefore increase their effective capacity a good bit (in terms of usable energy per pound), but is not likely to have nearly as great an effect on their energy per volume.

Speculative (Innovative) Development Prospects

Recall that EVs suffer from compounding of shortcomings. And indeed, current lead acid batteries suffer from their own sequence of extreme compounding of their flaws. Range is adequate but not great and when its gets cold half can be lost, when the battery gets old half or more of the remaining half can be lost, and when the draw rates are high, half of the half of the half (or even more) can be lost, but these must all be considered opportunities for improvement. A couple of potential strategies conclude this section and address what may seem like blue-sky prospects.

Addressing sulfation. Recall that a NASA/Cal Tech horizontal plate battery design reduces stratification, which apparently has a strong mollifying effect on many of the unhealthy sulfation issues and should help reduce electrolyte losses as well. Still, if such batteries were discharged and allowed to stand the formation of unhealthy sulfate must still be expected, and there is no solution for that. Or is there?

Recall that unhealthy sulfation may be exacerbated by stratification that causes internal charge and discharge currents. And if stratification is reduced a fully charged battery should have several-fold less internal concentration-gradient currents. Nonetheless standing discharged or standing when there are low-order parasitic currents, they may still ultimately form unhealthy sulfate that will accumulate over time.

Arthur Eugene Watson (1911) [**11**] cites a "sure-fire" cure for sulfation (especially unhealthy sulfation) on negative plates where unhealthy sulfation is the greatest problem. (remember: always check the old references). He calls it highly practical and effective, and it is to simply "reverse" charge them. After the battery has been charged (by flowing current into the negative electrode) treat them as positive plates and draw current out of them *but not as a discharge flow*. This is because flowing current into the opposing positive electrode and out of the negative could be damaging to the positive electrode due to potentially huge currents that would form.

So in 1911 when batteries were serviceable items, they would actually open them up and replace the positive plates with pure lead blanks, then force current into the pure lead blanks and out of the negative plates. Easy to do in 1911, impractical with today's sealed batteries. This acts like a forming flow for positive plates and converts any sulfate on the negative plate to lead peroxide (which apparently then reverts back to spongy lead when returned to normal service and normally recharged again). Watson says: "Except for such actual loss of material as may have resulted from flaking, this process restores a plate to almost its original vigor" [would that some similar process could restore original vigor to humans]). And it does it with normal rather than abusive actions.

Perhaps this has been abandoned for good reasons other than the inability to swap out the positive plates. However, it does not appear to be considered in any reference cited here other than in Watson. Hence, the immediate, but perhaps unobvious, thought is why not add not one but two new electrodes to future batteries that are just plain lead (or a lighter non-corrosion-prone metal if possible). Then after a battery has been charged normally, one could reverse-charge the negative plate briefly to vanquish any unhealthy residual sulfate. Remember, unhealthy sulfation does not have to be thick to be a problem because it creates an insulating layer. With uniform surface electrolyte composition (no stratification) and absent any sulfate, the battery could then stand for extreme periods (certainly months and perhaps even a year or more with little loss of charge). It would be as pristine as a new battery that has neither stratification nor sulfation and which often stands without problem for such long periods on store shelves before being purchased and holds its charge quite well.

The use of extra electrodes is not new and in the older texts they are called "idling" electrodes, but in the old days they were used to measure internal resistance. The second extra electrode might only be so that if any reforming of the plain lead would start to establish a battery surface, then the two could be both forward and reverse charged between themselves to clear them back to pure lead. A smart PC-managed charger might perform all these services with little or no user inconvenience.

Measuring stratification. Indeed, idling electrodes could also be used to very easily measure stratification. As of this writing, the web site www.batteryuniversity.com (and its related text by Buchman [**17**] has detailed discussion of how stratification does some of its dirty deeds, and discusses how difficult it is to measure stratification and other battery failings. Surely a major problem is that the voltage a battery produces is the cross-connected average of what its various regions of differing acid concentration produce. An "idling" four point probe (or even the provision of a port for inserting such a probe) into the electrolyte at the top of the case with small regions of spongy lead and lead peroxide would produce voltages consistent with the differing electrolyte compositions and those compositions could be read out using the data of Figure A-3. A four-point probe connected back-to-back would yield a zero voltage output at uniform concentrations and the greater the differential voltage, the greater the stratification.

Limiting stratification. So taking all of the technology that has been reviewed one might envision a hybrid design that splits the difference between horizontal and vertical designs as shown in Figure A–4. In this case, the standard plate of Part A which allows for acid to puddle over its full depth, is shown horizontal in Part B which restricts the amount of vertical distance that acid can puddle to a small part of what could puddle in Part A but perhaps makes it more fragile. Part C shows the vertical plates resolved into vertical segments that although shorter should still enjoy any structural strength benefits of the vertical design, and Part D shows the short segments configured to provide a hybrid geometry battery in which the individual cells are layered vertically rather than horizontally. Note that although the potentially stronger structural properties of the vertical plates are preserved, an inherent degree of stratification prevention is gained with the amount of vertical puddling being reduced by a factor equal to the number of layers deployed.

Indeed, the same benefit could result if the battery design was modified to produce a battery that was one fourth the height, but twice the length and width. Instead of installing these batteries side by side, they could be stacked to occupy roughly the same space in an EV and yet the stratification would be significantly reduced.

Will all of these work? No way for this commentator to say. But if so, the potential promise is for a sturdy lead acid battery with significantly greater practical range, with something between the cycle and term lifespan of current batteries and the 20+ year lifespan, and 2000+ recharge cycles claimed for horizontal AGM batteries of the NASA/Cal Tech design. That is just what the Cockroach paradigm needs.

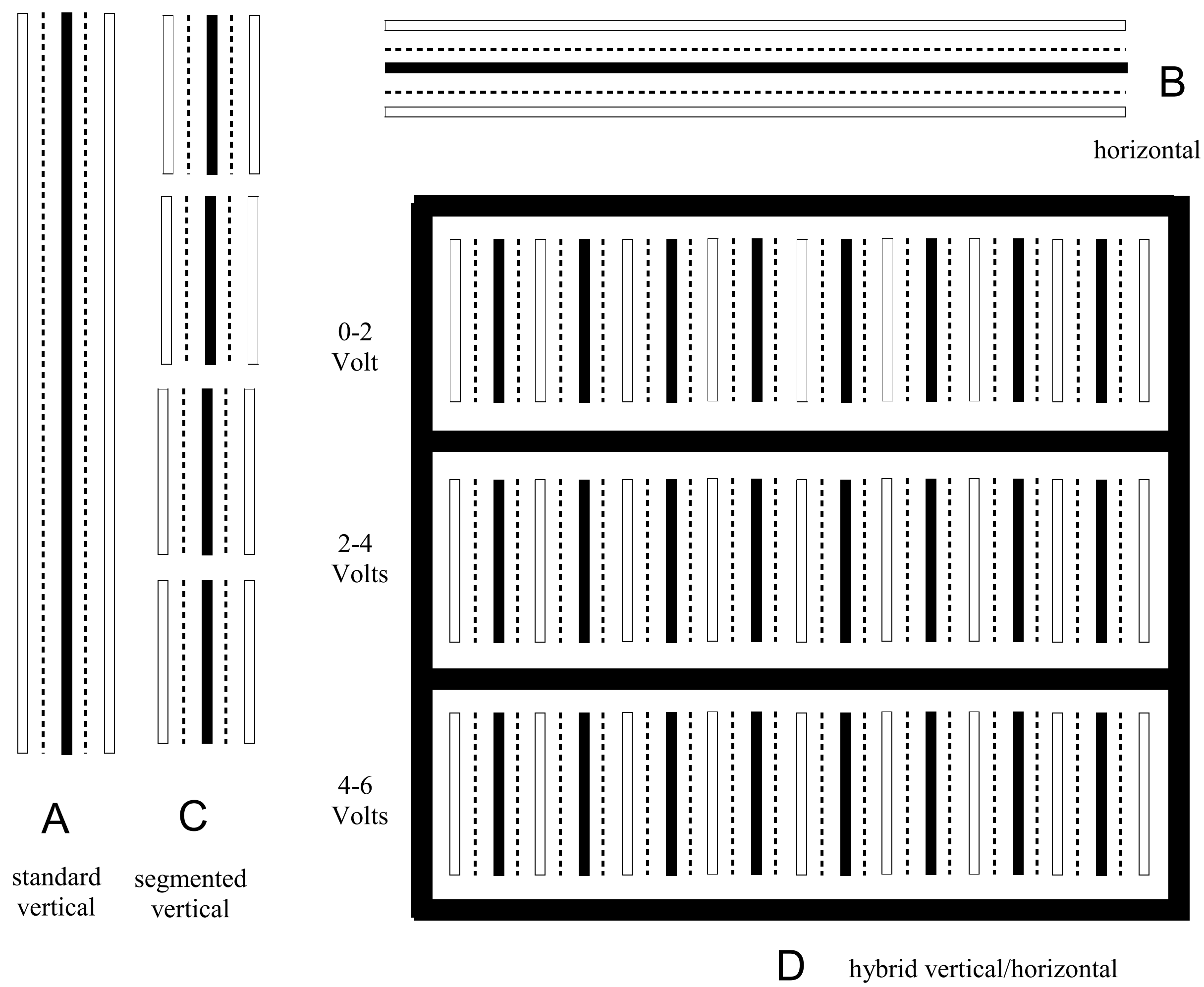

Figure A-4—*A compromise geometry, D, to preserve plate strength and reduce stratification.*

Inferring Battery Design Goals

It appears that stratification gradients allow differing regions of the plates to exhibit different voltages that will inherently produce internal cross currents and lead to unhealthy sulfate production. And this perspective suggests that temperature gradients should be similar culprits.

If a battery is located near heat sources or is insulated then it may develop severe temperature gradients, and temperature also affects local voltage development, and that should also lead to internal cross currents and ultimately to unhealthy sulfate.

Furthermore, during current draws and recharging alike both temperature gradients and stratification gradients can form.

Hence it might seem an ideal LAB should seek to:

- Keep as uniform a concentration of electrolyte as possible preferably near the level that produces minimum internal resistance
- Keep as uniform a temperature as possible.

Uniformity should lead to more uniform stresses on the battery and perhaps therefore reduce the strain on those regions that currently carry the bulk of the burden. These goals should lead to better capacity, greater energy delivery and range and better reliability. However "should" is not "would" and although there do not appear to be actual data in the consulted literature for batteries that have tested these ideas, there are data that suggest these "shoulds" are more than mere wishful thinking, and that case is to be made next.

Liebenow's Magnificent Experiments

As described in detail in Morse ([**15**], pages 127-129) and in lesser detail in Vinal ([**14**], page 222), back when batteries were first being invented (1897), the genius Karl Liebenow [**28**] conducted a seminal experiment (and maybe, just maybe, his results have crucial application here). He struggled with the way lead acid batteries lose apparent capacity when discharged at high rates.

For example we previously considered a constant-current draw (which is *not* what an EV requires) from the popular Trojan T-105 battery that provides 100 hours of constant current at 2.5 amperes (250 ampere hours) but only 1.9 hours of constant current at a 75 ampere draw (143 ampere-hours). And EVs may require two to four times the 75 ampere draw in some circumstances. This loss of *in-situ* capacity is again blamed at least in large part on both transient and long term electrolyte stratification. Therefore the battery may appear that its *in-situ* range in reduced by a factor of two to ten times under heavy EV loads.

Before the turn of the 19th century, Peukert (See Vinal [**14**]) and others would settle for prediction of this loss rate with his equations and the others, and their work is still being used to this day. This has been accepted in the EV community as an unavoidable LAB shortcoming. But is it really?

Conversely, Liebenow wanted to determine the cause of the progressive loss of capacity during these heavy draw rates. So he constructed an experimental battery like that of Figure A-5, often called a diffusion experiment, in which he could apply an electrolyte differential pressure across a battery's negative plate by increasing the depth of the electrolyte in the central container. He did this because he knew that negative plates were porous. By varying the depth of the electrolyte in the inner chamber, he could cause electrolyte to flow through the plate due to its porosity. In one instance, with no flow he measured 14.4 amperes-hours of capacity before the battery stopped. When he repeated testing with a flow through the negative plate, he was able to extract a total of 41.6 ampere-hours (nearly *triple* the output). Morse writes of more recent similar tests (nonetheless before 1912) and comments:

> "...it is a most interesting thing to see a plate which has been exhausted without flow, so that voltage drops to zero, pick up and come to life again as soon as acid begins to flow through it. Its voltage rises to 1.7, and it is capable of doing a great deal more work."

These hundred-plus year-old results are stunning. When there was no differential pressure across the plate, the battery capacity suffered extensive degradation during high draw rates. But when there was flow, the apparent capacity of the battery increased *three* fold. Liebenow attributed this shocking gain to acid being delivered into the plate's structure by diffusion replenishing the sulfate ions that were being depleted within.

Alas! When Liebenow repeated the experiment with differential pressure across a

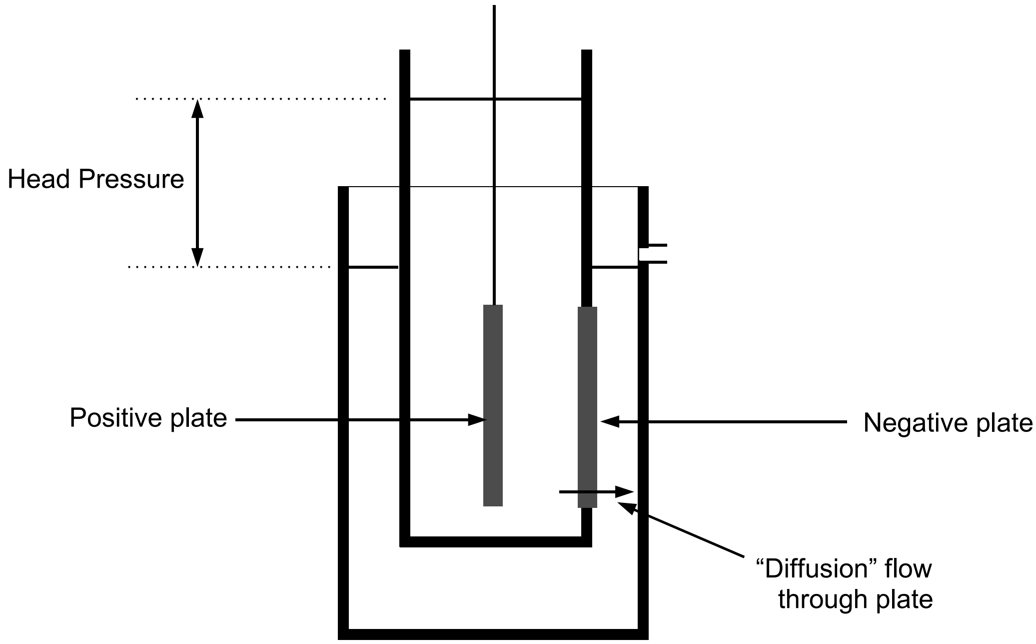

Figure A-5—*Liebenow's Incredible "Diffusion" Experiment.*

positive plate, he found they were too dense to allow flow. And yet, in both tests, the double sulfate reaction is occurring. For every sulfate ion consumed at the negative plate there is (and there *must* be) a simultaneous sulfate ion consumed at the positive plate also. Therefore when Liebenow was delivering acid into the pores of the negative plates, somehow the positive plates were keeping up, *without flow*.

If Liebenow had provided a path for flow to occur say through artificial porosity in the positive plates (say drilled holes), would the same stunning result have occurred? Indeed, it is probable that if he had simply provided porosity at the bottom of his vessel so that downward flow of fresh electrolyte swept *across* the surfaces that were releasing water a significant if not equivalent improvement would have also resulted. Similarly what if he had circulated the electrolyte against the plates. This argues that Liebenow's negative plate test result, may not have been due exclusively to the delivery of sulfate *into* the interior of the plate's active materials (even though there may have been some of that happening to some extent) but rather that depleted electrolyte (basically water) near the plates surfaces was being removed from between the plates and was being replaced by fresh sulfate-bearing electrolyte. A repeat of this test with a constant flow of fresh electrolyte *across* both plates rather than *through* the one plate would be easy to do but the writer has not seen such an experiment reported in any consulted reference.

However, later comments by Morse (his page 131) notes that a bulk surface motion can actually be visually observed during battery charging supporting the prospect that surfacial flow (sulfate during charging, water during discharging) even by itself establishes a barrier layer that impedes battery operation:

> "The difference in density between the concentrated acid formed during charge and the average acid of the cell also gives rise to convection

> currents which can be clearly seen by looking across the face of the plate toward a bright source of light. If the cell is charging, a thin stream of denser electrolyte can be seen running down the face of the plate and curling up on the bottom of the cell."

Clearly if more dense (probably nearly pure) acid can be seen flowing downward during charging, then one should expect a similar sheet of more nearly pure, therefore less dense, water to correspondingly buoy upward during discharging. And in either case this sheet of fluid should act as a flowing stream offering a barrier (a "boundary" layer) through which the normal electrolyte must diffuse and is therefore impeded.

Hence the recovery of a drained battery that is rested involves (perhaps among other effects) this barrier sheet of differing density fluid sliding or buoying away and/or mixing into the bulk electrolyte. And yet common popular battery design actually complicates and inhibits this. Modern batteries often use spacers between plates that trap a greater fraction of the electrolyte near the positive plate and a thinner layer near the negative plates.

We also know a dilemma of present lead acid battery practice is that one wants to keep the plates close together to minimize the current flow path and therefore internal resistance, but that closeness limits the available amount of sulfate and once the electrolyte between plates has been depleted, that it is a slow process bringing fresh sulfate from outside the plates (from the pores of the spacers or from above the plates where the acid level may be reduced through water stratification, and especially from the sump (where the acid level may well have been concentrated through acid stratification) into the thin layer of depleted liquid between the plates. And depletion of acid concentration also increases internal resistance. Dammed if you do, damned if you don't.

Nonetheless, Morse [**15**] page 127, states that the goal in operating a battery should be "to keep the acid concentration up during discharge and down during charge." And in keeping with this principle, on his page 130, discusses how the use of convection as a weapon against convection should work. When describing the speed with which a stratified liquid can mix, he says: "By convection we could mix the whole to a homogeneous average solution in ten seconds by violent stirring or shaking. By diffusion alone the same degree of mixing would take months." This is why the apparently abusive practice of "equalization" is accepted as providing more benefit than harm.

Exploiting Liebenow's Results

If circulating electrolyte *across* the surface of the negative plates provides a significant fraction of the improvement in battery capacity that Liebenow observed flowing it *through* the plate, then the value of mechanical circulation might justify its complexity and its cost. As a rough estimate, a 144-volt battery bank with twenty-four batteries of three cells each (72 cells) might require 72 small electric pumps to circulate the electrolyte. Assuming a small motor might draw 2 watts (148 watts total), this or even several times this, would be a small drain compared to the perhaps 1500 watts minimum (2 horsepower) and say 25 horsepower maximum that the traction motor might be consuming (from ten percent maximum to less than one percent minimum).

In fact, there is little or no mention of mechanical circulation in any of the common EV references consulted. However, a search for "battery electrolyte circulation" patents produced several citations of technology patents (most expired). Many of these were addressed to circulation systems for electric boat (that is, submarine [42]) batteries, in which they are referred to as "electrolyte agitation" systems (also good search terms), apparently used in subs made long before the atomic subs arrived. Some were for use during charging when the worst of stratification occurs but benefits during discharge are virtually axiomatic. These included, mechanical circulating pumps, methods to bubble air into batteries to simulate equalization charging, and some electromagnetic circulation schemes. And since circulation is not a major technical challenge none of these approaches should have a great impact on battery cost. The EV enthusiast community needs to consider and test these. The payout for a practical circulation scheme might well be:

- elimination of stratification and great reduction in sulfation
- more uniform temperature and so less non-uniform sulfation.
- better balance among batteries
- perhaps 2000-cycle$^+$ lives, perhaps ten to twenty year term life or more.
- range increases up to triple during high draw service.
- probable reduction in, or elimination of, electrolysis during charging.
- possible elimination of frequent maintenance requirements.

Even if only a subset of these benefits obtained, it would justify a surge of effort to find an optimum way to provide electrolyte circulation/agitation. Driving all the pumps on a given battery pack from one motor (saving capital expense but not pumping energy demands), driving the pumps from a flexible cable (ala the speedometer cable) so that the pumping occurs only when the car is moving and in proportion to the vehicle speed, would all be less complex than a series of individual motors.

Indeed, with circulation there could be significant benefit to increasing the inventory of electrolyte available per cell. With circulation, the electrolyte concentration could be maintained at a more optimum level increasing available voltage, power, and efficiency, as a LAB discharges. And since a discharged battery would be stored at a higher electrolyte acid concentration, any risk of freezing in cold weather would be reduced.

Is it possible that industry and EV advocates have overlooked this potential grail?? This obvious, simple reliable route to *practical* power? Check the references for yourself.

However, there is a fly in this ointment. If this series of simple modifications does yield significant improvement in LAB battery service as seems certain, there is no incentive to develop and market them. They will not make LABs more profitable unless they are overpriced. But if an inexpensive circulated battery could be brought to market (perhaps by some retirees group like the public service entity proposed earlier) it might just encourage every other producer to follow suit.

Hence, at worst the lead acid battery is a viable option for a Cockroach EV, and at best it may just be an outstanding option, potentially significantly better than Lithium or Nickel Metal Hydride alternatives.

[42] Clearly submarines that are battery-powered underwater are an application in which maximum range would be critical. And the indication in patents that circulation systems were used with them suggests that electrolyte circulation is proven, *both* realistic and practical. Indeed, twenty year life-spans have been reported for submarine batteries. This history deserves much more study.

Appendix B

Prospects for Bizarre Aerodynamic Drag Reduction

It is worth repeating, aerodynamic drag is a differential force that air exerts on a vehicle that must be overcome with a opposing force from the engine in an ICE-Car or the motor in an E-Car. At high speed, the force on current cars can be up to and even much more than a hundred pounds. In any car, the aero force can be *the* major consumer of energy especially on the highway. Literally, a major fraction of the gasoline we burn, the money we spend on gas, goes to pushing air out of our way.

This Appendix attempts (at great risk of self–embarrassment) to question the way aero drag has apparently been dealt with for more than one-hundred-and-fifty years. An apparently "new" approach to be examined here focuses on "driving *around* the air and being transparent to the air" rather than driving *through* the air, the latter meaning pushing or bullying the air out of the way. In other words, why not just punch holes through the car so that air can pass though undisturbed? If you do not have to push it out of your way then maybe it will make the car behave as though it has a smaller cross-sectional area. If reductions of the superficial (the external surface) cross-sectional area reduce aero drag, then maybe reduction of the subficial area (the internal surface) will act the same way. This approach (so elementary and yet not at all easy to analyze) can seem like the most simple of tactics and yet harbors a subtlety and unobviousness that may have, and apparently has, kept it out of the deliberate design of every car ever made (unless it does not work). Can that possibly be? Perhaps the mere question and idea are stupid?

Stranger things have happened. Perhaps it is akin to the discovery of Bucky balls in the 1990s. Chemistry always concluded there were only three allotropic forms of carbon: diamond, graphite and amorphous. Yet in the 1990s cosmologists seeking to understand the universe speculated that molecular forms of carbon might be possible in which sixty or more atoms of carbon might combine to form a spherical molecule, or other larger closed geometrical shapes of even greater numbers of atoms. And they argued they might exist out there in the cosmos. Then after coming to understand them better, they decided to check if there were any on planet earth, and it turns out the planet was lousy with them, but they were just subtle and unobvious. If graphite is such a good lubricant, imagine how good Bucky balls would

Figure B-1—*Hole punched in toy Prius (right).*

be.

So too it is with the fluid mechanics subtlety that applies to pushing air out of one's way. There are structures that this text suggests with some degree of ginger that may possibly aid in aero-drag reduction. And perhaps similarly as has happened with Bucky Balls, many claims of prior discovery and even honest prior discovery, itself, will surface.

Therefore be advised that the writer's lack of experience in aerodynamics and fluid mechanics may have resulted in a most foolish proposal of no practicality at all. But if that turns out to be the case, it will at least answer the question for future students of electric car practice.

Reducing subficial cross section.

Normally to reduce a vehicles cross-sectional area, one reduces its average width or average height. But the cross-section is also reduced when one punches a hole though the car, so that instead of having the car punch a full-size (superficial) hole through the air, at least some of the air passes through it. The bigger the hole, the more air can pass through "undisturbed", and the less air that must be pushed aside, and the less air that will have to chase the car to push on it. Sounds simple and that may be why it may prove to be completely wrong. However, in the degenerate case, a hole equal to the full cross-section of the vehicle (that is, no vehicle at all) would by definition have both C_d and A of zero. So therefore we know that really big holes work. However, any large-sized hole would have to pass through the passenger compartment and would squelch the car's practicality. So the ability to reduce drag this way may seem severely limited. *Or maybe not*.

Figure B-1, exhibits a toy-model second generation Prius and shows a similar model with a hole punched through it. Certainly these toys do not precisely scale the aerodynamics of a real Prius but nonetheless were the basis for desperate approximate small-scale testing in a crude home-made wind tunnel (based upon a leaf blower) and they suggest the aero drag of some modified holey Prii may be as much as several tens of percent less than for the starting shape. The impact of even this small improvement to every car in the United States would be a major reduction in the amount of energy consumed and an even larger reduction in imported energy, the reason why even a small success in this approach is so desirable and should not be ignored here until proven wrong (if it is, indeed, wrong).

If the "true" A decreases more than the drag, then that would imply that C_d has actually increased (just not as much as the area has decreased) and so even bigger gains might be predicted if this hypothetical design could be streamlined better, especially “internally”. This would be a significant improvement especially at higher speeds. But, alas!, there are two problems with this approach. The hole depicted in Figure B-1 does indeed pass through the passenger compartment but its size severely disrupts the ability to accommodate passengers, especially older passengers. Tilt!

Clearly, one could snake assorted smaller conduits through the passenger compartment (along the consol region, through the doors, along the roof, along and under the floorboards), but just as clearly the potential reduction of internal cross-section might not be major. Nonetheless, every little bit is important when you are dealing with a major contributor to parasitic loss of range.

A second issue is that one of the most favorable locations for such a conduit, the consol area, is already used in ICE cars for vital things, things not easily relocated to make space, things like the drive shaft, the exhaust pipes, the shift mechanism. Hence although this approach is very realistic in an E-Car (where the consol region has sometimes been used to contain a “great wall” of batteries in cars like the EV1 that can be more easily relocated to make space), it is much less available in an ICE car. However, the maximum practical size of hole that flows air through the consol region *is* limited. The hole shown in Fig B-1 is too big to disguise as a consol.

Enter Bernoulli.

And that brings us to Bernoulli’s Magical Theorem and still more complex fluid dynamic theory that will strain the writer’s competence, perhaps fatally. Bernoulli’s Theorem is a marvelous bit of physics. It allows planes to fly and a whole lot more. For more than a century, its use in carburetors was what allowed nearly every ICE car to drive. But it is a very difficult principle in science to grasp. It is not user friendly. It is unfortunately counterintuitive. One of the most counterintuitive of its applications is in the venturi.

Clemens Herschel [**29**] received a very early-American 1880s patent (one of the first U.S. patents) for a venturi meter and makes note that the Romans in Biblical times used to allow cities to tap water from their famous aqueduct system by connecting a pipe of size based on the city’s population, but he reports the cities learned that they could make a hole of a given size act as if it was bigger than it is. They did it by tapping venturis into the aqueducts. Was that cheating?

Venturis today are devices like those of Figure B-2 that are used to measure flows or to aspirate fluids (for at least a hundred years, carburetors have passed ICE engine air flow through a venturi to develop the “vacuum” that sucked gasoline, or rather more correctly allowed the atmosphere to push gasoline, into the engine). Many text-book analyses of venturis struggle with their applications in pressurized systems and they appear even more obscure in dealing with their use in reduced pressures.

The venturi is a converging/diverging (c/d) piping nozzle structure (not necessarily cylindrical, nor necessarily perfectly cylindrically symmetrical) for which in many design implementations can present as little restriction and apparently in some cases less restriction than an open pipe would—hence the apparent Roman use of them in their aqueducts.

Fig B-3 indicates how a venturi can allow passenger interior room in a Cockroach

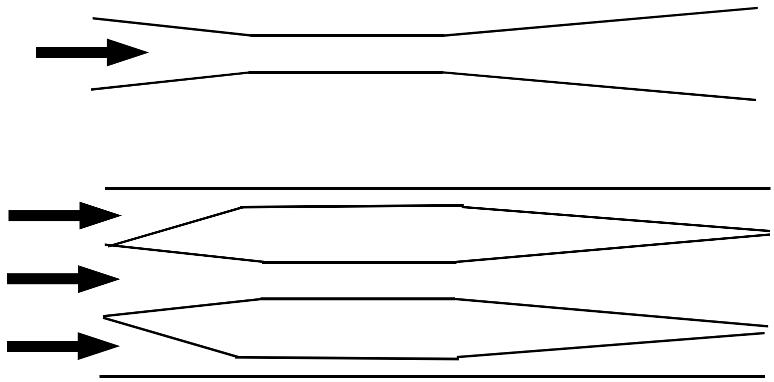

Figure B-2—*Venturis*

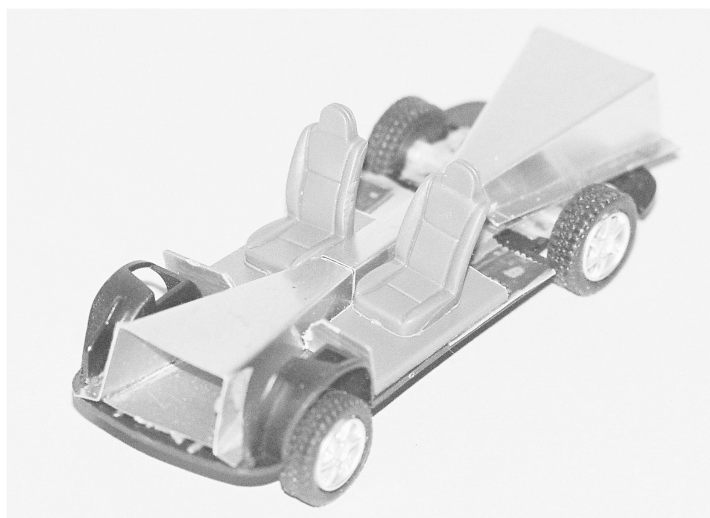

Figure B-3—*Venturi passing through passenger compartment.*

EV. Bernoulli's Theorem and an understanding of converging/diverging geometries and venturis can be speculated upon for the manipulation of air *through*, instead of *around* a car without too objectionable a squelch of its interior comfort. One exaggerated way this might be done (a way which is too extreme and did not work experimentally) is that shown in Figure B-3. An attempt to simplify analysis of it using standard methods follows shortly. An analysis using modern fluid dynamics software such as CFX-5 or Fluent, etc., might be desirable but is beyond this writers reach. In it, a modestly sized air conduit passes somewhat discreetly though the passenger compartment of a car (perhaps disguised as a maximum-sized consol as in Figure B-3—an interior feature that people have paid a premium to have in many past car model years). It can be made to act as if it is of much bigger size with regard to its ability for channeling air through the car rather than around it if is equipped with converging and diverging cones on its ends. Crude experimentation and even cruder math analysis suggests that even a well-streamlined car like the Prius ($C_d = 0.26$) may be improved,

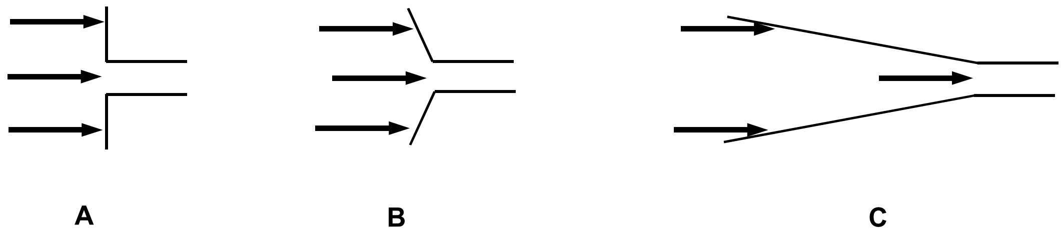

Figure B-4—*Channeling air.*

theoretically (unless my math sucks) at least to perhaps as low as an equivalent $C_d = 0.19$ by designing the vehicle with such pass-throughs (holes) using similar air manipulation effects.

And in this case a nice symbolic name for a car that would be somewhat invisible would be the Shadow, but in fact a car, a car that coincidentally was cited as a strong candidate for cockroach service, was already marketed under the name of the Dodge "Shadow". Other imagery that relates might be to call such a vehicle a Cockroach Black-Hole (or perhaps Gray-Hole) or Cockroach Worm-Hole model. Or how about a Cockroach Black-Magic hole or Magic Worm-Hole? The mind boggles.

So why is the venturi so counterintuitive to many and perhaps most? Here is why. Consider Figure B-4. In this figure air is impinging on three objects that might represent the front of a vehicle. In Part A two portions hit the surface head on and one part flows directly into the pass through. In Part B, two portions hit a conical surface that would deflect them towards the pass through. In Part C, the conical surface is more steep. It appears quite reasonably (but is not) that air impinging on the converging incoming "funnel/cone" is being *squeezed* into the narrow channel that passes through the passenger compartment. And that is true for the Cases A and B of Figure B-4. However, this reasonable perspective can be wrong if the funnel is sufficiently steep in Case C.

In Figure B-4 Case A, the impact of the air is being reflected back into itself, causes it to compress, and increases the force exerted against the vehicle. In Case B, the impact is less sever, so the compression produced is less sever (but the pressure might or might not be less). However in Case C, if the angle is steep enough, the impact of the air is to direct itself into itself in the same direction of motion and so it accelerates its own stream.

In fact as predicted by Bernoulli's Magical Theorem, the air entering the converging funnel (assuming the funnel is well designed) can be accelerated *more* than it is squeezed and so it is not being compressed at all, it is actually *expanding* and its pressure is actually *decreasing*. It is being sucked into the funnel. When it later vents into a diverging funnel where one might suspect it would expand, it is actually decelerating (again in a carefully designed funnel) faster than it is expanding, so it is actually *compressing* and its pressure is *increasing* and therefore "pushing" the car forward.[43] Hence with optimum design (assuming optimum design is possible) a venturi may just allow the Cockroach EV pass-through to act as if it was much larger perhaps even by several times than its smallest physical measure-

[43] A classic demonstration of this effect has involved placing a ping-pong ball into a well-designed funnel and blowing air into the small-diameter end of the funnel. One intuitively would expect the ball to be blown out of the funnel. However the shape of the ball against the funnel surface produces a circular converging and diverging venturi within the diverging funnel and hence as the air vents, its pressure increases, meaning the

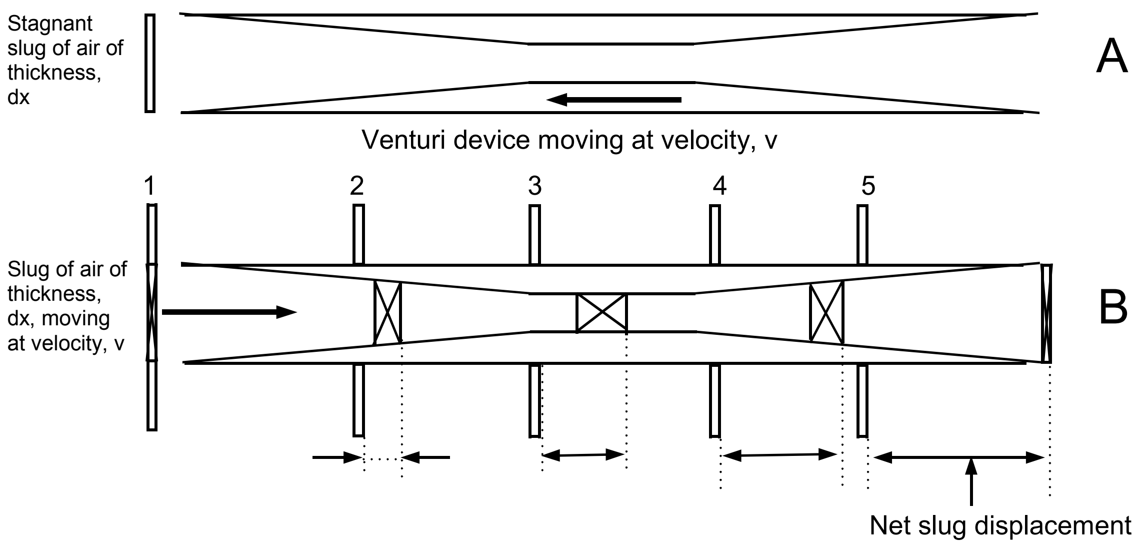

Figure B-5—*Displacement of air as an energy loss mechanism.*

ments (that is the dimensions of the consol) suggest.

The energy efficiency of well-designed venturis is often cited in the high ninety percent range. This is to say that if a vehicle could be shaped as a well-designed venturi, that at speed its cross-sectional area could appear to be more than ninety-plus percent less than the area of its inlet. Therefore, the tubular shapes of Figure B-5 might be optimal for a Cockroach EV, if the cargo and hardware could be fitted in the annular gap around its center. Lacking that perhaps pass throughs are the best that can be achieved at present.

To elaborate, Figure B-5, Part B, indicates how a thin slice of air moving at relative velocity, v, enters the venturi, its velocity increases and pressure decreases, so its length increases proportionately. When it passes into the "consol" region, its velocity is maximum, its pressure a minimum, and its length is therefore a maximum. As it passes out of the diverging funnel, the pressure increases (if the angle is small enough), its pressure increases (acting to push the vehicle forward, and its slug length returns to nearly it starting thickness. The losses in energy that result relate to the viscous drag of the air on the venturi surface and the fact that the incoming slug of air is displaced slightly.

This is a rough and perhaps too-extreme fluid-mechanic analysis, but it suggests a pass-through hole as in Figure B-5 can enjoy perhaps at least as much as an amplification factor (ratio of the intake area to the narrowed, but not "squeezed", area) of perhaps six when simulating a full length consol. With this amplification and a roughly one square foot consol cross section, something on the order of twenty-four percent of the Prius cross section can be channeled (might this mean the equivalent C_d might be reduced by up to the same twenty-four percent, or perhaps even more if the Roman effect is realized, which would be to a drag coefficient of 0.19 or less?). In an E-Car that has this pass-through, that would be equivalent to an extension of the vehicle's highway range by a large portion of that same twenty-four

←downstream surface of the ball experiences more pressure than the upstream side and that tends to hold the ball in the funnel and the circumferential venturi formed by the ball tends to form an even lower pressure "vena contracta" that also acts to hold the ball in place. Counterintuitive, yes?

percent. Not too shabby! With multiple pass-through holes, even greater improvements may be possible, indeed, maybe just maybe, a major portion of the aero drag may be "channeled". But perhaps this is all more like science fiction (like Star Trek's di-lithium fuel rather than real lithium batteries)?

Of course, the velocity of the air flowing through such a venturi can not exceed that of sound, so the potential venturi benefit can be obviated at higher vehicle velocities. However, most practical Cockroach EVs will not be capable of approaching one sixth the speed of sound (about 125 mph).

However, this might just be a beautifully simple (yet also devilishly complex) approach—no moving parts to fail, no maintenance. The beauty of such a "simple" approach, is that it seems so obvious while being so unobvious (or wrong) and yet is one of the more subtle and less understood fluid mechanical effects in physics (perhaps too subtle for this commentator?). Is this subtlety so severe, that so elementary (but not really "simple") a technique has apparently gone unused, possibly unidentified, for more than a hundred years while billions of gallons of gasoline have been inefficiently burned and even wars have been fought to burn more. Perhaps that means that this analysis simply must be fatally flawed, despite the empirical data that seem to defend it.

Unfortunately multiple transparency devices (pass-through holes/venturis) that can also be installed under the vehicle, over the vehicle and through the sides of the vehicle would be very difficult to retrofit into a existing vehicle conversion that have not been manufactured specifically as a Cockroach.

The comments of pedantic fluid-mechanic engineers on this point may prove very interesting, if not too obscure.

References

[**1**] Leitman, S and Brant, B., *Build Your Own Electric Vehicle*, Second edition, McGraw-Hill, New York, 2009, 329 pages.

[**2**] Brown, M. P., with Prange, S., *Convert It*, Third Edition, Business With Pleasure, 1993, 128 pages.

[**3**] Warner, M., P.E., *The Electric Vehicle Conversion Handbook*, First Edition, HP Books, New York, 2011, 170 pages.

[**4**] Boxwell, M., The 2011 Electric Car Guide, Third Edition, Gulfstream Publishing, United Kingdom, 2011, 181 pages.

[**5**] Leitman, S., *Build You Own Plug-In Hybrid Electric Vehicle*, McGraw-Hill, New York, 2009, 281 pages.

[**6**] Shacket, S. R., *The Complete Book of Electric Vehicles*, Domus Books, Northbrook, Ill, 1981, 224 pages.

[7] Christensen, C. M., *The Innovator's Dilemma*, HarperCollins Books by arrangement with Harvard Business School Press, 2006, 286 pages.

[**8**] Shnayerson, M., *The Car That Could: The Inside Story of GM's Revolutionary Electric Vehicle*, Random House, New York, 1996, 295 pages.

[**9**] Murphy, P.A. (Ed.), *Automobile Repair Manual*, 30th Edition, Chilton Company, Philadelphia PA, 1959, 1024 pages.

[**10**] Ahlstrand, A., and Haynes, J. H., *The Haynes Automotive Anti-Lock Brake System Manual*, Haynes Publications, Inc., Newbury Park California, 2000.

[**11**] Watson, A. E., *Storage Batteries, Their Theory, Construction and Use*, Second Edition, Bubier Publishing Company, Lynn, Mass, 1911, 166 pages

[**12**] Arendt, M., E., *Storage Batteries: Theory, Manufacture, Care and Application*, D. Van Nostrand Company, Inc., New York, 1928, 285 pages.

[**13**] Pagé, V. W., *Storage Batteries Simplified*, Lindsay Publication, Inc., Bradley IL, 1986, Original copyright Norman W. Henley Publishing CO., New York, 1917, 208 pages.

[**14**] Vinal, G. W., Sc.D, *Storage Batteries: A General Treatise on the Physics and Chemistry of Secondary Batteries and their Engineering Applications*, Fourth Edition, John Wiley and Sons, Inc., New York, 1955, 446 pages.

[**15**] Morse, H. W., *Storage Batteries, The Chemistry and Physics of the Lead Accumulator*, The Macmillan Company, 1912, 266 pages.

[**16**] *Rechargeable Batteries*, Books LLC, Memphis TN, USA, 170 pages.

[**17**] Buchman, I**,** *Batteries in a Portable World, A Handbook on Rechargeable Batteries for Non-Engineers***,** Third Edition, Cadex Electronics, British Columbia, Canada, 2011, 328 pages.

[**18**] Rand, D. A. J., Mosley, P. T., Garche, J., and Parker, C. D., *Valve-Regulated Lead-Acid Batteries*, Elsevier, B. v., The Netherlands, 2004, 575 pages.

[**19**] Howard, G., *Automobile Aerodynamics: Theory and Practice for Road and Track*, Osprey Publishing Limited, London, 1986, 191 pages.

[**20**] Auto Editors of Consumer Guide, *Encyclopedia of American Cars, From 1930*, Publications International Limited, Lincolnwood Illinois, 1993, Page 469 of 816.

[**21**] *New Car Assessment Program (NCAP), Frontal Barrier Impact Test, Report CAL-89-N04, Chrysler Corporation, 1989 Dodge Daytona*, 2-Door Hatchback, NHTSA No. MK0304, Calspan Test No. 7689-4, Calspan Corporation, Advanced Technology Center, Buffalo New York, Jan 23, 1989, 169 pages.

[**22**] *Insurance Institute for Highway Safety Status Report, Special Issue: Older Drivers*, Vol. 36, No. 8, Sept. 8, 2001.

[**23**] National Commission on Terrorist Attack Upon The United States, *9/11 Commission Report*, Modified 27 July 2004, Available free on the Internet, 567 numbered pages, 585 pdf pages.

[**24**] Michel, L. and Herbeck, D., *American Terrorist: Timothy McVeigh and the Oklahoma City Bombing*, Regan Books Imprint of Harper Collins, New York, NY, 2001, 426 pages.

[**25**] Home C. D., writer, and Childs, T., producer/director, "**Whirlwind: Bombing Germany September 1939-April 1944**", *The World at War*, Thames Television, 1973.

[**26**] Hurley, P., *The Battery Builders Guide*, Wheelock Mountain Publications, Wheelock VT, 2008.

[**27**] Rowlette, J. J., *Lead Acid Battery*, United States Patent 4,405,697, U.S Patent and Trademark Office, 20 September 1981, Assignee: California Institute of Technology, Under contract to the National Aeronautics and Space Administration.

[**28**] Liebenow, K., Über die Berechnung der Kapazität eines Bleiakkumulators bei variabeler Stromstärke, Z. Elektrochem., 4, 61 (1897) as cited in Vinal [**14**] page 222 and Morse [ ] p.126-128.[**39**]

[**29**] Herschel, C., "**The Venturi Water Meter,"** *Transactions of the American Society of Civil Engineers,* Vol. 17, 1887, pp. 228-259.

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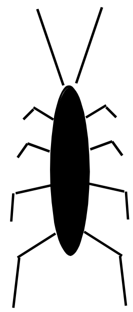


The Cockroach EV
(Electric Vehicle)

Vol. 2—Design and Performance Math
- Circa 2018 -

Barry L. Werley

"Build the Cockroach…..Save the World"

Public-Service, Public-Duty, Public-Domain
Commentary for the USA

This is the first published edition. If serious flaws or errors are identified, later editions may seek to clarify, if possible.

Fifth Amendment Notice:
In keeping with the authority and duty of an American citizen, the writer executed his fifth amendment rights permanently in 2007/2008 under the terms stated in the publication: *The System Work by T. S. Harbinger* under the anonym K. F. Ziuerqnxo. This publication recalls and reasserts that notice.

Contents

Appendices

1

Introduction

This second manuscript, the same as for its preceding Volume 1, is *not* a mystery novel. Therefore, you do not have to read to the very end to find out who done it. This overview tells you what I am going to tell you. And once again the rest of the book is a more detailed exposition.

Volume 1 of this set surmised a "Cockroach" EV (Electric Vehicle) should be possible to serve a niche audience of retirees (especially of lower incomes) and others who only require a short range vehicle, typically driven infrequently, but who can also benefit from *practicality that is not present in today's cars.* The concept was defined and the worst obstacles to new production, namely political tyranny were explored. Lesser technical obstacles were rationalized on the bases that many conversion electrical cars are already viable street machines today, but they would demand too much money, attention and care (diddling) to meet the niche's needs, especially for reliability, therefore practicality. Most of these obstacles should not be fatal to overcome with existing technology. However, the size of the niche that can be served is extremely dependent on the realized ATSR (acceleration, top speed and range), that a practical Cockroach could achieve. These key parameters were not estimated in Volume 1 for lack of adequate data. This volume explores and in some cases develops the needed data into a spreadsheet to better estimate both an optimum and best-theoretical-case Cockroach design. This is an attempt to assemble the math and science. It "attempts" to both elaborate and extrapolate the more cryptic treatments that are available today, hopefully with a degree of success, but cognizant that simplification can have it own pitfalls.

A fairly detailed (attempt at) exploration of the writer's recommendation for the most optimum Cockroach design (the 1990s Dodge Daytona) is presented that can be a basis for a new Cockroach or for hobby conversion EVs. Previous literature, especially in the enthusiast's "Bible", all three editions by Leitmen and Brant (L&B) [***1-3***][1] and internet software re-

[1] Numbers in square brackets refer to the references listed at the end of the text. Leitman and Brandt is referenced so often that the short form citation, L&B, will often be used.

sources (such as the EV Calculator software at evconvert.com as of this writing) are used as models and are hopefully improved upon to yield more understandable and more realistic estimates of what should be possible, *if somehow political will could be mustered*. These include a proposed equation of state for the most popular motor used today, and data for both real (but marginal) lead-acid batteries used today and theoretically ideal limits that should be possible with upgraded batteries by adapting technology some of which is already in use in stationary power sources and in submarines.

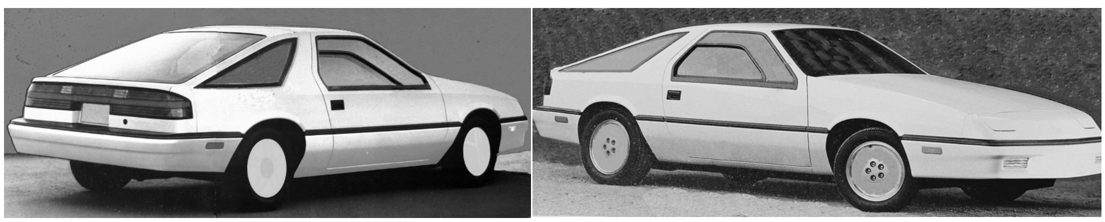
In addition an additional strategy for manufacture of the Cockroach and extension of the user niche is proposed that can ensure affordability for the final product.

These results predict that the proposed model might resolve all of the issues of a Cockroach, providing a reliable relatively maintenance-free vehicle for a small cost (meaning affordable), and should deliver a very acceptable range of 50-100+ miles, should last up to ten or even 20 years or more with little or no required repairs, accelerate to city speeds competitively and to highway speeds (say 60 mph) in times ranging from adequate to slow (taking up to twice as long or more to achieve than for common vehicles). Hence it has a built-in disincentive to populate high-speed thoroughfares (being slow but not nearly glacial) and has a short-term top speed on level roads of about 70 mph. This in combination with the identification of additional construction resources suggests the possibility of a true "appliance" vehicle.

Time will show how well this attempt achieves that goal. Apologies for any discrepancies or flaws. Hopefully any can be worked around.

2

The Signature Cockroach EV Source



Quintessential Cockroach Donor Vehicle: 1990/1991 Dodge Base Daytona.
Shown with aero modifications including :“Moon” style alloy wheels, blanked grill, flush parking lights, deleted antenna and side-view mirrors (replaced with CCTV screens), Delorean-style side windows with flush surrounds, enlarged rear quarter windows, raised body (about 1 inch), and narrow 14-inch high-pressure tires.

The Proposed EV:

Design Basis: 1984-1993 Dodge Daytona
Two door, two passenger hatchback.
Length 179.3 inches,
Width 69.3 inches
Height 51.1 inches
Wheel base 97.1 inches
Weight 4100-5200 pounds including cargo and passengers
Four-wheel disk antilock brakes
Manual low-effort brakes
Electric power steering
Phase-change air conditioning
LED Lighting
175-R14 Narrow High-Pressure Tires
Drag coefficient <0.34
Target Price < $10,000
9 inch Series DC electric motor
500 ampere low Frequency controller
24 each 6-volt batteries (variable 12-30)

Projected Level-Road Performance:

Current Flooded Lead-Acid Batteries:

Range (30 mph): up to ~70 miles
Range (50 mph): up to ~54 miles
Full Charge, top speed: ~52 mph Cont.
Full Charge, top speed: ~62 mph. 1 hr.
Full Charge, top speed: ~70+ mph, 5 min.
Full Charge, 0-60 mph: ~23 sec.
Full Charge, 0-30 mph: ~6.6 sec.

Best-Case Lead-Acid Battery Limits:

Range (30 mph): up to ~180 miles
Range (50 mph): up to ~126 miles
Full Charge, top speed: ~52 mph cont.
Full Charge, top speed: ~62 mph 1 hr.
Full Charge, top speed: ~70+ mph 5 min.
Full Charge, 0-60 mph: ~23 sec.
20% Charge, 0-60 mph: ~6.6 sec.

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3

Some Missing Pieces

Volume 1 proposes the Signature Cockroach should be based upon the 1984-1993 Dodge Daytona, a K-car sibling which was a very practical car-like hatchback, many models of which pretended to be sporty-cars, rated for four passengers but with a mostly useless rear seat. It would be economic to produce for a niche audience formed principally of retirees, students, poverts (persons of poverty), and those better-off who can use a "city-errand-car" to reduce abusive short range driving with primary cars, all of which drive seldom and/or for short distances. Other 1980s/90s Chrysler corporation K-car designs (Shadow, Sundance, Lebaron coupe and sedan, Aires, and Reliant) employ the same running hardware with different bodies and they have their own advantages (including station wagon, four door and convertible formats) that could be preferable in some instances. The designs were to be cajoled or wrestled from Chrysler control, and built under the auspices of volunteer retirees (and other to be discussed in Chapter 8), potentially with capital financing from the Social Security Trust fund to be repaid with royalties or by voluntarily acceptance by the beneficiaries of the products they make as alternative benefits.

In addition, waiver of a series of tyrannical regulations that benefit no one (besides a taxation-addicted,...that is to say: tyrannical, government) would make the vehicles especially practical. Waiver of crash testing requirements is warranted on these vehicles that have already been tested often and are already amongst the most crashworthy ever made, while seeing service that would be among the lowest in expected risk. Waiver of pollution testing for cars that are zero pollution and for which low mileage is inherent. Waiver (or warranty) of frequent safety inspections on the basis of these vehicles not having toxic exhausts, toxic cooling systems, can be equipped with highly reliable safety lighting, and other materials that for their low annual mileages and limited top speeds would function for ten years or more before well-designed tires, brakes, and steering components might reasonably pose a risk.

Overall, a vehicle was imagined that would be of new manufacture, would achieve a range of 50 to 100+ miles on a charge, and would be reliable for up to 2000 or more trips over a ten- to thirty-year period, and that it might be possible to sell new for as little as a $7500-$10,000 dollar purchase price. However, these speculations were predicated on data reported by hobby electric car makers, and texts [***1-9***] that discuss the theory of EVs, and the writers own preliminary calculations and testing.

However, when Volume 1 was electronically released (in May 2014), the writer was unable to obtain definitive data to perform a more detailed calculation than those that were being done in the enthusiast community. This volume presents several years worth of further study and detailed analysis of the recommended Cockroach and reconciles many of those data that are available. More importantly, it examines the theoretical best case lead-acid battery that might be produced with technologies that may be deployed based on lead-acid electric-boat (submarine) technology for low-cost batteries that may be significantly better in specific high-draw capacity, term-life and cycle-life performance than is achieved today by the conversion market and believed possible by many today. This math suggests that a Daytona-based Cockroach with a typical traction motor, and state of the art flooded lead acid batteries (FLABs) will significantly exceed the writer's rough predictions.

This could return the meaning of "affordable" to its original definition. Instead of parasitic benefits for low income people (poor people) by taking from their peers to give to them, this would reduce the economic burden they would face and would be an opportunity for them to benefit themselves and each other and the nation, and is in some ways more valuable than would be tax incentives combined with the pretense of a loan up to $43,000 to buy a Volt or Leaf.

Torque, Horsepower and Energy (a.k.a. Acceleration, Top Speed and Range, ATSR)

The original VW Beetle is the benchmark car for the Cockroach EV. The Beetle's following was large and loyal, despite its slow acceleration, low top speed, but excellent range. Notwithstanding the loyalty for it, few Beetle owners would have refused more power if it did not compromise the cost and range. Could a Cockroach build the same kind of following?

Every car is measured by its acceleration, top speed and range. E-Cars are often praised for their initial acceleration some of which can apparently humble many ICE car competitors at very low speeds. And the truly huge low-speed torque many can produce eliminates many of the hassles of driving ICE-Cars. No more stalling when a clutch is engaged too quickly as happens on an ICE car with too-scant grunt, indeed feathering of the clutch is never needed. And if one is patient, there is no need to use a clutch at all, even for shifting.

Indeed, in the movie "*Who Killed the Electric Car*" a GM promotional film is shown in which the EV-1 outruns a Mazda Miata, no slouch, and an even more impressive Nissan 300ZX (but not the turbo version for sure). However, the EV-1 used a high voltage alternating-current (and expensive) motor. In comparison, the lower cost, less hazardous, direct- current motors used in most hobby conversions, and which are of most potential interest for a Cockroach EV are reported to provide quite impressive low speed performance, but alas!, it will have much less high speed muscle. Their strength is low speed torque (for initial acceleration) and their weakness is horsepower (for top speed). Range is something else entirely.

And these may be the Achilles heel of the Cockroach EV. If a Cockroach were go high-tech for the batteries and motor, the added cost would knock it out of the *practical* genre. And the alternating current motors with their really high voltages do not appear to this cautious observer to be as reliable. EBay has listed auctions of failed A/C vehicles at a rate that seems much higher than for D/C equipped E-Cars, some despite rather low mileages. If a Cockroach were to deploy with typical lead acid batteries and direct current motors, its acceleration at highway speeds and top speed (seldom detailed to great extent in the conversiont community) could be seriously lacking.

When reading the liturgy of the conversion crowd, very few acceleration data are provided. Often a zero-to-sixty measurement is omitted. Sometimes top speeds will be cited and the values reported are often not for continuous operation and hence are disappointing. And scant comments often suggest that the time required to get to the top speed can be inordinately long and can only be achieved on warm days and on level (or perhaps downhill) terrain with fully charged new batteries. And what is more curious is that the ability of these cars to sustain their top speed may not be adequately stressed, and this commentator suspects that successful hobbyists exercise great care and endure much anxiety in any "high-speed" operations.

There is valid theory on torque and horsepower published (specifically the-often-referenced herein 2nd Edition L&B [***1***]) that implies there are challenges facing EV hobbyists, that would also be faced by the Cockroach, but they do not do justice to the potential dissatisfaction that may be faced. Hence this aspect will be elaborated upon here to make a few important points.

Whereas a well-conceived EV might well be capable of truly trouble-free service, it seems rather more likely that many of the EV converters out there who are in no way lacking in desire, energy and motivation, very often find themselves burning out after a few years of struggle to get a conversion running and as soon as their first set of batteries fails, (usually in the same time frame) their mechanical progeny wind up for sale on EBay, and they take a financial bath (often more than a 50% loss) on their investment. This is bad for everyone, and is one of the motivations for this book to try to suggest a better option.

For some people a car like the old VW Beetle that must struggle mightily to break through 50 mph, if that, and then can only do it on a good day would be a real turn-off. And yet perhaps often the problem lies not in our stars but in our selves. In the 1980s, when GM and Toyota were entering into a new venture (New United Motors), Toyota needed a car plant and apparently the only one available was a failed GM plant at which labor relations were so caustic the cars were often being sabotaged by the workers, and that, before its closure, reports indicated it had produced the *lowest* quality car GM ever made.

Toyota bought the plant even though it had no modern robots thought to be absolutely vital to car manufacture at the time and took the disgruntled union workers back. Despite the acrimony they had exhibited, and with old technology but with great human attention to detail, they manufactured in the very first year, using outdated methods, the Corolla vehicle for Toyota dealers and the Nova vehicle for GM dealers, the latter of which proved at the time to be the *highest* quality car GM had ever sold. More recently that plant has manufactured Teslas. So maybe similar attention to details can give a *practical* EV like the

Cockroach the boost it needs to live up to the theoretical promise of Cockroach electric cars. This volume will therefore go into much detail about design choices.

This manifesto is devoted to *practicality*. Hence, although the cubic money E-Cars today (including and especially the defunct EV-1) achieve good performance many do it by including an incredibly expensive, lithium battery pack (perhaps half the price of the car, or more), a complicated motor with a heavy full-blown cooling system (for both the motor, its controller, and the battery pack) not unlike those on ICE cars, a Cockroach EV would wish to avoid these if possible. Remember the original VW Beetle is the insect car on which the Cockroach is modeled.

So how is this torque and power reality handled in the enthusiast press? It is common to read that if one lives in hilly country an E-Car *might* not be one's best option. And even Leitman and Brant [***1***] who include a slew of formidable technical analysis, and their analysis is praiseworthy, indeed, note on their page 125 (edition 2),

> "But beware of under powering your vehicle. If given the choice, always go for slightly more rather than slightly less horsepower than you need. The result will always be higher satisfaction with your finished EV conversion."

And after they present a protracted analysis they suggest an empirical experimentation on parameters, fine tuning (also on their page 125) as a way to squeeze the last bit of performance from an EV that may be as underpowered in some ways as the VW beetle was. However, a careful first-draft design effort up front would be much preferable, and suggests future projects in this vein might benefit from a spreadsheet or high level language PC algorithm that would allow for identification of clear problem areas and "what if" analysis of EV configurations. Hence this volume will follow many of the analyses of Leitman & Brant [***1***] but will seek to elaborate and simplify and extend and extrapolate on the crucial issues of torque, horsepower, and efficiency with energy to put the Cockroach in as true a light as possible. And to begin an open-source spread sheet that can be validated and revised as necessary. And as of now these analyses indicate the Cockroach will not be a jackrabbit but depending on configuration may be quite adequate .

There have been at least a few earlier efforts to take this same approach. The design facility EVCalculator at evconvert.com (as of this writing) is based upon and cites two earlier efforts (from Uve Rick [who lists a personal Mercury Capri (based on the Miata) conversion EV on the EVAlbum.com] and someone referred to only as "Hemp") and that facility allows one to plug in variables and estimate the expected results. They can be used to compare with this effort or as an alternative to this effort, but their precise math is not well documented (they simply reference L&B) and is somewhat obscure and may not fit every need. In some scenarios the writer believes the analysis herein is more appropriate. It appears they can be significantly, even massively, flawed. It can be pretty depressing to plug in data and see how much fairly modest changes to a design can suddenly reduce the top speed or predicted range of an EV. Not to mention choosing admittedly bizarre parameters that predict outrageous 1000+ mile ranges. The writer can only sympathize with someone who "designs a conversion EV using these resources expecting to go 80 mph, and 100 miles and then finds out after spending ten-plus thousand dollars and a slew of sweat equity, that they can only get 50 mph and thirty miles, if that….and take a very long time to get to it.

But again be reminded the writer is not a battle-scarred expert in E-Cars never having built or even driven one and again apologizes for his hubris in seeking to develop answers to questions he alone may consider critical that do not appear to be addressed else-wise in the common literature he has reviewed. If possible, math or other flaws will be corrected.

Basic Motor Give and Take

For an EV to operate the battery pack must giveth and the motor must taketh. Both limit performance. No motor can deliver performance better than the battery delivers, and no battery can feed good performance to an inadequate motor. The approach taken here, largely based on L&B [***1***], is itemized in Figure 1.

If this volume contributes to the National EV debate and helps EV hobbyists, too, it will be in improvements to both the qualitative and mathematical approaches to addressing battery and motor performance. The math used to characterize motors is tackled in Chapter 4 and may be significantly more valid than what the writer has seen in the cited references. Motor performance estimates seem to be misdirected and so a more mathematical approach (and equation of state are proposed herein) is presented.

The situation with lead-acid batteries is less clear and much more problematic. Too often the writer has seen battery internal resistance neglected or outright ignored when in his opinion it appears, and this book will seek to prove it, to be a very crucial, in some cases even a dominant, factor. This is understandable because the data and discussion of it is limited. *The role of battery internal resistance appears to be massive, especially so for lead acid batteries.* Also the nature of internal resistance apparently draws from several parallel mechanisms that do not lend themselves to a single equation.

Lead-acid batteries are taken herein as the preferable option for the Cockroach paradigm. And indeed, L&B[***1***], and Brandt alone, [***3***] (2nd and 1rd Edition of the same book, respectively) also recommended lead-acid batteries once upon a time but have reconsidered.[2] Much better battery data are needed and even more detail is needed than was covered in Volume 1 of this effort. Volume 1 stumbled across the topic of electrolyte agitation and since then the topic of "surface clogging" has been encountered along with additional perspective on plate "shedding" and sulfation and all of these are covered here, as well.

Indeed, this volume must be harshly critical of garden variety deep-draw batteries available today. The possibility of a much better design (elaborated upon in Chapter 5) is desirable and should be sought from the popular vendors. However if these vendors are happy with their markets, an open-source, public domain design can be developed (several features of which are suggested in the appendices) that might disrupt their lives and businesses for them.

The Design-Math Protocol

In order to calculate any of the three key parameters (range, top speed and acceleration), the basic procedure of Figure 1 will be used. The first six steps are consistent with traditional analysis of internal combustion engine vehicles and duplicate similar steps of L&B

[2] As Volume one of this effort was being distributed, the third edition of L&B went on sale and in it, the main hypothesis of its Editions 1 and 2 and of this effort (lead acid battery practicality) is rejected.

As a function of steady state speed calculate:

1. The required force and power due to acceleration
2 The required force and power due to incline
3. The required force and power due to aerodynamic drag.
4. The required force and power due to rolling friction
5. Sum 1-4 above for the total required force and power.
6. Convert the required force and power of Step (5) into drive-wheel speed and torque.

7-11 For each gear, the max. available drive-wheel torque the motor can produce for three battery states of charge, with the equation of state and within assigned heat dissipation limits, controller current limits, and motor centrifugal force limits.

12. For each of the three SoCs, plot the power-dissipation-limit torque data of steps 7-11 for all five gears.

For the known range of motor torque production (0-160 lb-ft) calculate:

13. The motor steady-state current, speed, power and efficiency for each SoC.

For the three states of battery charge:

14-16. Convert the data of Step (13) into available torque versus steady state velocity for each of the five gears.

For the five gears:

17. Re-examine these data of Steps (14-16) for the three SoCs.

For the three states of battery charge:

18-20 Select the maximum allowed and available torque versus velocity curve and calculate the resulting time to achieve each velocity.

Examine the acceleration times:

21. Compare the three levels of acceleration to 1960s GM Corvair Benchmarks.

Calculate range vs. velocity

22. Calculate required motor current for each gear, each velocity.
23. Calculate constant-current draw time for each gear, each velocity.
24. Base absolute best-case ranges for fungible max. theoretical battery energy and fungible chemically-limited battery energy in 1st and 5th gears.
25. Calculate range with losses due to battery, controller, and motor DC resistance and rpm-induced friction for fungible battery energy.
26. Repeat 25 with fungible energy from the batteries split into two parallel strings of 24 batteries, three parallel strings of 8 batteries, and four parallel strings of 6 batteries.

Figure 1—*Math Steps to estimate Acceleration, Top Speed and Range Based Upon L&B 2ndEd, and EV Calculator (Circa 2014) and the writer's independent analysis.*

2nd Ed. and EV Calculator (2014). Steps 7 through 26 will be patterned after L&B (2nd Ed.) and EV Calculator but will substitute a proposed motor equation of state (Chapter 4) and battery performance approaches (Chapter 5) developed in this text. These appear to be key previously-missing pieces.

So the next Chapter 4 will develop and defend a motor equation of state. Chapter 5 (supported by Appendices A-G) will pursue a better battery perspective. Chapter 6 will carefully complete in abusive detail the full compliment of constituent calculations. Chapter 7 will examine a spreadsheet that if hopefully meritorious, allows for variations to be tried or to be modified to apply to other candidate vehicles and scenarios.

Chapter 8 will "shift gears" and explore new business aspects beyond those in Volume 1 that can be applied to the manufacture of Cockroach vehicles and Chapter 9 will look to the future.

These chapters will be supported with more detailed derivations and analyses from the full set of Appendices: Appendix A elaborating on the prediction of lead-acid battery capacity, Appendix B elaborating on the role of connection chopping as a route to variable vehicle velocity, Appendix C on the speculative design for an improved lead acid battery, Appendix D elaborating on the testing and measurement of battery internal resistance and internal voltage, Appendix E elaborating on the potential for electrolyte agitation, Appendix F elaborating on the use of supplemental batteries to compensate for lead acid limitations, and Appendix G elaborating on highly speculative but perhaps potential routes to maintain battery activity and thereby limit unhealthy sulfation.

And then the Cockroach EV concept will be ready for promotion. And ready to be censored, marginalized, and excluded like the efforts from so many nothing man of the Author's ilk.

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4

An Ideal-Motor Equation of State

To repeat: in an EV, the batteries give and the motors take. The vehicle is constrained by the limits on *both* of these components. If the batteries can not give enough, then you are limited to whatever they *can* give. And even if the batteries can give plenty, the motor may not be able to take it and again you are limited by whatever it *can* take. And even when the batteries can giveth and the motors can taketh, one may face a flawed combination, or cross an overloaded condition that can lead to catastrophe.

It is not simple to obtain really good and complete data for either battery give or motor take. Such data probably exist but are not publicized. Therefore this exercise will employ both theoretical and empirical approaches starting with the motors.

Commonly used direct-current motors (the most popular being the nine-inch from Advanced DC Motors or Netgain) are cited with horsepower ratings of up to about a continuous 20 to 30 hp. However these continuous horsepower ratings are simply so low that EV advocates are perhaps too quick to invoke Charles Kettering's original overload insight (Volume 1 p. 14) that brought us the successful starting motor for ICEs. Namely that electric motors can be over-loaded (at least temporarily) and so the ratings are not definitive to the driving experience that is possible. And indeed, if one is on the highway and if one has reserve battery power available, one *can* overload these motors to pass the car in front or to climb a short hill. And although these motors appear to be designed with a good amount of robustness, there is no substitute for an overall robust bulletproof design. The ability to achieve 80 mph is not the same as the ability to drive at 80 mph. How many disillusioned hobbyists resulted from not being able to discover or achieve an optimum or even favorable configuration?

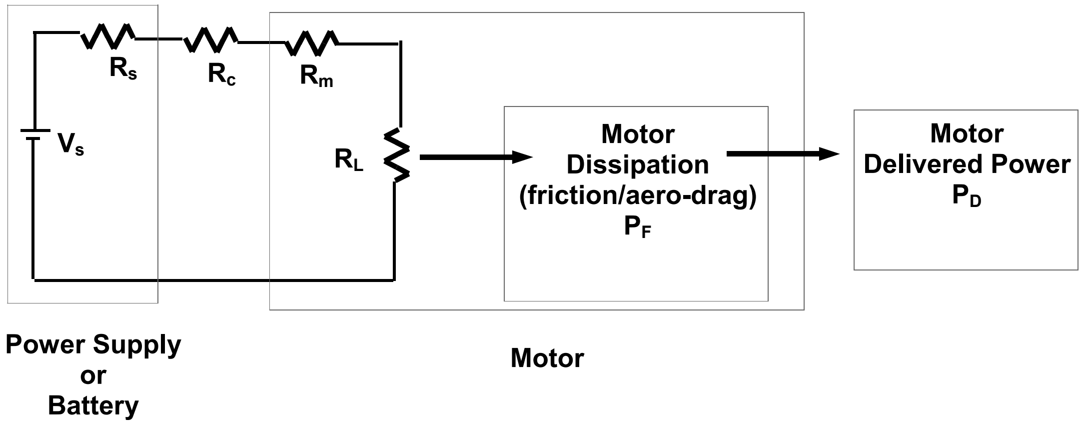

Figure 1—*Elements of an Ideal Motor Equation of State (EOS).*

Electric motor performance data on the Net could be much more useful. The Electric Vehicle Discussion List web site (EVDL.COM) has an album (evalbum.com) of thousands of EV conversions and by far the most commonly used motors (as of October 2017 in 801 vehicles) are the Advanced DC Motors (ADC) among which the 9 inch diameter FB1-4001 is perhaps the most popular, *and perhaps the most thoroughly documented*. A distant second are the motors from Netgain (as of October 2017 at 342).

Typical vendor motor performance data are apparently dynamometer tests of steady-state motor operation, that is to say, operation at constant velocity and load. One of the more useful examples available is a plot with output motor torque (0-160 lb-ft) on the abscissa (x axis) and on the ordinate (y axis) are shown separate typical curves for motor current (0-800 amperes), motor speed (0-8000 RPM), horsepower (0-100 hp), and motor efficiency (0-90%).

As will be explored in this chapter, it appears that often these data are misapplied or used in calculations that can at times be flawed or at best approximate. In the case of L&B, they do their example calculations only for the specific conditions of graphical data, and indeed, (1) there is not an abundance of graphical data available, and (2) there are some conflicts among those graphical data that are available. Later attempts to develop a performance algorithm leading up to the EV Calculator, employed a statistically-fit generic curve family and was a big step forward, but could not be extrapolated without sometimes introducing significant error that will be explored. Hence this will first attempt to derive an equation of state based in large part on the physics of motors for a theoretical motor having performance comparable to the FB1-4001.

Fig 1 shows the elements that will support the equation of state. In it the power supply (battery or grid-fed power) provides a constant source-voltage, V_s. However, real-world voltage sources, such as batteries, may provide constancy for only brief periods of time.

The power source feeds current, I, through a series of resistances. Internal to the voltage sources is the source resistance, R_s, which affects the amount of current drawn and may (and usually does) change over both shorter and longer periods of time, typically increasing, and the total increase may be large. The resistance will increase several fold as the battery discharges and as it ages. However it largely decreases with increasing current draw.

Next the current is supplied though a controller which will have a high resistance, R_c, in the "off" state and a low but significant resistance in the "on" state[3] that will be taken as a constant in this analysis but may depend on current flow Many vendor performance data indicate they were collected without a controller installed, so R_c can be zero. Various lumped contact resistances and cable resistances could be included or added into R_s or R_c but in a well-designed system these are negligible and are taken as zero in this analysis.

When the current passes into the motor itself, it encounters two effects: motor resistance, R_m, that includes winding electrical resistance and commutator contact resistance that is taken here as a constant (but may need future refinement), and then into the windings where the motor's magnetism, torque and horsepower are produced and for which steady-state operation will be treated as an equivalent load resistance, R_L. R_L depends on the amount of current being drawn and the motor speed.

When the current produces mechanical torque, T_m, and horsepower in the windings, that power is deposited as rotational energy into the armature and some amount of the torque, T_f, is used to overcome friction (in the rubbing bearings and commutator and aerodynamic drag on the spinning motion) and the rest is ultimately the delivered torque, T_D, to the output shaft. Perhaps too often, the enthusiast literature ignores the frictional torque, T_f , but it can apparently be very significant. Equations 1 and 2 express the resulting power balance as follows:

$$P_s - P_{Rs} - P_{Rc} - P_{Rm} - P_f = P_D \quad (1)$$

And replacing each term yields:

$$V_sI/746 - I^2(R_s + R_c + R_m)/746 - T_fS_m/5252 = T_DS_m/5252 = P_D \quad (2)$$

Where:

P_s = power from the source, VsI watts, VsI/746 hp
P_{Rs} = power dissipated in power supply resistance, I^2R_s watts, $I^2R_s/746$ hp
P_{Rc} = power dissipated in the controller resistance I^2R_c watts, I^2R_c /746 hp
Pg = gross electrical power supplied to motor terminals, $V_mI_m/746$ hp
P_{Rm} = power dissipated in the motor electrical resistance, I^2R_m watts, I^2R_m /746 hp
P_f = power dissipated by friction in the motor, $T_fS_m/5252$, horsepower
P_D = power delivered to the vehicle, $T_DS_m/5252$, horsepower
V_s = power supply or battery internal voltage, volts
I = motor circuit current, amperes
R_s = power supply internal resistance, ohms
R_c = motor controller "on" resistance, ohms
R_m = motor electrical resistance, ohms
T_f = torque to overcome motor internal friction, lb-ft
T_D = torque delivered by motor, lb-ft
S_m = motor speed, RPM

[3] The User's Manual for one common controller, the Curtis 1231C, cites a voltage drop of 0.3 volts when it is carrying 100 amperes, and this implies a resistance (V/I) of 0.003 ohms Curtis Manual, p/n 98827, Rev D, Aug 1999, p. 37. It does not say if these are chopped average readings or steady direct current readings. The former could introduce a small error if the chopped waveform is not a square wave, in which case RMS math applies.

Equation 1, states that the power from the power-supply/battery, (P_s) is reduced by the dissipation in the internal resistance ($-P_{Rs}$), then by the dissipation in the controller resistance, ($-P_{Rc}$), The amount of power leftover ($P_s - P_{Rs} - P_{Rc}$) is the power supplied to the motor as measured at its terminals using voltage and current measurements.

This motor power, P_m, is then decreased by the dissipation in its internal resistance ($-P_{Rm}$), and the remainder, ($P_s - P_{Rs} - P_{Rc} - P_{Rm}$) is converted into gross torsion power (P_g). This gross torsion power is reduced by any frictional dissipation losses present in the motor itself, ($-P_f$). In this analysis, this frictional loss which is often ignored in the enthusiast literature will be taken as one horsepower (1.84 lb-ft of torque) at 2850 rpm that is linear in motor speed, though a more sophisticated formulation may be needed if this approach is valid or gains acceptance.

Finally the last remaining power, P_D, which is now equal to ($P_s - P_{Rs} - P_{Rc} - P_{Rm} - P_f$) is what is delivered for use at the motor output shaft and is apparently calculated based upon torque and shaft speed measurements.

One can calculate the power terms of Equation 1 by substituting (1) the voltage term with its product with the current divided by 746 to yield horsepower, (2) the resistance terms with the products of the resistance in ohms and the square of the current in amperes divided by 746 to yield horsepower, and (3) the mechanical torque terms with the product of torque and motor speed divided by 5252 to yield horsepower units. This is shown as Equation 2.

Equation 2 is generic and, regardless of any shortcomings in it, will be used to estimate steady-state *or* transient operation of any motor, however, the only data available to test the equation are the vendor test results for steady state operation. Those cited previously are available for assorted source voltages, 75-144 volts, for a vendor-cited constant power supply internal resistance, 0.03 ohms, and for measurements of delivered torque (T_D), motor speed (S_m), and current (I). And these are all sufficient.

Data for most parameters in Equation 2 can be measured or estimated, except for two unknowns: current versus motor speed. However if these were known, a full set of steady-state performance curves could be generated. Vendor (ADC) performance curves make this possible.

The generalized and theoretical torque produced by electric motors is cited in various literature [***10,11***] to be directly proportional (linear) to the current flow, regardless of other factors. However, when one examines real curves measured by vendors, this is close but not quite the case. For the FB1-4001 motor available data indicate that current exhibits some curvature. This analysis will be based on a curve available widely for the FB1-4001 that covers torque delivery from zero to 160 lb-ft and is simply identified with “C-59, Sheet 1” on its right hand edge.

Figure 2 Parts A and B exhibit data points extracted from the manufacturer’s curve every ten lb-ft of torque. EV software available on the web, empirically fit curves to these data. The calculator at evconvert.com and an earlier version of it by Uve Rick available on the Electric Vehicle Discussion List evdl.com fit these data to an equation of the form:

$$T = kI^n$$

where:

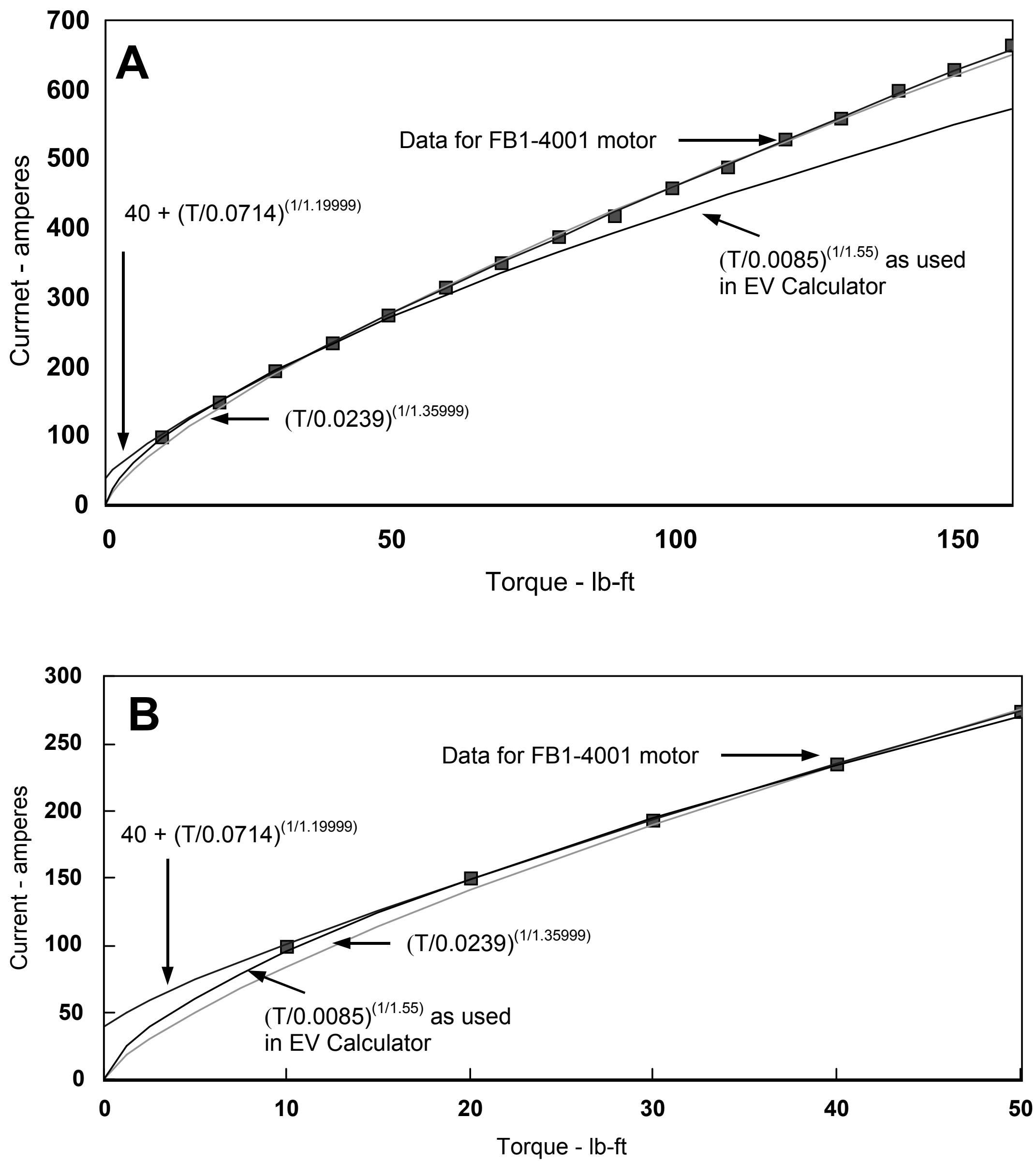

Figure 2—*FB1-4001 motor normal currents to provide various delivered torques, T.*
Data points from Cloud Electric Vehicles Web site (2011)

T is the torque in lb-ft,
I is the current in amperes,
k and n are constants provided by a curve fitting algorithm.

Both of the calculators currently (Summer 2014-2017) cite the value of the constants as being: k = 0.0085, and n = 1.55. The fitted curve these constants produce is shown on Figure 2. This provides a pretty good fit for torque between 20 and 50 lb-ft. However, it provides a poor fit at lower and especially poor fit at still higher torque levels.

When this writer enters data into the fitting algorithm for the curve, it generates values for the constants of k = 0.0239, and n = 1.3599, and the curve this produces is shown in Figure 2. Clearly the curve is a very good fit for the data above about 40 lb-ft, but below this level it diverges away for the data on the low side.

It appears that if the manufacturers data on Figure 2 are extrapolated to a torque of zero, that they will intersect the ordinate at a current above zero. This may seem unrealistic, however, remember that these curves are for steady-state operation. Although, theory predicts torque as being linear in current which suggests the curve should pass through zero, real motors (especially large motors) do not obey this theory and exhibit the frictional torque term shown in equation 2. As a result for motors running at high rpm, but low torque speeds, the frictional term as the motor approaches zero speed in the limit is *not* nearly zero. Indeed this friction limits the top speed of the motor but at a level above the point at which it would "shell out" (centrifugally rupture). The current for a stationery motor at breakaway would, indeed, pass through zero, but that is not a steady state of motion.

Hence the intersect may be a limiting result as the terms of Equations 1 and 2 approach zero. Therefore, an intersection of 40 amperes was chosen by eyeball and the curve fitting algorithm Rick used was again used to generate constants for the portion of the curve *above* 40 amps (in other words it was used to fit the data to an equation of form $T = k(I-40)^n$. This yields the approximate constants: k = 1.19999, and n = 0.0714. The curve this equation produces is shown on Figure 2 and clearly fits all of the data points better over the entire range of 10-160 lb-ft of the manufacturer's curve.

As a result, the last equation, rearranged as follows:

$$I = 40 + (T/0.0714)^{(1/1.19999)} \quad (3)$$

will be used to estimate steady-state current as a function of torque regardless of applied power supply voltages in this analysis.

So How Good is this "Ideal" Motor?

An ideal motor has now been described by Equations (1), (2), and (3) that could be used to estimate the performance of various EVs, if it is, or if it can be made, sufficiently accurate. It will only be useful to design EVs if it predicts performance reasonably close to real world motors. Figure 3 Part A, exhibits, as circular markers, the ADC performance data for the ADC FB1-4001 motor that were used to develop the ideal-motor equation of state at 144 volts. Part B exhibits circular markers for ADC data for a 75 volt power supply. These manufacturer data were apparently based on a constant parasitic resistance of 0.03 ohms in series with the motor between the constant voltage source and the motor. Data for how the manufacturer measured these data were not available, and so this approach may be subject to later criticism.

Notice the several curves on Figure 3 for electrical horsepower from the power source in each part. These were generated by multiplying the source voltage (144 or 75 volts) by the current as predicted by Equation 2 and subtracting the power losses in the power supply internal resistance (of 0.03 ohms times the same current) or $(V_sI/746)$ - (I^2R_s).

Manufacturer data indicate there is no controller used to test and so the controller loss term in Equation 2, $I^2R_c/746$, is taken as zero.

Two curves compensate for an additional loss due to an assumed motor resistance,

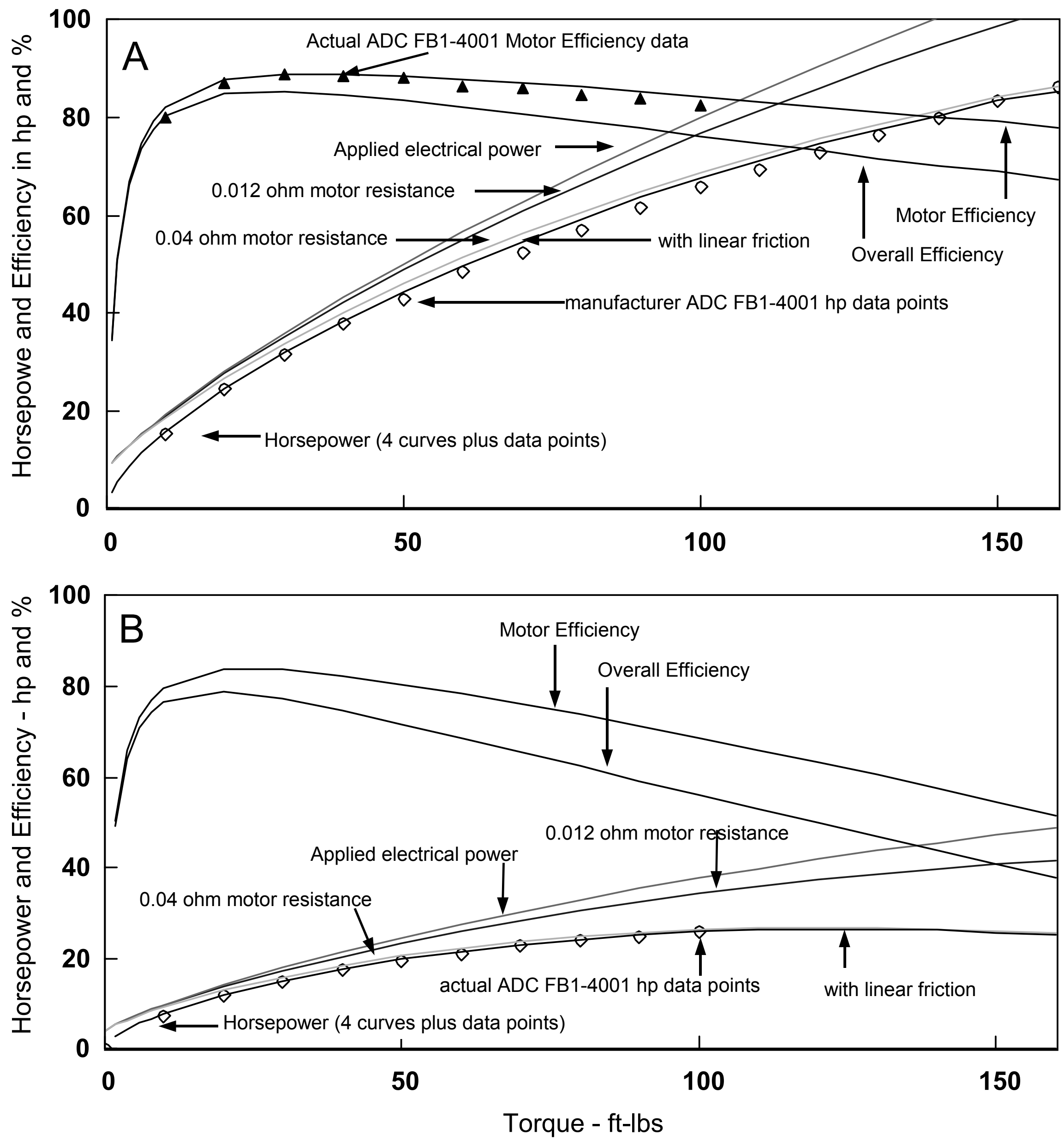

Figure 3—*Performance data for the ideal motor versus the ADC FB1-4001 motor: Part A with 144 V power source (top), Part B with 75 V power source (bottom). Power source with 0.03 ohm internal resistance.*

I^2R_m /746. The curve marked "0.012 ohm motor resistance" assumes R_m is 0.012 ohms (based on motor stall data on the internet). However other data on the Internet suggest the normal motoring resistance of the motor would be higher and by experimenting, the curve marked "0.04 ohm motor resistance" was drawn for an R_m of 0.04 ohms. In the latter case, the predicted horsepower curves conform well at high torque levels with the vendor data for horsepower (shown as circular markers). However at lower torque levels there is a small *but important* gap between them.

This remaining discrepancy is taken here to be the motor linear friction loss due to rubbing friction in the motor (such as from the brushes, or bearings) or viscosity in the air, and as a result the curve marked "with linear friction" subtracts an additional term, $P_f = 1.84S_m/5252$, for the loss due to a friction, which assumes a small friction force is present at high torque levels and low speeds that increases as torque decreases and motor speed increases. Both would be present in a real motor but are not cited in vendor data. Hence the curve labeled as "with linear friction" exhibits the complete Equation 2 for power delivered and it nicely conforms to the manufacturers data points for power delivery over both the 144 volt and 75 volt levels.

Very nicely these latter estimated data at both voltages (marked "with linear friction") produce excellent fits with the vendor data (circular points), even though these data are from two different plots and the torque/current relationship for the 75 volt curve indicates slightly different currents at each torque level.

In addition, the estimated motor efficiency curves are shown on Figure 3 for both voltages and manufacturer data (which were only available for the 144-volt curve) agree well. The efficiency was calculated by dividing the output power, P_D, at each torque level by the power being supplied to the motor from the power supply, ($V_sI/746$ - $I^2R_s/746$). *Notice*, calculating the efficiency this way yields significantly higher efficiency numbers than would be calculated compared to the significantly higher overall system power (shown as a dotted line), $V_sI/746$, before the power supply losses are wasted. Hence the overall efficiencies of EVs which include the source losses would be much less favorable than is often boasted. In a few pages, we will see why this is important when we discover that power losses due to internal resistances in batteries are often much greater than for this manufacturer's apparently very robust power source. Furthermore, *typical EV batteries will return a much smaller fraction of the energy it takes to re-charge them than what these efficiency data might suggest.*

So far the fit between the proposed ideal-motor equation of state and manufacturer test data for power and efficiency is quite good. Figure 4 now generates a family of curves for common steady-state motor speed-versus-torque at four constant source voltages with a 0.03 ohm source internal resistance for this ideal motor and compares it to similar manufacturer test data points published for the FB1-4001 motor for commonly cited source voltages of 75 volts (triangle points) and 144 volts (square points). Again, the data agree very well at both voltages.

Finally, also shown are nine data points using the "**x**" marker, and these are older manufacturer's calculated estimates of the motor's performance at 144 volt source voltage, and they are apparently calculated (extrapolated) from the data that were measured for the 75 volt curve (triangle markers) in 1991. Curiously, a dotted curve is shown that fits these "**x**" marker data extremely well, however, the dotted curve is based upon the equation and empirical constants used in the EV Calculator software, perhaps suggesting that the factory used the same method of fitting the data that Messrs: "Hemp", Uve Rick and Jerry Halstead used in their various software that led up to EV Calculator. And although they allow estimates that are meaningful and approximate, they are not nearly as good a fit for what are apparently the actual (and probably later) measurements that were apparently actually made compared to the ideal Equation of State results developed here. Therefore this equation is suggested to be a much better tool with which to estimate EV performance.

Keep in mind that if these data of Figure 4 are used in the style of L&B [***1***], they would imply the internal resistance of any practical battery pack is 0.03 ohms. *This is way*

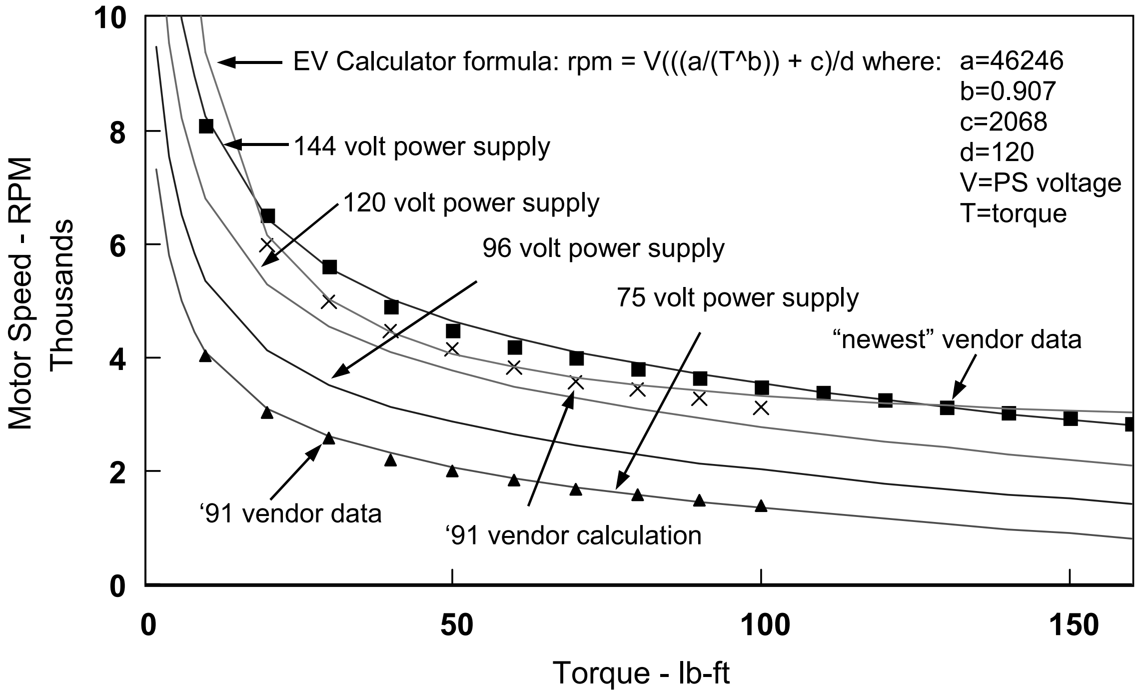

Figure 4—*Motor speed/torque behavior of ideal motor in Figure 3. Expressed in terms of the open circuit voltage of a power supply with a 0.03 ohm internal resistance.*

far in error. Lead acid battery internal resistance is a very unpleasant subject and its complexity is deferred to Chapter 4. To illustrate a point, rather than be precise, this Chapter will treat the internal resistance of the model Trojan T-105 battery to be 0.004 ohms (as is often cited) for a new typical fully-charged battery. Hence a 144 volt system will have a starting internal resistance of perhaps, 0.096 ohms, and (as will be seen later) this will roughly triple (to 0.288 ohms) when the batteries approach their "discharged" states. Figure 5 compares the 144-volt factory performance curve from Figure 4 to potentially more realistic curves that the Ideal Equations here would predict for new fully charged batteries and "discharged" batteries.

In Figure 5, Trojan data are used that indicate that new flooded lead-acid batteries have a 2.122 volt/cell (100% state of charge) voltage and that at 20% state of charge (80% discharged) their equilibrated (settled) voltage would be no more than 1.942 volts/cell (indeed somewhat less). Hence the middle curve of Figure 5 was drawn with a 152.8 volt internal source and 0.096 ohms of internal resistance, while the bottom curve was drawn with a 139.9 volts internal voltage source and a 0.288 ohm internal resistance. Notice the really significant difference this makes compared to the factory data. The writer argues that this makes it possible and desirable to fine-tune estimates provided by the software of Halstead, Rick and "Hemp".

Clearly, Figure 5 indicates that a more realistic EV may start a spirited journey approaching the performance one would predict from factory data, but when it returns near the end of its charge it will be much more like a wimp. And as it ages, its wimpiness will magnify. All mostly because of internal resistance and loss of internal voltage and capacity.

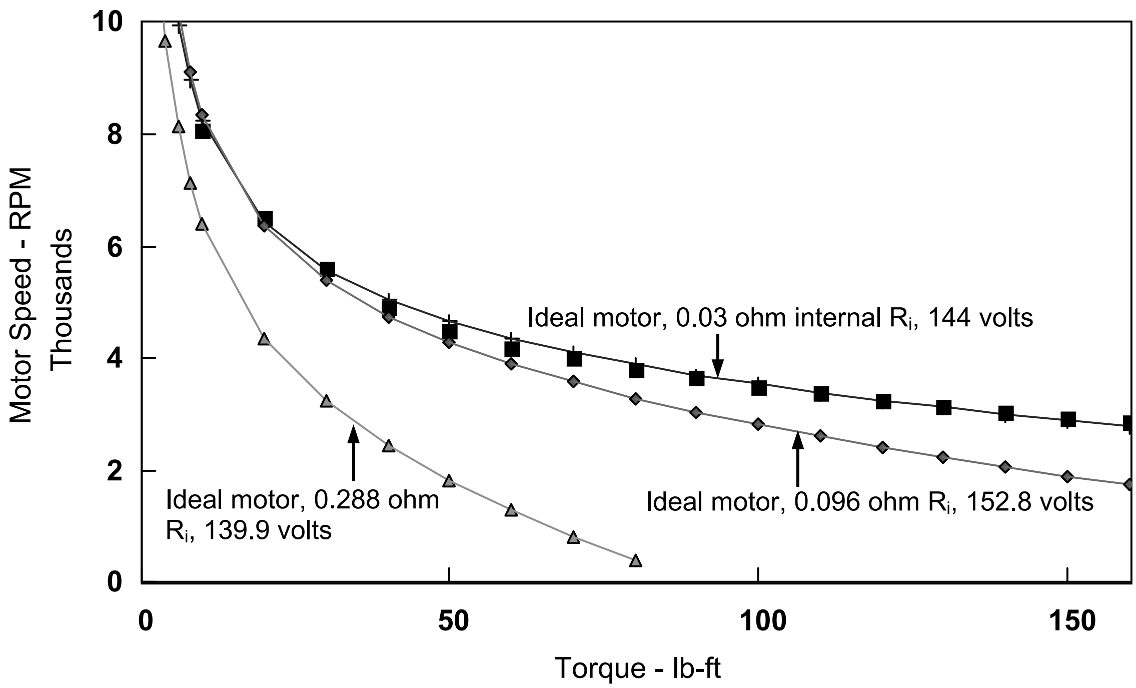

Figure 5—*Motor speed/torque behavior of ideal motor in Figure 4 for true 144 volt source and 0.03 ohm source internal resistance (top curve) with factory points shown as square markers . Middle curve with a fully charged (152.8-volt) battery pack based upon Trojan T-105 performance data and a 0.096 ohm battery pack internal resistance. Bottom curve for 80% discharged pack (139.9-volts) and an elevated internal resistance of 0.288 ohms.* ***Caution!*** *This figure assumes a* ***constant*** *internal resistance, but real batteries have higher resistance at lower current levels which could make the two lower curve still lower on the left side.*

Therefore internal resistance *is something we should obsess over*.

Figure 6 shows the horsepower (torque times motor speed divided by 5252) for the three systems. Again the factory data show a robust performance up to 85.5 hp (though this is above the motor's safe continuous service level). In comparison, when realistic internal battery resistance is present in the middle curve the horsepower peaks at about 55.5 hp and when the state of charge is low, horsepower peaks at only about 18.7 hp. Again stressing, *obsess over internal resistance.*

Finally, Figure 7 exhibits efficiency for the three hypothetical configurations of the same motor. As if to add injury to insult, again the effect of the internal resistance and voltage is severe. With the discharged battery approaching zero efficiency as the motor approaches its stall condition at under 100 lb-ft of torque. So as internal resistance climbs, the torque (acceleration potential), the horsepower (top-speed potential) and efficiency (range potential) all significantly degrade. One last time, *obsess over internal resistance*.

Indeed, in real batteries, the internal voltage will also decay and make the situation still worse. The Appendices will comment on loss of internal voltage which is also worth obsessing over.

The torque-speed data of Figure 4 are highly reminiscent of, and approximate, hyperbolas. Similar curves in the Ideal Gas Theory for gas pressure versus volume at various temperatures also approximate hyperbolas. That theory posits that for pressure, P, volume, V,

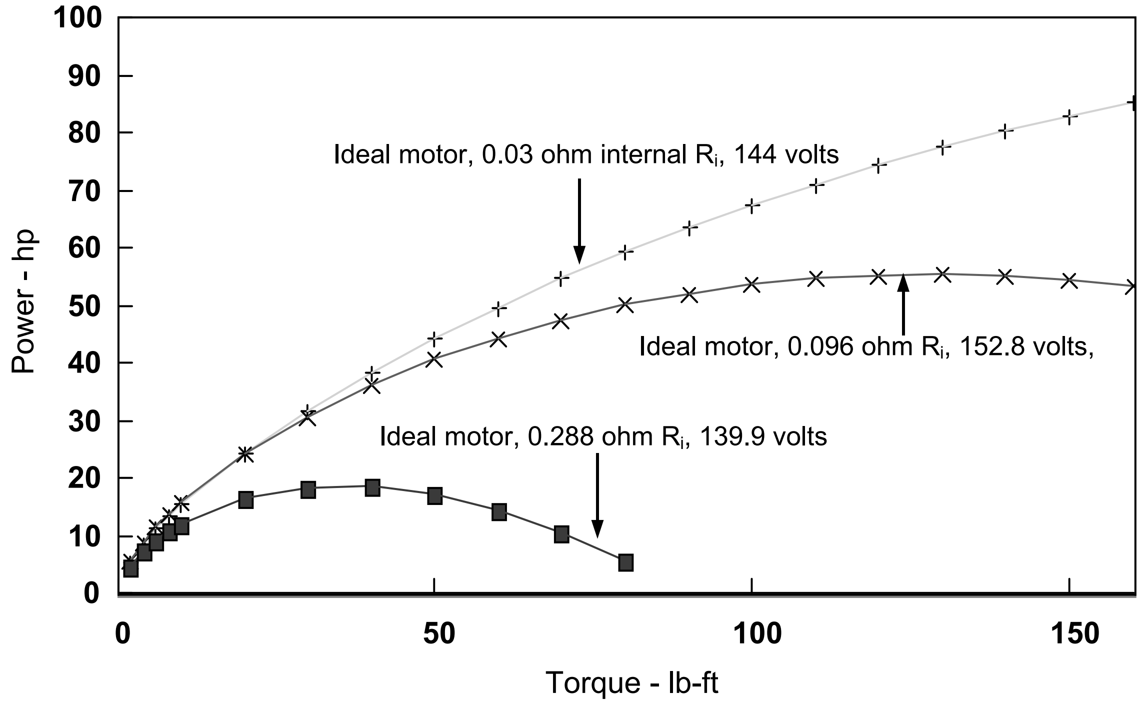

Figure 6—*Motor horsepower behavior of ideal motor in Figure 4 for true 144 volt source and 0.03 ohm source internal resistance (top curve) with factory points shown as square markers. Middle curve is for a fully charged (152.8-volt) battery pack based upon Trojan T-105 performance data and a 0.096 ohm battery pack internal resistance. Bottom curve for 80% discharged pack (139.9-volts) and an elevated internal resistance of 0.288 ohms.* ***Caution!*** *This figure assumes a* ***constant*** *internal resistance, but real batteries have higher resistance at lower current levels which would make the lower curve still lower on the left side.*

and temperature, T, the equation of state for ideal gases is given by the equation

$$PV = nRT$$

Where R is a constant, called the Universal Gas Constant.

This equation is very useful for analyzing many gas system designs and theories on things such as the internal combustion engine but it does not perfectly fit gases at certain extremes of pressure, volume or temperature (and is especially bad at low temperatures where gases collapse into liquids). Indeed, many scientists have attempted to refine this equation with more sophisticated versions that compensate for deviations. At present, for many gases, the National Institute for Standards and Technology (NIST, formerly NBS) publishes software based on more involved equations of state that seek to extract better estimates of the behavior of gases.

Similarly, an ideal motor is posited here and is now specified by an equation of state that is recapitulated in, and validated by, Figure 4. Hopefully this will yield better inferences about EVs than has been possible using empirical approximations or presumably less relevant factory data. In time (and perhaps in future writings or revisions of this book), it can be fine-tuned and refined into an even more precise form or can be succeeded with something even better.

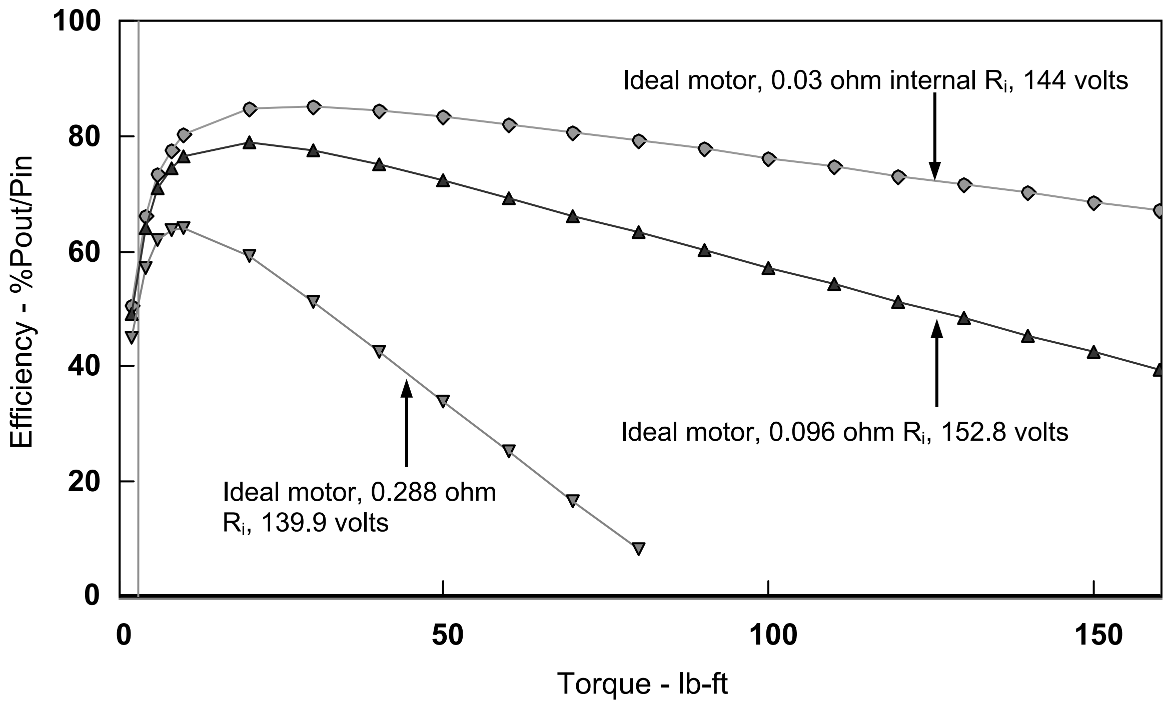

Figure 7—*Motor efficiency behavior of ideal motor in Figure 4 for true 144 volt source and 0.03 ohm source internal resistance (top curve) with factory points shown as square markers. Middle curve with a fully charged (152.8-volt) battery pack based upon Trojan T-105 performance data and a 0.096 ohm battery pack internal resistance. Bottom curve for 80% discharged pack (139.9-volts) and an elevated internal resistance of 0.288 ohms.* ***Caution!*** *This figure assumes a* ***constant*** *internal resistance, but real batteries have higher resistance at lower current levels which would make the lower curve still lower on the left side.*

Steady State and Transient Operation

Equations 1 and 2 (the power balance) are now somewhat validated and may be applied to either steady state (cruising) conditions or transient (accelerating) conditions. However in order to generate the performance curves, Equation 3 (the specific motor torque versus current equation) is also needed *and it applies only to steady-state operation*. In order to do acceleration calculations later on, the writer will take note here that when the motor is not operating at a steady state with a friction loss linear to motor speed, that if the speed were to be cut to zero, the only change would be that less of the torque calculated with Equation 3, would be lost to friction and so that “free extra torque” would be available to accelerate the vehicle. This is the approach that will be used to approximate transient performance for steady state data in Chapter 6.

Furthermore, in order to appropriately obsess over internal resistance, the writer will attempt to offer independent measurements of not only the internal resistance of a typical deep-draw battery model, but also how the resistance varies with both current draw and state of charge. It is one thing if a battery develops resistance proportionately, quickly and another thing if as appears to be the case the development is delayed (if it develops fastest when the battery is near it discharged state).

Limits on Motor Performance

Figures 5 and 6 plot the two key performance parameters necessary and sufficient to propel a vehicle at a given speed: they are torque (related to force requirement) and power (related to energy delivery rate requirement). There are limits on these and other parameters. For example EVs are limited:

1. In motor speed, too high a speed and the motor can centrifugally break apart. Typically ~6,000 rpm is the limiting speed cited for 9-inch ADC motors.
2. In the amount of current a battery pack can deliver.
3. In the amount of current a motor controller can pass.
4. In the amount of heat a motor or battery pack can dissipate.

If a motor is overloaded for too long, it can fail. This failure mode is apparently through overheating (for example, melting the windings or burning the carbon commutator brushes). And there are two principal modes of heating present: joule heating (due to the resistance of the motor's windings and the electrical arcing at the commutator), and rubbing (in the bearings and at the commutator).

Joule heating occurs throughout the armature and field windings. Bearing friction occurs at the motor's ends. Arcing and rubbing occurs at the commutator and specifically heats the carbon brush interfaces. One YouTube video[4] shows a converted Daytona with a nine inch Netgain motor at the EV Conversion Convention in 2012 running a dynamometer test (inherently maximum loading) but never completing it because it overheats apparently at about 141 hp and throws sparks or burning carbon apparently from a commutator brush.

Manufacturers therefore cite peak horsepower specifications. Clearly, they are far less than what that Daytona was pulling when it burned its commutator. For example an Advanced DC Motors Electric Vehicle Application Guide (available on the Net) cites thermal tests "per DIN and ISO Standards" from 12-1-92 for several of its motors including the nine-inch FB1-4001 of potential Cockroach EV duty. Table 1 recapitulates (first four columns) and expands upon these data (column 5). The three groups are apparently for three different constant-voltage sources of 96, 120, and 144 volts with each having a same constant internal resistance of 0.03 ohms. Real battery packs behave differently with both voltage and resistance varying.

The last column "HP Dissipation" was calculated by the writer by multiplying the Volts and Amps column data and dividing by 746 watts/HP to get the power being supplied to the motor terminals, and subtraction of the HP delivery data (column 5) to result in the amount of HP dissipated in the motor as heat. The rows labeled "Continuous" were where the motor dissipated this heat and maintained a constant safe temperature, indefinitely (continuously). The rows labeled "5 minutes" and "60 minutes" were where over a period of time (one hour or five minutes), it heated up to unsafe temperatures.

The warmer the environment, the greater the risk of overheating the motor. Hence less ability to endure horsepower.

Notice that for continuous operation the heating HP values are 2.92, 2.86 and 3.18

[4]www.youtube.com/watch?v=h1g7SAGwvpI and www.youtube.com/watch?v=2_r5-aHGeMs or search for Daytonaev Jason Horak.

TABLE 1 — *ADC Thermal Tests for the FB1-4001 Motor .*

Time-on min	Volts	Amps	RPM	H.P. Delivery	H.P. Dissipation
5	88	360	3300	35.0	7.47*
60	89	210	3600	23.0	2.05
continuous	90	190	3900	20.0	2.92
5	109	340	3520	43.0	6.68
60	114	205	4800	27.5	3.83
continuous	115	182	5200	25.2	2.86
5	134	320	4200	48.8	8.68
60	138	185	5700	30.4	3.82
continuous	139	170	6000	28.5	3.18

*Suspect data point. Extrapolated to 4.5 hp on Figure 8.

HP. Apparently this motor in the test conditions was able to dissipate about 3.1 HP and so this is the continuous rating. The one hour (60 minute) data for motor heating (apparently from a cold condition) are 2.05, 3.83, and 3.82. The first datum (2.05 HP) is probably in error and the other two suggest that a heating rate of 3.83 HP is as much as the motor can withstand (at the test conditions). Fortunately most EV trips are less than an hour long and so these numbers are potentially equivalent to continuous service. Finally, overheating (from cold?) in five minutes appears to have occurred when the motor was heated in the range of 7.47, 6.68, or 8.68 HP. This third test would have been the most difficult to conduct which may explain the large variations. Figure 8 exhibits all of these threshold data on the applicable torque/RPM curves (from Figure 4) *for this specific power supply*. On Figure 8, one extrapolated point is shown replacing another suspect test (that more knowledgeable workers are free to challenge later). However the five minute result for the 96 volt supply does not fit with the 96 volt performance curve and is above it almost at the 120 volt curve level. So an extrapolation is shown on the 96 volt curve which is at roughly the 38.5 HP delivery level and would suggest about a 4.5 HP dissipation in the motor (suggesting a sequence of dissipations of 7.47, 6.68, and 4.5 hp, and appears more realistic . This point seems more reasonable but perhaps some actual expert may explain it differently or refine it otherwise.

If one takes the equation of state for this motor surmised by Equations 1 and 3, then the heating rate would be approximated as the sum of two of its specific terms shown in the Equation below that are picked out to form Q_m, the amount of motor heating due to joule heating and friction.

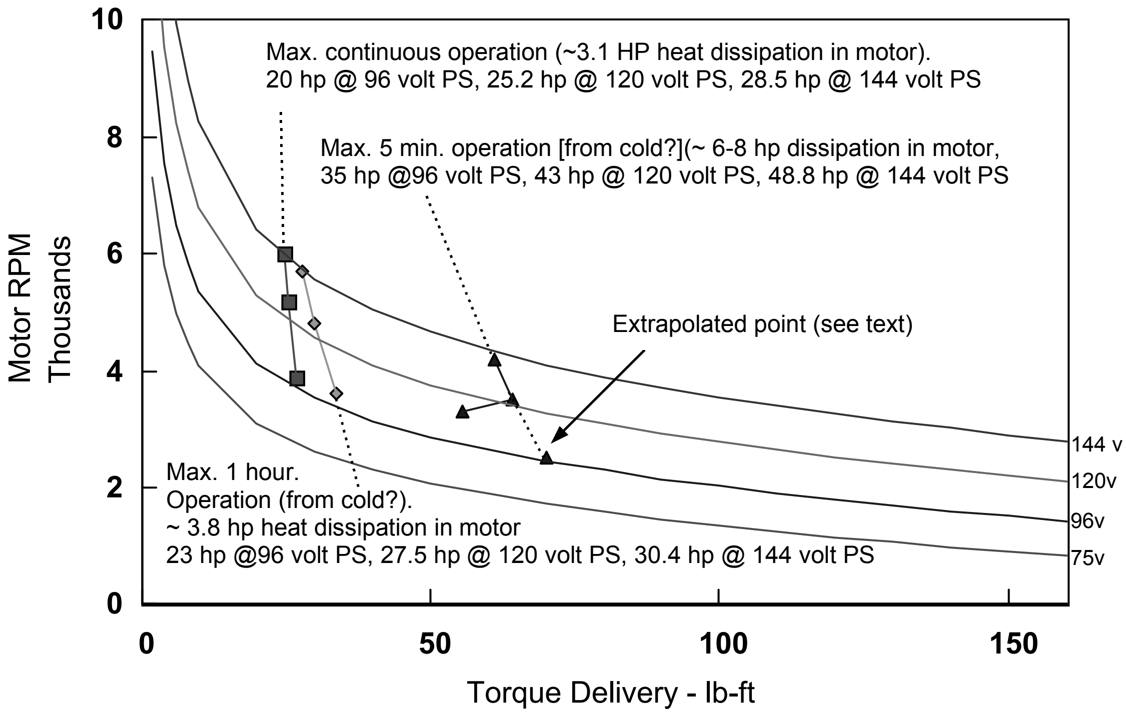

Figure 8—*Motor maximum delivery rating at 96, 120 and 144 constant-voltage supply, 0.03 ohm power supply constant-resistance.*

$$V_sI/746 - I^2(R_s + R_c + R_m)/746 - T_fS_m/5252 = T_DS_m/5252 = P_D \quad (1)$$

$$Q_m = I^2R_m/746 + T_fS_m/5252 = V_sI/746 - I^2(R_s + R_c)/746 - T_DS_m/5252$$

Where $I^2R_m/746$ is the Joule heating due to the motor resistance and $T_fS_m/5252$ is the friction heating due to the RPM = S_m. Clearly both of these terms may be much more complicated than this simplified treatment. It is possible to over-milk these data dry. Nonetheless, these curves are plotted on Figure 9 on top of the data of Figure 8. Also shown are dotted lines that exhibit the maximum motor speed (~6000 RPM) and current limited maximum torque (for a typical 500 amp controller).

Note that if friction heating were zero, then for a constant torque delivery (constant current), the peak power delivery curve would be a vertical line, regardless of power supply voltage. As friction heating is introduced, the top of the peak power curve slants to the left meaning that the current, therefore Joule heating, must decrease to limit total heating. Since torque increases with current, this means the torque must decrease as friction increases for constant heat dissipation in the motor.

Of course, it is likely that the heat developed by arcing at the commutator varies with current, that heat developed by friction and motor resistances vary in their own way. So lacking statistical data for how these motors fail, this analysis is very crude at best.

Notice that for the continuous ratings curve and data of Figure 9, the test measurements are nearly vertical which is more consistent with a constant-current behavior. The one-

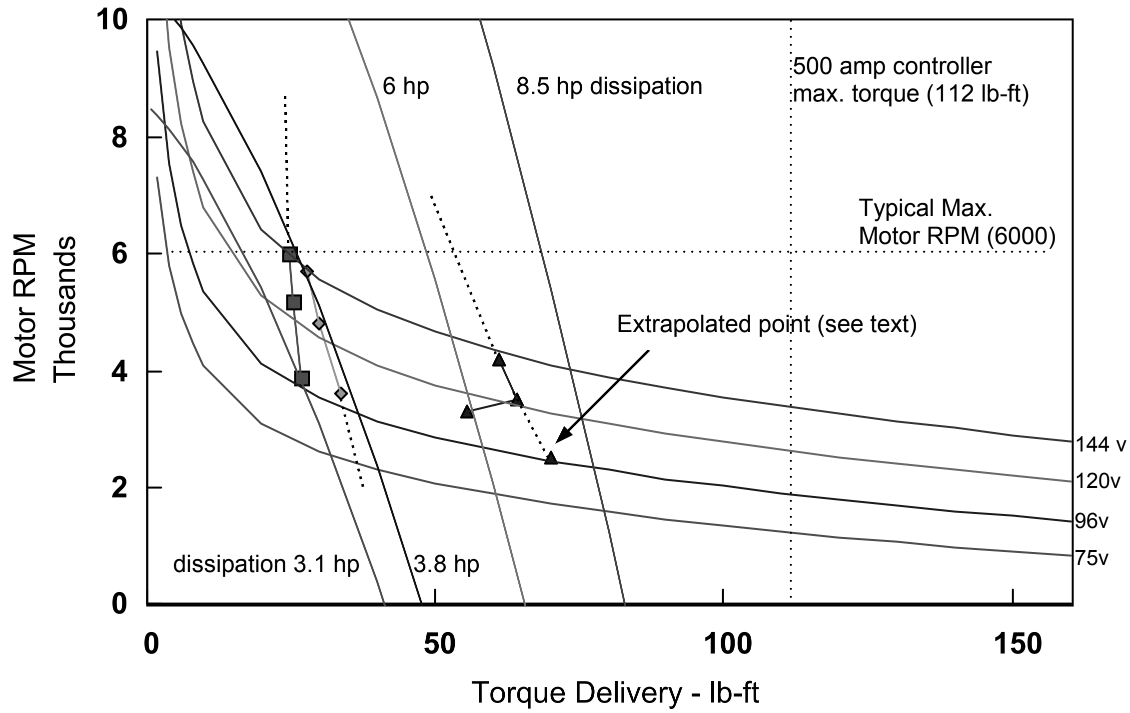

Figure 9—Data of Fig. 8 with m*otor dissipation for 3.1, 3.8, 6 and 8.5 hp.*

hour data actually fit the theoretical curve quite nicely and are consistent with a trade-off of joule heating and friction heating. Finally the five-minute data (as extrapolated) for the range of power dissipations at 6 to 8.5 HP also exhibit a slant suggestive of a friction versus Joule-heating trade-off but are displaced somewhat from the theoretical projections.

However, this equation now allows rough estimates to be made of the power limits on this motor for various combinations of operating parameters within the upper limits on speed and current and is included in the associated spreadsheet developed in Chapters 6 and 7.

Recall that the ADC power supply (constant voltage, constant internal resistance) appears to be much more robust than typical lead acid battery packs would be. Also recall that as the battery pack discharges, things can change and Figure 10 exhibits the situation for the hypothetical motor examples of Figure 5. The top curve is a vendor data curve and the lower two curves are for a perhaps more realistic, but only theoretical, battery pack fully charged and near fully discharged. However, the theoretical limiting-dissipation prediction curves are unchanged and hence again provide at least some crude guidance.

This analysis argues that one should not rate the motor in terms of peak horsepower. Given a peak horsepower rating, one can indeed calculate two key parameters of acceleration and top speed,...but this writer advises against it. It should be preferable to use the dissipation limits to calculate if there is any torque available over and above that required to propel the vehicle at a given speed to assess whether it can accelerate (whether it is at its top speed) and the rate at which any further acceleration can occur.

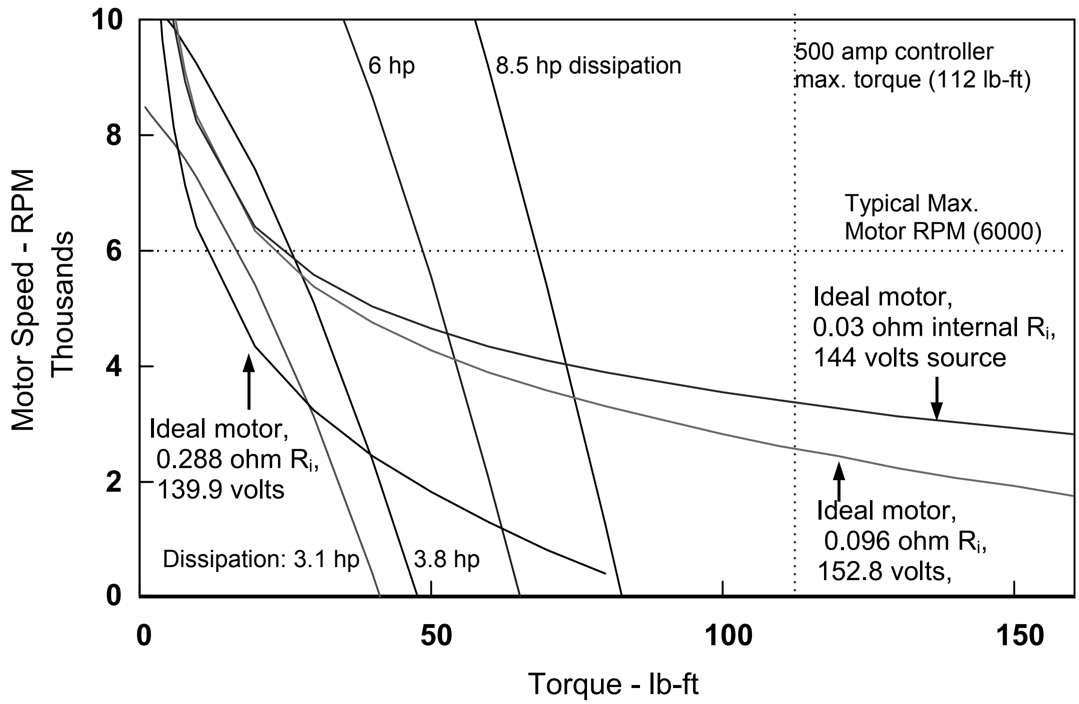

Figure 10—M*otor dissipation for 3.1, 3.8, 6 and 8.5 hp shown against ideal motor performance.*

Therefore, these relationships now suggest how one can estimate where to operate an EV in terms of power supply voltage, motor current and RPM, so as to prevent overheating and damage. The application of Kettering's insight to traction motors is still a valid but more risky process that astute drivers (or perhaps someday a microprocessor-monitored smart car) can safely use to overload the motor intermittently and extract better acceleration and top speed performance. However, it is not a trivial thing to do. More likely for a general-purpose "appliance" EV like the Cockroach paradigm, one is better off to eschew overloads. Choose a conservative limit and stick to it until smarter cars are designed.

Since battery packs can almost always provide enough power to "fry" the motor, as well as themselves, the limit for acceleration and top speed must be limited on the motor's heat dissipation ability. That will be better in colder weather and where the motor has better cooling (like perhaps at high EV velocities), worse in warmer weather and where the motor is more insulated (like when stationary). Notice that in choosing the limit, the horsepower rating is governed by the chosen curve's top left intersection with the motor's RPM limit (~6000 RPM for the ADC motor). However where one has computerized motor control, or the math chops and motivation to manually track the instruments, the rating can be increased at lower RPM provided one does not exceed the current-limited controller torque boundary (~500 amperes for typical controllers).

As an example of a problem area. Consider the curves of Figure 10. Assume the vehicle is on a hill, stationary, and the force needed to hold the EV in place is 86 lb-ft or so. If the motor is nearly discharged (~0.288 ohm R_i, ~139.9 volts) then it will be stalled, velocity is ~zero therefore the HP delivery is ~zero. Yet, notice that the discharged battery will allow this motor to overheat even though its Max. continuous horsepower rating is ~30 hp. In fact one needs to select the maximum motor heat dissipation he will accept, and use a curve like those developed here (or better if someone provides them) or refinements of these.

Indeed, later material and appendices will illustrate how chopping allows horsepower developed to *momentarily* exceed the maximum ratings without exceeding the motor heat dissipation ratings. Therefore acceleration and top speed (being the point at which acceleration is zero) are both limited by the motor heat dissipation depending upon the risk the user is willing to take). Hence for calculations in this text and the associated spreadsheet, the continuous, one-hour, and five-minute heat dissipation numbers for the 144 volts tests in Table 3 will be used as defaults (namely 3.18 hp, continuous, 3.83 hp for one hour, and 8.68 hp for five minutes).

5

Real- and Best-Case FLA Batteries

Today among hobby EV converters, and they are people who live with EVs most nearly approximating the Cockroach paradigm, lithium batteries are gaining ground, but lead acid batteries appear to still be the principal choice. Factory manufactured elite EVs all appear to have glommed onto lithium in some rather expensive vehicles. In the second edition of the Bible for EV conversions, ©2009, Leitman and Brant [***1***] said, "….this book recommends lead-acid batteries as the best solution for today's EV converters." However, in the more recent third edition [***2***], ©2013, it flips and says: "If you're planning an electric vehicle and you're debating whether to use the traditional lead-acid batteries, ….. or lithium-ion, forget the lead." Quite a turnaround. Does this mean lead is now officially dead?

The prices for lithium-based batteries may be declining, and one can find perhaps overly optimistic and careful claims (at least some of which focus only on *lifetime* costs) that in cost/performance lithium is now less expensive than lead-acid. However, when one performs the EV converter exercise of adding up the cost of present lithium batteries versus the lead-acid alternative for the Cockroach paradigm, the lithium are up to several times more expensive and could double or triple the *initial* cost of even a modest Cockroach.

Table 1 presents one perspective. One typical Li-ion battery being advertised as of this writing delivers about 100 ampere hours at about 3.3 volts for about $130 or $400.00 per kwhr making it seem several fold more costly than lead acid. Today (2017) the most popular FLA battery has a rated electric delivery of about 250 ampere hours at about 6 volts for $120-140 or about $86.66 per kWHr). It can deliver this performance in some applications... but not in electric vehicles. Unfortunately, in most if not all EV cases, this FLA battery may only achieve 25-50% of its potential (yielding up to a more realistic $347 per kwh). Hence

TABLE 1—*Initial Battery Cost Comparison*

Battery	Price	Amp-Hr Capacity	Voltage	Watt-Hr Capacity	$/kWH
Li-Ion	$130	100	~3.3	~330	~$400
Theoretical FLA	$130	250	~6	~1500	$87
Realistic FLA	$130	250/4	~6	1500/4	~$347

on the basis of cost alone, the FLA battery is still a bit more economical, but of lower performance, even with all its most serious limitations. In addition, today, lead acid batteries require such care and pampering that only a die-hard EV enthusiast would be willing to put up with them. But better, *much better*, FLA batteries are possible, and may even approach their theoretical best-case performance.

Lithium metal is limited in availability and limited in sources and when the cost drops, other battery (and other) applications [5] will compete for the supply. All of these do not auger well for ever achieving parity. However, if the cost of lithium should drop to parity or better with lead-acid (something more difficult to achieve if lead can be made still more competitive), they can surely be adopted for use and their benefits can serve as an upgrade or an added-cost option to the Cockroach paradigm.

As a result, *Volume one* of *The Cockroach EV* argues, and this volume reaffirms the argument, that lead-acid batteries remain the preferred choice for the cost-conscious Cockroach paradigm. Indeed they are the Hobson's Choice (the free choice for which there is no real alternative). This is largely because of their much lower cost, but also because they are much more practical (less risk, less temperament, and quite possibly more room for improvement since lithium cells operate closer to their theoretical best case). Lead-acid designs are possible and proven, and hybrid strategies are possible that may expand their possible uses significantly. It may not even be a close call. And this second volume will examine additional new and obscure data on the potential for upgrading lead performance.

There is little new under the sun. It is highly likely that lead-acid batteries are thoroughly understood but, as noted in *Volume 1*, the understanding may not be common knowledge. Numerous texts [***12-23***] and internet resources were consulted writing both texts, nonetheless, while preparing *Volume One* of *The Cockroach EV*, it was more than a little frustrating for the writer to tenuously and timidly surmise that the adequate, but not exciting, lead-acid battery performance should improve significantly with a few rather obvious straightforward changes (no-brainers) especially if the electrolyte were to be circulated (or "agitated"). Then only at the last minute to find obscure data (and not the only obscure data out there) in the form of patents and commercial batteries that have already proven this conclusion and

[5] For example, lithium can be added to aluminum to the tune of several percent producing a several percent reduction in density . Lithium aluminum alloys like this can reduce airplane body weight by this same several percent, every pound of which can be shifted to increased cargo capacity.

reduced it to commercial practice, but not in EV traction batteries. These data are not commonly discussed in the EV community literature, nor the other references consulted, possibly because such batteries do not appear to be available to EV hobbyists...yet (are they being deliberately withheld?).

Indeed, in a case of history repeating itself, additional data (specifically on surface "clogging" and "shielding" and to lesser extent plate "shedding") have been found following further study and testing of batteries including with agitation that are again frustrating to examine here but for which mitigation would move the Cockroach closer to full viability. So why are these data addressed so little in the common literature and perhaps mentioned so little in the EV hobbyist community? Why isn't everyone champing for better batteries. After all, doesn't Rule One say the customer is always right, and when the customer is absolutely wrong, Rule Two says to refer to Rule One? These measures are not only obvious, but they seem so reasonable that one wonders why better lead batteries are not being marketed. *Repeat: Why aren't they available*? How can they be made available? Could the hobby EV community configure its own open-source battery design and instigate its manufacture?

Instead, thousands of the budget hobbyists most reflective of the target Cockroach audience can hope to get only two to five years of marginal and deteriorating service from even the most pampered current lead-acid batteries (in this case pampered being a form of tough-love) when, as ultimately realized in Volume 1, electric boats (submarines) have apparently been getting twenty to thirty years (do I exaggerate?) of comparatively good service from remarkably similar batteries in good part but not only because they have their electrolyte circulated/agitated[6] (but perhaps also have other tactics used that are still more obscure). This can not be mere oversight, can it?. Maybe it is another case of the market seeking to maximize profits again (ignoring the customer-driven "quality" precepts of the 1980s that imposed devotion to Rule One).

So while far better data and better battery designs *must* doubtless be known, or certainly be possible, this section must struggle through an effort to improve the community perspective on lead-acid batteries using the available open-literature and theoretical data that are readily available to the community and supplementing it with a few hard-won data of the writer's own collection. This includes attempting to improve the perspectives on (1) How best to use present-day commercial LA batteries, and (2) How best to improve the designs of LA batteries with modifications ranging from slight to major changes in the gospels for using these devices, some of the latter are perhaps inadequately validated but worthy of consideration because of the scale of the potential they may provide if they prove valid.

However, if the case for lead-acid can still be successfully proved, and this book is going to try to propose a case, do not be surprised if much more useful data comes out of the

[6] Some of the modern impetus for electric cars came from President Jimmy Carter's administration which promoted them as a means to cope with the 1970s energy crisis. Carter's Department of Energy was big on grants and doubtless helped convince Detroit to cooperate with the provision of "glider" (engine-less new cars) for pilot tests to several small converters such as "Electricar" and "Soliton". Carter was ex-Navy and served in the later 1940s on the diesel-electric submarine *USS Pomfret* which may have been the source of Carter's belief that EVs could be practical. After all, if batteries can power a large electric boat, why not a car? The *USS Pomfret* had been converted to Sargo II class and had electrolyte agitation and perhaps other advancements, and Carter served as her Electrical Officer at one point, but must not have learned how important this aspect might have been to the potential success of his own EV strategy. Shame!

shadows confirming that it was actually known all along…. and was not secret even though it might as well have been secret.

Best-, vs. Real-, vs. Potential-Case Lead Acid (LA) Batteries.

It is actually pretty easy to do the math for "best case" or "perfect" or perhaps more descriptively "fantasy" batteries. Best case (theoretical) lead-acid batteries (being up to several times better than current commercial batteries in key parameters) would be much more than just competitive with lithium options if they could be realized. But this section also seeks to examine the performance of what is being obtained from real, present-day flooded lead–acid (FLA) batteries as the most economical option. Current FLA batteries are not "best case" nor "perfect" by a long shot. We know what current commercial FLA batteries can do and it is far short of the best case. However, the math for these "real" batteries is much less pleasant to deal with.

Finally we know that with something as simple as agitated electrolyte that current FLA battery performance can be significantly improved (towards "best-case" performance) in ways crucial to practical EV use. And additional data allow for speculation on other potential improvements to capacity and reliability, but can only be partially defended with the writer's modest facilities. There is room for modifications to extend both the service and cycle life of FLAs and effective capacity dramatically. However, can they yield improvement on range that would bring it closer to the best case and can they be combined with vogue lithium batteries in a hybrid design to good effect? We begin with simplistic description of a lead acid battery's operation, an improvement over that earlier perspective in Volume one, hoping there is not still more uncommon yet crucial knowledge about them to be uncovered.

Best Case LA Batteries

Best-case lead-acid battery math is not only easy to do, it is way robust and represents an absolute hard ceiling on what one might expect from FLA battery performance. Range at velocities within the ability of the car is dependent on the maximum energy in a battery which is simple to estimate (voltage delivered times ampere-hours capacity). Other factors can further limit all of these performances and require further math. However the best case is like saying the motor can taketh any way it wishes and the battery will just comply. The degree to which lithium-ion batteries do this better than FLAs may be their greatest advantage. Acceleration and top speed are most dependent upon the maximum power both the motor and batteries can deliver and in the present situation, the motor is the limiting (smaller) factor and was addressed in the previous section (based upon one factory's specs).

While lithium ion batteries may drain nearly 100% of their capacity with little if any deterioration (due to little internal resistance increase), present-day FLA batteries may exploit much less than half their capacity effectively in the worst case. Later sections will examine how the hobby EV converters and Cockroach designers alike might be best served by taking empirical fractions of Best Case performance estimates (Warner's [***5***] approach) rather than using math contortions that can yield, and have yielded, exorbitant errors not only on the too-high side, but even above the best-case possibilities.

Vehicle Range. Batteries produce electron flow. The chemicals in a battery contain only so many molecular reactions therefore so many available electrons just as a gas tank contains only so much fuel. Drain them all and the car is stuck. The rate of electron flow is called current and is measured in amperes. If a battery has Q electrons and they are drained at the constant rate, R, then the maximum period of flow will be Q divided by R (Q/R). Therefore, the battery can be rated in terms of its total available electron content or amperes times its period or hours of flow (ampere-hours),… and ampere-hours is the most common commercial battery electrical parameter that is specified. If a vehicle requires any specific current to produce the torque (as it does) and horsepower (as it also does) that are both necessary to produce any velocity, then the maximum distance one could travel (the first range-limit benchmark) at that velocity would be the ampere-hour rating divided by the required current (in amperes) times the velocity. This assumes battery energy is fungible,...it is not.

If the battery were perfect, it would also provide a constant voltage to push the electrons and the product of those volts times ampere-hours would be the absolute maximum energy content (watt-hours) of the battery. Hence one can take the rated maximum fully-charged voltage times the commercial ampere-hour rating to use as a ceiling (a least upper bound) for the available-fungible-energy term in any performance calculation.

For this simple case, if one knows the horsepower and force requirement of an EV at any velocity, one can merely divide the total battery pack amp-hour capacity by the current requirement and/or divide the energy capacity by the horsepower requirement in consistent units to calculate the time the EV can sustain the speed.

Hence the range *at that constant speed* is the smaller of these two intervals times the speed. However, today with real batteries, the period of time the power or torque can be supplied may be a quarter of the best-case maximum or less. However, neither of these limits can be exceeded. Potential battery redesigns to address these issues will be proposed later.

Best-Case Examples

For the Signature Cockroach example (page 149), Table 2 lists required horsepower estimates for various speeds relying heavily on the guidance of Leitman and Brant [*1*] among others. If powered by a robust contingent of twelve, eighteen, twenty-four or thirty 250-ampere hour FLA batteries and each provided a constant six-volt delivery (6 x 250 = 1500 watt-hours = 2.01 horsepower-hours per battery), then one can easily calculate the very best-case range, and the absolute highest hill that can be climbed.

The upper-bound best-case constant-velocity ranges (2.01 x battery count x velocity/ horsepower-hours) are shown in Table 2. These ranges are the absolute best the signature Cockroach could ever be expected to do with even perfect battery packs. But these ranges are pretty good.

Table 3 takes the next step of multiplying each battery pack option by 2.01 horsepower-hours per battery, converting it to foot-pounds (~4 million ft-lb/battery) dividing by vehicle weight to get the absolute maximum height (in feet and miles) that can be lifted to.

Note that the results of Table 2 and Table 3 are alternatives to each other. An EV can not exceed the ranges of Table 2 nor can it not exceed the hill climbs of Table 3. It also can not do both. If one drives a circuit that includes climbing half the maximum hill size then it can not exceed half the maximum range.

Before committing to drive an EV one might wish to purchase an inexpensive altime-

TABLE 2—*Theoretical Absolute, Best-Case Constant-Velocity (CV) Range of Cockroach in Miles Based on Power.*

	12 Batteries 4115 lbs		18 Batteries 4451 lbs		24 Batteries 4847 lbs		30 Batteries 5213 lbs	
MPH	HP	Miles	HP	Miles	HP	Miles	HP	Miles
10	1.50	161	1.62	223	1.75	275	1.88	321
20	3.53	137	3.81	190	4.10	236	4.38	276
30	6.39	113	6.85	158	7.31	198	7.76	233
40	10.36	93	11.01	131	11.67	165	12.32	196
50	15.70	77	16.58	109	17.46	138	18.33	164
60	22.71	64	23.83	91	24.96	116	26.01	139
70	31.66	53	33.05	77	34.44	98	35.84	118

Required HP estimated with the procedure of Chapter 6 for the specs of page 149. Range in miles is velocity x 2.01 HP-H x battery count /required HP.

ter and drive the circuits they normally do. The writer purchased a imported altimeter for just about $20 that allowed him to determine he lives at the top of a 300 foot mountain (higher than the tallest building in Allentown), that is very easy to get off of but that nearly every where he would drive, his return trip would end with the draining of ~300 feet worth of energy from his battery pack. Those living in places like the Rockies, the Sierra Nevadas, the Smokies, and the more serious parts of the Appalachians need to do such a survey, lest you find you can't go home again. If one lives on the Great Plains, one is much better off.

If these maximum range estimates are not adequate to meet any users needs, then that user has no shot at making a Cockroach serve them, since current FLA batteries may deliver less than half of these ranges, sometimes less than a quarter, of these ranges, and similarly less than half and a quarter respectively of these hill-climbs. However, for those whom these estimates might serve, it is worth the efforts in the next sections to glean better estimates from more practical data to discern of how much less an actual lead-acid equipped Cockroach might deliver.

Real-Case Lead Acid Batteries

Real-case lead-acid battery math is not only difficult to do, efforts to simplify it to date appear to have produced a somewhat flimsy result. In addition, experience has shown the performance of real batteries is so much less than for best case estimates that it begs for efforts to improve them to close the gap. Real case range at velocities within the ability of the car is dependent on the maximum available energy in a battery which is estimated as voltage delivered times ampere hours of "*actual*" capacity. So this section will seek to sim-

TABLE 3—*Theoretical Absolute, Highest Hill-Climb for Cockroach in Miles.*

	12 Batteries 4115 lbs		18 Batteries 4481 lbs		24 Batteries 4847 lbs		30 Batteries 5213 lbs	
	ft	Miles	ft	Miles	ft	Miles	ft	Miles
Hill size	11,664	2.12	16,067	3.04	19,806	3.75	23,019	4.36

Height in feet is ~4 million ft-lb of energy per battery x battery count / vehicle weight.

plify an understanding of how real batteries work in order to enable the last section to propose a re-engineered design. This will be a more detailed and thorough and complete analysis than the writer was capable of providing for volume one, and hopefully will allow for use in estimating EV performance...if it proves valid.

How a Lead Acid Battery Works... Again

A recapitulation and upgrade to the perspective on lead battery operation as described in Volume one, is in order. This section will repeat and revise the material covered in volume 1, with a more mathematical approach.

Think of the battery having three *necessary and sufficient* ingredients: the negative plate chemicals, the positive plate chemicals and the acid in the electrolyte. All three must be present (are necessary) and when all three are present they are enough (are sufficient) for the battery to work. Fully charged, the negative plate is pure, but porous, lead, the positive plate is lead peroxide and the electrolyte is a sulfuric acid/water mixture. When a negative-plate lead atom combines with a sulfuric acid molecule and a hydrogen atom, both provided by the sulfuric acid in the electrolyte, and *also* a positive plate lead-peroxide molecule combines with a sulfuric acid molecule and two waters (again provided by the electrolyte) then two electrons can be drawn from the battery, The battery fails to work if any one of the three ingredients is missing.

In other words, the battery will cease any current flow (1) if the lead is depleted or inaccessible, or (2) if the lead peroxide is depleted or inaccessible, or (3) if the acid in the electrolyte is depleted or inaccessible. All three of these depletions can happen in differing ways and at differing times. More specifically:

(1) A stoichiometric battery can be discharged in which all of the lead and lead peroxide and electrolyte have been completely combined and the full theoretical ampere-hour capacity of the battery has been extracted. If a stoichiometric battery is discharged slowly and patiently this condition can be approached and the full rated capacity of an FLA battery can be realized. For current popular commercial batteries, this would allow 250+ ampere hours to be extracted. Some batteries today are not stoichiometric and instead have only about half the acid for complete reaction of the lead ma-

terials; their capacities are therefore half what they could be.

(2) The electrolyte can become stratified and have widely differing mixture compositions in various locations. For example, sulfate ions can be removed from the thin liquid layer next to the plates. Also, electrolyte that is not between the plates may not diffuse into the gap between the plates and therefore would be slow to react. And materials released by the plates may layer and isolate the electrolyte. All of these can act as though the electrolyte has been depleted of sulfuric acid. Stirring (agitation, mixing, of the electrolyte) can reduce this effect greatly.

(3) A portion of the negative plate surface can become coated with a hard crystalline lead sulfate layer that does not react and that prevents portions of the plate from coming into contact with electrolyte. This is called sulfation and can act as though the lead has been depleted when in fact it is just inaccessible to the electrolyte. When half of the negative plate area is coated, half of the capacity of the battery can be effectively lost at normal current draw rates.

(4) A portion of the positive plate can be converted into a sub-micron-sized powder (called shedding perhaps a misnomer). This is actually a depletion of the available lead-peroxide ingredient. If half of the positive plate peroxide is converted to powder then half the battery capacity is permanently lost.

(5) Lead sulfate molecules that form during discharge on either plate surface diffuse into the plate interior and if the rate of formation on the surface is high (meaning at high current draw rates) it can build up faster than it can diffuse away from the surface of either plate (though apparently much more commonly on the negative plate) and isolate the interior lead or lead peroxide from the electrolyte. This can act as a depletion of either or both plate materials. When the surface becomes “clogged” like this, the current available must decrease to a level matching the rate at which the lead or lead peroxide is diffusing to the surface. This limits the number of ampere hours that can be extracted at higher current draws. Furthermore since the area of the plates is artificially reduced, and since the plate surface acts like resistance in parallel, when half the area is lost the internal resistance will be doubled or more.

The internal voltage has also been observed to fall although the mechanisms for this may be due to these or other consequential factors like the above. All of these mechanisms can occur simultaneously or in any combination. If they all occur at the same time and to the same degree the effects are apparently no different than if just one of them occurs to that same degree. In other words losing half of any one of the constituents will reduce the battery delivery by half. Losing half of all three constituents will also reduce the capacity by the same half.

There may be, and very probably still are, other mechanisms, that can also operate but these seem to be the principal effects and the writer believes he has witnessed all of

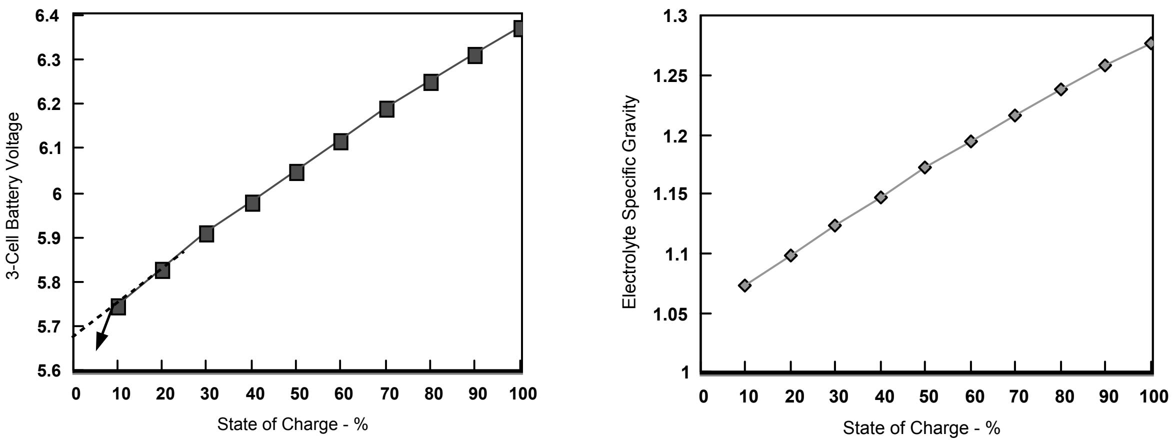

Figure 11—*Battery Voltage and Electrolyte Specific Gravity Dependence on State of Charge. (Trojan Battery Company data also Figure* A-4 *in Appendix A).*

them in operation in his limited testing. Most significantly if they can be overcome, they suggest a much more reliable, durable, accommodating and powerful lead-acid battery might be possible.

Batteries in Equilibrium

If a lead-acid battery is allowed to stand idle for a period of time, it will settle into a uniform state, called equilibrium. In this case, the voltage delivered is established by the amount of acid in the electrolyte and Trojan provides the data of Figure 11 to compare this voltage to the battery's precise state of charge (its minimum amount of reactive materials). The amount of time to achieve equilibrium of typical lead acid traction batteries is at least hours. Hence if one draws current from these batteries at a very low rate, then the battery will remain in approximate equilibrium throughout the draw.

During discharge the voltage will decay and the internal resistance of the battery will rise. At a low current the required load resistance will be much larger than the internal resistance of the battery. Hence the load will be nearly constant and the current will decay only under the influence of the decaying voltage. Furthermore since the internal resistance is much smaller than the load resistance, the internal voltage of the battery will be very nearly the same as the voltage measured across its terminals. At high current it is much different.

Commercial FLA Batteries.

Present deep-cycle FLA batteries in electric car conversions fare pretty well at providing and exceeding the (admittedly dog-like) acceleration and top speed estimates in this book because the batteries are not typically the limiting factor. The motor ratings limit those parameters. But these batteries suffer greatly at providing the best-case range estimates. One can hope that remediating the earlier cited issues can narrow the gap (and such improvements appear to be possible).

Current FLA batteries suffer the assorted short-comings previously described in *Vol-*

ume One of *TCEV* and the several additional issues listed here (perhaps surface clogging being the worst of those identified in recently obtained references and observed in actual testing). These are presented in more detail in Appendix A and C. Real EVs also use real batteries with connection chopping to provide the variable control that is needed. Appendix B tries to make sense of the chopping process. The writer only recently learned some of these issues that are to be reviewed since the publication of Volume 1. However, current deep-cycle batteries leave a lot to be desired. An awful lot.

When current batteries are new and fully-charged they initially provide electrons in a fairly favorable way (almost comparing well to, but not equaling, the now-iconic lithium-ion batteries), especially at low draw rates. However, as they age and/or discharge and/or get cold, their internal (open-circuit) active-voltage decreases and their inherent losses (due to internal resistance, etc.) increase. All of these reduce the amount of electrons (the ampere-hours) that can carry sufficient energy (as volt-ampere-hours). In severe service (high rates of acceleration, hill climbing, or high speed) these batteries then may deliver less, even much less, than half of their theoretical best-case performance. Indeed, the way these batteries are discharged can also seriously alter not only the number of electrons they can deliver, but the period over which they can deliver them.

For example, an initial heavy draw from them, even though of short duration and little impact, can choke their delivery and linger to handicap subsequent operation. To wit, if the apparent capacity of the battery is 50-60% of ultimate at 60 amperes, you may not then be able to extract the remaining 40-50% except at very low draw rates. This also applies if the battery output is chopped in accordance with the cycles described in Appendix B. Chopping may allow you to extract more power but you may have to wait a long time for the battery to come back into equilibrium, and yet curiously the staunchest warning that is published is to not let partially discharged batteries stand because that can accelerate hard sulfation.

This math is very much more difficult to perform than for the best-case math. Remember there are two criteria a vehicle must satisfy to allow motion. It must *both* be pushed with sufficient force (related to drive train torque) *and* it must receive sufficient energy, or force acting over distance, (related to drive-train horsepower) from exposure to that force.

In many cases today (2018), EV performance is estimated using Peukert's Method (1897) to predict how long a constant required-current can be drawn. The EV torque requirement imposes a minimum value on the required current in order to provide the necessary force to sustain a given velocity. The product of this constant-current time with the velocity provides an estimate of the EV constant-velocity range.

This approach has some problems and can overestimate or underestimate the range. This is in part because the battery must supply a minimum required current *and* a minimum required voltage to supply the required power to sustain a constant velocity. Hence the range depends on how long the battery can sustain the required voltage. But the voltage decays and so to measure constant current draw-times, testing has employed load reductions to preserve the constant current. Reductions in load means reduction in required power delivery (I^2R) and so constant velocity may not be possible. However with connection chopping, one can apply a constant average, but higher, current and constant power to yield a constant velocity with a decaying voltage.

Appendix A examines the extent to which this procedure affects range estimates and

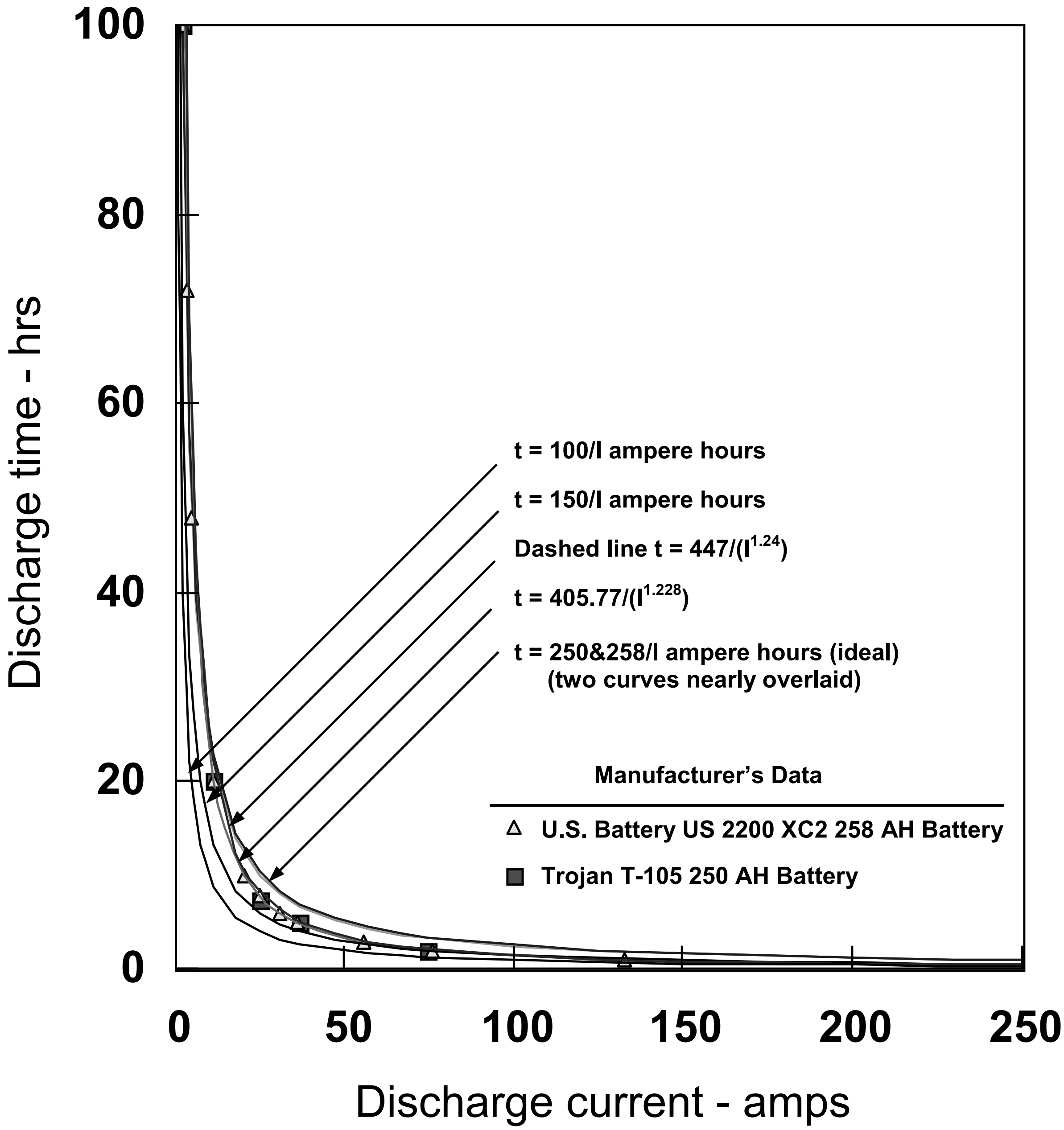

Figure 12—*Battery discharge times versus current draw for two batteries and six interpretations.*

Appendix B finds that the effect of chopping can at least in some cases yield the same or even longer current draw times than real cases. Therefore a Peukert-like estimate may nonetheless serve as a useful approximation. Appendix A also suggests the equation below, plotted on Figure 12, is useful for interpolating factory data of the most common GC2 batteries.

For current draw less than 7.5 amperes, $t = 250/I$
For current draw greater than 7.5 amperes, $t = 405.77/(I^{1.228})$

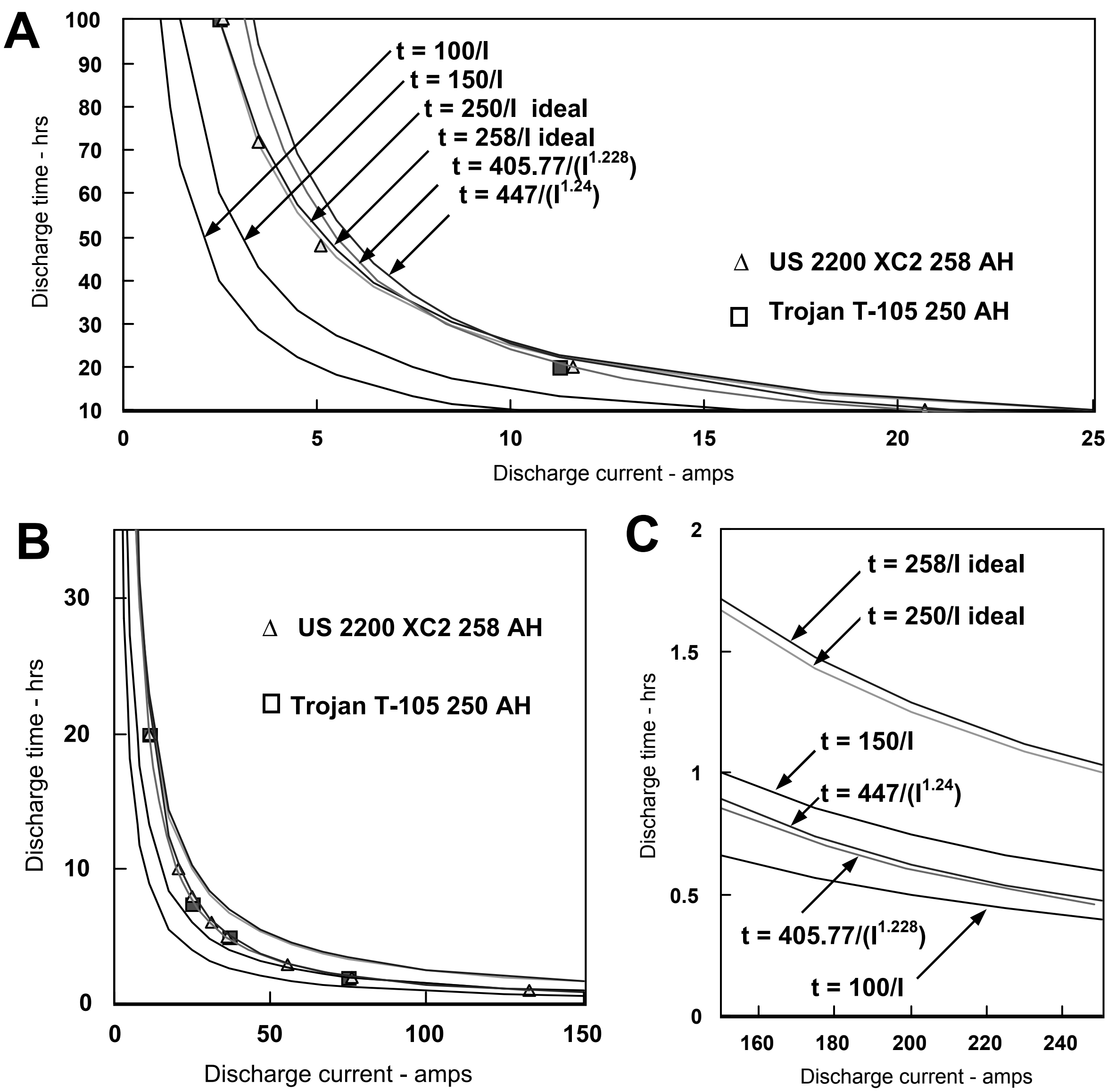

Figure 13—*Data of Figure 12 magnified over small sections.*

Figure 12 also shows data points for both Trojan T-105 and U.S. Battery US 2200 XC2 batteries. Six curves provide context. Several of these curves are hyperbolas that would apply to ideal batteries, but also included are polytropic curves as Peukert prescribed (see Appendix A). These data all tend to huddle near the coordinate axes and are especially crowded at the ends (at high discharge-times/low-discharge currents, and low-discharge-times/high-discharge currents). Therefore to clarify this behavior, Figures 13 Parts A, B and C are exhibited to magnify local regions.

Note that the for up to 7.5 ampere-draws the ideal/perfect battery equations (shown as t = 250/I and t =258/I fit best and are shown nearly overlaying each other on logarithmic

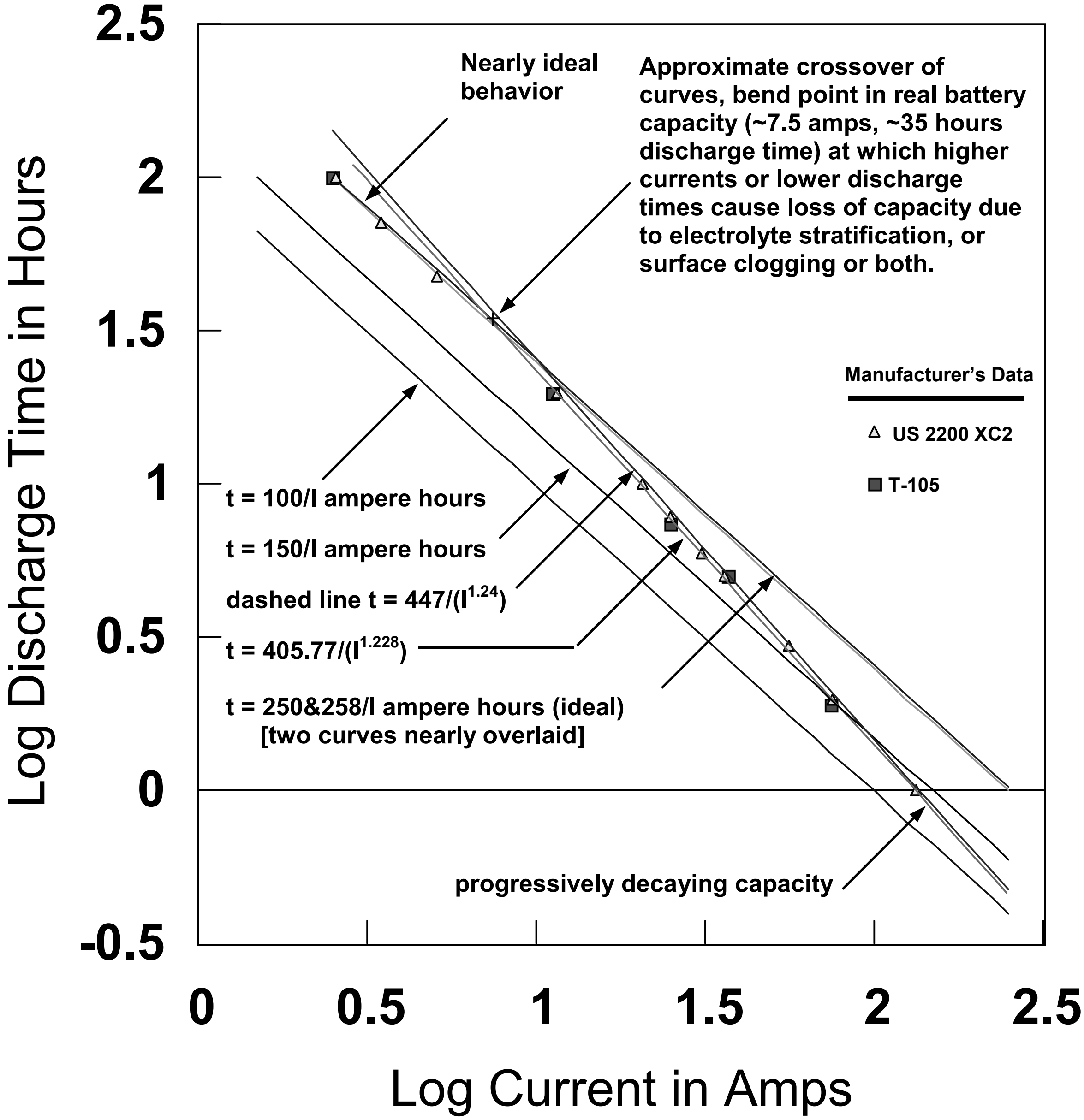

Figure 14—*Data of Figure 12 plotted with log-log coordinates.*

Figure 14. Unfortunately, because rolling friction is greater than zero at zero velocity, EVs spend very little time drawing less than 7.5 amperes. However above 7.5 ampere-draws (meaning less than C-35 [35 hour] draws), the "real battery" curve departs and diverges from the ideal curve and the higher the current draw the greater the departure. Up to 250 amperes, perhaps a common upper limit on what cruising draw rates might be, the draw time falls to less than 50% of the ideal. And this is why the 250 ampere-hour battery can behave like it has <125 ampere hours of capacity. This deviation is largely, if not entirely, due to the five

TABLE 4—*Theoretical Real-Case Constant Velocity (CV) Range of Cockroach in Miles.*

	12 Batteries 4115 lbs		18 Batteries 4451 lbs		24 Batteries 4847 lbs		30 Batteries 5213 lbs	
MPH/Gear	**HP**	**Miles**	**HP**	**Miles**	**HP**	**Miles**	**HP**	**Miles**
10 (1st)	1.50	48.07	1.62	63.35	1.75	74.4	1.88	83.08
20 (1st)	3.53	47.60	3.81	64.52	4.10	78.05	4.38	88.87
30 (1st)	6.39	42.41	6.85	59.29	7.31	71.45	7.76	82.34
40 (2nd)	10.36	35.19	11.01	47.94	11.67	58.25	12.32	66.54
50 (2nd)	15.70	29.56	16.58	40.69	17.46	49.92	18.33	57.55
60 (3rd)	22.71	22.76	23.83	31.09	24.96	37.84	26.01	43.28
70 (3rd)	31.66	18.98	33.05	26.12	34.44	32.04	35.84	36.90

Required HP estimated with the procedure of Step 25 of Chapter 6 for the specs of page 149. Range in miles estimates draw time, drive train efficiency, and both resistive and frictional loss in power train. Gears chosen to limit motor RPM.

mechanisms itemized in the "How a Lead-Acid Battery Works—Again!" section several pages back.

Furthermore as the battery ages or in cold weather, all of these curves are forced even further downward and further reduce available range, and the internal resistance can similarly increase. However on the basis of the suggested discharge equation, anticipated range estimates for the Cockroach model of page 149, that factors in series batteries, drive train efficiency, resistive and frictional losses per Step 25 in Chapter 6 (and the associated spreadsheet) are shown on Table 4 which compare to the conditions of Table 2 except the estimates are more realistic.

Fantasy-Case FLA Batteries

It may not be pure fantasy to believe that FLA batteries can be modified to operate near if not at their best-case performance levels. Furthermore to believe that reliability can be far better than what is being achieved today. Indeed, that they can operate at the true "appliance car level" that the Cockroach EV aspires to provide.

We have seen the best that FLA batteries can hope to be, and we have seen how far short of these limits they fall. They fall far and that means there is a lot of room for improvement.

This futuristic section summarizes speculation that is rooted in some, but by no means definitive, literature data, and testing by the writer (as detailed in appendix C: *Re-Engineering the FLA Battery*) and certainly no small amount of gut feel. These insights and the resulting proposals may be completely valid and already known and censored in the key quarters, or they may be critically short of key understanding needed to work. This speculative and hypothetical battery design is developed in Appendix C and recapitulated in Figure 15.

Whereas, lithium batteries appear to be working near their ideal limit, FLA batteries appear to suffer in major degree from at least the five previously cited issues: (1) there is too much local self-heating, (2) local electrolyte transient depletion can cut voltage and current, (3) surface clogging by sulfate during high discharge rates can block capacity, (4) negative plate surface hard-sulfate formation during use can shield capacity, and (5) positive plate deterioration ("shedding") during harsh recharging that seeks to repair/remove the hard sulfate of factor (4) can erode capacity. Mitigation or at least amelioration of each of these seems realistic (but may be naive). *However, the mitigation and amelioration appears to be a package affair, for any to fully work——all of them may need to work together.*

Just how much FLA improvement might be possible? After reviewing a good sampling of references, and the Net and running a series of tests over four years on three USB 2200 XC batteries (BCI 2GC competitors with the Trojan T-105) this commentator proposes the thorough analysis of Appendix C as bases for the following FLA battery remix (Figure 15) for consideration:

First, A reconfigured polypropylene case for one or possibly two cells (instead of much smaller surface-area-to-volume ganged three, four or six-cell batteries) having about a 20 pound weight per cell. This is so that increased exterior surface area is present for cooling and is the same for all cells and so that molded external polymer fins can improve heat transfer from the cells. Appendix C examines several possibilities.

Excessive heating is widely reported to seriously damage FLA batteries. Localized heating causes local regions to carry the bulk of the discharge and charge. In personal testing, of GC2 six-volt batteries, the center cell typically got significantly warmer during high draws, even as low as 60 amperes, because the outer cells insulate the inner cell, and in addition within a cell the outer plates insulate the inner plates and even within the center plates, the plate perimeters insulate the plate centers. When prompt recharging of discharged cells is employed, as is desirable, the center of mass starts out at risk of overheating. The center of mass of FLA batteries is therefore clearly under the greatest thermal stress. When SLI batteries are used in EVs (something universally labeled a massively stupid thing to do) they are under still much greater thermal strain especially at their centers of mass, so much so that their thin plates may just not be their greatest problem. Additional protection against localized self-heating for the plates would also result from air-lift pump agitation of the electrolyte which would aid in producing a more uniform temperature. Indeed, if absolutely necessary, perhaps thicker center plates could be combined with thinner outer plates to increase active surface area.

Second, local electrolyte depletion due to stratification can reduce effective battery capacity. The faster a battery is discharged the less likely it is that remote electrolyte will find its way to the plates. The GC2 FLA battery is apparently manufactured with nearly or exactly stoichiometric amounts of positive plate, negative plate and electrolyte materials present. If any one (or two or all three) is in short supply the capacity of the battery will be reduced in direct proportion to the greatest individual shortfall. Appendix C reviews how the

Hypothetical Improved EV FLA Battery Design

Case Modification: One cell per case. Molded external fins. Increased volume for electrolyte of lower specific gravity. Use segmented bottom case supports to prevent acting as baffles that interfere with electrolyte agitation.

Air lift pumps: Install air lift pumps as a substitute for several of the plates in each cell. Center them under the fill caps on the case to allow compressed air powering of them and the insertion of a central thermocouple.

Plate geometry: Reduce the thickness of deep draw plates perhaps even to the thickness of starting batteries to reduce surface sulfate clogging.

Electrolyte: Reduce the specific gravity of fully charged electrolyte by 10-20%, to allow a larger gap between full charge voltage and electrolysis onset voltage to mitigate positive plate deterioration/ shedding.

Design Constant-Activity Circuitry: Employ a supplemental load or battery and inverters to automatically apply a low level recharge current anytime a discharge is interrupted. When supplemental battery is discharged use cross charging and/or low level constant discharging to mitigate hard sulfate formation following discharge.

Charging Regimen: Charge with temperature monitoring using high initial charge rates and tapering rates as final voltage is approached with a limit based on central temperature.

Computer Control/Tracking: Provide a small computer to track battery usage, need for maximum current abeyance and charging/discharging, limits.

Figure 15—*Seven battery design possibilities to pursue best-case performance.*

acid supply in the electrolyte can be significantly reduced in its ability to provide current flow. Furthermore, when the acid availability between the plates is reduced, the electrical resistance of the electrolyte increases and further reduces the batteries ability to provide current flow while magnifying heating. During high current flows, nearly half the acid in the electrolyte can become isolated in the sump and head space alone and be unavailable for prompt reaction. Air-lift-pump agitation of the electrolyte can ensure homogeneity of the liquid and remedy this issue. It can also improve efficiency and speed possible during recharging of the cells (partly by keeping the voltage down and partly by keeping the temperature down). If plate thickness could be reduced (despite any frailties this might produce) and if the number of plates were increased to maintain the active materials content, the increase in surface area can also act to make more of the acid available to the plates and reduce capacity reduction while at the same time allowing for lower internal resistance and therefore greater maximum current draws and less Joule heating. Appendix C elaborates.

Third, negative plate surface clogging denies the battery access to its full potential the same as acid depletion does. Appendix C reviews how clogging apparently operates. Here again clogging effects would be reduced if thinner plates can be employed in deep cycle use. If the plate count could be doubled by halving the thickness, it would double the plate surface area. Twice the area would mean the sulfate deposition rate on the surface would be halved at every current draw rate perhaps doubling the time-to-clog the surface. If clogging is a near-synchronous limit on capacity with electrolyte stratification (as the writer believes it is) then halving the plate thickness, doubling the surface would nearly erase the loss of capacity due to this effect at perhaps up to the 250 ampere draw level.

Fourth, a reduction in the specific gravity and increase in electrolyte volume might mitigate two mechanisms. It would make it less necessary to abusively end-stage charge batteries to remove hard sulfate by increasing the gap between the charging voltage and the onset of electrolysis. Numerous references cite how thin plates do not last in deep draw service. Indeed, some suggest the currents overload them and yet starting batteries are rated for much higher current densities than deep-draw batteries. It may be that the problems of thin plates are largely due to (1) heating (which should be mitigated with additional heat transfer efforts listed above) or (2) due to positive plate "shedding". Shedding is when surface area is lost when the pasted filler is swept off these plates in the end stages of charging. However, this "shedding" may be largely due to bubbling on the plate surface during electrolysis in the end-stage of recharging which carries away lead sulfate particles (or perhaps dissolved lead-sulfate liquid). Testing by the writer reported in Appendix C suggests electrolysis bubbling can be largely prevented and may result in reduced positive plate shedding through less aggressive charging with little or no electrolysis bubbling….. resulting therefore in less (or no) need for frequent watering of the cells.

Fifth, circuitry to keep deep-discharged batteries active may reduce the formation of hard sulfate by preventing liquid sulfate ions from bathing sulfate-clogged negative plate surfaces. The writer's experience and lore has it that hard sulfate forms most aggressively when one fails to immediately recharge a battery after any discharge, and when one then fails to completely (meaning to abusively) recharge the battery as it nears full charge. The latter apparently allows the surface sulfate to "harden" ever more so perhaps by providing seed crystals to aid in future growth following any further discharge that is not *immediately* recharged (not withstanding the fact that only light charging, if any, is recommended on a warm discharged battery).

Circuitry can be designed to apply a low level load to a discharged battery (one in an EV that is sitting parked while an errand is run), or to use the accessories or supplemental battery with an inverter to perform a low level charge, or even to split the battery pack into two parts and use one part to alternately charge the other part and switch roles on a schedule.

Indeed, if there is no hard sulfate formed after discharge, then there should be no need to so aggressively finish any recharge. And if as Appendix C posits, hard sulfate does not form during discharge (due to low levels of sulfate ions in the electrolyte near the plate surface), nor during recharge (due to the low level of surface sulfate ions), then a less-aggressive charge/discharge procedure might reduce crystalline sulfate formation near-completely and allow for a much more gentle recharge by always keeping the battery in at least a minimal state of either charging or discharging.

S*ixth, charging should be based upon battery status*. Thermocouple sampling of a least some key battery temperature should be used to set a recharging protocol. This should allow charging as quickly as the temperature will allow, but tapering off to minimize electrolysis in any end-stage sulfate resolution.

Finally seventh, a small computer should track all battery use. This can serve to dictate maximum allowed current draws (through limits on duty cycles) to keep thin plates from excessive heating and enable any benefits the above designs might (or might not) provide without risking battery excessive and protracted current draws that may (or may not) jeopardize thin plates.

Several conditions examined here (and there may be more) may cut FLA capacity: surface clogging or shielding of either plate, shedding of positive plate or local depletion of acid. These design tactics may mitigate each possibility, and *if they are the only mechanisms of importance*, may move FLA performance quite near to its best-case level. Keep in mind all of these measures may need to prove out, for if any one, even just one, of the factors is not resolved, it may impose the same limits that presently obtain. A PC can monitor all of this and optimize each effect for the EV's driving patterns.

Regardless, these seven realistic steps might more than double the practical range of current batteries in some circumstance, slash internal resistances, and narrow the differences between the range entries of Table 2 versus Table 4, and similarly increase the hill-climb entries of Table 3 , while also massively improving the reliability and life cycle performance of FLA batteries. Might sound too good to be true. As a result the calculations herein provide the current technology cases but also cite the best case targets as realistic or near-realistic goals.

Of course the writer may merely be embarrassing himself with this speculation and may still need to climb further up on the learning curve before he can truly understand any further mysteries of the FLA battery. Nonetheless he persists with future work because the benefits that a fully realized appliance Cockroach EV promise are too valuable to the nation to be ignored.

6

Cockroach Performance Math

Vehicle Design Protocols

Three key vehicle performance parameters (a trichotomy?) have been focused on so far: torque, horsepower and efficiency. These correspond respectively to the three performance parameters: acceleration, top speed and range, ATSR. When you take the wheel, your vehicle has certain maximum capabilities and you can *not* exceed them. The outline of a twenty-six step procedure that is based variously in texts (but principally L&B [***1-3***]) and on the net (principally and presently EV Calculator at evconvert.com) was given on page 155, and with the new additional material from the prior two chapters and the Appendices, will be elaborated upon in detail in this section and will be based on the quintessential Dodge-Daytona-based Cockroach specified on page 149.

Steps 1-6. Force and Power Required Due to Acceleration, Hills, Friction or Velocity

The power and torque provided by the battery and motor to a design vehicle, specifically the Daytona-based Cockroach EV example, are used in the following principal ways as summarized in numerous references and specifically by Second Edition Leitman and Brandt (L&B)[***1***]:

- Step 1: to accelerate the vehicle mass to speed (L&B, p. 99).
- Step 2: to climb hills (L&B, p. 100)
- Step 3: to push air out of the vehicle's way (L&B, p. 104)
- Step 4: to overcome rolling friction in the drive train and tires (L&B, p. 109)

Each of these tasks requires a specific force be exerted on the vehicle (which is directly proportional to and derives from the torque delivered to its wheels), and a specific

TABLE 5—*Equivalent force terms.*

0-60 mph time (Seconds)	A_{ave} (mph/sec)	Equiv. Climb (Degrees)	Equiv Climb (%)
5	12	28.6	54
10	6	15.3	27
15	4	10.3	18
20	3	7.8	14

power delivery (which derives from the force/torque being delivered at specific linear or angular speeds), and is sustained by a specific efficiency (which relates to how much power is wasted as heat).

Furthermore, the forces required for each of these four tasks are additive. If you wish to accelerate on a hill to a high speed you must provide all four forces. From basic Newtonian Mechanics, the total force required to move the vehicle is:

$$\Sigma F = F_{aerodynamic} + F_{rolling\text{-}friction} + F_{acceleration} + F_{climb}$$

And the power, which sums the products of force and velocity, v, is:

$$\Sigma Fv = F_{aerodynamic}v + F_{rolling\text{-}friction}v + F_{acceleration}v + F_{climb}v$$

Step 1: *Accelerating vehicle mass to speed.* This means application of Newton's most famous law of motion between force (F), mass (m), and acceleration (a):

$$F_{accelerlation} = ma$$

When this is applied to rotating machinery, it can be also written for torque (T), moment of inertia (I) and angular acceleration (α) [which is the rate of change of the angular velocity (ω) which is in turn the rate of change of angular position (θ)], and the moment of inertia (I):

$$T = I\alpha$$

The corresponding horsepower that must be supplied is:

$$P = T\omega = mav$$

The efficiency with which this is accomplished is still the same:

$$E = P_{out}/P_{in}$$

where in old-school English units (for those like the writer who haven't fully metricated yet), F is measured in pounds, M is measured in slugs, and, a, is measured in feet/second. Assuming a constant acceleration rate, we can choose brackets by which to evaluate acceleration performance. Table 5 lists assorted uniform acceleration benchmarks in terms of time-honored velocity changes from zero to sixty miles per hour. In the writer's life exotic high performance cars (the 60s Plymouth/Dodge Ramchargers to the current electric Tesla), have been able to achieve 60 mph in as little as three to five seconds, merely fast cars (like

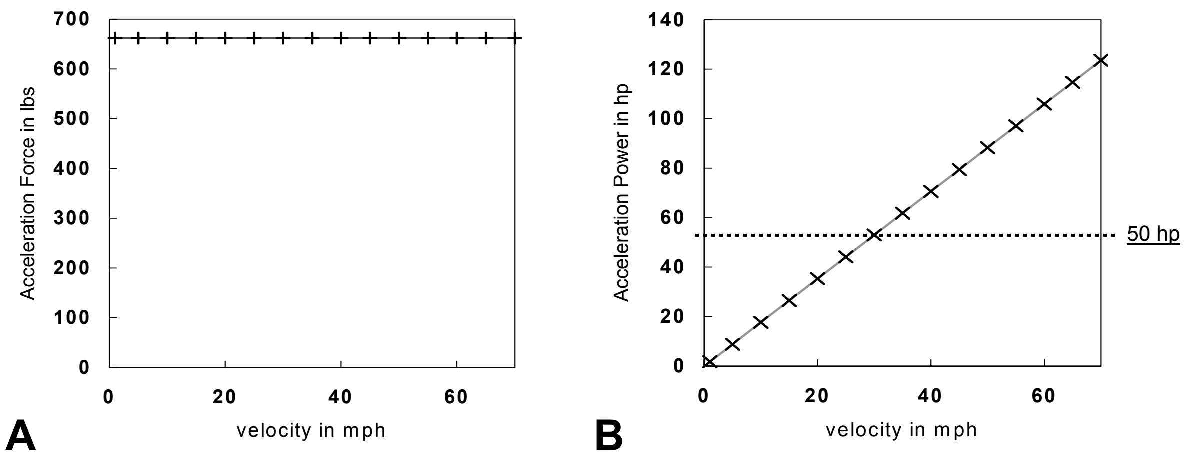

Figure 16—*Force and power to accelerate EV mass at 3 mph/sec. Step 1. (Set to zero mph/sec in CockroachEV.xls spread sheet default)*.

early Corvettes have traditionally reached 60 mph in from five to ten seconds but today many cars can do this. Commoner's cars have reached 60 mph in from ten to fifteen seconds. Slow but nonetheless roadworthy "dog" economy cars like the original VW Beetle (many still in service today) have taken much longer, and often like many electric conversions, are not able to exceed it by much (if they can achieve it at all) and are subject to deterioration of it when even slight hills were encountered. In the 1960s, the Corvair lineup of cars ranged from 12.5 seconds for the turbocharged Spyder to 15-22 seconds for basic 80 hp Monza sedan, to 32+ second for the 80 hp Greenbrier van. Hence, zero to sixty times in brackets as multiples of five seconds have been chosen for this example.

While a scant (but growing) few electric vehicles (like the Tesla) can qualify for the under-five-second bracket, and although *many* electric vehicles can apparently achieve that same 12 mph/second acceleration at low speeds, it appears that most current conversions (that would compare to the Cockroach paradigm) may begin accelerating like five-second cars at low speed but as the speed builds up, they wind up struggling like twenty-plus-second cars as they approach sixty mph, and many do not make it.

Figure 16, Part A, depicts the primary force to accelerate the car mass itself at a 3 mph/sec rate. Figure 16, Part B, exhibits the corresponding power demand. Clearly both the force and the power are independent of any efficiency of delivery. On the power curve, B, a dotted line shows where an overloaded 50 hp motor would cease to provide a 3 mph/sec acceleration rate at ~28 mph. This 50 hp car might accelerate at 12 mph/sec or better up to about 7 mph, or at 6 mph/sec or better up to about 14 mph, or at 4 mph/sec or better up to 21 mph, but at or above 28 mph, the maximum acceleration is limited to 3 mph/sec and less. Without overloading, many converted EVs have much less than fifty hp available to accelerate their vehicle mass and keep in mind a large portion of their perhaps 30 horsepower must go to overcoming rolling friction, aerodynamic drag, and hill climbing).

Note: In the associated spread sheet, the default acceleration is set to zero so that level road constant speed performance is shown for the top speed and range calculations.

Accelerating vehicle rotating mass to speed. This means applying the rotational form of Newton's Laws of Motion and is analogous to the equation F = MA, and it is written:

$$T = I \cdot d^2\theta/dt^2 = I \cdot d\omega/dt = I\alpha$$

$$P_{ft\text{-}lb/s} = T\omega$$

Where T is the torque in ft-lb, I is the moment of inertia in slug-ft^2, θ is the angular position in radians, ω is angular velocity, $d\theta/dt$, or the rate of change of the angular position in radians/sec, $d^2\theta/dt^2 = d\omega/dt$ is the angular acceleration of the angular position of the rotating components in radians/sec^2, P is the power in ft-lb/sec. When converted to horsepower and motor speed, S, in rpm, the last equation for power becomes the now familiar P = TS/5252.

Leitman and Brant [***1***], on their pages 99-100, include a small term (that increases force/torque requirements by 6-20 percent) for this drive train reciprocating energy. This aspect will not be belabored upon here since they suggest it is usually small, especially in well designed EVs. But it may be a ripe topic for fine-tuning a later version of this text (if there ever is one). A significant portion of this factor in an ICE car is the force and energy to accelerate the flywheel and four wheels. The flywheel serves two key purposes: it absorbs energy from the "jerkiness" of the engine combustion, thereby smoothing the engine power delivery, and it stores energy and allows that stored energy to be recovered to help launch the vehicle from start and thereby acting as a engine torque supplement. However, after the vehicle is launched, the flywheel continues to smooth the power pulses but then becomes a parasite and reduces the power and torque available for acceleration. Since the early days of hotrodding, flywheel lightening was a performance tactic that allowed improved acceleration but a rougher more temperamental ride. [7]

Step 2: *Pushing a vehicle's weight up inclines*. Hill-climbing is calculated as a simple statics problem. The force required to push a wheeled mass (so there is negligible sliding friction) up a hill (Figure 17) is simply the force to balance the tangential component, W_t, of the vehicle weight, and it is an equal and opposite climbing force, W_c.

$$F_c = W \sin \Phi = W_c$$

The horsepower required at constant velocity is:

$$P = Fv = W_c v$$

Table 6, previously compared the force necessary to climb hills to the force necessary to accelerate mass. Notice that the faster a car can accelerate on the level, the steeper the equivalent hill it can climb.

The force required to accelerate at one "g" (unity times the acceleration due to gravity, 32 ft/sec^2, or 21.8 mph/sec) is roughly the same as the force required to climb a hill that is vertically upwards, 90 degrees. To accelerate upward at one "g" requires a force equal to twice the mass's weight.

As a result hills are devastating to battery capacity. The maximum amount of hill

[7] ICE flywheels are designed to store energy, for smoothness and torque supplementation. In many EV conversions that are extremely smooth in power delivery and do not require pulse smoothing, the flywheel and clutch are eliminated or lightened (by removing the unneeded ring gear and/or machining of the thickness). Since a series DC motor also has enormous torque, the torque supplementation at launch is not needed nor is feathering of the clutch. Hence the remaining clutch function only serves to decouple the remaining rotating inertia of the motor and flywheel at speed to allow the transmission synchronizers to slow the spinning clutch disk enough to allow smooth and quick meshing of the synchronizer teeth without grinding. Without the clutch and flywheel, the gears can still be shifted by interrupting power to the motor, but because of

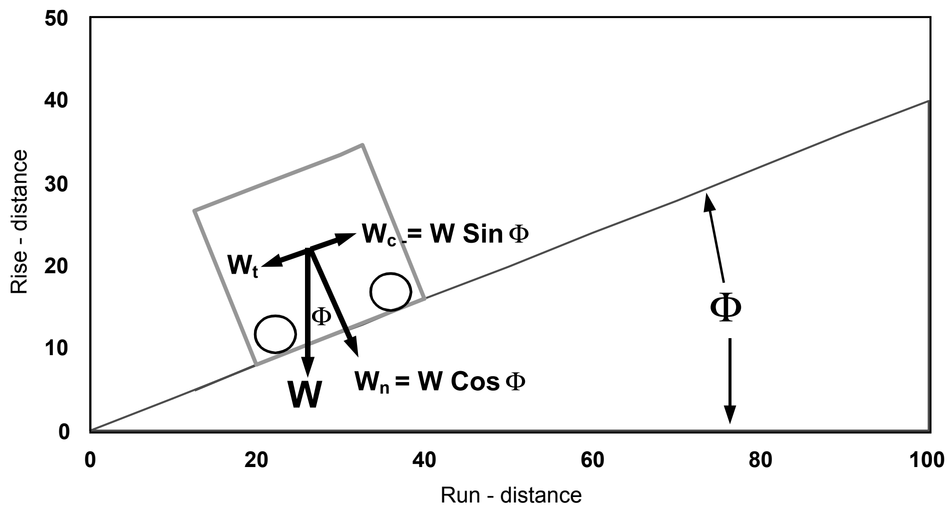

Figure 17—*Force to push a vehicle weight up a hill.*

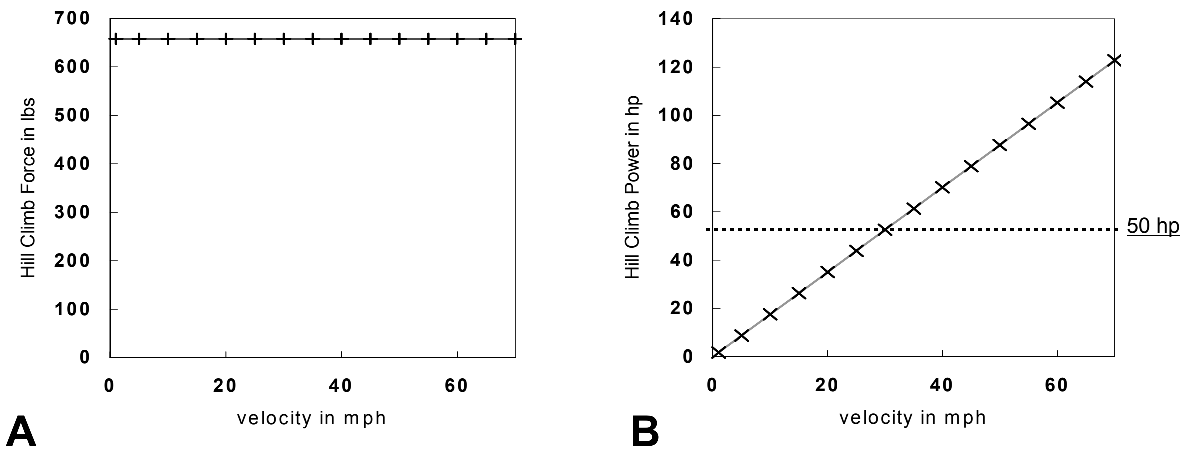

Figure 18—*Force and power to climb 14%, 7.8º hill. Step 2.*

climbing possible for various weight vehicles is a function of battery pack capacity. Table 3, page 183, shows climbing even common long hills even at low speeds requires forces (easily available from EVs) and power (not so easily available from EVs) comparable to those delivered by even high performance cars and even best case range can fall to a few miles. Figure 18 exhibits the force and power level that correspond to the 3 mph/sec acceleration rate

the motor's spinning inertia (and the relatively large intentional spinning inertia of the flywheel if it used without a clutch) is left, shifting must be slowly performed to allow the synchronizers and spin-down to match the speeds, but that also puts increased stress and wear on the synchronizers. In this case, a lightened or hot-rod aluminum flywheel can allow the best of both worlds. Indeed, since the clutch is not needed to absorb and convert high speed torque to low speed grunt on vehicle launch, a process that involves extreme friction, a heavy iron/steel facing on the flywheel may not be necessary and perhaps a simple high-tensile-strength aluminum disk might suffice instead of a standard flywheel. The writer has heard of some aluminum alloys that have been used successfully used to endure friction as brake rotors, a still more demanding service.

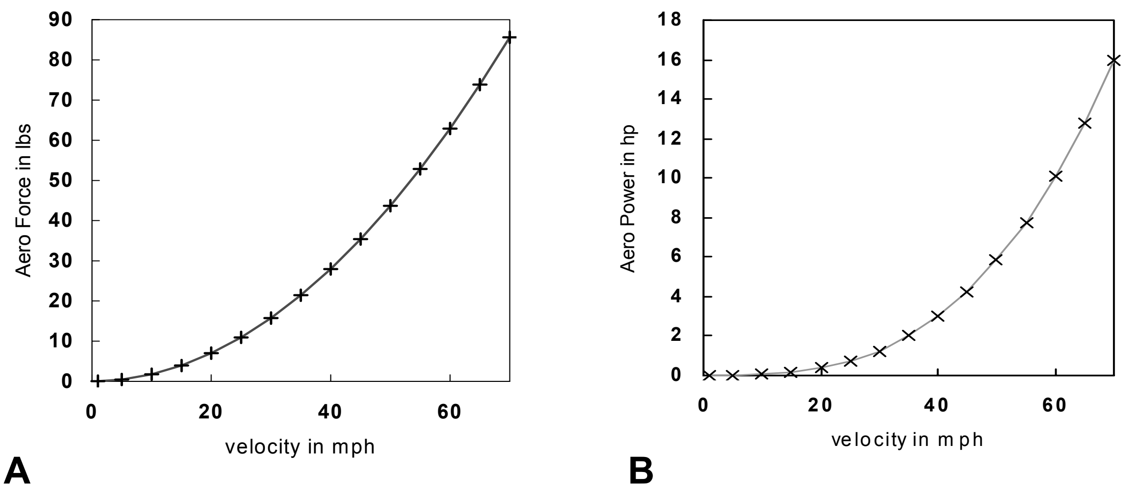

Figure 19—*Force and power to push air out of an EV's path.* Step 3.

of Figure 16 for a 7.8º , or 14%, climb.

Step 3. *Pushing air out of the vehicles way.* Air resists penetration according to the following equation in (Leitman and Brant, [***1***], p. 104):

$$F = C_d A v^2 /391 \text{ lbs}$$

Figure 19A exhibits how air drag pushes back on the Daytona body. This curve is predicated on the Daytona having about a 0.34 drag coefficient and cross-sectional area of about 20.13 ft^2 for a C_dA of 6.84.

Hence the horsepower (P = Fv) to push the air varies as to:

$$P = Fv = C_d A v^3 /391 \text{ hp}$$

Which is shown plotted on Figure 19B. Notice that energy consumption is a cubic power in velocity and hence aerodynamic drag has an important limiting effect on both top speed and on range.

Indeed, since many electric cars are quite challenged to achieve highway speeds, air drag is a very critical factor because it is spiraling up at highway speeds and can become the dominant force and power consumer.

Note: Leitman and Brandt [***1***], their page 106, discuss "wind" drag. They argue that in the United States there is a wind blowing almost always and it has an average 7.5 mph velocity relative to ground. When it blows into the front of your car it increases aerodynamic drag. When it blows from the rear it reduces the drag. However if it blows equal amounts of time in both directions they do not offset because the drag is to the second power in force and third power in horsepower. Most of the time it will blow from the side reducing both terms significantly. So in this treatment the wind drag will be treated in the same way we will assume the road is level even though few roads are actually level. If we encounter a hill it does not affect us in the "average". So to factor in a head wind, one can add the wind ve-

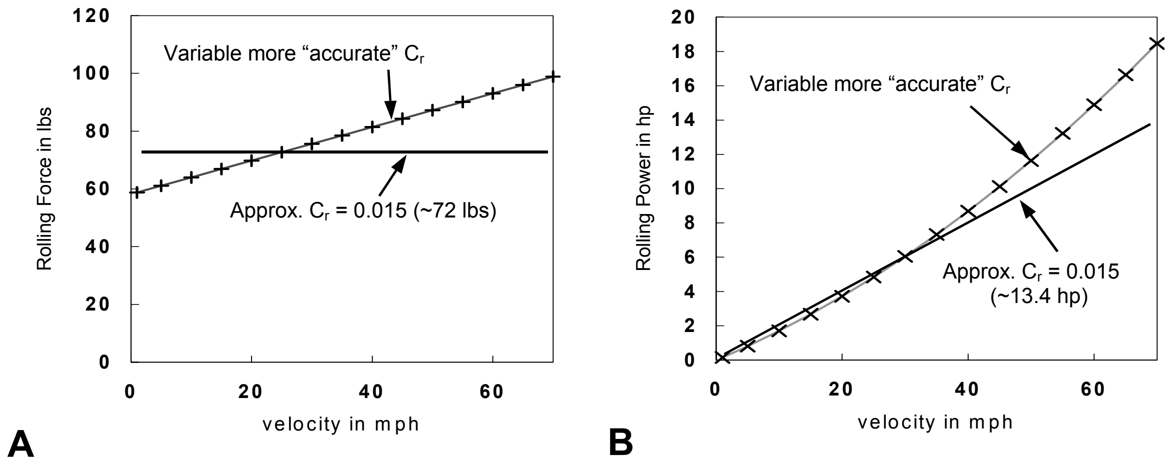

Figure 20—*Force and power to "roll" the example EV. Step 4.*

locity to the vehicle velocity, and the related spread sheet has a place to include a head wind (or negative tail wind for that matter) in the future. The default here is taken as zero mph.

Step 4. *Overcoming a vehicle's rolling friction.* Leitman and Brant ([*1*], page 109) apply the following equation for estimating rolling friction force:

$$F = C_r w \text{ Cos } \Phi$$

where Cr is a dimensionless rolling friction factor, w is the vehicle weight in pounds, and Φ is the angle of the incline. The rolling resistance factor is estimated at 0.015 for hard surfaces such as concrete, 0.08 for medium hard surfaces (not specified), and 0.3 for soft surfaces such as sand (and presumably loose snow would be even worse). For fine-tuning of accuracy, Leitman and Brant [1] suggest adjusting the rolling resistance factor with the equation:

$$C_r = 0.012\ (1 + V/100)$$

where V is the velocity in mph. This equation yields the nominal rolling resistance factor when V = 25 mph. However, algorithms on the web (both apparently traceable to the same Uve Rick's spread sheet procedure) suggest that if low rolling resistance tires are used, then the rolling resistance factor should be reduced significantly. However one cites a reduction to 0.0015 and the other a reduction to 0.00615 (the latter perhaps more plausible) and this is so large a difference that it needs to be sorted out in the future.

The corresponding horsepower required is again the product of force with velocity, P = Fv. Figure 20 exhibits rolling force (Part A) and horsepower (Part B). These curves both assume default vehicle weight of 4847 pounds (with 24 batteries weighing 61 pounds, two occupants), and level roads and show both friction coefficient factors. Clearly the difference between the more "accurate" and approximate friction factors is significant and warrants use of the more accurate equation here.

Step 5. *Sum the force and power factors.* Leitman and Brant [*1*] (their page 120) "Calculation Overview" walk through the addition of the five forces and similarly therefore horsepower requirements. Since wind resistance is being treated differently here, one would

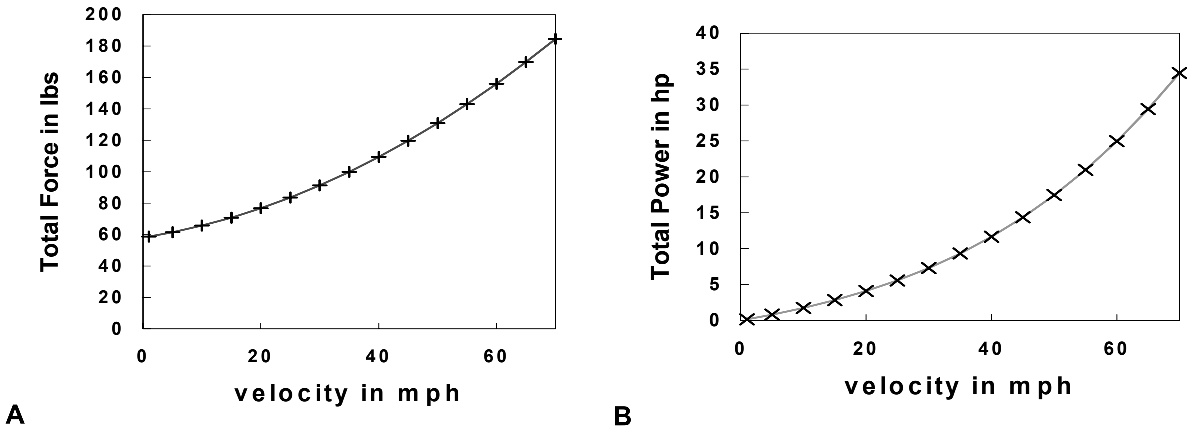

Figure 21—*Summations of four force and power terms to operate the example Cockroach EV. Step 5.*

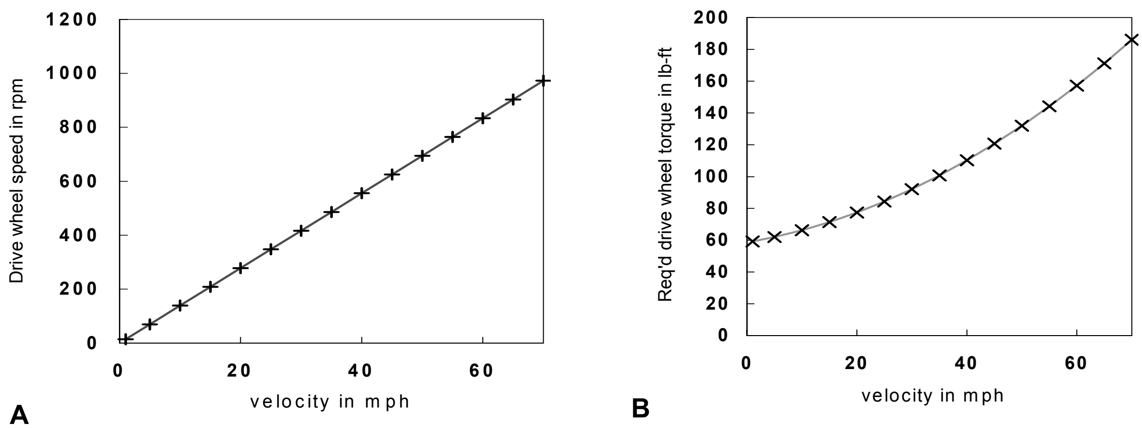

Figure 22—*Calculation of required drive wheel speed and torque. Step 6.*

sum the remaining four forces and horsepower data of Figures 16, 18, 19, and 20. In this default case for the associated spreadsheet, the steady state speed (zero acceleration force) and level road (zero incline force) is used to allow for standard interpretation of typical ATSR (level-road acceleration, top speed, and range) and is shown in Figure 21.

Step 6. *Calculate required drive wheel speed and torque.* The next two steps are shown in the reverse sequence of Leitman and Brant [***1***], their page 121, because the required drive-wheel horsepower and torque do not vary with the efficiency of the drive train (even though the order of doing the math does not change the resulting numerical value).

Drive- wheel required speed, Figure 22A, is given by the velocity of the vehicle divided by the circumference of the drive-tires.

$$S = v/2\Pi R$$

Tire diameters are used to relate drive-wheel torque, horsepower and speed to vehicle force, horsepower and velocity. Tire diameters can be looked up in manufacturer's and industry specifications but can also be calculated. For the base tire size of the Daytona,

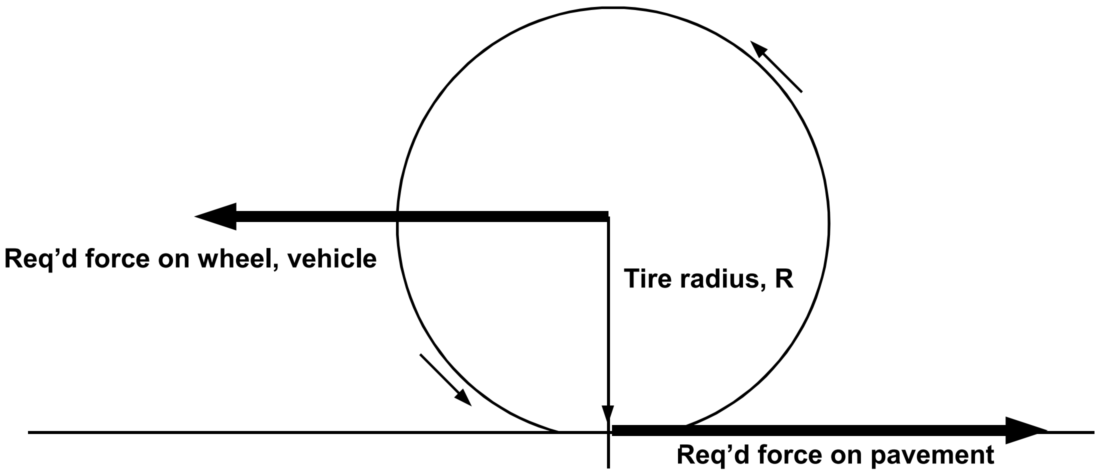

Figure 23—*Required torque to produce required force to the pavement through the tire radius.*

P185/70R14, the rim diameter is 14 inches, the 185 is the rim width in mm and the 70 indicates the aspect ratio meaning 70% of the rim width is the tire height. Hence the Daytona Cockroach tire diameter is:

= rim size + [(2 x aspect ratio/100) x (tire width/25.4)] -
(2 x (wear percent/100 x (new tread depth –3/32))

Ignoring any squat in new tires, for the default Cockroach, it is

=14 + (2x[(70/100) x 185/25.4]) - ((2x 0/100)x((13/32)-(3/32)) = 24.19685 in.

The torque radius is half this diameter (1.008202 ft).

The resulting diameter allows a circumference to be calculated to do velocity-to-tire-rpm calculations and is good, especially for radial or other belted tires. However, when calculating torque, the distance from axle to pavement is altered by the amount of deflection (squat) the weight of the car causes to the tire. There is no guidance available for estimating this deflection but measurement of it can be made for actual cars. Many EVs use the highest tire pressures allowed and low rolling friction tires are designed for high pressures and should exhibit smaller deflections than ICE cars.

Torque is defined as the component of a force perpendicular to a lever arm. Figure 23 exhibits a drive wheel in contact with pavement. In order for the total force F, calculated in the previous section to be exerted on the vehicle, an equal and opposite force F must be exerted on the pavement. The lever arm, R, (which is the radius of the drive tire) is perpendicular to the force and so for the rotational "force" the required drive wheel torque, Figure 22B, is FxR = T. With the earlier data the required torque can also be calculated as:

$$T_r = Px5252/S$$

Steps 7-12. *Calculate Limits on Available Torque and Speed to Safely Operate the Vehicle for each Gear.* Manufacturers specify the maximum safe speed a motor can produce before wear, or centrifugal rupture are at a risk, and the maximum safe current the controller will supply to a motor before the controller is at risk. Chapter 3 proposed equations of state to predict motor current versus torque, and motor speed versus torque based upon the variables of battery pack internal voltage and internal resistance, motor controller resistance, and motor resistance. This allowed example motor performance curves of Figures 5, 6 and 7 having more practical internal resistance and voltage properties than vendor curves provide and allowing estimates of safe boundaries for motor electrical and friction dissipation. Figure 24 (Steps 7-11) depicts all three of these estimates for each gear.

When the motor is spinning at its limiting speed, S, typically cited as 6000 (sometimes as 7000 rpm), then the equivalent road speed (mph) is

$$V = S / (5280 \text{ x gear ratio x differential ratio} / 60 \text{ x } 3.1416 \text{ x tire diameter}/12)$$

This is shown on the plots of Figure 24 as a vertical dotted line. Typically for higher gears, the line does not appear on the plot since it is greater than the right hand edge of the graph.

The available torque limit resulting from the controller current limit is given by using the current equation of state [$I = 40 + (T/0.0714)^{(1/1.19999)}$] on page 164] to obtain motor torque for the limit current and then multiplying by the gear and differential ratios and drivetrain efficiency factor as:

$$T = [0.0714\text{x}(I - 40)^{1.19999}]\text{x gear ratio x differential ratio x efficiency factor}$$

This limit is shown on the plots of Figure 24 as a dotted horizontal line that covers the velocity range from 1 mph to where it intersects the maximum velocity limit calculated above.

The motor power dissipation limits P_m (in hp) for continuous, one hour and five minute service are developed in Chapter 4, pages 171 –176, given as:

$$P_m = V_sI/746 - I^2(R_s + R_c)/746 - T_DS_m/5252$$

which after converting motor speed, S, into vehicle mph, and motor delivered torque, T_d, into drive wheel available torque resolves to:

$$T_D = \text{Gear ratio x Differential ratio x efficiency x (motor current } - 40)^{1.19999} \text{ x } 0.0714$$

Where: $\text{motor current} = ((P_m - ((\text{motor rpm}*1.84)/5252))*746/\text{motor resistance})^{0.5}$

Figure 24 exhibits the safe torque limits for continuous, one-hour, and five minute periods of operation for three battery pack states of charge: the default example uses estimates for full charge, 60% charge, and 20% charge.

Figure 25, page 206, (step 12) re-plots the temperature limits for the three estimated battery charge states, with each curve containing the five gear possibilities. Some of these limits of Figures 24 and 25 are rigid (like the motor-rpm limit) some are automatic (like the controller current control) and some are recommendations (like the continuous, one hour, and five-minute dissipation estimates).

With regard to the dissipation estimates, as Kettering taught us (Volume 1, page 14) one can safely overload the motor (and batteries for that matter) if they offset the excess with appropriate time reductions (so that the total heat transfer is the same). We will see later that the wisdom to do that is a vital skill or else a control to do this must be designed into the motor controller circuitry.

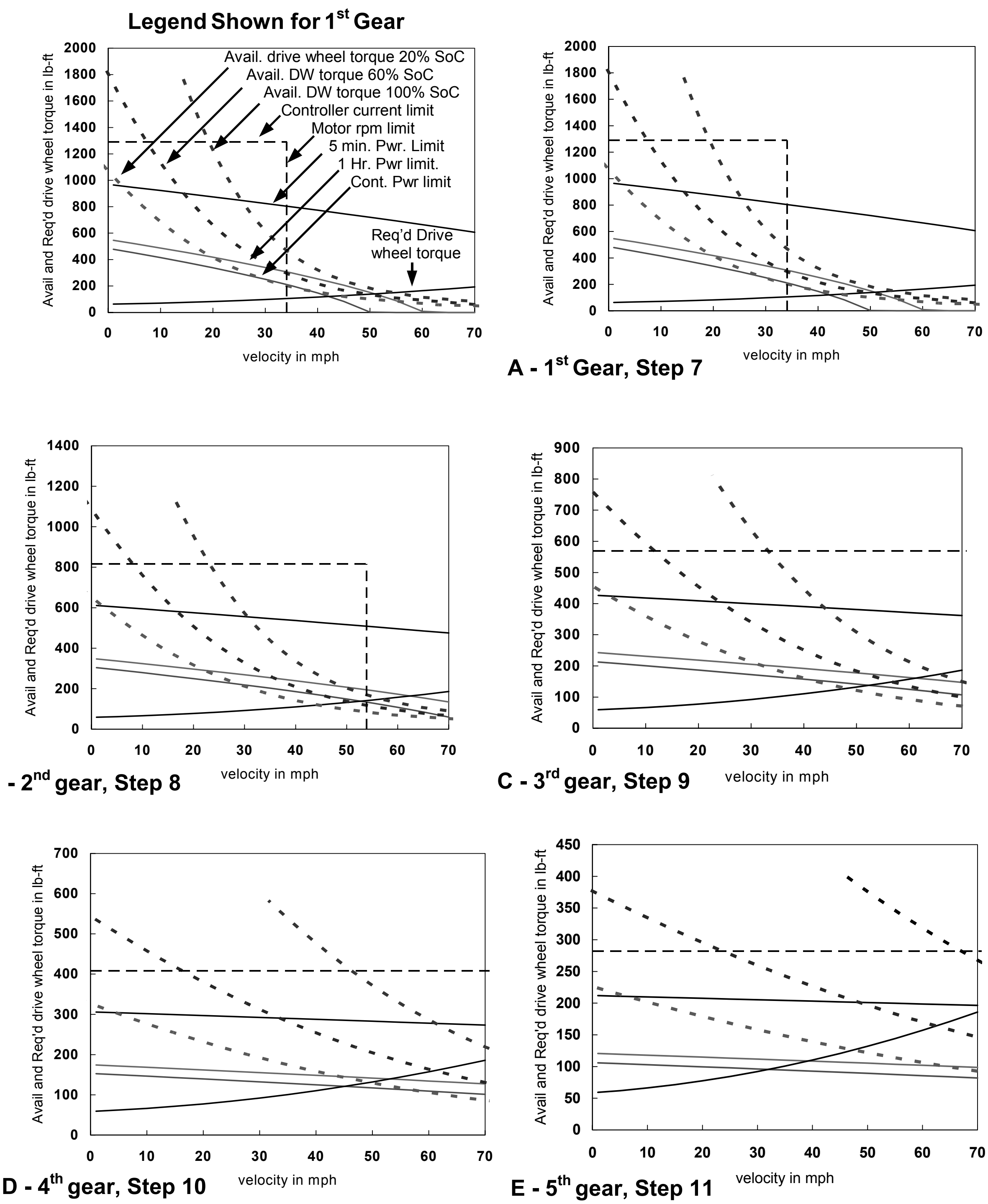

Figure 24—*Required drive wheel torque, available drive- wheel torque including drive train efficiency for three states of charge, and estimated power dissipation limits for each gear vs. velocity. Steps 7-11.*

Step 13. *Calculate Motor Maximum Steady-State Current, Shaft Speed, Motor Power, and Motor Efficiency Versus Motor Delivered Torque for Each Battery Pack State of Charge.* The motor equation of state for current ($I = 40 + (T/0.0714)^{(1/1.19999)}$ on page 164)

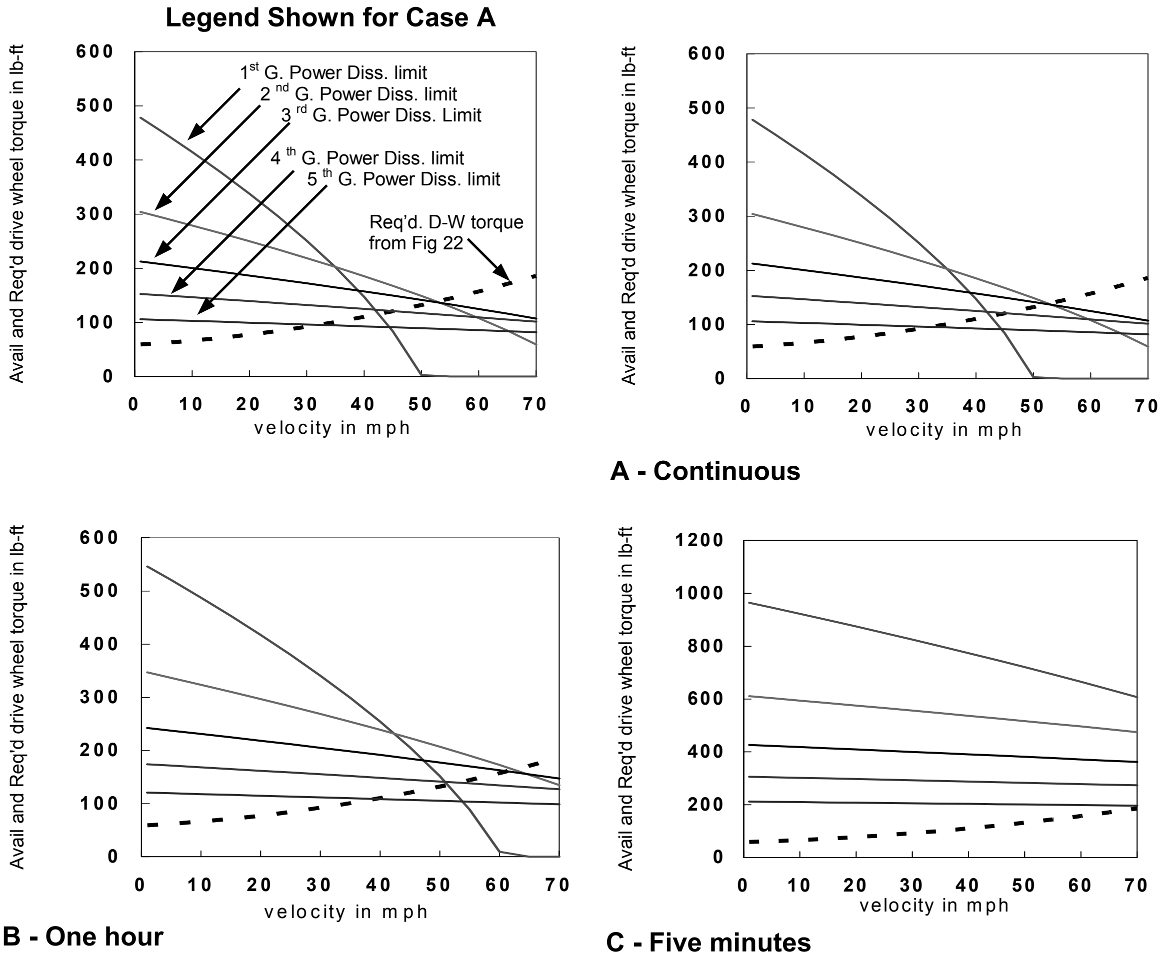

Figure 25—*Required and available drive- wheel torque including drive train efficiency as limited by power-dissipation estimates in each gear vs. velocity. Step 12.*

was used in Steps 7-12 and is now plotted in Figure 26 Part A. Notice there is only one curve, because the texts treat motor torque as purely a function of current regardless of voltage at the motor terminals. Motor steady state speed as a function of torque is given by the other equation of state from page 161:

$$V_sI/746 - I^2(R_s + R_c + R_m)/746 - T_fS_m/5252 = T_DS_m/5252 = P_D$$

This equation yields the three curves shown on Figure 26 Part B. Two of these curves are comparable to those produced for Figure 5.

Figure 26 Part C, exhibits motor delivered power in the style of Figure 6 using the data from Part B and the equation:

$$P = TS/5252$$

Finally, Part D exhibits the efficiency for these three States of Charge by dividing the power delivered in Part C by the power by the battery pack (Efficiency = 100 x $P_{ou}t/P_{in}$):

Efficiency = 100 x Power delivered /
(Volts per battery x battery count x motor current /746)

Steps 14-16. *Calculate Motor Maximum Steady-State Available Torque Versus Vehi-*

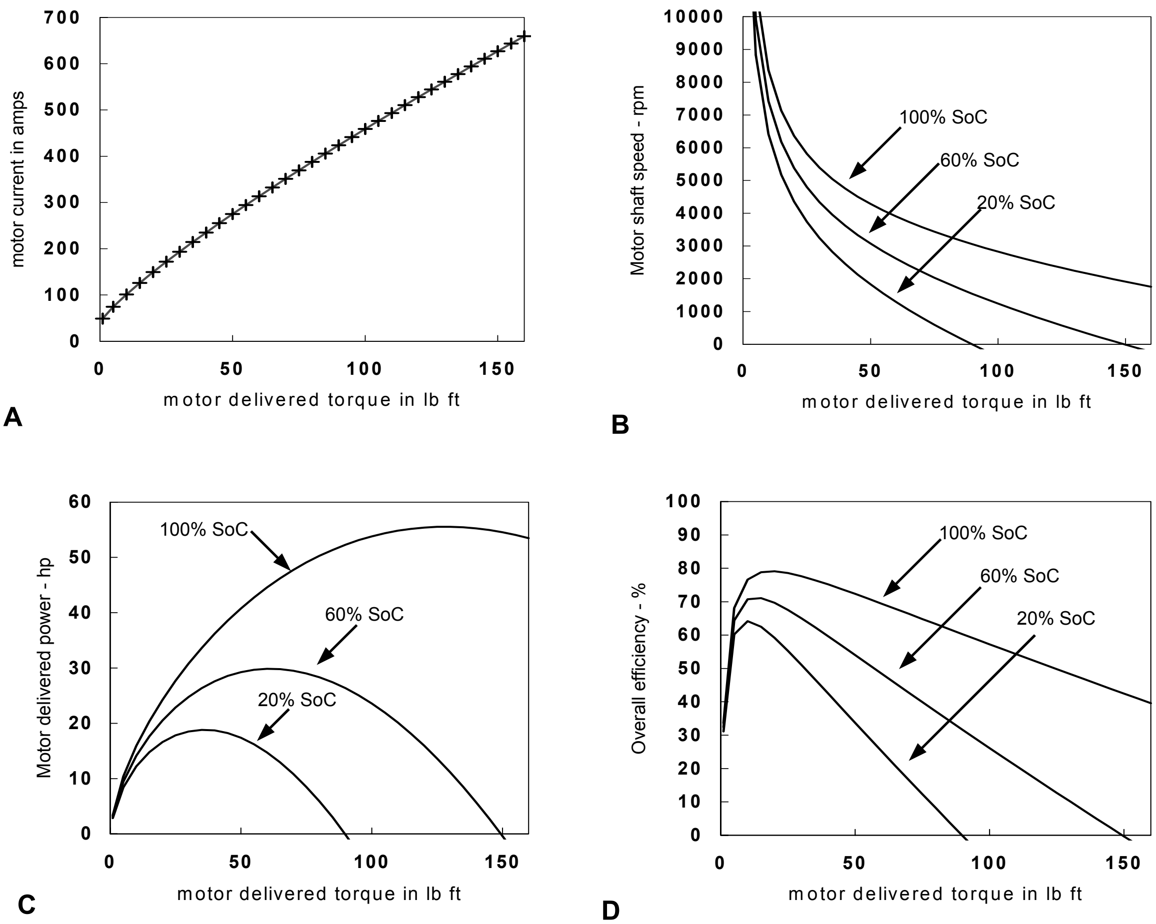

Figure 26—*Motor current (A), speed (B), power (C), and efficiency (D) as a function of torque (Step 13).*

cle Velocity For Each Gear for Each Battery Pack State of Charge. The motor torque values of step 13, Fig. 26 Part B, are multiplied by the drive-train efficiency and then by the gear ratio and differential ratio, while the respective shaft speeds are divided by the gear and differential ratios and then converted to velocity using the tire circumference from Step 5.

Figure 27 exhibits results for the three SoCs. The rpm and controller current limits are also shown for reference. The required drive-wheel torque versus velocity is obtained from Figure 22, Part B.

Step 17. *Reorganize the data of steps 14-16 into plots of Maximum Vehicle Velocity for each State of Charge for Each Gear.* Figure 28 is merely the portrayal of five graphs of three curves each extracted from the previous three graphs of five curves each. All of these curves also include the respective data for the required torque levels calculated in Steps 7-11.

Steps 18-20. *Estimate the Maximum Available Torque at Each Velocity and Then the Minimum Time Required to Accelerate to Speed and Compare to a Benchmark.* Steps 14 through 16 calculated the torque/velocity relationships for all five gears. The vehicle velocity increments for which there are *available* torque data do not in general correspond to the ve-

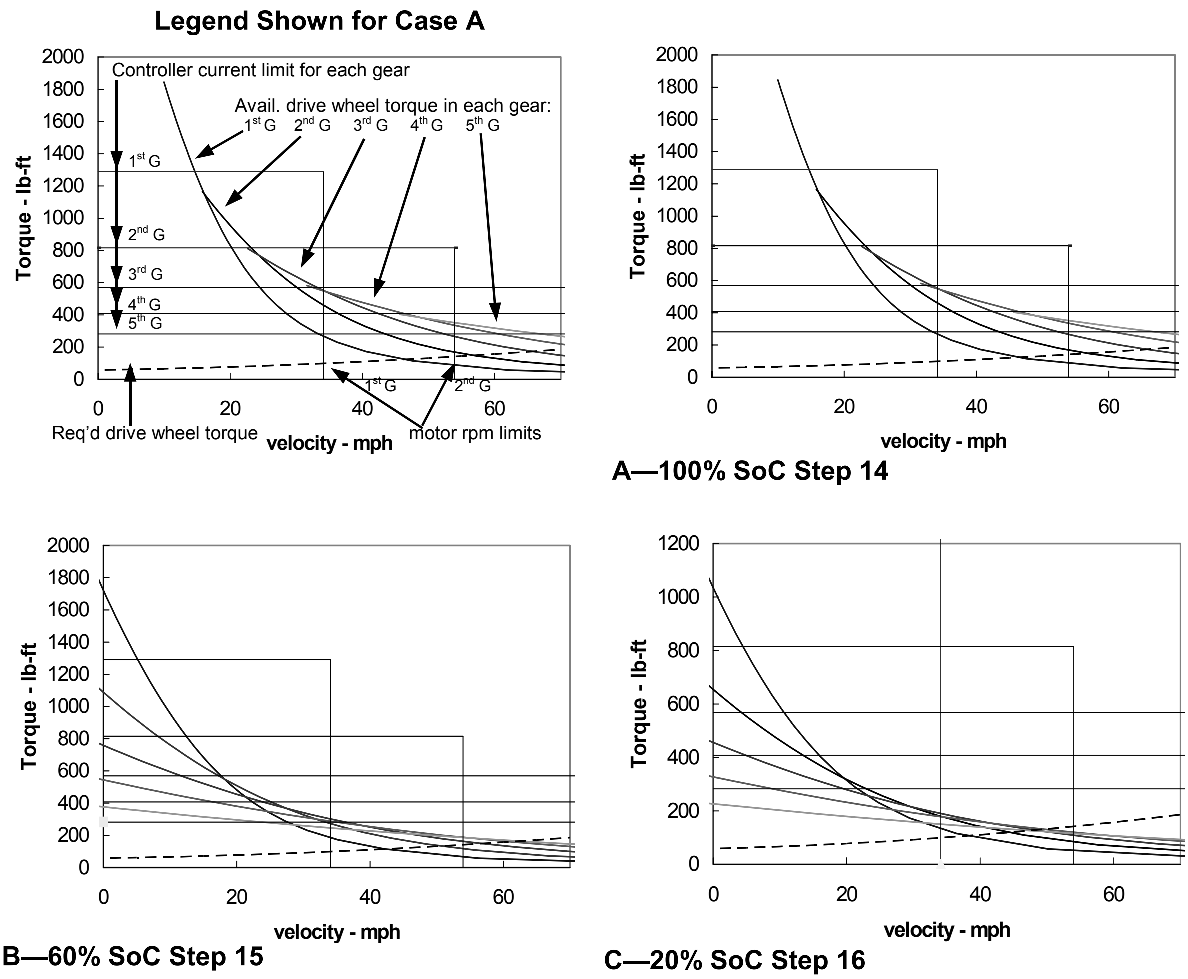

Figure 27—Available and r*equired drive-wheel torque in each gear for three SoCs. Steps 14-16.*

hicle velocity increments for which there are *required* torque data points.

To calculate acceleration rates one can subtract the required torque at any speed from the available torque at that speed and if greater than zero, any acceleration will be proportional to that difference. If equal, then the vehicle is at its top speed for that situation. If negative then the vehicle is decelerating. Hence the resulting available torque data points need to "fit" with the same velocity points as were used for the required torque data.

However, since these curves exhibit only a rather gradual curvature, and have no points of inflection, and are calculated here over short intervals of differential velocity, one can interpolate the available data points to estimate corresponding available torques for each required torque point and consequently allow calculation of incremental acceleration times. Figure 29, page 210 illustrates the interpolation method used here and in the associated spreadsheet.

Figure 30 Parts A,C, and E, page 211 illustrate the optimum torque and shifting curves for best-case acceleration of the example Cockroach at the theoretical three states of charge (100%, 60%, and 20%). These optimum curves are based on maximizing the available torque delivered by the motor. The flat, horizontal, sections are where the controller current limits the torque and the sloping, curved, regions are where the produced torque is

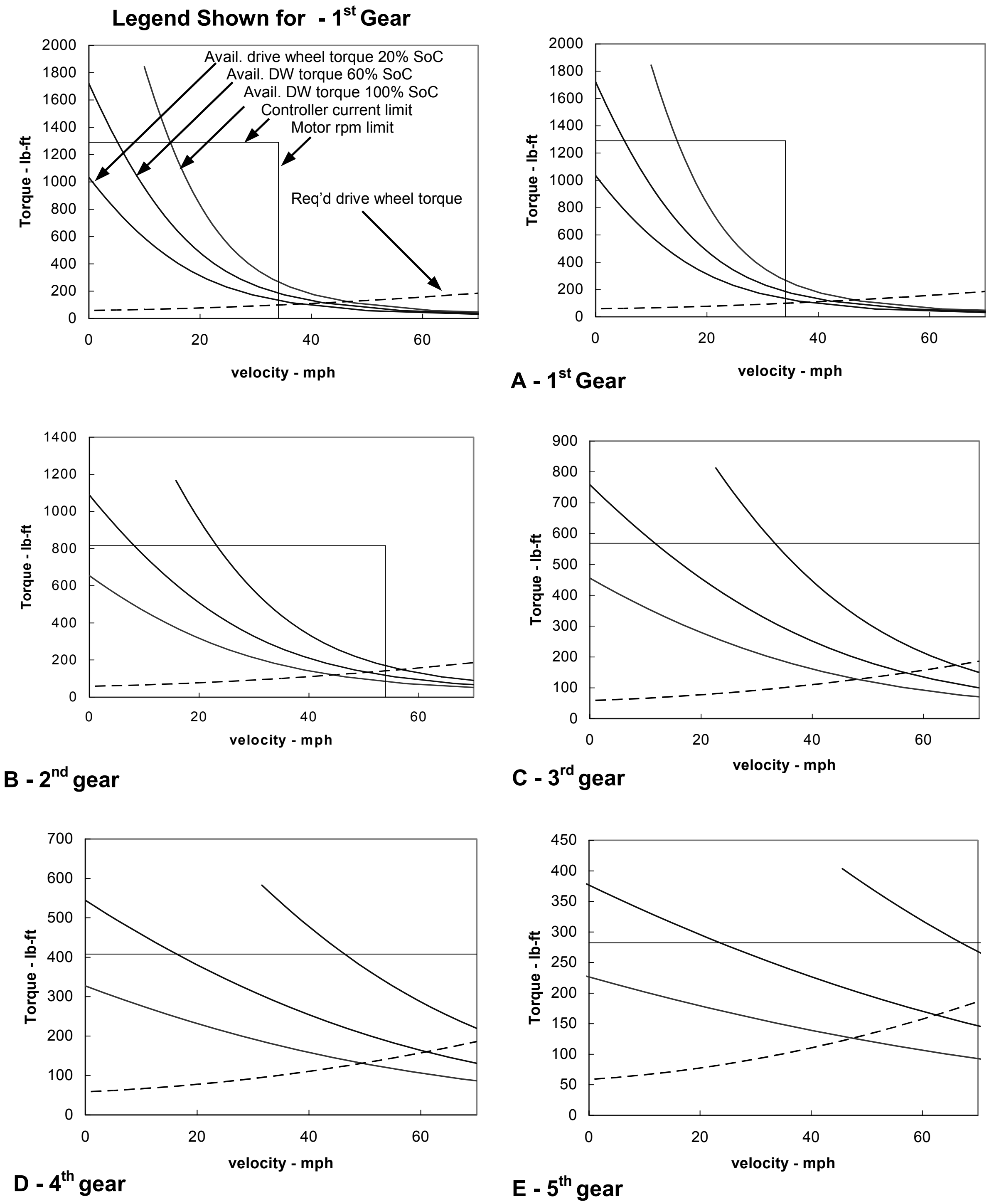

Figure 28—*Replot of data in Figure 27 for the three states of charge in each gear versus velocity. Step 17.*

less than those limits, until a velocity is achieved where the torque in a higher gear would be greater.

Figure 30, Parts B, D, and F, page 211, plot the resulting acceleration curves for the three states of charge (100%, 60%, 20%) examined earlier. For these plots the average accelera-

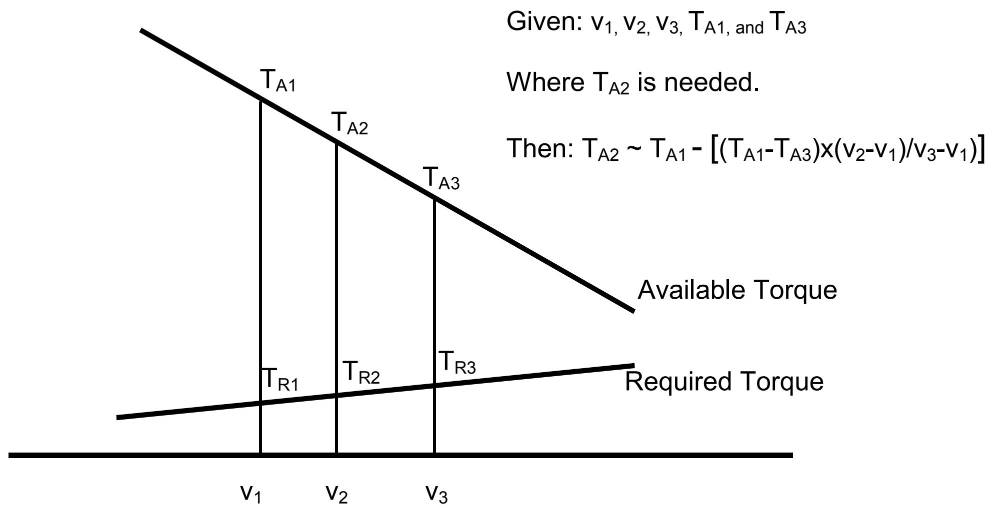

Figure 29—*Interpolation of Available Torque Data.*

tion was estimated over roughly 5 mph differentials in velocity which were summed. This was done using the equations,

$$F = Ma, \text{ therefore } a = F/M = \Delta v/\Delta t$$

and

$$\text{Force, } F = \text{Torque, } T, \text{ x Tire radius}$$

And after adjusting for units,

$$\Delta t = ((v_2-v_1)/(T_2-T_1)) \text{ x tire diameter x car weight x } 5280/\ 32.2 \text{ x } 12 \text{ x} 3600 \text{ seconds}$$

Step 21 Compare Cockroach to 1960s Corvairs. Figure 31, page 212, exhibits these accelerations in comparison to benchmark plots of data that were extracted from test reports of the 1960s Corvairs published by *Car Life* [***24***] magazine. Notice that for the default Cockroach, these estimates affirm its "dog-like performance. The full-charge example Cockroach would accelerate like the slowest Corvair variant at higher legal speeds, but would be much more competitive in its normative "city-car" capacity at lower speeds (below perhaps 30 mph). And keep in mind these estimates are for the maximum-case performance possible using Kettering Overloads. If one observes the safe continuous rating, the less-safe one-hour rating or even the least safe five-minute motor power dissipation ratings, these acceleration and top speeds (per Step 12) will be up to several times slower. And still slower when the battery pack is 80% discharged. Therefore because use of the Kettering Overload Practices is crucial to even minimally acceptable acceleration times, methods to improve or manage the motor's dissipation rating (hopefully short of an expensive water-jacketed cooling systems) are as worthwhile as improving battery performance is to highway range performance. Speculation on both of these is provided later.

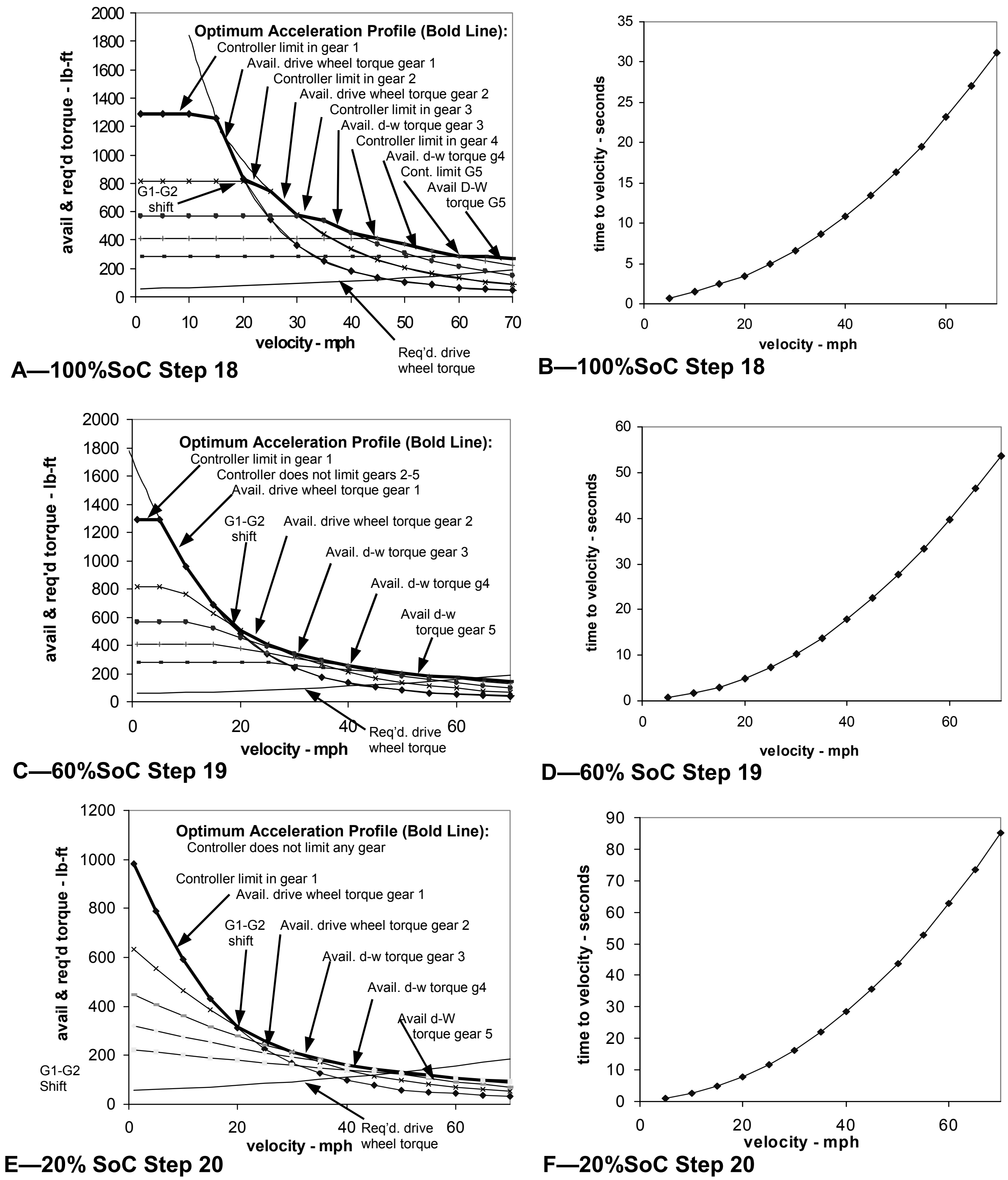

Figure 30—*Optimum acceleration profiles (left side) and resulting time-to-speed (right side). Steps 18-20.*

Range Estimates

To estimate range two sets of preliminary calculations are needed (1) for the current requirements needed at speed and (2) the time the battery pack will provide those currents.

Step 22. *Calculate Real-Case Battery Pack, Level Road, Full Charge Constant-*

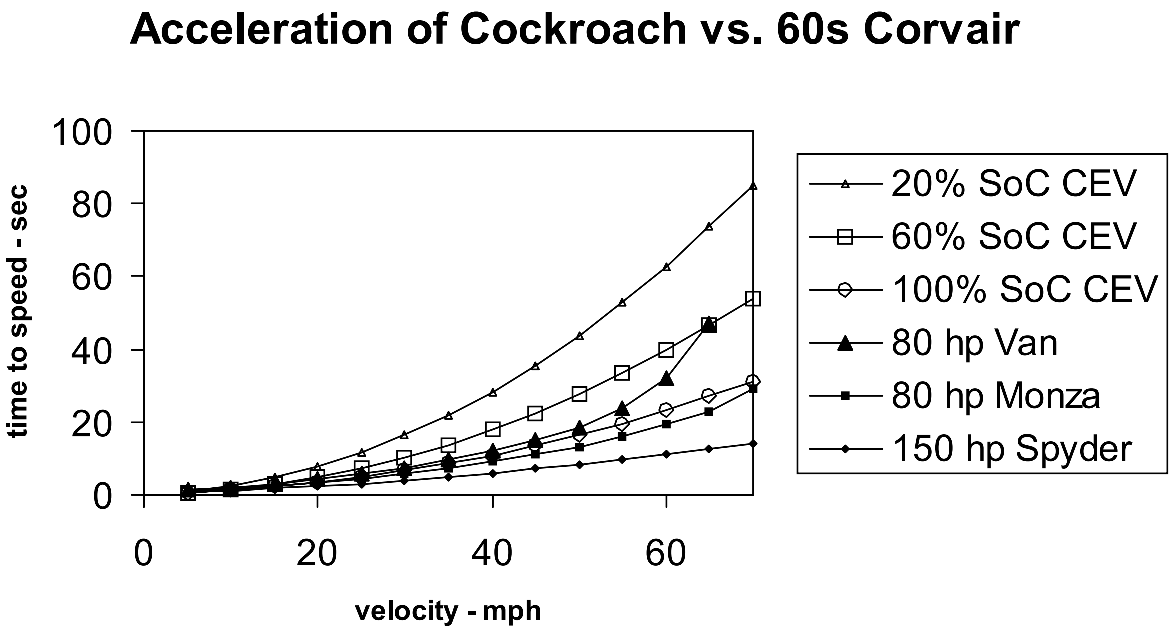

Figure 31—*Estimates of Signature Cockroach Acceleration versus 1960s Corvairs. Step 21.*

Current Requirement, To calculate motor current requirement the motor toque requirements calculated in Step 6 are divided by the drive train efficiency and gear ratios then inserted into the equation of state for motor current:

Req'd amps = ((Req'd drive wheel torque / (differential ratio x gear ratio x drive train efficiency x 0.0714))^0.83334) + 40

These calculations are exhibited as Part A of Figure 32 for the quintessential Cockroach EV example.

Step 23. *Calculate Real-Case Battery Pack, Level Road, Full-Charge Constant-Current Discharge Time.* To calculate the time the battery pack can be drained at velocity (subject to the significant errors that may be present due to constant-power not just constant-current requirements, page 243) the Peukert-like (or actual Peukert Equation as the case may be) developed on pages 187, 252 is used.

Discharge time = 405.77/(Req'd current$^{\wedge 1.228}$)

These calculations are exhibited as Part B of Figure 32 for the quintessential Cockroach EV example.

Step 24 *Estimate the Best-Case Range Level-Road Steady Speed, Full-Charge with No Losses in the Batteries, Controller, or Motor, and also for Chemically-Limited Battery Energy Per Constant-Current Testing.* The best-case level-road, constant speed range is treated here as reviewed in Chapter 5, pages 180-182, by estimating the maximum chemical energy that can be extracted from the battery pack and dividing it (treating it as fungible) by the energy the Cockroach expends per mile at any given speed as calculated with Steps 1-6

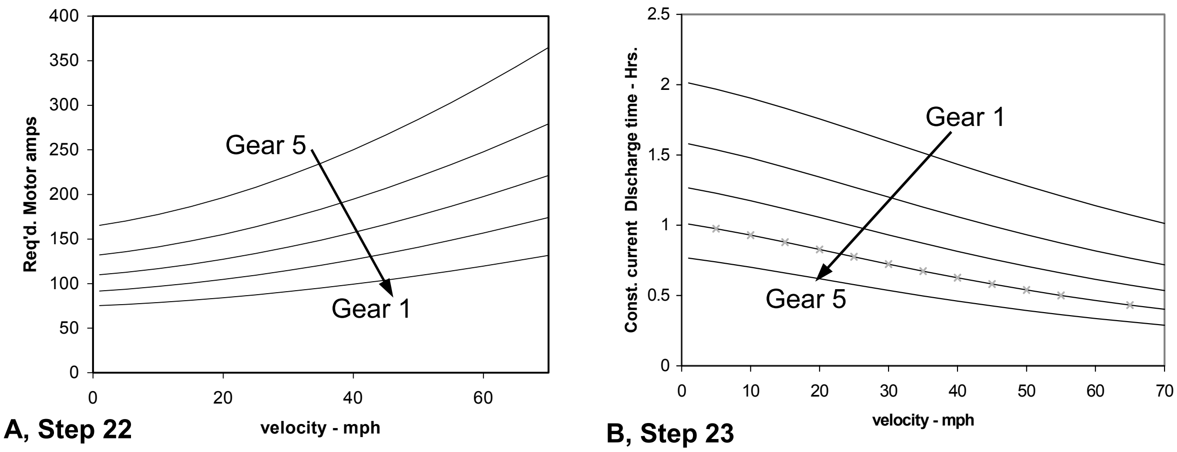

Figure 32—Required motor current and constant-current discharge time estimates. *Steps 22 and 23*.

(with incline and acceleration of zero) .

For the best case of the example Cockroach, the battery pack here is taken as a nominal 6 volt per battery source with a 250 amp-hour capacity times the number of batteries, divided by the power required to maintain any given velocity as calculated in:

Best-Case Fungible Energy Range = battery count x nominal voltage x
max. amp-hr rating x velocity / ((req'd aero drag hp + rolling friction hp) x 746)

These data are plotted as Figure 33 with the square markers, and show the absolute maximum range they could be anticipated but are in fact much better than most of the ranges being obtained from lead-acid battery-based conversion EVs today. They assume the full battery chemistry can be used and that the drive train efficiency, motor and controller and battery efficiencies are all 100% (but they are, in fact, significantly less). Clearly these loss mechanisms can reduce the range significantly. Figure 7, page 170, shows how efficiency of the overall system can vary with state of charge and system base voltage.

The lower two curves (circle and triangle markers) of Figure 33 exhibit how the incomplete reaction of battery chemicals (Appendix A) reduces best-case range estimates even in the absence of parasitic losses. To adjust the best case curves, the chemistry-limited amp-hour capacity of the battery pack is calculated by multiplying the data of Steps 22 and 23 and inserting into the previous equation as:

Chemically Limited Fungible-Energy Range = battery count x nominal voltage x
req'd current x discharge time at req'd current in gear x velocity x
drive-shaft efficiency factor / (req'd aero drag hp + rolling friction hp) x 746

Figure 33 exhibits the range estimates for first gear (circle markers) and fifth gear (triangle markers) which bracket the other three gears. Notice that the chemistry limitations produce a major reduction (about 50%) in the theoretical available range.

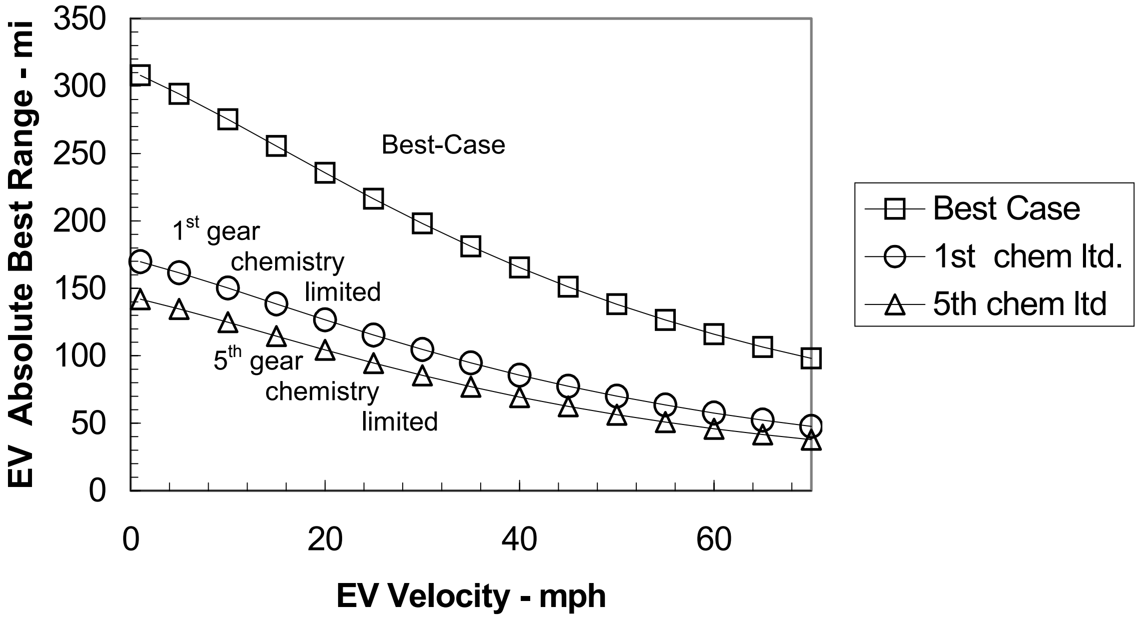

Figure 33—*Best-Case Range Estimates. Step 24.*

Estimate a More Realistic-Case Range

Step 25. *Estimate real-case fungible energy range with resistance and friction losses*

When steady state current flows to provide motion, the current wastes energy in heating the internal resistance of the battery, the controller, and the resistive windings of the motor, and in friction heating in the motor. These loses add to the power required by aerodynamic and rolling friction drags. Bold face font indicates how the equation of Step 24 expands:

Chemically Limited Fungible-Energy Range = battery count x nominal voltage x
required current draw x battery discharge time at req'd current in gear x
velocity x drive train efficiency / (((aerodynamic drag power +
rolling friction power **)** x 746) + **(reg'd motor current^2 x**
(controller R + motor R + (battery count x battery R))) +
(motor rpm x (2850 rpm friction loss/2850 rpm) **x** 746))

Range estimates for all five gears are shown in Figure 34 along with the chemistry limited and best-case curves of Figure 33 included for context. Note that although curves are shown for all five gears up to 70 mph, each gear may is limited in how far it can actually be used. For the signature example Cockroach paradigm, first gear is limited to ~34 mph, second gear to ~54, in order to prevent centrifugal motor rupture above ~6000 motor RPM.

The more realistic real-case range estimates here are much more involved and warrant some discussion.

There is always a chance the humble writer has blown the math and may need to issue a correction when others get to analyze it. However for the math as proposed, notice that

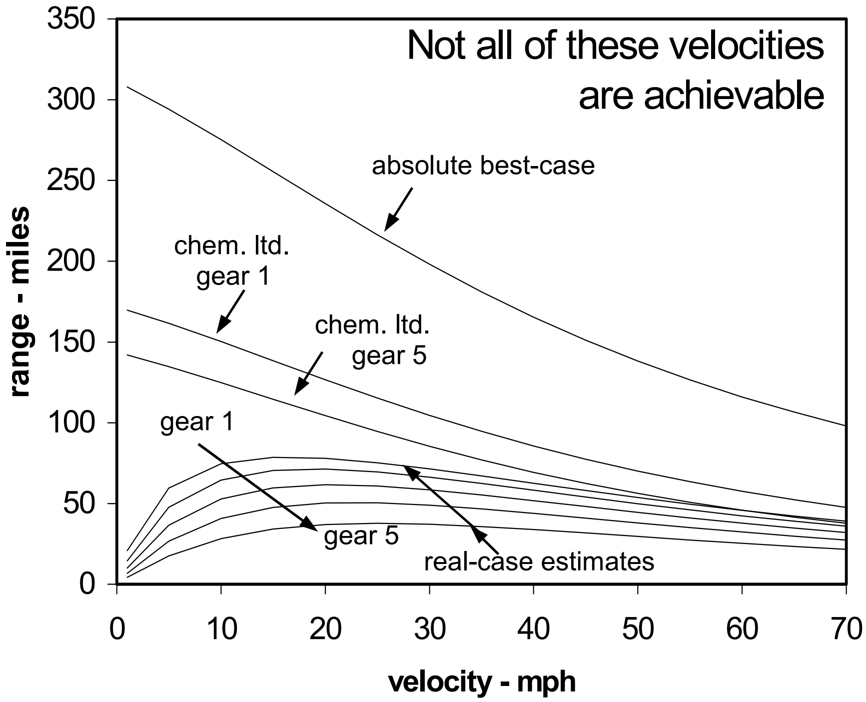

Figure 34—*Best-Case, chemistry-limited case and best estimate case range estimates. Step 25. Based on a single series string of 24 batteries.*

it appears at present (if this is correct) that the individual gear ranges do not intersect and each exhibits a maximum. Furthermore at very low speeds, the range falls off quite a bit. These suggest that still lower gear ratios might be useful and the writer is considering testing that hypothesis. Keep in mind that if one doubles the differential ratio, to halve the overall ratio for all five gears, then first gear would be only useable to 17 mph, second gear to 27 mph but if it provides for more low speed range (assuming these estimates have merit), it would be worth it. But perhaps someone will notice a flaw.

Also, Appendix B posits that there would be benefit in running a variable series/ parallel battery connection scheme. For example 24 batteries can be used as a series connected 144 volt pack, or as a 72 volt parallel pack with 12 series batteries in each parallel string, or as a 48 volt parallel pack with eight series batteries in three parallel strings, or as a 36 volt parallel pack with six series batteries in each of four parallel strings, etc. These contingencies can be phonied into the associated spread sheet by specifying a 12 battery pack with 122 pound batteries instead of 61 pound batteries, and with half the internal resistance (0.002 versus 0.004 ohms) and twice the ampere-hour rating (500 instead of 250 ampere-hours) however, the spreadsheet has included a final Step 26 (Parts A for two strings of 12, B for 3 strings of eight, and C for four strings of six) to illustrate that although high voltage benefits acceleration, lower voltages (as in parallel strings) can benefit range. For the case of two strings, instead of all the current running though the full series resistance, half the current runs through half the resistance, and this should result in more battery energy being used for motion and *most importantly* less being used for battery heating. Since many a conversion EV has been sold when the owner drove too far or for too long and (I believe literally) "smoked the batteries", the reduction of battery heating possible might argue that most driving should be done in this "overdrive" simulation mode and a switch should connect the strings in series when "power-pack" , "passing gear" or "kick-down" performance is needed.

This then leads to further obvious extrapolation. If two, and three and four-strings in parallel can yield benefit, how about higher numbers. And some of these clearly would yield similar estimated range improvements...if they could provide a practical vehicle velocity. All of these alternatives can be phonied up in the spread sheet. They doubtless will each yield diminishing returns, but for 24 batteries one can play what-if for 1x24, 2x12, 3x8, 4x6, 6x4, 8x3, 12x2, and 1x24 combinations.

Step 26. *Estimate real-case fungible-energy parallel- battery strings "overdrive" operation*

To estimate range performance of a battery pack split into N parallel strings, in the equation of Step 25, one must divide the battery count by N, multiply the battery discharge time by $N^{1.228}$, and divide the product of battery count and battery resistance by N^2. The range equation of Step 25 changes as shown with bold-face font :

Real-Case Range = **(**battery count/**N)** x nominal voltage x
required current draw x battery discharge time x $\mathbf{N^{1.228}}$ x
velocity x drive train efficiency / (aerodynamic drag power +
rolling friction power + (reg'd motor current**)**^{2} x (controller R +
motor R + (battery count x battery R **/ (**$\mathbf{N^2}$**)**)) + (motor rpm x
(2850 rpm friction loss / 2850 rpm)) x 746)

This results because the equivalent battery pack has a voltage of 1/n times the series connection, its resistive heating is controlled by its equivalent resistance of N battery resistances in parallel ($R_{battery}$ /N) times a length of 1/N times the total battery count, and finally with an equivalent draw time based on 1/N times the total current per string or

$$t = [405.77 / (\text{req. current}/N)]^{1.228} = [(405.77 / \text{req. current})^{1.228}] \times [N^{1.228}]$$

More detail on this is presented in Appendix B. The graphs for the cases N = 2, 3, and 4 strings are shown as Figures 35, 36, and 37. If this analysis has any merit, this suggests a way to significantly improve the range of Cockroach EVs.

This approach must also be taken to determine the estimated top speed and acceleration of parallel string batteries. Fortunately while top speed in gear drops significantly withparallel strings, low speed acceleration is altered less, and so even a 24 battery EV like the Cockroach Signature example, may be drivable in city service with the greater range-ability premium of parallel connection.

Cautionery Final Note

Some of these analyses make the standard assumption that battery energy is fungible (that it is interchangeable in how it is used). To wit, that there is a rough equality between energizing a motor at a low voltage continuously and energizing it at a chopped higher voltage for briefer periods of time. This is, perhaps, rooted in the presence of reactive components in the system, including capacitance in the battery and controller and inductance in the

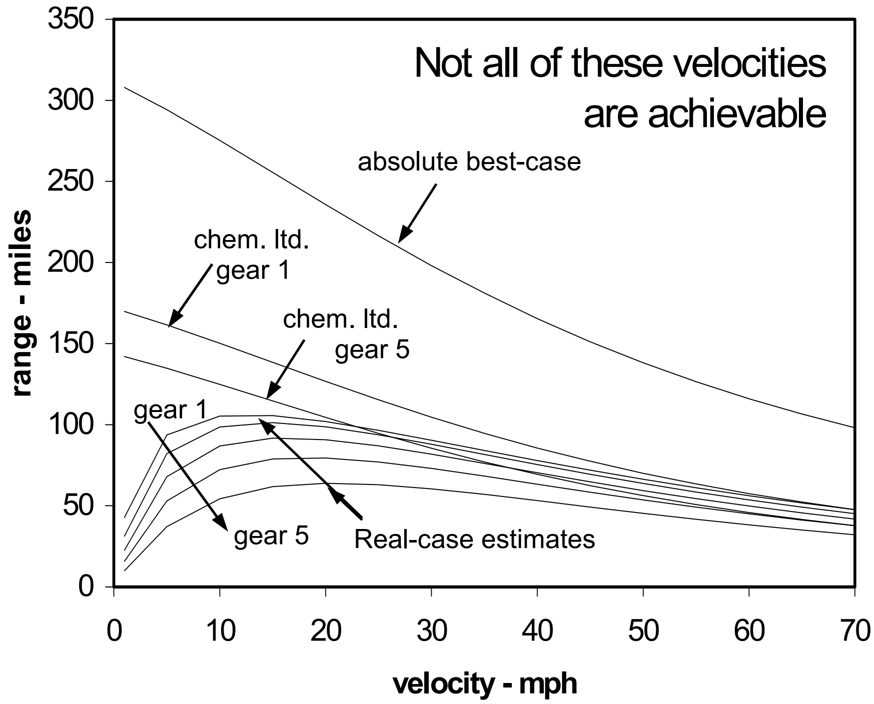

Figure 35—*Range estimates for two strings of 12 batteries each. Step 26A.*

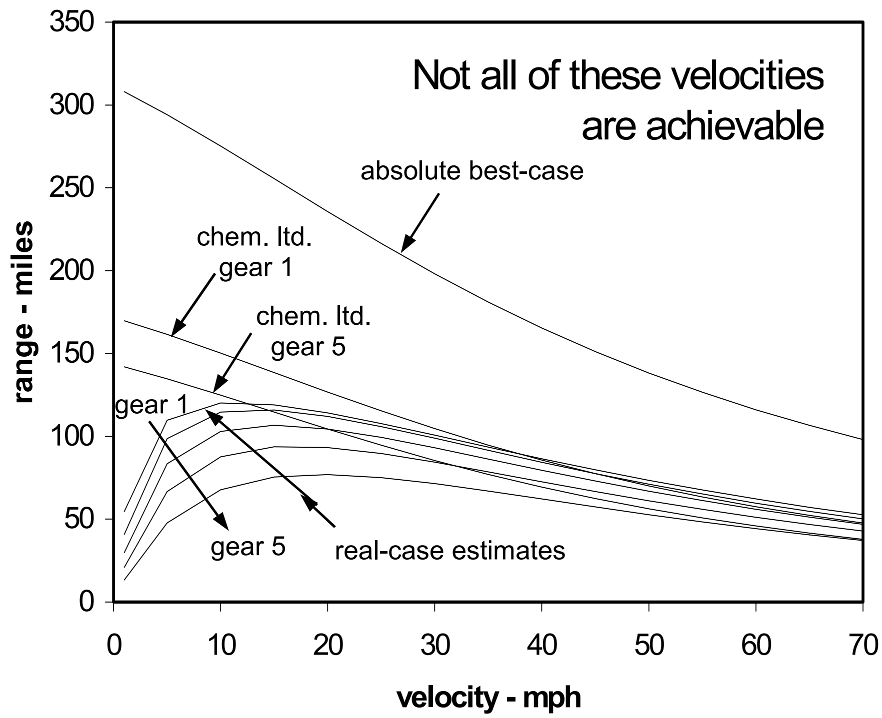

Figure 36—*Range estimates for three series strings of 8 batteries, each. Step 26B.*

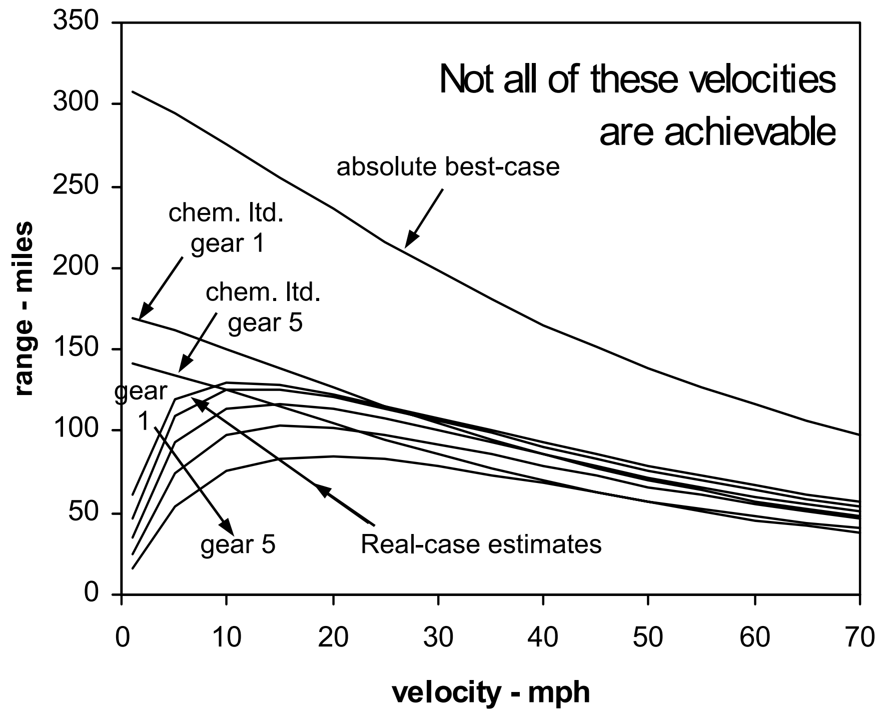

Figure 37—*Range estimates for four series strings of 6 batteries, each. Step 26C.*

motor. All of these can store and filter or resist energy flows and thereby could average out what is happening. This is unlikely to be a precise relationship (unlike D'Arsonval meters that are excellent at reading average current when fed chopped square waves).

Mathematically, chopped and constant current can be much different in a resistive system. Appendix C illustrates how a chopped higher voltage source that yields a higher periodic current of the same delivered power as a constant lower voltage source, can suffer greater relative resistive loses and therefore be less efficient. This requires RMS (root mean square) calculations but that requires precise waveform shape data which are not available here.

To the extent that this effect takes place in a chopped EV system, can mean that actual range estimates may be lower than those calculated, and therefore, it may be desirable to break the battery pack into as many lower voltage parallel strings as possible, when operating at velocities that allow lower voltage and therefore a greater duty cycle that should provide better efficiency.

Also, operating a battery pack as a single series string can allow some batteries to fall out of balance. Some warm more than others and their voltages will change in consequence. Suddenly connecting them in parallel may be problematic if the imbalance is too great. More discussion of this prospect is included in Appendix B.

Thus endeth this performance analysis.

7

A Cockroach EV Performance Spread Sheet

Chapter 6 worked slowly, and hopefully correctly, through a rather detailed calculation in sufficient detail so that conversion of the entire process into a spread sheet should be straight forward if a bit onerous. Indeed, the figures in this book were generated with various components of the writer's own spread sheet, coded originally in Lotus 1,2,3. However, this book claims to be in the spirit of a public duty, public service, which is why it is donated to the public domain and electronic pdf copies are free and the writer seeks to convince on-demand printers (Amazon, GoogleBooks and others) to allow archiving of the electronic files so that single or bulk on-demand copies can be ordered for the cost of printing. Therefore (under protest) all of the elements have been merged into a single Microsoft Excel 97 spread sheet (with a small number of Visual Basic for Applications macros) and copies are free (but certainly, as is, use at your own risk, and without warranty) in the spirit of the GNUGPL (GNU General Public License). With apologies for any flaws that may be present, that will hopefully be identified and worked out, you are free to use and modify the file at your own risk, but if you modify it you must rename it so there is no confusion with my original, and you can not sell modifications for profit (If you wish to profit, write your own from scratch). A copy may later be prepared in Open Office, if anyone actually ever reads these volumes.

The associated spreadsheet, Cockroach1.xls, is divided into several sections, Figure 38. First on its upper left side, Section A, it populates the input cells with default data for the Dodge Daytona-based quintessential Cockroach (page 149) and other commercial hardware and the same configuration data (24 batteries, 0.004 ohm/battery resistance, 6.37 volt full charge/battery, etc.) used to generate the figures in the previous chapter. Some of the cells are locked to prevent inadvertent alteration of the defaults, however, for the bold of heart, the spreadsheet is not pass-worded and may be unlocked. When launched the use of macros will

The Cockroach EV Spreadsheet Layout

A

Specify all Cockroach EV physical characteristics:

Dimensions, weights
Motor data
Battery data
Controller data
Miscellaneous

128 Rows, 13 columns

F

Steps 22–26
Calculate and plot the required current versus velocity for each gear. Calculate and plot the max. current draw times for each of the gears and velocities in prior step. Estimate and plot best-case fungible energy range and chemistry-limited range. Estimate and plot fungible energy real-case range in each gear and at each speed .for series battery pack and for two parallel strings.

118 rows x 13 columns

B

Steps 1 -6
Calculate and plot required forces and powers as a function of EV speed:
- acceleration
- hill climbing
- aero-drag
- rolling friction

Sum and plot four forces and powers
Convert required forces into required drive-wheel torque at speed

111 Rows x 12 columns

C

Steps 7-12
Calculate and plot available drive-wheel torque at max recommended Joule and friction motor-heating levels and plot for five gears at continuous, one-hour and five minute ratings. Replot for three ratings in each gear.

176 Rows x 12 columns

D

Steps 13-17
Calculate available motor torque for 100%, 60% and 20% battery pack states of charge, and convert to available drive wheel torque in each gear after loss of efficiency in drive train.

For each gear, plot as a function of EV velocity, (1) the required torque on level road at constant velocity from previous section, and (2) the max. available torque for the three states of charge, and (3) the continuous, one hour and five minute limiting available torque

For each state of charge, plot as a function of EV velocity, (1) the required torque on level road at constant velocity from previous section, and (2) the max. available drive-wheel torque for the five gears and (3) the continuous, one hour and five minute limiting available torque

192 rows x 26 columns

E

Steps 18-21
Calculate and plot from the previous section optimum shift vs. velocity pattern and the motor-limited acceleration times . Plot comaprison to 1960 Corvairs.

88 rows x 26 columns

Figure 38—*Draft Spreadsheet Organization.*

have to be accepted or several of the calculations will not be possible. It allows users to change any of the non-permanent data to explore other potential configurations.

This chapter briefly walks through the remaining regions of the spread sheet and explains why each set of choices was made the way it was in estimating ATSR (Acceleration, Top Speed, and Range). The upper middle section B calculates the force, torque and/or power requirements of the Cockroach example as a function of steady-state velocity. These calculations are based upon the procedures of Leitman and Brant [*1*] with modification, EVCalculator at evconvert.com (with changes), and numerous physics and chemistry books. These sections are sequentially numbered in agreement with the calculation steps provided in Chapter 6.

These include the four force and power factors: to accelerate (default setting to zero to provide level road constant speed default conditions), to climb hills (also by default set to zero), to overcome aero drag and to overcome rolling friction. Each are both tabular and plotted. Further down, these are summed (Step 5) and converted (Step 6) into drive-wheel speed and minimum required drive-wheel torque versus vehicle velocity up to 70 mph (taken as a physical practical limit on Cockroach operation).

Below that (Steps 7-12), Section C, the equation of state in Chapter 5 is used to estimate available drive wheel torque and power that the motor can provide in each of the five gears. Added to this are the velocity limits in the various gears to prevent the motor exceeding its maximum speed and the maximum torque that the controller will allow to prevent it exceeding its own current limit. Also added are three curves that estimate the maximum drive-wheel torque that the motor can provide continuously, for one hour, or for five minutes before overheating is likely. Finally the required drive wheel torque is also shown to indicate which velocities the vehicle should be capable of attaining.

Further down the data of Steps 7-11 are re-plotted as Step 12 to exhibit the performance of the EV in the three stress levels (continuous operation or transient operation periods of one hour or five minute before overheating) for all five gears. Again the minimum required torque is shown.

In the fourth region to the right at the top (Step 13), Section D, the motor's current requirement is calculated as a function of it torque delivery at its output shaft, and the current is related to the motor native speed and power delivery for three hypothetical states of charge of the battery pack (100%, 60% 20%).

Below Step 13 are three Steps (14-16) that estimate the Available Drive-wheel torque as a function of velocity for each of the five gears, for each of the three hypothetical battery pack states of charge (100%, 60%, 20%). All are plotted along with dotted lines indicating the maximum velocity in gear and maximum controller-limited torque for each gear. These curves also allow maximum velocity in gear to be surmised.

Below Steps 14-16, are curves that re-plot the data of Step 17 except as three states of charge as a function of the five gears.

Still further down, Steps 18-20, Section E, interpolate the data of Step 13 to provide Estimated drive-wheel torque delivery as a function of EV velocity for all five gears. These data are then sifted through along with the controller limits on drive wheel torque to determine the maximum available torque available at every speed increment for every gear. This is the optimum driving pattern to maximize acceleration, Then time for average acceleration between each pair of velocity increments is calculated and summed to surmise acceleration to each speed. Plots exhibit the optimum shift patterns and the cumulative time to velocity.

At the bottom of the right-hand section, Step 21 compares the acceleration times of the Cockroach to 1960s Corvair vehicles that ranked from quick to slow, but all of which were much superior at achieving the higher velocities. The Cockroach is adequate but like many EVs, it is a dog.

The sixth section F of the spread sheet in on the bottom of the left side, under the Cockroach parameters section, and presents the range estimates. At the upper region Step 22 and step 23 calculate the Required motor current and the amount of time that the battery pack can supply that level of constant-current, respectively. The current requirement is calculated with the motor equation of state for current and the draw time is patterned after Peukert's approach based on overall vendor data as described in Appendix A. Both sets of calculations are plotted.

Below that (Step 24), the Best-case range is easily calculated assuming fungible energy and required power delivery. A table and plot are provided. Also the best case ranges possible with chemistry –limited battery draws are calculated and plotted.

The next level further down, Step 25 calculates the most realistic estimates of vehicle range as a function of velocity that are attempted here in all five gears, and the associated plot also displays the Best case range and how the best case range is limited by chemistry.

Finally, because of the potential value, Step 26, Parts A, B, and C calculate the effect of switching battery pack connections into two, three or four parallel strings, and at low speed the improvement that results (hopefully valid) is rather impressive. That completes the performance analysis.

Below the analysis section is an elaboration of the calculations that were applied to the simulation of "overdrive" operation.", because this could prove controversial, especially if the writer has blown the math. To the right of the analysis are three figures prepared to illustrate chopped cycles for Appendix B.

Many of the figures in this book come directly from the default spreadsheet.

8

Manufacturing the Cockroach (A Hearkening Back to Vol. 1)

The Soft Bigotry of Parasitic Welfare

Volume 1 of *The Cockroach EV*, examined automobile manufacturing and surmised retirees, including some highly talented people, possibly some who designed the original ideal donor vehicles (to wit, the Chrysler K cars, most especially the donor Daytona, see page 149), might be willing to volunteer key energies to launch and build new production runs configured for *practical* electric vehicle service especially to serve those with lower Social Security benefits. The writer's combined costs to drive a new Subaru Impreza "small car" for fifteen retirement years have been about $30,000 and might have been as low as $10,000 for a Cockroach EV. That would count as practical and affordable in any paradigm.

These specialized electric vehicles would also benefit other selected niche users (students, those on welfare and those needing a "city" car" to commute with). And with financing from the Social Security Trust fund, or from donations, would be a way to improve retiree and some other lives (in some cases perhaps as partial non-monetary Social Security benefits) without the tyranny of taxes savaging their savings. But how can they be built?

In the years since that was published, an additional niche labor pool has been identified. There is a way to fund and build the Cockroach and to make it truly affordable (not Democrat "affordable" but actually honestly affordable) to its original target audiences and to a potentially larger niche. At the same time it could help to reduce parasitic welfare bigotry. That niche is based upon enormous numbers of currently poor people ("poverts") who are victims of the soft discrimination of parasitic welfare.

The U.S.A is an enormously generous and charitable nation providing billions upon billions of dollars to aid so-called "poor" people, some fraction of which are among those who would benefit most from the Cockroach paradigm, but who would have the greatest difficulty in affording even its very favorable (albeit semi-Socialized) price.

- Family Planning
- Consolidated Health Centers
- Transitional Cash and Medical Services
- State Children's Health Insurance Program
- Voluntary Medicare Prescription Drug Benefit—Low Income Subsidy
- Medicaid
- Ryan White HIV/AIDS Program
- Breast/Cervical Cancer Early Detection
- Maternal and Child Health Block Grant
- Indian Health Services
- Temporary Assistance for Needy Families (TANF) (Cash aid)
- Supplemental Security Income
- Additional Child Tax Credit
- Earned Income Tax Credit (refundable component)
- Supplemental Nutrition Assistance Program (SNAP)
- School Breakfast Program (free/reduced price components)
- National School Lunch Program (free/reduced price components)
- Special Supplemental Nutrition Program for Women, Infants and Children (WIC)
- Child and Adult Care Food Program (lower income components)
- Summer Food Service Program
- Commodity Supplemental
- Food Program Nutrition Assistance for Puerto Rico
- The Emergency Food Assistance Program (TEFAP)
- Nutrition Program for the Elderly
- Indian Education
- Adult Basic Education Grants to States
- Federal Supplemental Educational Opportunity Grant
- Education for the Disadvantaged—Grants ot Local Educational Agencies (Title I-A)
- Title I Migrant Education Program
- Higher Education—Institutional Aid and Developing Institutions
- Federal Work Study
- Federal TRIO Programs
- Federal Pell Grants
- Education for Homeless Children and Youth
- 21st Century Community Learning Centers
- Gaining Early Awareness and Readiness for Undergraduate Programs (Gear-UP)
- Reading First and Early Reading First
- Rural Education Achievement Program
- Mathematics and Science Partnerships
- Improving Teacher Quality State Grants
- Academic Competitiveness and Smart Grant Program
- Single-Family Rural Housing Loans
- Rural Rental Assistance Programs
- Water and Waste Disposal for Rural Communities
- Public Works and Economic Development
- Supportive Housing for the Elderly
- Supportive Housing for person with Disabilities
- Section 8 Project—Based Rental Assistance
- Community Development Block Grants
- Homeless Assistance Grants
- Home Investment Partnerships Program (HOME)
- Housing Opportunities for Persons with AIDS (HOPWA)
- Public Housing
- Indian Housing Block Grants
- Section 8 Housing Choice Vouchers
- Neighborhood Stabilization Program-1
- Grants to States for Low-Income Housing in lieu of Low-Income Housing Credit Allocations
- Tax Credit Assistance Program
- Indian Human Services
- Older American Act Grants for Supportive Services and Senior Centers
- Older Americans Act Family Caregiver Program
- Temporary Assistance for Needy Families (TANF) Social Services
- Child Support Enforcement
- Community Services Block Grant
- Head Start HHS
- Developmental Disabilities Support and Advocacy Grants
- Foster Care
- Adoption Assistance
- Social Services Block Grant
- Chafee Foster Care Independence Program
- Emergency Food and Shelter Program
- Legal Service Corporation
- Supplemental Nutrition Assistance Program (SNAP) (employment and training program)
- Community Service Employment for Older Americans
- Workforce Investment Act (WIA) Adult Activities
- Workforce Investment Act)WIA) Youth Activities
- Social Services and Targeted Assistance for Refugees
- Temporary Assistance for Needy Families (TANF) (employment and training)
- Foster Grandparents
- Job Corps
- Weatherization Assistance Program
- Low Income Home Energy Assistance Program (LIHEAP)

Figure 39—*Congressional Research Service means-tested Federal welfare programs.*

In 2012, The United States Senate Budget Committee [*25*] requested an overview from the Congressional Research Service on means-tested welfare spending for the year 2011, you can look it up on the Net. They identified the 83 items listed on Figure 39, which they concluded represented $1.03 trillion *per year* in spending. This does not include the fraction of Social Security payments or Medicare benefits for low income earners that are subsidized at the expense of Social Security and Medicare taxes paid by higher income workers. And in 2012 the costs, other than the borrowed startup costs, of the Affordable Care

Act (ObamaCare) had not yet begun and were not counted and would be a substantial addition but are hopefully drawing to an ignominious end. Indeed, Democrats had cleverly hidden much other welfare spending in really slick ways. These massive benefits which do indeed derive from a host cohort (including the writer) and by virtue of asset depletion (which is real injury) truly does qualify as parasitism. It is detailed in the writer's 2016 political protest public-service book: "*Clever...Way Beyond Fault*."

Aghast at the Senate Budget Committee revelation, in 2012, A clueless (obviously liberal) "journalist", Drum [***26***], writing for the liberal Mother Jones Magazine asserted that it was misleading and that only a mere $235 billion (that's $235 ***BILLION***) is spent on the *nonworking* poor (again not counting Social Security nor Medicare nor ObamaCare and much more). In either perspective, this is at least from 235-1,000+ times more money than would be required to startup, launch and begin production of the Cockroach EV, which would benefit many of these exact same people, and possibly to a greater degree in some cases.

Furthermore neither of these include the funds derived from taxes within the various states (including public education for families that do not pay property taxes). Nor does it include the various free-lance charitable resources that seem to be constantly soliciting, just a few of which are listed on Figure 40.

Why is this important? Because *none* of these programs are quid pro quo. We *give* a lot of quid and we get *nothing, no shred of quo,* back, even though the Democrat party has at times tried to convince us that the payback comes in the form of them spending the money). It is amazing we don't have to go and do the spending for them. Thus this actually saddles these recipients with a parasitic existence (precise definition of parasitic: "2: an intimate association between organisms of two or more kinds; *esp*; one in which a parasite obtains benefits from a host which it usu. injures". This demeans them and denies them the dignity that comes from honest productive work. From making their own way. It allows their work skills to deteriorate making it just that much harder for them to be desirable as new hires, and leads to ever expanding Democrat calls for more wasteful unnecessary educational programs[8] and the ever-expanding tyranny of ever-greater taxation. And it creates perverse Darwinian incentives for the poor to make babies and nurture them on how to apply for this vigorish, as if the nations biggest problem is too few people to spend the money. Welfare should not be an alternative lifestyle. This has led to some despicable moral hazards of the thereby privileged poor in which Democrat-Party policy breeds socially-accepted parasites that can only be compared to domesticated pet animals but who perpetually consider themselves to be victims.

Furthermore it saddles the taxpayers with nondeductible parasitic dependencies. In recent years, Democrats have been calling for an increase in the minimum wage, another very generous gesture from them that the writer would doubtless wind up paying for. Hence this writer has suggested we offer sexual access "insurance" to millions of sex-starved poor men by granting them the entitlement to explore the Mikas, the Jennifers, the Milas, of our

[8] In his 2015 State of the Union Address, the President Obama called for yet another new Democrat tax to spend billions of dollars to give free community college and free preschool. And while this is not targeted to the poor alone (as clever Democrats did, for example with Social Security and Medicare and Medicaid) it gives this largesse to everyone, but only a fraction of *us* windup paying for it.

- United Way Worldwide
- Task Force for Global Health
- Feeding America
- Salvation Army
- YMCA of the USA
- St. Judes Children's Res….
- Food for the Poor
- Boys and Girls Club …...
- Catholic Charities USA
- Goodwill Industries …..
- Habitat for Humanity ….l
- World Vision
- American Cancer Society
- Patient Access Network Fdn.
- Compassion International
- Direct Relief
- Americares Foundation
- Lutheran Services America
- Nature Conservancy
- American Heart Association
- American Nat'n'l Red Cross
- Samaritan's Purse
- MAP International
- Step Up for Students
- Cru
- U S Fund for UNICEF
- Wounded Warrior Project
- Feed the Children
- Mount Sinai Health Systems
- Save the Children Federation
- CARE, USA
- Good 360
- Catholic Relief Services
- Planned Parenthood Fed….
- Doctors Without Borders USA
- Bill, Hillary Chelsea Clinton Fdn
- Make-a-Wish Fdn.
- Dana Farber Cancer Inst.
- Leukemia & Lymphoma Soc.
- Boy Scouts of America
- Cross International
- Mem. Sloan Kettering Cancer
- Catholic Medical Mission…
- Alzheimer's Association.
- Population Services International
- Mayo Clinic
- Rotary Foundation…
- Marine Toys for Tots Fdn.
- American Kidney Fund
- Operation Blessing Int'l R&D
- American Jewish Joint Dist…
- Entertainment Industry Fdn.
- Shriner's Hospitals ….
- Susan G. Komen
- Project Hope
- Brother's Brother Fdn
- ACLU
- ChildFund International
- International Rescue Comm
- Young Life
- World Wildlife Fund
- Easterseals
- Nat'l Multiple Sclerosis
- Public Broadcasting Service
- Metropolitan Museum of Art
- Helen Keller International
- Foothill Land Conservancy
- JDRF
- Smithsonian Institution
- UJA/Federation of New York
- Teach for America
- Scholarship America
- Paralyzed Veterans of America
- Children International
- Mathews 25: Ministries
- Harlem Children's Zone
- Medical Teams International
- ClimateWorks Foundation
- Robin Hood Foundation
- Wycliffe Bible Translators
- March of Dimes Foundation
- Humane Society of the US
- United Service Organizations
- N. York Presbyterian Hospital
- Metropolitan Opera Assoc.
- American SPCA
- Christian Broadcast. Network
- United Negro College Fund
- Houston Food Bank
- Educational Media Fdn.
- Project Orbis International
- PATH
- Museum of the Bible
- The Arc
- Junior Achievement USA
- Smile train
- Jewish Fed. Of Metro Chicago
- Cleveland Clinic
- Am. Museum of Nat'l History
- American Diabetes Association

Figure 40—*Forbes.com Largest U.S. Charities for 2016.*
(Top 100 ~ $50B, Range $3.7 Billion to $140 million).

nation. And once we, and especially, men have this new right we will not give it up anymore than those on Obamacare were willing to give that up *without an equal,* ***or better****, replacement*. I trust the one-per-center Mikas, Jennifers, and Milas will not mind being asked to give a little bit more for their country.

And yet while a raise in the minimum wage would benefit (albeit parasitically) some Americans, allowing them to spend more, it will send others to the land of unemployed none-quid-pro-quo welfare. What we need are more jobs. More honest cash flow, and more ways to move into the employment stream. And yet so called visionaries like Elon Musk are predicting the end of the job and the need to provide everyone with a minimum guaranteed yearly income (a parental-like allowance he called Universal Basic Income). That yearly income would doubtlessly be obtained from those who are still employed with as yet not-extinct jobs. If it sounds like failed Soviet Communism, that is only because it is exactly like that. And it is why I have come to fear Democrats for the same reason I once feared the Reds.

And as a (for the most part) Conservative Republican (generally) the writer finds it offensive that the Democrat Party has found it possible to turn these millions of American into these human domesticated pets, regardless of the number of these human-pets that are okay with that. Still for those who find it as offensive as the writer there must be options available. If Democrats want to argue health care should be a right, I would argue employment should be even more so a right. *The Cockroach EV (and perhaps similar ventures) is a way to create non-parasitic jobs*.

Jobs, Jobs, Jobs

Darwin did not write *The Origin of the Economy*. But like the species, economy evolved in accordance with a survival of the fittest process and included many unfit failures along the way. Before there were jobs, before there were laws and even nations, we were all responsible for ourselves. We learned (and it may have taken a long time) that instead of doing everything for ourselves, we could barter: and barter was the origin of the original quid pro quo economy.

It was both efficient and economical and hence came to be called “the economy”. We were better off if each of us did what we do well and then trading it (bartering it) to others. Animal skins for food was a big initial market. We all needed skins and we all needed to eat and we got more of both when we traded. In root principle, we trade hours of our own labor for hours of someone else’s labor. The trades were not always one hour for one hour. If food was scare, the guy who had food to trade got more skins then when it was cold during harvest season.

This simple truth gets lost in today’s complex economy. Today robots threaten to eliminate some common labor. And already in combination with the automation that preceded them, robots have produced an excess supply of surplus human labor. Poverts who are chided, reproached even scolded to get jobs have little chance of doing that. When supply outstrips demand, the economy fails. While it was possible for a while to sustain a parasite/pet class with taxes, we can not all be parasites. The system is destroyed when everyone has a hand out and no one is producing things to hand out. Robots can be our slaves and do not earn wages, but like real slaves were, they are not cheap.

Forever, we have manufactured human beings with unskilled labor. Today visionaries foresee a world in which robots reproduce themselves and serve our every need like good slaves. Their paradigm is reminiscent of the Ottoman Empire where the Ottoman Turks sat on their namesake chairs while slaves served them. Their system model did not work out.

And indeed, as in later France over time, some in the parasite class will rebel. Like Oliver Twist, they will want more. They can try to take it violently, but this is to argue it is better for them to revert to an original economic system. They can revert to quid pro quo.

Today our poverts can not get jobs, can not sell their labor to other countries. Indeed, our welfare system creates evolutionary pressure on them to not even seek jobs. They are like our distant ancestors. So perhaps barter provides an answer. If they were few in number, the prospect of a barter economy for them would not be realistic. However today we are lousy with them. They number in the tens of millions. They outnumber many small, yet successful, nations. They can sell to each other and work for each other. Hour-for-hour.

If we allow and encourage and even launch a sub-economy based on barter principles, and even encourage it with devices like the Cockroach EV, our poverts can barter, buy and sell to each other. They enjoy peer parity. Quid pro quo: time for time. If Republicans want to see our poverts back at work (and I certainly do) and Democrats want to see them with "more stuff" then we should encourage an alternative sub-economy among them. Many of them would be among those who benefit most from a Cockroach EV, but Detroit is not going to build one, and can't. It makes no sense for Detroit. So we need to drop the regulatory obstacles to barter and help set up a Cockroach production mechanism (as described in *Volume 1*), within a barter economy, call it a parallel-economy within our system.

Let poverts work in the low-skilled assembly of Cockroach EVs as a way to work off their welfare (yes, run a tab on everyone) as well as in exchange for credit against a Cockroach purchase. Exempt such labor from taxation, and from disqualifying poverts from welfare, but include an incentive to move them off of welfare.

Poverts can by definition afford to hire other poverts because of the quid pro quo nature. It does not matter if a povert is credited with $5 an hour for their labor or $25 for their labor, because they are both getting back one hour. It is like buying a $1000 dog with two $500 cats. Other nations can not compete because this money is already spent.

The Cockroach does not have to meet any sales goals. Normal competitive pressures are relaxed. It does not have to turn any specific ROI. If demand is low then production can be low. If demand is high, supply can do the best it can. The Cockroach does not have to be face-lifted every three years. Fortunately, the K-car line predated massive robots. It can be assembled without robots (or genetically upgraded gorillas). It is not trying to compete in the regular economy. It can be a foundation beneath the regular economy providing low skilled jobs. Imagine that! Jobs that robots can not take away.

Build the Cockroach EV….Save the World.

The Nobility of Work

We are told charity is good for you. Well, work is good for you too.

In a distantly similar and not too obnoxious example, the former Democrat President Carter, boosted the charity: Habitat for Humanity (HH) which according to their web site helps needy families get home mortgages by contributing 400 hours of sweat equity towards the down payment of a home built in part by their own charity (to themselves). However, HH does not allow for sweat equity paying for an entire home.

How well HH polices this payback, how much real payback is actually received, is not known to the writer, it may be more cosmetic, more symbolic, than real (Democrats are better at symbolism than reality), but the idea of repayment of all the charity with at least some sweat equity is in principle a way to dignify their lives and to benefit them.

Indeed, here in Pennsylvania (and doubtless other states as well) there are cases where school districts (Figure 41) force community service (charity) on students to teach them (nay indoctrinate them into) responsibility and duty. If this can be imposed on minors, shouldn't some payback be required of those who receive the charity? Don't they need

Bethlehem Are School District
Community Service Program

The Community Service Program offers the opportunity for high school students to provide service to the community. Each student is required to perform sixty (60) hours of unpaid service to ***non-profit organizations*** *or experimental situations approved by the district.*

Goals of the Program
- Foster community participation
- Promote responsible citizenship
- Develop leadership
- Acquire life skills
- Explore careers

Credit for Graduation
- 60 hours of service is required for 0.5 credit toward graduation.
- 120 hours—1 credit
- 135 hours or more will be recognized at graduation as Outstanding Community Service! Students receive the "Silver Cord."

Figure 41—*Quotation from Bethlehem School District Public Service requirement.*

teaching, too?

And today, you can't turn around without another charity soliciting (a partial listing of what the author is exposed to was shown on Figure 40). In 2008, *the great humanitarian (?),* Presidential candidate John Edwards wouldn't drop out of the race and endorse Barack Obama until Obama promised to do something to help the poor (which in Democrat-speak means gives them some more free stuff—see footnote 8 again).

The writer, who has been subsidizing the majority if not all of these charitable efforts has nonetheless been categorized by the Democrat party as a politically-incorrect idealess heartless, gun-crazy, systemic racist, endemic-sexist, homophobe, xenophobe misogynist, white supremacist, no-damn-good, jack-booted storm trooper in the war on women and their health, and who (for sure) hates poor people. And yet my annual share of government plunder has been upwards of the order of ten thousand dollars (each year). Looking at these examples one might easily feel the United States is too obsessed with poor people.

So I want to ask here: Where are the "good" noble poor people, victims, who are offended by their parasitic peers and by being demeaned in this degrading system? Where is *their* pride? Why do many of their millions accept living like leeches, of being designated irrelevant societal parasites using politically correct alternative descriptions. Those with pride should be demanding to repay society. One way they could seek to provide some quo in exchange for their quid, would be by providing labor and energy to produce Cockroach EVs outside of the normal commercial stream for the benefit of not only they, themselves, but others with similar needs (niche retirees, students, and *their* peers). They can think of it as their own mandatory community service with all the same benefits that accrue to public school students who do public service work and are expected to reap a bonus from the dignity in honest work.

Today, we are told many (but not all) parasites vote for Democrats not to get out from under this parasitism, this victimization, but to make it even more comfortable, to increase the unrequited largesse they reap. To make that largesse more "livable". And in an almost prophetic way, the more they get the more at least some of them seem to despise those who provide it. We lure illegal immigrants to this country with these policies (and other magnets such as the 14th Amendment which current tyrant politicians decline to clarify).

And so, if retirees, volunteers, and upstanding presently parasitic segments of society get together and help exert a political will to make a noncommercial Cockroach available for their peers *to earn*, it would represent doing good that does not involve the raiding, the taking, the exploiting, the blood-sucking of our other peer's assets like thieves in the night. And it would incrementally reduce the incentive our tyrant government is giving some of us these days to once again resort to violent revolution to fix what is wrong with our badly screwed up country (notwithstanding it being the best in the world). Hey! We took our nation to the moon. We invented incredible computer technology, and even robots. And we invented great destruction also (namely the two kinds of nuclear bombs and *we used one type of them twice*). But we should not need, nor should we be forced, to resort to such destruction. Destruction is all too easy to accomplish, even without the most awesome technology, by even the least among us (See Volume 1 *"Warning! Our System is Blinking Red Again"*). The tyranny, a tyranny of the poor no less, is here now, and it is real and extreme. So what do we do about it? The Cockroach EV is my small suggestion to resolve a small but not trivial piece of it. To set an example for similar efforts. It is not enough by any means. But hey if anyone likes civil war or violence better, then you are on your way to getting what you want. You can easily achieve *that* if you just stay the course.

To repeat: "Build the Cockroach….Save the World.

9

Closure:
What next?

Volume 1 of *The Cockroach EV* proposed a niche concept and surmised its politics. This Volume 2 has attempted to provide math and data needed to validate and support and prove the concept EV and estimate its performance and maybe it succeeded. Maybe it will need corrections. It also explores an additional mechanism to manufacture it (namely the material in the previous chapter). Either or both of these efforts may be grievously flawed but hopefully they contain the germ of a worthwhile concept: The Cockroach EV. *Build the Cockroach...Save the World*.

Since I retired, nineteen years ago, I have purchased one new car, a Subaru Impreza (and it is a very good car) but a Cockroach EV as detailed in these two volumes is the vehicle that would have served me best. I don't think I am the only one for which that would apply. I have already noted, a Cockroach might have saved me as much as $20,000.

Practical, meaning low cost (honestly "affordable"), reliable, electric transportation,...an appliance…was initially aimed at selected retirees like the writer. Now it might also serve a number of other similar categories of drivers (including perhaps most significantly some poor people) and seems realistic. This analysis argues the Cockroach's current performance should be adequate but lackluster with current hardware, yet if much improved lead-acid batteries measure up to their promise as surmised herein, and if they can be coaxed or forced into the marketplace, a very nice vehicle with still dog-like but nonetheless acceptable acceleration, top speed and range could obtain. In addition to repairing any bad science that may be found in these two volumes, where to go next?

Publicity

The writer's primary next efforts will be to publicize the conception, and allow critics to point out any perceived or real flaws. If the Cockroach is a bad dream then perhaps it should be ignored. But it deserves a reasonable objective assessment. This is America, and we fought a violent revolutionary war over a lousy tea tax, a stupendously stupid war over slavery, and tyranny is currently rife through out the land...in this writer's judgment.

Lead Acid Batteries

Testing "state-of-the-art" lead acid batteries as speculated upon herein is the most important technology quest. Batteries with several times longer life, little or no maintenance, and perhaps twice or three times the range of current FLA deep draw batteries, would be a huge advancement. Sporadic data and clues suggest these batteries are fully realistic, but their absence in the marketplace is a quandary. If they can be proven technically, the reason for their absence must be discovered and dealt with. If the batteries can be realized, it should be straight-forward to promote and/or develop a smarter controller for supplemented/smart systems and continuous-activity systems. As terrific as all this this would be, is this as far as the Cockroach can go? Can the Cockroach still improve? Can the politics improve? In the writer's mind, the next two avenues promise the best yields: improve motor performance, and reduce rolling friction. A third aspect is as daunting as it is has been for Detroit for decades, and that is——paint.

Improving Motor Performance

State-of-the-art FLA smart batteries with high tech supplementation and constant draw activity should increase the efficiency, capacity, range and maximum currents that can be supplied. Possibly by large margins. Can all this potential extra electrical power lead to still better performance?

At present, with enhanced power available, the use of the nine-inch motor described by the Equation of State in chapter three is a next limitation. The availability of the power delivery for typical steady-state continuous (~28.5 hp @ 144v), one hour (~38.4 hp @ 144v.), or five minute (~48.8 hp @ 144v.) is still a limitation that forces too much reliance on Kettering's Overload Practices. However this limitation is not imposed by the amount of torque and horsepower the motor can generate. The nine inch motor can produce much more force, at least twice as much, but it will overheat if asked to do that too often or for too long. Indeed, apparently the way these ratings are established is to increase the power supplied to a test motor until its temperature puts it at risk of melting some key component. Some people drag-race these motors drawing far higher power levels, but a drag race is for only a few seconds at a time.

Hence, this motor's longer-term ratings could be significantly increased in two ways: (1) by more effective dissipation of the heat it generates or (2) by reducing the heat it generates. Higher voltages can accomplish this (with negative effects on controller and battery stress) and could be pursued to their practical limits. The cubic money EVs (like the EV-1, Volt and Leaf incorporate liquid cooling systems much like those in ICE cars (they coolant-jacket the motor and controller and "cool/condition" the batteries as well). The same approach could increase the Cockroach ratings as well but at significant expense and with the introduction of new undesirable un-appliance-like issues.

Inexpensive forced-air cooling is already available in which a blower pushes air through the series DC motor and it yields some nominal gains in ratings. Well worth doing but probably not a game changer. Ditto ram-air methods? Also good but not a world changer. The coolant air may not get to all the vulnerable regions.

Reduction of motor electrical resistance offers improved power ratings but also improvements in efficiency. However copper wire is standard and has as good a conductivity and about as high a melting point as is available. Still. it is long known that under some circumstances, current flows only through the "skin" of a conductor and so a study of the skin effect in nine-inch motor windings is indicated. Do these motors use the full cross-section of the wire. If not would multiple parallel windings (like Litz wire) reduce resistance. Would square (or other geometry) cross-section wire yield more skin to lower resistance? The writer has little familiarity with current rating practices and apologizes if clueless.

The melting point of the enamel insulation that is used on magnet wire may be the temperature limiting factor and so heat removal must also be a focus. It would be worthwhile to do a study of the hot spots where these motors actually fail. Such data again are probably known but not publicized. Motor rebuilders know whether the armature, the field coils or the commutator or bearings suffer greatest melting in a typical failure,... the writer does not know. Efforts to lower temperature, to cool the hot spots would be the most useful. If the armature windings are at risk of melting, the armature could be polished or plated to reflect heat from the field coils. Vanes could be added to the armature to provide proportional air cooling and increase surface heat-transfer area. The faster the armature spins the more air would be circulated. Perhaps square cross-section wires might reduce the resistance by fitting more copper into the windings (generally or strategically). And indeed, square cross-section wire would improve heat transfer from the windings as a result of the increased contact area between winding wires. These would be worthwhile open-source projects for a Cockroach EV-advocate community to pursue. The hot spots in the motor must be addressed.

Perhaps three-dimensionally printed windings and armatures would offer benefits in all these areas if it is possible to vary the cross-section of the conductor as a function of location in the motor and to fill in voids to improve heat transfer.

It would be nice to take a standard motor and remove the armature from the case, then mount them on a common shaft and provide a transparent sleeve around the armature and a heater in the cover so that each could be studied as the amount of pseudo-power is raised. There may be no commercial incentive for current motor vendors to do this but the user community has a different perspective. Again, perhaps these data are known and are just trade secrets worthy of public self-discovery.

Any robustness that can be achieved for the motor would yield less need to computer-track the history of the motor's load so as to avoid relying excessively on "Kettering Effect" overloads to achieve peak or sustained performance [*TCEV* Vol. 1, pages 13,14] .

Of course there are greater electrical power resources possible. There are bigger motors available such as eleven and thirteen inch motors that are also prospects but are bigger and heavier and more expensive. And dual motors are also a very realistic approach. But one has to be careful not to scale up the motors and batteries (and cost) so far that the inherent benefit of the "appliance" Cockroach to its target niche(s) is lost.

Reducing Rolling Friction

For the signature Cockroach, page 149, we have seen that the four parameters that require power and force to overcome are:

Acceleration
Hill climbing
Aero drag
Rolling friction.

The forces to climb hills and accelerate, depend on the vehicle mass. With so large a fraction of that mass based in the FLA battery pack, other weight loss efforts would seem to be of marginal benefit at best. Aero drag force is greatest at high speeds, which are antithetical to the Cockroaches paradigm (the Cockroach is principally a "city car").

Hence, rolling friction may be the most ripe for pursuit. And it could prove very worthwhile. Note that on level ground at a constant 45 mph, the predicted signature Cockroach rolling force represents more than two-thirds the total force requirement, and that even at 70 mph is slightly more than half the force requirement.

Note that low speed range where the Cockroach spends most of its time (Figures 34-37) might nearly double if rolling friction could be halved.

And rolling force may be responsive to several approaches. Smart dynamic alignment of all four wheels, and narrow low friction tires operated at high pressures to minimize flexing and heating, are just two possible areas, examined in Volume 1, to pursue.

Paint

For decades, the engine was the most expensive component in new cars. In the early 1990s the environmental regulations regarding spray painting changed that. This led to robot sprayers and water based paint that was not very durable but still very expensive. The Cockroach does not warrant an elegant paint job, it's a workhorse not a race horse, and a less costly yet presentable way to protect its steel panels would be a major breakthrough.

Adaptation

How to make EVs and especially Cockroach EVs serve well may benefit from a lot of quality thought. They seem ripe for improvement. For example, should CEVs have communication screens in the back. When a CEV has to venture onto a freeway or above 45 mph, or near its top speed, should a LED panel on the rear light the Message: "Slow—EV". If a battery fails and a CEV has problems and has to pull over, what messages might the LED panel convey? Should CEVs be excluded from using the passing lanes on divided highways by either law or common etiquette.

How can CEVs be most readily recharged at home or when away? Can inductive couplers be placed under the cars so that when parked near them, the car can send a signal, have the coupling lift and credit card info be exchanged to automatically begin recharging.

How about CCTV cameras instead of side view mirrors to improve aerodynamics? Apparently this is already a campaign of Elon Musk's. In the Daytona donor car a massive rear window could be replaced with solar cells and a CCTV camera provide the rear-view function. To go further, how about a solar panel instead of the massive rear window and another CCTV screen to replace the rear view mirror. The solar panel might help to provide long term (yet low level) power to prevent battery sulfation by providing continuous battery activity.

Bottom Line:

The Cockroach EV conceptualized and designed herein is the car I, a Conservative Republican, have wanted and needed since 1999. If the analyses in these two volumes of *The Cockroach EV* is not too badly flawed, it suggests a way for liberal supremacist Democrat factions to achieve some of what they say they want (but are probably only lying about anyhow). And it does it in a way that should not be too obnoxious to capitalistic, free enterprise Republican factions. But both are not likely to be eager to support it. Neither does even a marginally good job of finding solutions. So what the Cockroach EVs most important contribution may be is to reveal the two parties to both be tyrannical, yet unequal, monsters that are risking another violent revolutionary war. That might well be a war that unlike the earlier tyrant King George III, they might win, probably would, one side usually wins…...but they must be willing to pay a terrible price? In the Civil War, Sherman could rampage across the south and burn down everything in his path to demoralize his foes. Today, fires could burn in every state, simultaneously, pumping massive carbon dioxide that Democrats fear and hate so much into an atmosphere they want us to believe already contains too much. Yet, they seem hell-bent on justifying such a rebellion.

On 19 April 1995, the stellar American war hero, Sergeant Timothy James McVeigh, who had reached his tipping point, exercised his prerogative as an American to fight tyranny in our government with the functional equivalent of a militant reprisal in Oklahoma City. Since then the tyranny has gotten significantly worse including when Sgt. Timothy McVeigh went to his patriotic death (in 2001 prophetically exactly 60 days before the WTC attack). At his execution he noted that the score stood at McVeigh 168, to Government 1 for his Oklahoma City Tax Party Protest...but the disparity could have been much much greater. Of course, President Clinton (that grand ol' horn-dog scamp of The Democrat Party) had killed about 80 in the Waco church/sanctuary, but we are assured those deaths were merely suicides. Perhaps ignoring, nay censoring, ideas like this means the two parties are both actually suicidal also? Perhaps allowing them to continue their malfeasance means we are all suicidal.

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Appendix A

Battery Capacity and Peukert's Equation

Battery capacity, in purest terms the number of electrons that can be supplied, is rigidly limited by three simultaneous resources that combine (act in parallel) to release electrons. The lesser of (1) the mass of active chemicals available in the negative plates, (2) the mass of active chemicals available in the positive plates, and (3) the amount of acid available in the electrolyte, dictates when depletion has occurred,...that is, when the battery is "dead". The battery is dead whenever (1) it runs out of accessible negative plate lead, (2) it runs out of accessible positive plate lead peroxide, or (3) it runs out of accessible sulfuric acid. An FLA battery contains only so much of the active materials lead, lead peroxide, and sulfuric acid. If there is just enough of each to react completely with each other, it will contain the maximum amount of available electrons for its weight. However you may or may not be able to extract all of these or even a majority of this maximum. Therefore any capacity specification involves a lot of arbitrariness.

Figure A-1 exhibits factory (Trojan and US Battery) capacity data points as a function of the current, I, drawn for the most popular type of deep draw batteries (the BCI GC2) used in EV conversions, golf carts, forklifts and other equipment. It also shows two curves that almost lie on top of each other for what these data would be if the batteries were mathematically ideal, that is to say, if their capacities (current draw multiplied by the draw time, t) were a constant, or in other words, if for every draw, I, the capacity were equal to about 250 or 258 amp-hours, respectively. Knowing how long one can draw any given current can help to estimate vehicle range.

If you extract the electrons slowly (at a low current) you will typically measure a capacity close to the maximum possible capacity, approaching or achieving the theoretical limit. The data points on Figure A-1 for low draw rates (up to about 8 amps) fit the ideal curves rather nicely. But when current draw rates are larger, there is a manifest progressive reduction in the amount of time that constant current can be drawn. Indeed, at the highest tested current (133 amps) the cited draw time is only about half of the ideal amount, and this

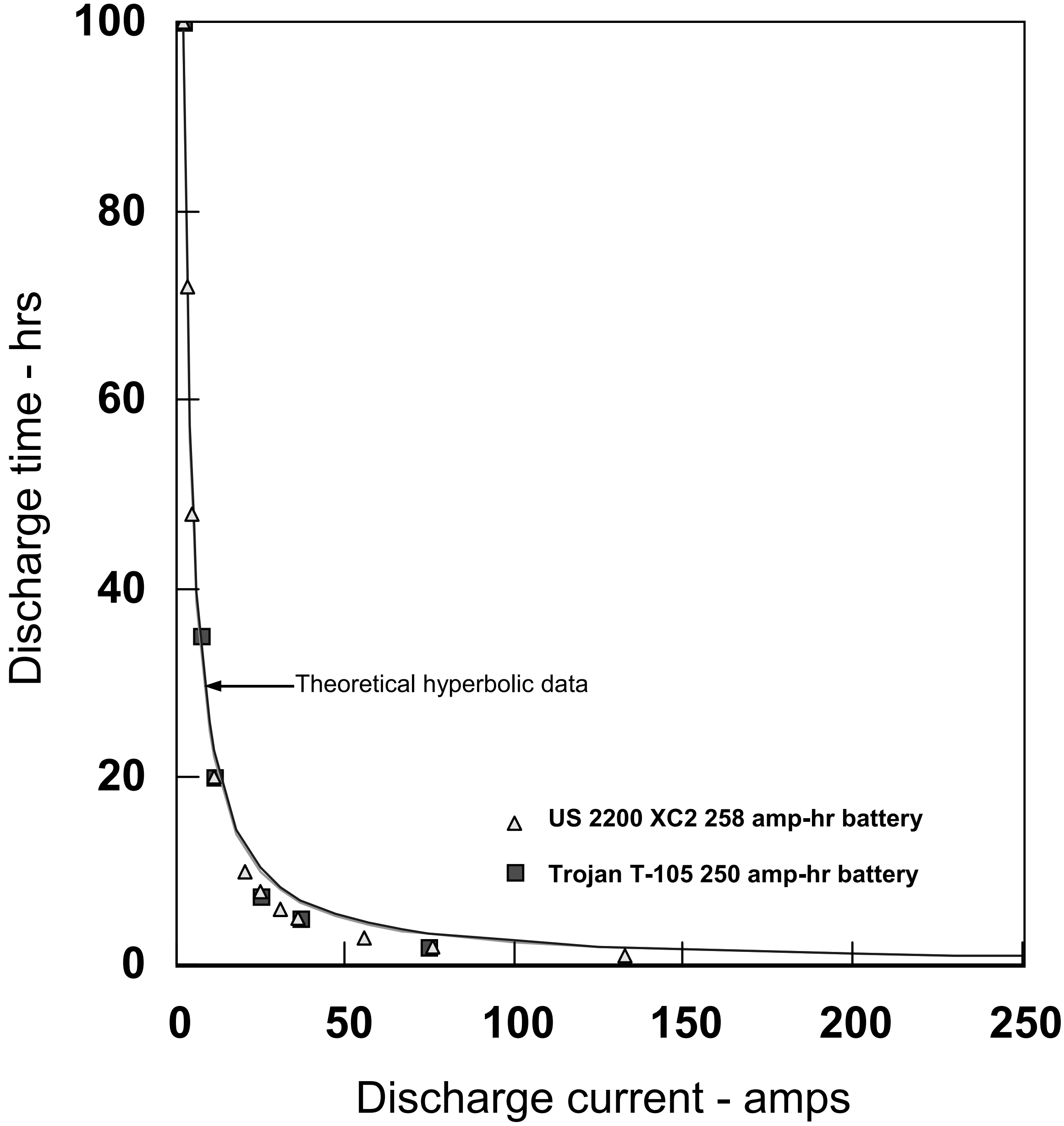


Figure A-1—*Factory test data and ideal curves for T-105 and US 2200 XC2 Batteries.*

is because one or more of the three necessary and sufficient materials were impeded. The impediment may be temporary or permanent.

The measured current/time product is considered the *effective* ampere-hour capacity of the battery, even though resting of the battery may allow it to provide more current later. The depletion(s) may occur because any one or all three constituents is impeded. However, if you draw current very rapidly when your power needs are high, you may consider the battery "drained" (of little value) before you have removed even a majority of the capacity. Several mechanisms interfere with draining of the capacity including:

(1) electrolyte stratification.

(2) surface clogging of the plates.

(3) hard sulfation formation (surface shielding)

(4) shedding (surface deterioration) :

Stratification is when the electrolyte develops widely differing mixture compositions in various locations. As the chemicals react, the acid may not be able to get to the plates fast enough. This is stratification. Electrolyte that is not between the plates may not diffuse into the gap between the plates in time to participate and be too slow to react. Bulk regions of greater acidity may become concentrated during charging (usually in the sump), and even in the electrolyte immediately between the plates, layers of low acidity near the plate surfaces may form that increase the electrical resistant and lower its activity and therefore lower the voltage of the cell. In the most common measurement scheme the battery is considered drained when the voltage measured at the battery terminals drops below 1.75 volts (whether or not any appreciable amount of lead has reacted).

Surface Clogging is when the chemicals react so rapidly that sulfate from the acid that combines with either plate may form so rapidly (at high currents) that the entire exposed plate surface(s) may become covered (clogged, temporarily shielded) with lead sulfate rather than lead (or lead peroxide). Lead may diffuse to the surface and sulfate may diffuse into the plate so slowly that the battery becomes a lead-sulfate-to-lead-peroxide or lead-sulfate-to-lead cell rather than a lead-to-lead-peroxide cell and its voltage and current will be reduced and its internal resistance again increased. The battery appears then to provide a much reduced current at a much reduced internal voltage. If you are patient, you may still extract the remaining electrons, but they may be produced too slowly to be of much use to an EV.

Sulfation (permanent surface shielding) is when lead sulfate that is principally on the surface of the negative plate grows into a hard crystalline structure that is not only non reactive, but prevents contact between the electrolyte and the plate (shielding the plate) and reducing its effective surface area. If it covers half of all the plates, it can reduce the effective capacity by that same half.

Shedding (positive plate erosion) is when the positive plate is slowly converted into a sub-micron-sized powder and is loose and therefore lost. This is actually a depletion of the available lead-peroxide ingredient. If half of the positive-plate peroxide is converted to powder then half the battery capacity is lost. It appears this erosion occurs almost totally during traditional charging of the battery near its end stage.

Efforts to predict battery capacity are more successful when the battery is new but can become very complex as the battery ages and each of these mechanisms becomes operative to differing degrees.

When the factory data for battery capacity drop below the ideal-battery curve of Figure A-1 any or all of these mechanisms, and perhaps still others the writer may still be oblivious to, may be the cause, and different data point deficits may result from different mechanisms.

When these batteries age, hard sulfate may have reduced some plate effective areas, shedding may have reduced positive plate inventory, acid may have been lost. All of these are relatively permanent losses with only the clogging mechanism being purely temporary. Hence the battery may then act as though its best-case capacity has been reduced even when it is at its maximum charge level. At that point these several mechanism may act to then further reduce that already reduced capacity data to a point where the batteries may not be practical power sources.

Nonetheless for new batteries, the prediction of battery performance is largely a matter of reading and extrapolating and interpolation of the data on Figure A-1. Wilhelm Peukert in 1897 proposed the use of a polytropic equation to predict the relationship of discharge time, t, with constant current draw, I, of the form $t = C_u/I^n$ (referred to as Peukert's equation) fitted to the data with two constants, C_u, related to ultimate capacity and a dimensionless exponent, n. The two constants can be estimated [***13,15***] using any two discharge data points but the results can be seriously in error.

The Problems with Peukert

Peukert's Equation, but also the data on which it is based (the data of which are apparently ***the*** standard used in the industry today: capacity in ampere-hours and cranking currents in minutes at constant current) often do not appear to serve the EV community well, or even adequately. Peukert's system has been described in several publications with Arendt [***13***] and Vinal [***15***] being the more thorough treatments in this writer's view. Peukert's approach attempts to predict the length of time that one can draw a constant current from a battery. This allows a "capacity" or ampere-hours available from that battery at various discharge rates to be estimated as the product of the constant current and its duration in time until it fails to deliver enough voltage.

These data, as noted, can be seriously flawed. To collect these data, batteries are discharged at various constant-current rates as shown on Figure A-1 meaning a variable resistive load is placed upon them and it is continuously reduced to maintain constant current until they are considered fully discharged. In the case of Trojan batteries, and many others, they are considered fully discharged when the terminal voltage they deliver falls to 1.75 volts/cell or thereabouts. However, because of the wide variability Vinal [***15***] recommends using a cutoff voltage which may be much less than 1.75 volts per cell and that is a function of the constant current but this is also flawed. The higher the rate of discharge, the shorter will be both the discharge time and the product of discharge time and discharge current.

This appendix explores more valid methods to make these predictions.

The Data for Peukert

Battery manufacturers today, worldwide, appear to specify performance data for their traction FLA batteries as capacity in ampere-hours at various constant-current draw rates. These rates are flawed for predicting how long an EV can be driven at a required draw rate.

Assume an EV with a 144-volt battery traction pack were to be drawing 60 amperes of current flow. At 60 amperes, the default battery pack would be producing an equivalent 0.096 ohms (24 x 0.004 ohms per battery) of (parasitic) resistance. This would actually be a rather low draw for the typical Cockroach but was chosen to facilitate testing.

Figure A-2, top curves, exhibits the writers measurement for a new US Batteries US 2200 XC2 battery connected to provide an initial 60 amp current. The top curve is a con-

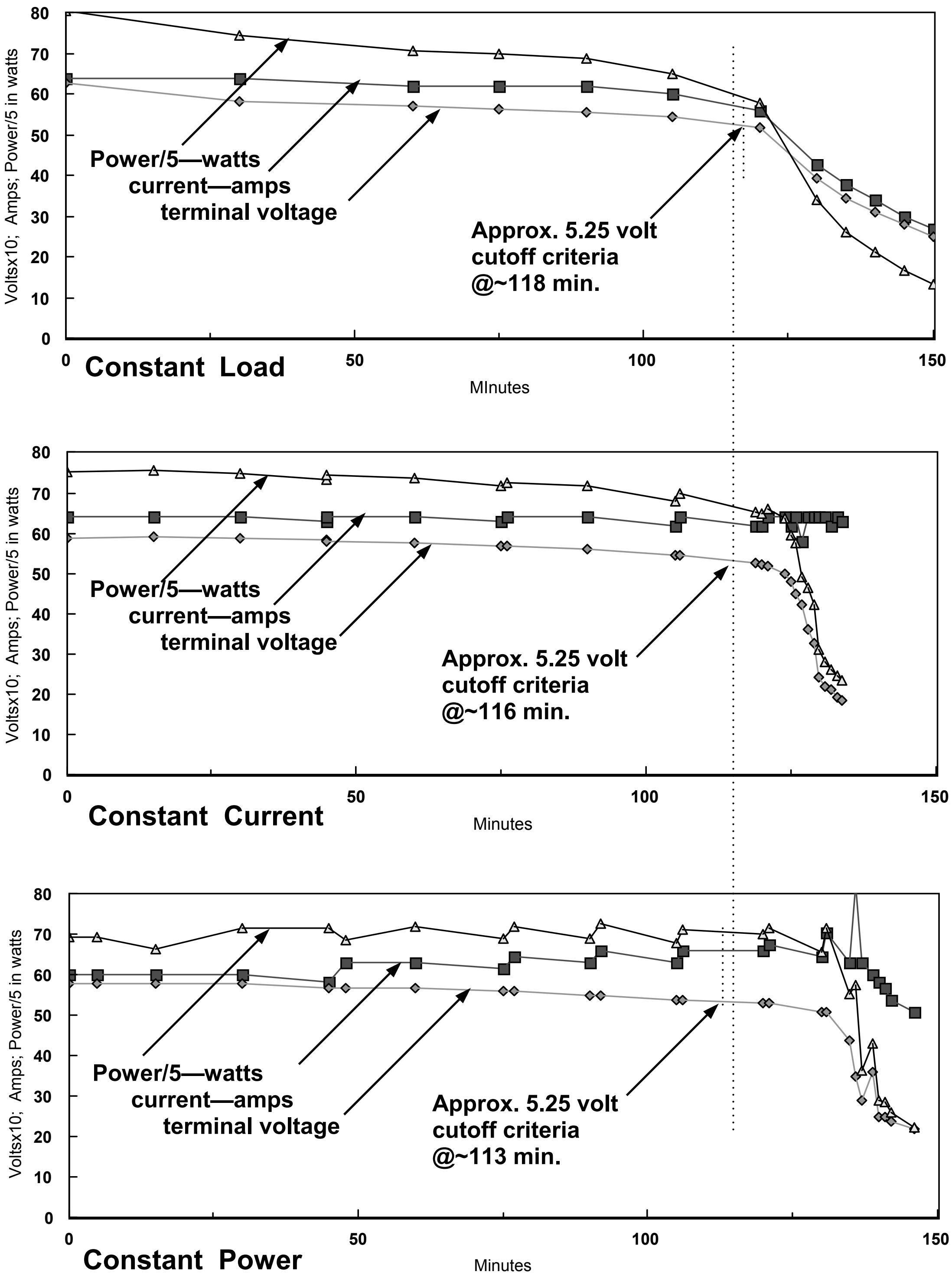


Figure A-2—*Three "constant" parameter tests of battery capacity.*

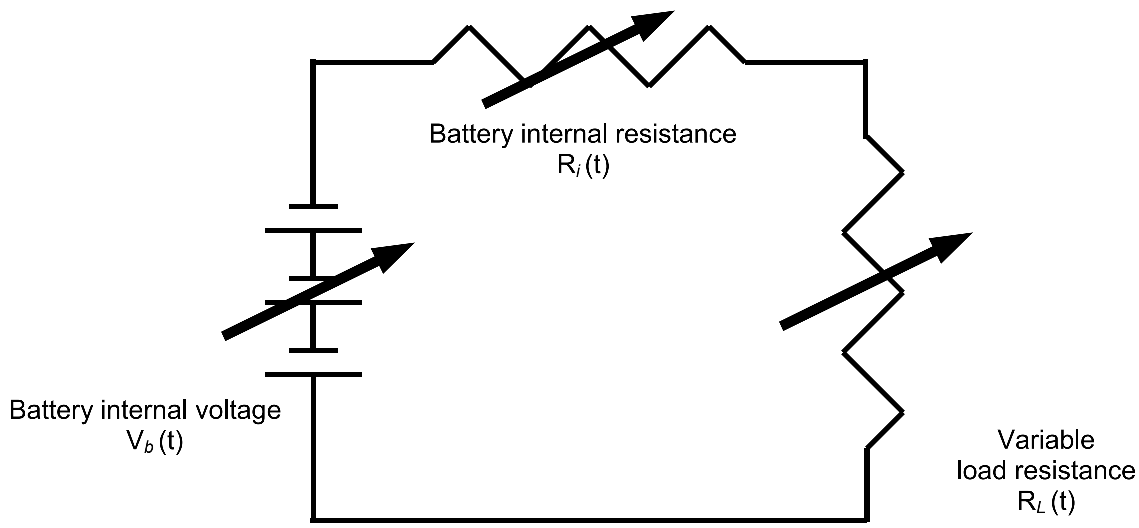


Figure A-3—*Too-Simple Model FLA Battery.*

stant-resistance draw. In the middle curves the resistance is progressively adjusted (reduced) to approximate a constant-current draw. The bottom curves exhibit an initial average 60 amp draw using a chopper with the chop duty cycle varied to provide an approximate constant average power draw for an initial resistance (non-reactive load) that yields a roughly 90 ampere peak current. Figure A-2 shows where the 5.25 volt, 1.75 v/cell, cutoff would be taken. Factory data for this battery indicate that a 60 ampere draw would persist for about 2.5 hours (150 minutes) while these tests found only about 113-118 minutes. Since new battery capacity improves during early cycling, this agreement may be reasonable.

However, looking at the three curves, suggests that the power delivery from the battery did not collapse until about 125 minutes for the top two curves and until about 135 minutes for the bottom (chopped) curve. Hence the use of this testing approach is approximate at best but in coarse terms is perhaps adequate.

Consider this method of testing further. Figure A-3 depicts a theoretical battery circuit. A battery of variable voltage with a variable internal resistance delivers current to a variable load. In this example let us assume the battery will be in equilibrium throughout even though batteries are far from equilibrium during standard testing (a much more difficult calculation to do). Figure A-4 provides Trojan data for what equilibrium FLA battery voltage and electrolyte specific gravity would be as a function of the state of charge (SoC). This assumption of equilibrium means when the battery temperature would be uniform and constant throughout, and when its electrolyte specific gravity would be uniform and constant throughout, and there would be no surface clogging present. In this case, when the battery is discharged to a 5.25 volt level it would be in the nonlinear region of the left curve of Figure A-4 at a state of charge below 10% that is shown extrapolated but which is actually curving downward. It would be collapsed….dead!

So let us examine what this fantastical battery would do in a standard capacity test. Often the internal resistance of this battery is taken as a low constant value (the web site evconvert.com uses 0.004 ohms). However Vinal [***15***] cites that the internal resistance of this

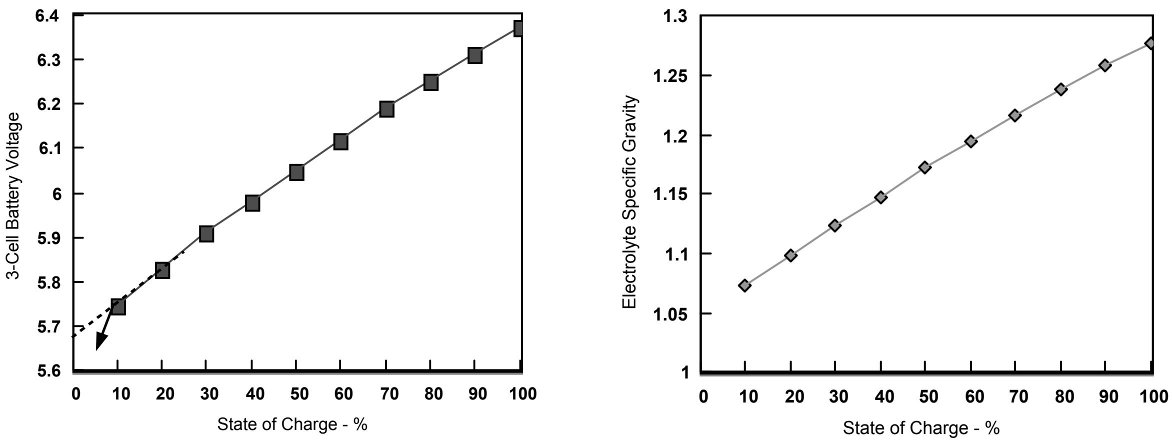


Figure A-4—*Battery Voltage and Electrolyte Specific Gravity Dependence on State of Charge. (Based on Trojan Battery Company data).*

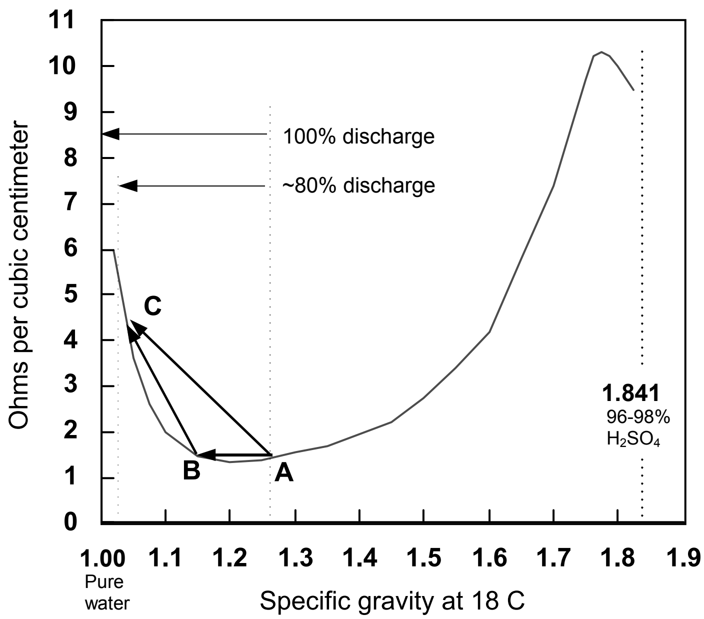


Figure A-5—*Electrolyte resistivity based on Arendt* [*13*] *page 65.*

type battery rises during discharge oftentimes tripling or more before the battery is fully discharged. Data, see Appendix D, also show however that the resistance does not rise linearly with the degree of discharge. Nor should it.

Figure A-5 depicts data from Arendt [***13***](his page 65) for the resistivity of electrolyte. A large fraction of new battery internal resistance is the resistance of the electrolyte. Fully charged new batteries begin with a specific gravity of about 1.27 at point A on the graph. As the battery discharges the resistivity dips a little then recovers to point B and then curves up tripling at point C. Note that at point B the equilibrium battery would be about 60-70% discharged. And so one might reasonably conclude the internal resistance would not increase greatly for the majority of the discharge time in normal EV use.

During constant-current discharge, a full battery in equilibrium might be approximated as linearly decreasing from 100% SoC at 6.37 volts to zero percent SoC at the extrapolated 5.68 volts (a 0.69 volt decrease) as the integral of the product of current and time, I x t, for constant current, increases from zero to 250 ampere hours and the time, t, increases from zero to 250/I hours, hence:

$$V_b(t) = 6.37 - [0.69 \times I \times t/250]$$

Notice again that the voltage versus SoC curve is based on open-circuit *equilibrium* voltage measurements. Hence we can approximate the anticipated equilibrium performance that this battery model would provide. All six examples of Figure A-6, show time in hours on the abscissa and voltage on the ordinate. For a battery of capacity, C = 250 ampere-hours, the SoC is shown decreasing roughly linearly in time with several constant-current draws.

The effect and the extreme importance of internal resistance must be emphasized, even though it is often neglected. More and better internal resistance data are vital and yet appear scarce. *EV Calculator (presently on evconvert.com)* cites internal resistance of the T-105 as a constant 0.004 ohms. As noted, Vinal [***15***] indicates the internal resistance of lead acid batteries can triple during discharge consistent with the resistivity of the electrolyte. This rise, like the rise during battery aging, may not be linear, but nonetheless, this analysis will consider two hypothetical cases where the internal resistance is constant (roughly close for at least most of discharge) and where it rises linearly with time upon discharge.

Figure A-6, exhibits six hypothetical sets of discharge current rates of a hypothetical GC2 class (~250 AH) battery similar to the T-105 discharging with its internal voltage decreasing according to Trojan equilibrium data. The top solid curves on each are the internal voltage drawing down with time as described above. Subtracted from each top curve is the constant voltage drop that would produce the terminal voltage resulting from a constant 0.004 ohm internal resistance (second solid curve with "+" markers") and, finally, the terminal voltage that would result from an internal resistance that is increasing from 0.004 to 0.012 ohms linearly (which is not the actual case) as the battery SoC drops (bottom solid curve). The equation for this third drop is the initial resistance plus a linearly increase to produce a tripling (from 0.004 to 0.012 ohms) as the battery discharges:

$$IR_i(t) = I \times [R_o + \{(R_f - R_i)/250\} \times I \times T)]$$

Also shown is a horizontal dashed line at 5.25 volts (1.75 volts per cell) to show where the test would be terminated as being officially "dead". At 2.5 amperes the two terminal voltages are virtually identical to the internal voltage. All three decay to the right hand margin (SoC of ~zero) and then plunge through the dotted cut-off condition at about 100 hours. This is consistent with Trojan data. It is similar at 11.25 amperes, in that the curves separate a little but all three plunge through the 5.25 volt criteria at about 22.2 hours close to the manufacturer's rating of 20 hours.

At 37 amps, the three curves separate much more but all three still plunge through the criteria at about 6.2-6.75 hours, while the real battery is rated at 5 hours and a dotted line estimates how its terminal voltage might be responding. It suggests lower internal voltage and/or higher internal resistance.

At 75 amperes, the trends continue. The three curve diverge still more and now the

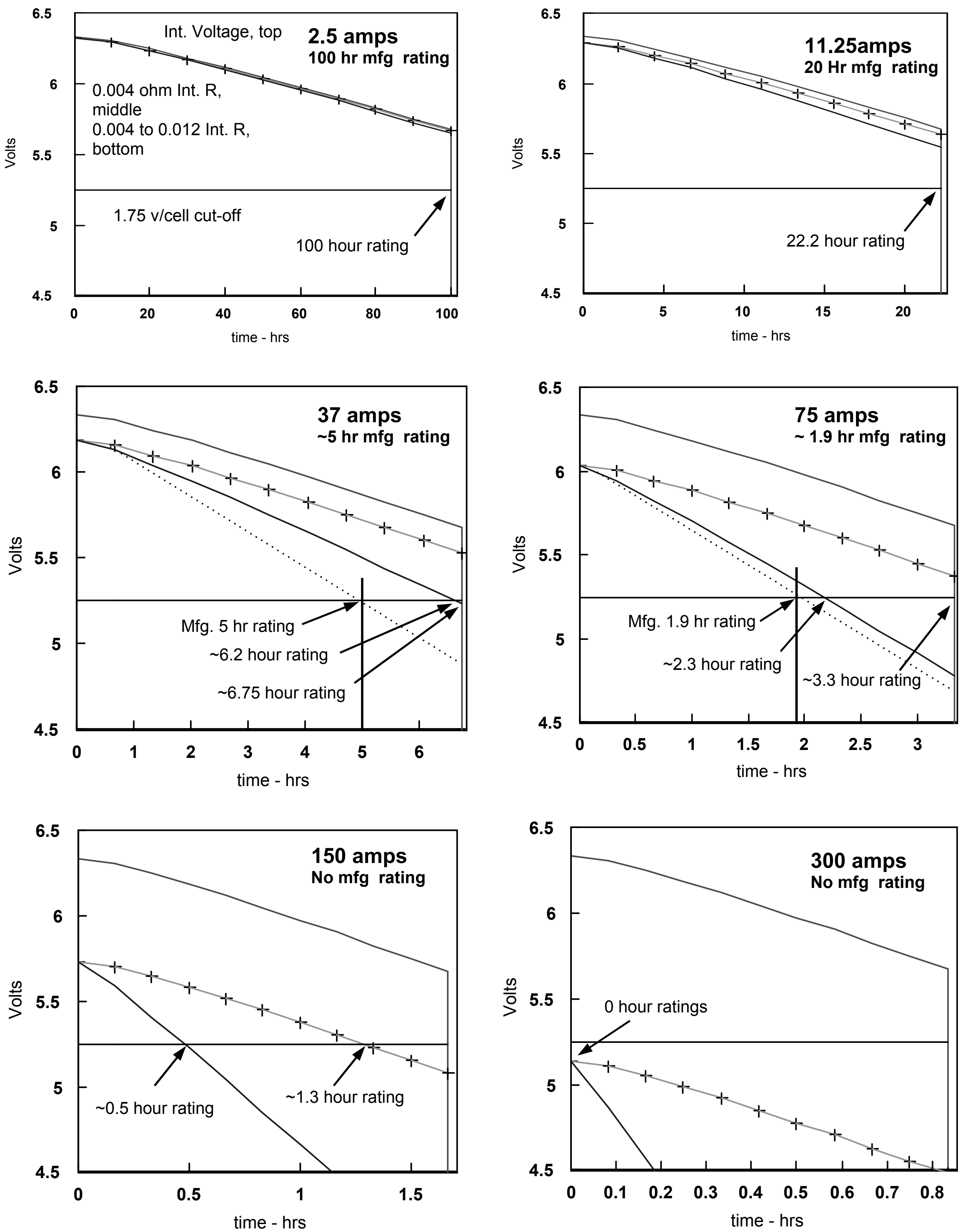


Figure A-6—*Six Model Peukert Scenarios .for the T-105 Battery.*

lower curve cuts through the criterion before it gets to its plunge. The upper curve's resistance would rate the battery at about 3.3 hours, but the higher resistance would rate it much lower at about 2.3 hours much closer to the manufacturer's rating of 1.9 hours again estimated with a dotted line.

The 150 and 300 ampere curves, show how the internal resistance can radically alter the ratings, but there are no manufacturer's ratings to compare at these discharge rates. Yet these discharge rates are typical of EV operation.

However notice that as the drain current increases, at 300 amperes, when the fully charged battery begins its draw, the terminal voltage would be less than 5.25 volts (1.75 volts per cell) for both internal resistance prospects yielding zero-hour ratings in both cases,...and yet clearly the battery would provide 300 amps of current (at reduced voltage) for some significant time from either scenario. Clearly this way of testing capacity has some serious issues.

Keep in mind the internal non-equilibrium open-circuit voltage of the cell would be still lower than that based on SoC cited above. Therefore, Figure A-6 illustrates why Vinal's method of adjusting the cut-off voltage downward with increasing current draw rates can improve the estimates of "useful" capacity that result. However, there does not appear to be a magic formula to indicate just where to set the cut-off level. Indeed one could argue that, in principle, it should be set at the voltage level at which the battery fails to provide the current when there is a zero resistance across its terminals….even though this number, itself, might be problematic,… as problematic as this analysis will next argue the Peukert's approach is.

And all of this is addressing those issues the writer is familiar with...so far... at his point on the learning curve. Clearly it must be admitted again, there may be other mechanisms that may also affect capacity.

Methodology of Peukert's Equation

To repeat, Peukert proposed that the discharge of batteries be estimated with a polytropic (constantly curving) equation of form:

$$C_u = I^n t$$

where C_u is the constant "ultimate" or "maximum" limit capacity of the battery at the lowest draw rates and is cited in ampere hours. The current, I, is initially chosen but thereafter constant (presumably) continuous current is drawn in amperes. The constant, n, is an empirical dimensionless variable exponent, and t is the total time that the continuous, constant draw from the battery can be sustained in hours, which coincidentally would be when the load approaches a dead short across its terminals. It appears that "Peukert's Law" as thus presented was contrived, simply because the polytropic equation produces a curve that is similar in appearance (constantly curving) to the battery data that are measured. The equation can produce poor results even when used properly, and alas! is often misused badly. Even though Peukert apparently did not derive his equation from first principles, the same equation format appears in other physical sciences, where it *has* been derived from first principles, such as in the prediction of isentropic behavior of gases, in which a compressed or expanded ideal gas will experience a relationship among its state variables, pressure, volume and temperature according to the corresponding relation:

TABLE A-1—*Trojan T-105 battery capacity specifications.*

Constant Current (Amps)	*In-situ* Capacity (Amp-Hours)	*In-situ* Capacity (C-Hours)
75	***144***	1.917
37	185	5
25	***186.25***	7.45
11.25	225	20
2.5	250	100

$$C_g=V^{\gamma}P$$

Where C_g is again a constant for a given amount of gas, V is the gas volume, P is the gas absolute pressure and γ is the ratio of the gas specific heats at constant volume to constant pressure. This (and variations on this theme) is the equation that predicts whether Diesel ICE engines will compress air to a sufficiently high temperature to be able to ignite the fuel even in the absence of a sparking plug. And interestingly, the value of γ for gases falls in about the same range as for the value of Peukert's exponent, n, (1.0-1.4) for lead acid batteries, with γ ranging from 1.2 for monatomic gases like helium to 1.4 for diatomic gases like air, and up to roughly 1.6 for the smallest gases like helium and hydrogen. And like Peukert's Law, this equation is also frequently a bane to use, often is misused, and so PC algorithms have been developed to at least avoid some of the errors due to that misuse.

Peukert's parameters tend not to be published by lead acid battery manufacturers, perhaps because of the problems with them (to wit, perhaps because the inaccuracy that might lead to lawsuits). Hence they are often calculated (apparently often with significant error) by users and based upon manufacturer's data for constant current discharge results at several rates. But these equations are not intransigent and so a basic algebraic approach is presented here based upon these multiple draw data specified by manufacturers to illustrate the problems with Puekert's Law.

In the case of a Trojan battery (Product Specification Guide, ©2011), such as the popular Model T105, discharge performance is cited in two related ways that are also cited in their literature and listed in Table A-1.

- First it is cited as an *in-situ* "Capacity" in minutes at a constant-current flow at (a presumably starting) 80°F until the battery is "drained" (meaning cell voltage measured at its terminals drops to 1.75 volts), and the T-105 can supply a 25 amp draw for 447 minutes (7.45 hrs), or it can supply a 75 amp draw for 115 minutes (1.917 hrs).

TABLE A-2—*Peukert's parameters based on binary point set.*

Point 1 C-Rating	Point 2 C-Rating	Peukert's Exponent (dimensionless)	Peukert's Capacity (ampere hours)
C 100	C 20	1.07005	266.6
C 100	C 7.45	1.12784	281.1
C 100	C 5	1.11174	277.0
C 100	C 1.917	1.16270	290.2
C 20	C 7.45	1.23670	399.0
C 20	C 5	1.16442	335.0
C 20	C 1.917	1.23502	397.4
C 7.45	C 5	1.01718	196.8
C 7.45	C 1.917	1.23381	395.3
C 5	C 1.917	1.35370	663.5

- Second it is also cited as an *in-situ* "Capacity" in Ampere-hours at a constant-current flow at (a presumably starting) 80°F (some other models use 77°F) until the battery is "drained" (meaning cell voltage measured at its terminals drops to 1.75 volts), and for the T-105, five hour, twenty hour and one-hundred hour data are cited as 185, 225, and 250 ampere hours respectively.

Table A-1 exhibits the Trojan data. In the cases where the *in-situ* capacity is cited as time-at-constant-current, the ampere-hour equivalent has been calculated by multiplying the parameters and showing them as bold-faced italic font. Where the *in-situ* capacity has been cited as amp-hours at constant current, the time equivalent has been calculated by dividing the ampere hours by the constant current and showing them in bold-faced italic font.

Each of the five entries in Table A-1 now contain two of the four parameters cited in Peukert's Law. Namely the time and constant-current draw. Therefore, as cited in Arendt [***13***] and Vinal [***15***], any two pairs of these data can be used to create two equations in two unknowns (C_u and n being the two unknowns) and can therefore "in principle" be solved to determine the value of Peukert's exponent and predict the ultimate capacity of the battery. [A1]

Table A-2 exhibits the range of exponents and limit capacity values that would be

[A1] The details of the solutions suggested by Vinal [***15***], his page 216, are as follows. Take any two values of current (I_x) and time (t_x) such as from Table A-1 and form two equations using Peukert's equation, $C_u=I^n t$, which are then $C_u=I_1^n t_1$, and $C_u=I_2^n t_2$. With them C_u can be eliminated leaving: $I_1^n t_1 = I_2^n t_2$. Take the log of both sides so that:

$$n\text{Log } I_1 + \text{Log } t_1 = n\text{Log } I_2 + \text{Log } t_2$$

This manipulates to

$$n(\text{Log } I_1 - \text{Log } I_2) = \text{Log } t_2 - \text{Log } t_1$$

And then

$$n = (\text{Log } t_2 - \text{Log } t_1)/(\text{Log } I_1 - \text{Log } I_2)$$

Then insert the known value of n, into either $C_u=I_1^n t_1$, or $C_u=I_2^n t_2$, to solve for C_u. From this, one can then solve for any random combination of I or t, given either one. Or for any in-situ capacity as $I_x t_x$.

calculated for all ten possible combinations of two sets of Peukert's parameters. Peukert exponents ranging from a near-perfect 1.017 to a huge 1.35 are present and ultimate capacities are predicted ranging from 196.8 amp-hrs (less than known actual) to 663.5 (clearly far above known actual). Figure A-7, Parts A and B exhibit how the various parameters predict battery performance, and they clearly are flawed for predicting EV performance. Recall that the evconvert.com performance utility (EVCalculator) cites 1.24 as the exponent it uses and 447 as the ultimate amp-hour capacity for the T-105, neither of which precisely match any of these entries.

Keep in mind that a typical hobbyist conversion EV with a thirty mile range at 60 mph would "drain" its batteries in just thirty minutes, nearly four times faster than the fastest (C-1.917) reported specification for the T-105, and would be estimated with the data on the left-most portion of Part B where, depending upon the curve used, these data would estimate a capacity from ~80 to ~175 amp-hours. Indeed, for a battery pack to last two hours at 60 mph, the range of the EV would have to be 120 miles. Therefore depending on how one extrapolates these data beyond the range of the measurements, large errors might result.

Vinal [***15***], his page 218, indicates several better estimation formulae have been developed and at least one web site seeks to modify Peukert's equation for better results. This Appendix will propose a graphical approach can be used to form a battery equation of state that can then be used for more appropriate estimates.

A Better Way

If one wishes to use constant current test results for predicting EV range (perhaps because at least there are some data at constant current published), Peukert's approach can be improved upon. Figure A-8, page 251, (a log-log plot) replicates data from the U.S. Batteries data sheet for their US 2200 XC2 battery that was used to collect most of the new data in this book. They provide 12 data points for various constant current tests and they plot their data in logarithmic current versus logarithmic discharge time. There are also data points plotted similarly for the T-105 battery (of about 3% less capacity) as were seen in Table A-1. Notice that the data appear to lie on a bent straight line.

Recall Peukert's formula:

$$C_u=I^n t.$$

Can be algebraically manipulated to

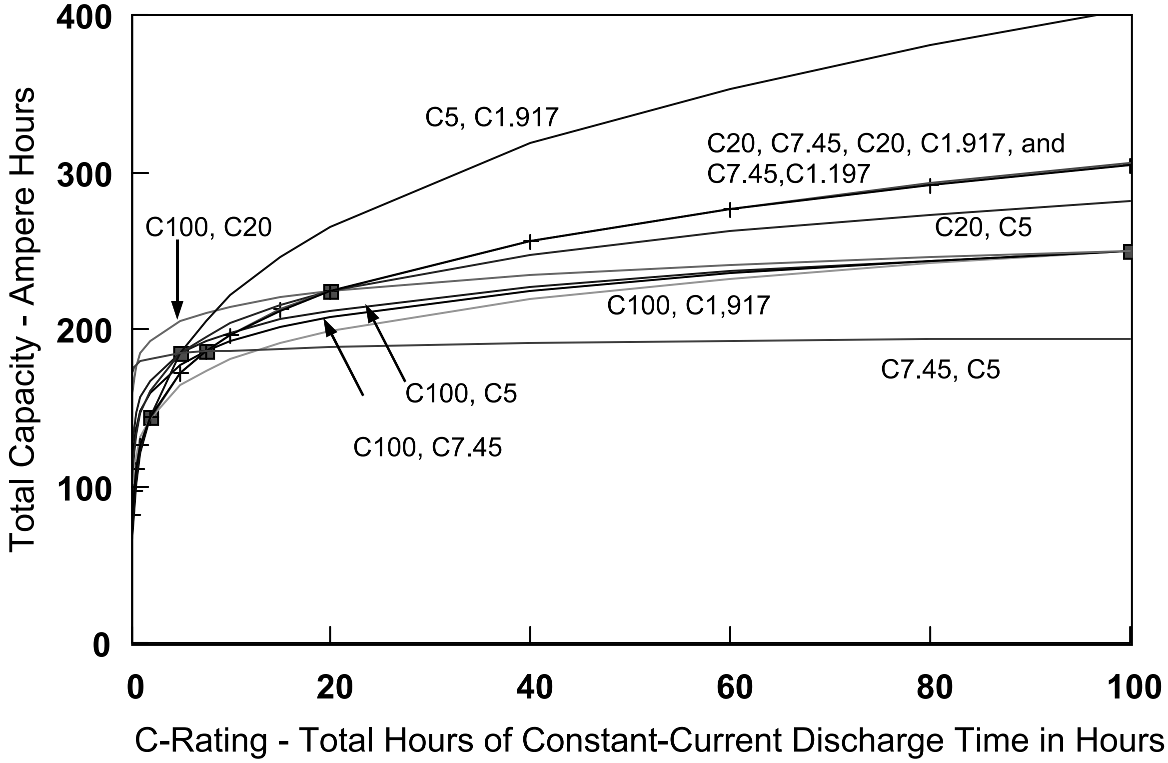
$$\text{Log}_{10}C_u = n\text{Log}_{10}I + \text{Log}_{10}t$$

or

$$Y = \text{Log}_{10}t = -n\text{Log}_{10}I + \text{Log}_{10}C_u = mX + B$$

Which is the formula for a straight line. Since the line the data points form on Figure A-8 is bent, it is formed of two intersecting straight lines. When one applies the procedures for Peukert's Law in the previous section they are drawing straight lines through any two data points. Clearly since the line is bent, there is no straight line that can represent it from end to end. Some options may be less wrong than others but no option is correct.

One can always approximate any curved line as a series of conjoined line segments. In this case only two segments are required and by the writer's math they are:



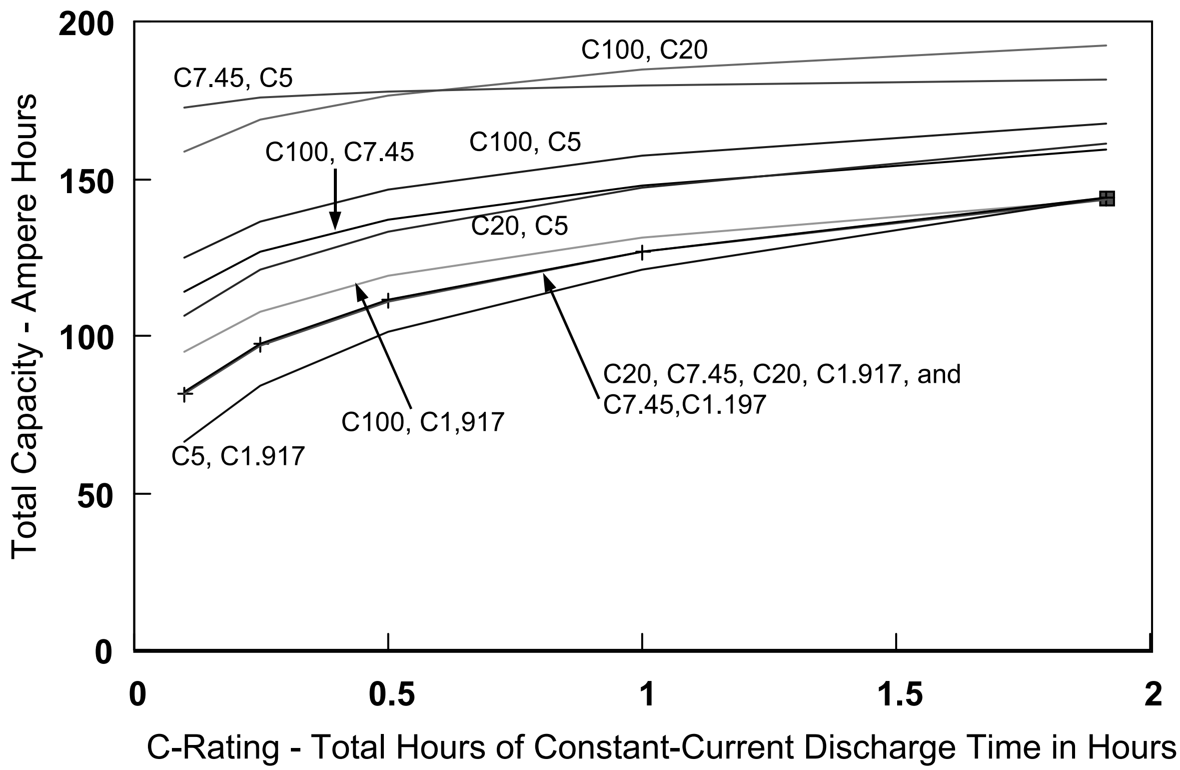


Figure A-7—*Ten Peukert's Curves for T-105 Battery.*

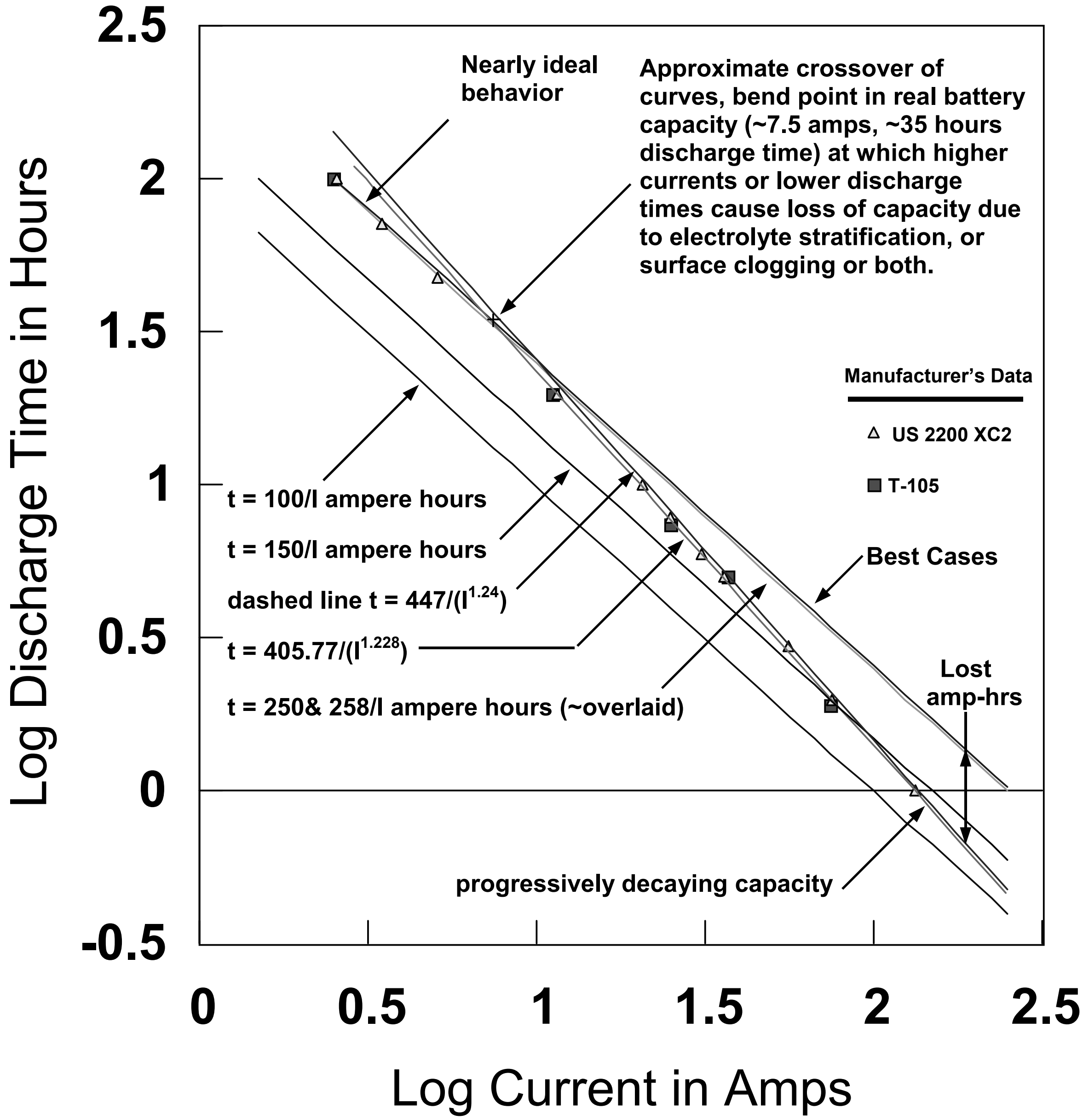


Figure A-8—*Battery discharge times versus current draw for two batteries and six interpretations.*

For I <7.5 amps, $t \sim 250/I$, $\sim 258/I$

For I > 7.5 amps, $t = 405.77/(I^{1.228})$.

Figure A-8, exhibits these equations over the full range of the ordinate axis and in addition similarly shows how ideal batteries with a capacity of 150 amp-hours (t = 150/I), and 100 amp-hours (t = 100/I) would behave. Finally it shows the curve used by EV Calcu-

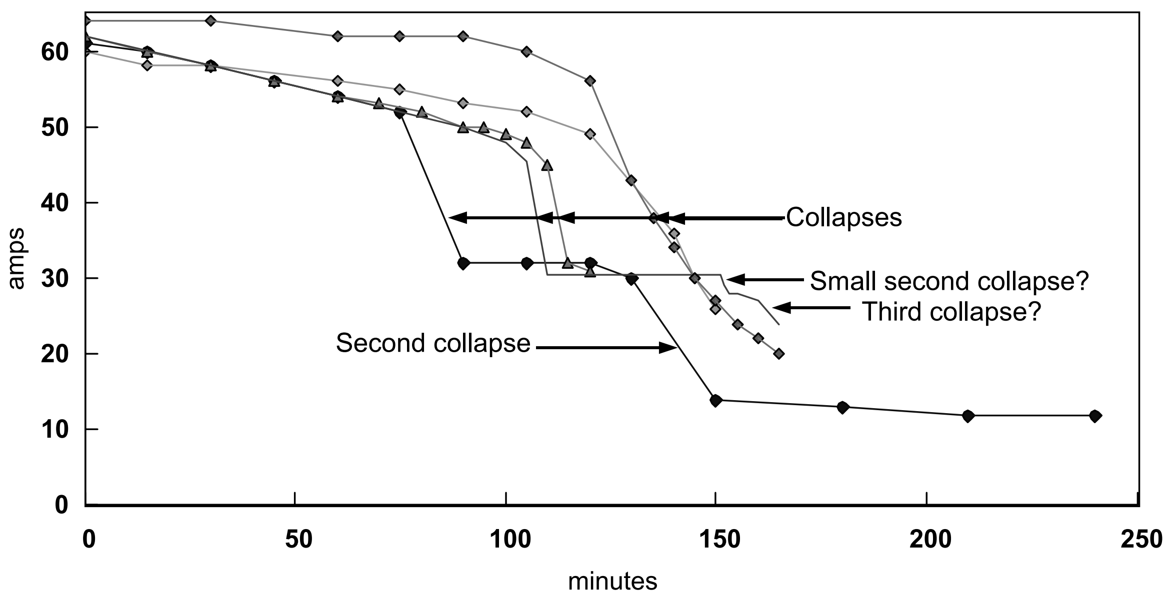


Figure A-9—*US 2200XC2 Battery discharge curves with constant load resistance, various ages, abuse, and condition.*

lator at evconvert.com, ($t = 447/[I^{1.24}]$) which is also a rather good fit above 7.5 amps.

Notice that up to the bend in the curves at ~ 7.5 amps, the factory data fit the 250/258 amp-hour ideal curves quite well. Above the bend, the data fit the writer's curve $t = 405.77/(I^{1.228})$.well and are also quite a good fit to the EV Calculator curve ($t = 447/[I^{1.24}]$). However below 7.5 amps neither of these curves fit well.

As current draw increases both well-fitting curves ultimately cross through the ideal battery curve for 100 amp-hours then at even higher current draws approach the ideal curve that would apply for a 100 amp-hour battery, meaning both batteries would deliver less than half their low-current capacities.

In an attempt to physically explain these curves, the writer offers that up to 7.5 amperes, the batteries are behaving ideally. However at 7.5 amperes, two of the capacity limiting mechanisms previously cited may be beginning to kick in: surface clogging, electrolyte stratification. Either or both in concert may be responsible. Indeed whether intentionally or not it seems that both mechanisms seem to kick in at nearly the same time.

Consider Figure A-9. These are five discharge curves at an initial ~60 amps current in a US 2200 XC2 battery that was abusively tested over several months. Notice that the battery is providing substantially constant power until about 70-120 minutes, at which time both the internal voltage and current collapse, In some cases, they fall to about 30 amps (and voltage falls also) and plateau for 20 to 40 minutes and then go through a second collapse abruptly falling to about 12 amps. The battery is not spent. It is still providing current and voltage but only at a low level. It is acting just like something is limiting its access to both electrolyte and lead materials. Namely, clogging and/or stratification. But maybe there are still other mechanisms the writer has not found nor identified in his own testing yet. Doubtless these abrupt collapses occur at differing times when differing currents are drawn and are factors in the relationships between capacity to draw rates.

Bottom Line

This section argues and defends the use of two empirical equations to predict discharge time for a battery pack comprised of T-105, US 2200 XC2 or their equivalent GC2 batteries. Above 7.5 amperes, the best equation is:

$$t = 405.77/(I^{1.228})$$

Below 7.5 amperes or for best-case estimates, one uses the ideal battery equation:

$$t = (250,\ 258,\ \text{or other mfg rating})/I$$

which applies when estimating best case range for current draws over the full range.

In Figure A-8 the way that the ideal curves diverge from the manufacturer's ratings, illustrates how Best Case capacity is lost as the current draw increases and that illustrates how much improvement might be possible in an FLA battery. Power at higher legal speeds and therefore current requirements can double or more in comparison to city driving. To lose this much capacity and then also lose another factor of two in battery capacity due to age or temperature, can be daunting. Clearly improvement of the FLA battery capacity would be desirable and would make them much more competitive with lithium batteries not only in cost but in vehicle performance also. An argument can be made (perhaps even a valid argument) that significant improvement should be possible in lead FLA batteries to provide more nearly best case range from them. As a result, Appendix C will speculate on a re-engineered FLA battery in a desperate search of better or even best-case performance.

However, we are told that free-enterprise competition should have already identified and designed such a battery, and it should be on-sale in the local battery store. So perhaps, like the Fish carburetor of olden days that promised outstanding gas mileage, but which many conspiracy theorists claimed was suppressed by evil companies, this speculation may prove grossly in error and "the battery with twice the range of regular FLA batteries" may be doomed to myth...but at present that needs proving.

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Appendix B

"Constant" Power from Chopped Motor/Battery Cycles

In the days before LED flashlights, everyone learned that power drawn from batteries was a losing battle. With new batteries, flashlights produced a bright light for awhile but then it got progressively less bright until finally with a whimper gave up its last electrons and we called the batteries "dead'. An EV's velocity is a lot like flashlight brightness. When the batteries are full you can achieve a certain range of velocities for awhile, but there comes a point where there is just not enough power in the batteries to achieve some given velocity and so you are at that point beyond the constant-velocity (CV) range, where your EV's top speed is less than what you want to drive at, ….but the car does not necessarily stop[B1]. It may be at only 25% to 50% of the CV range when the batteries were new and fully charged and warm, but that does not mean you necessarily come to a halt. It means like the flashlight you limp along, driving at your decaying top speed, with that top speed progressively dropping, until the last of the battery power is spent. Hence, when we say the car's constant velocity range has halved, it does not necessarily mean you can not get home. It may instead signal when you start limping along or when you give it potentially damaging rest. Hence the battery that gives you 25-50% of its 250 ampere-hours at constant velocity, may give you a significant portion of the remainder in limp-mode or rest-and-drive mode. Appendix C will speculate on technology to reduce this dilemma.

This chapter first examines chopped constant-power application in some detail, in hopes of developing "simplified" energy relationships for those to whom this material is not obvious. In studying combustion (thermal) engines (or thermodynamics) one quickly en-

[B1] Recall from Appendices B and C of *Volume 1* and Appendix A of this volume that in rapid discharging, the electrolyte becomes locally depleted of acid between the plates and the plates can "clog" with sulfate near the surface of the plates, and in any pores of the plates, which acts to reduce the voltage of the cell, increase its internal resistance, and create the appearance of a lower state of charge than would be represented by the amount of active materials that have actually reacted. However, when allowed to rest its "apparent" state of charge can recover to a significant degree.

counters the generic topic of combustion "cycles". One of the earliest was the Rankine (steam) cycle engine. Cycles have been defined for numerous combustion engine protocols, the most famous being the Otto cycle, but also many well-known others: Diesel, Stirling, Brayton, Ericsson, Atkinson, Miller, and many more. All of them are idealized (meaning approximate) and this examination of motor/battery chopping will be couched in similar approximate descriptions as cycles, specifically simplistic cycles. They will consider only resistive circuits (and low chopping-speed circuits) for simplicity but also for lack of knowledge of EV reactive properties. At high chopping speeds reactive effects, filtering, additional averaging and more math are needed and this writer would need to refresh or learn before he would have the "chops" needed.

Each combustion cycle divides the operation of an engine into a sequence of steps (themselves also called cycles), or sequential steps, such as intake, compression, expansion, and exhaust, that are repetitive. In engines, cycles often relate to the strokes (unidirectional motions) of the pistons (hence two-stroke and four-stroke engines), but they do not have to.

Chopping in EVs (in which there is no crankshaft and there are no "strokes") can also be viewed as a sequence of steps, and chopping can be accomplished in ways that will alter the performance characteristics of an EV and (if not already named) eventually may warrant names for specific important examples.

Chopping Cycle Examples

Please do not feel your intelligence is insulted by the following attempt at a very basic review. Hopefully this will develop into a useful perspective, but if it doesn't, I repeat my many apologies and if possible will try to clean up any mess I make.

First consider the equations that apply to approximate a nominal 144-volt battery pack made up of twenty-four typical (T-105-like) batteries feeding a steady-state ideal motor as was seen in Chapter 2. Figure B-1 exhibits performance curves of Chapter 2, Figure 5. The top curve represents a fully charged new battery pack (152.8 volts) with a minimum commonly accepted internal resistance (0.096 ohms). The lower curve represents a theoretically rapidly discharged pack (20% state of charge at equilibrium) with 0.288 ohms of internal resistance and with 139.9 volts (though the actual rapidly discharged voltage might be much lower) with an assumed internal resistance three times the initial. A third curve is added half way intermediate between them with an assumed 60% state of charge with an assumed rapidly discharged internal resistance of 0.192 ohms (potentially both in significant error) and an average voltage of roughly 146.4 volts. However, as we have seen, this midway resistance and voltage may occur well before the battery is at 60% SOC and, due to loss of equilibrium, very often will occur when the battery is less than 60% SOC (will be closer to where the bottom curve is). The real battery can act like it is discharged when its real state of charge is 50% or more. These assumptions are for illustration only and are not risk-free and quite possibly have significant error to be corrected in later effort or by smarter people.

To stress the point, the assumed voltages for the lower two curves may be significantly in error on the high side (rapid discharge likely pushes internal voltage down faster than it reacts the active materials in the cells). And indeed the internal resistances of the lower two curves would not be constant. Vinal [***15***] indicates they would be still higher at lower torque levels. Hence real curves might lie somewhat below the lower two curves, but

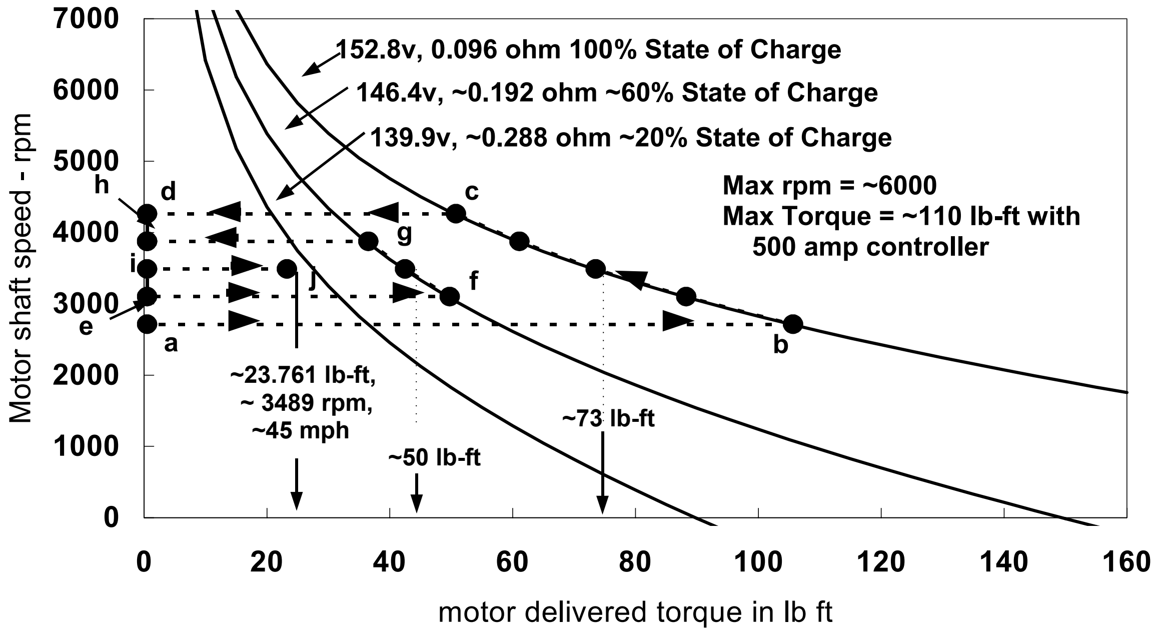

Figure B-1—*Motor cycles for three states of battery-pack charge.*

this hypothetical construct will serve to illustrate a concept, not a fact.

Consider the quintessential Cockroach EV of Chapter 2, of weight ~4800 lbs with a 24 battery pack driving in third gear on a level-road at a speed of about 45 mph. Chapter 7 and the companion design spread sheet indicate that in third gear, this requires constant torque from the motor at the point indicated with a marker on the lower axis of about 23.76 lb-ft of torque. It will require a motor speed of about 3489 motor rpm (at about 16 hp).

Notice that this condition lies just below the lower performance curve, and was deliberately chosen to be there. Therefore, this is its end point, its top speed for an 80% "discharged" equilibrium battery pack. Any operation would drain the pack down below its recommended operation point (reducing its voltage, increasing its internal resistance, lowering its state of charge below the 20% level) and make this torque and power unsustainable. Hence, soon the vehicle will no longer sustain the velocity and *must* slow down. It will not stop moving at lower velocity, but therefore this point demarcates the end-point of its range *at that constant velocity (CV)*, as well as its ultimate top speed at that condition.

Now let us hearken back to that moment when the battery was fully charged and one began driving at this steady-state ("average") velocity, made possible by interrupting, chopping, the power connection. Assume the vehicle is towed to 45 mph, with zero battery current flow and therefore zero motor torque delivery (though in generator mode the motor may be circulating current equivalent to the torque requirement) and the car then released. We will start with manual chopping, in which case the driver allows the speed to drop a little below 45 mph, to point "a", then will turn on the motor and accelerate to slightly above 45 mph and turn the motor off again and coast down. Repeating this process over an over again to maintain an average 45 mph.

TABLE B-1—*Req'd and avail. motor delivered-torque and hp at speeds in 3rd gear on Figure B-1.*

Point	mph	Motor rpm	Req'd T* lb-ft	Req'd hp*	Avail. T* lb-ft	Avail hp*
a	35	2714	19.83	10.24	0	0
b	35	2714	19.83	10.24	~105	~54
c	55	4264	28.38	23.04	~50	~41
d	55	4264	28.38	23.04	0	0
e	40	3101	21.71	12.82	0	0
f	40	3101	21.71	12.82	~49	~29
g	50	3877	25.99	19.19	~36	~26
h	50	3877	25.99	19.19	0	0
i	45	3489	23.76	15.78	0	0
j	45	3489	23.76	15.78	~27	~18

*Torque or hp delivered to or available at motor output shaft.

Idealized cycles are exhibited for such coarse chopped operation by the sequence of points, "abcd", "efgh", and "ij", on Figure B-1, but for simplicity the figure neglects potentially important factors such as reactance (inductance and capacitance). When the velocity has fallen by 10 mph (to ~35 mph) power is applied at point "a", voltage is connected to the motor, and ignoring any reactive issues in the "ideal" case, current will quickly build from its coasting level (called the free-wheeling current) and its point of operation shifts as predicted by the equation of state to the performance curve at point "b". This point delivers more torque (and more horsepower) than is needed to sustain 35 mph or even the constant "average" velocity, v = 45 mph. As a result the vehicle is not in a steady-state and will accelerate, meaning, it will move *up* the steady-state curve (to the left). *Increasing* speed means *decreasing* torque and *decreasing* current and so over a period of time the operating conditions will shift to point "c", which is at a velocity about 10 mph greater than 45 mph (or ~55 mph). At this point the switch is turned off to interrupt voltage and power and the operation shifts to point, "d". From point "d" to point, "a", the vehicle is now "coasting" and losing velocity (due to aero drag, rolling friction, and any free-wheeling current flowing through the motor's resistance, etc). The amount of time it takes to accelerate from b to c may be different from the amount of time it takes to coast down from point "d" to point "a" (being either circumstantially longer or shorter).

Notice, it appears the time required to build current during make and for current to fall during break does not appear to be dictated by the reactances (capacitive and inductive) but rather by good old Newtonian mechanics: by the mass and its acceleration under its dissipative influences (rolling friction, aero drag and hills).

Applying the theory of Chapter 6, or this book's companion spreadsheet, based on the source references, one can surmise that at point "b", the vehicle requires: a force of about 100 pounds, which with drive-train loses (9%) means a power delivery from the motor to roll of about 10.2 hp, and a torque delivery from the motor of about 19.8 lb-ft at 2714 rpm for a constant velocity at 35 mph. However we see that the motor would be supplying about 105 lb-ft of torque at about 54 hp. Hence, this is why the vehicle will accelerate.

After some time, it will arrive at point "c", at about 55 mph. At this velocity, the Cockroach requires a force of about 143 pounds to sustain the velocity, and with the 9% drive-train loses, power from the motor of about 23 hp. In third gear, that means a torque from the motor of about 28.4 lb-ft at 4264 rpm for a constant velocity at 55 mph. However we see that the motor would be supplying about 50 lb-ft of torque at about 41 hp. Hence the vehicle will still be accelerating but at a slower rate than at point "b".

The time to accelerate from point "b" to point "c" could be several seconds. Then the power is disconnected and the vehicle state shifts to point "d".

In coasting from point "d" back to point "a", the motor provides no assist and the required sustaining force is drawing from the vehicle's kinetic energy (its momentum). The force to keep the vehicle rolling at 55 mph (at 23 hp) is still 143 lbs plus drive train loses which will now become the force slowing the vehicle down. This force will decay with velocity until the vehicle velocity decays to 35 mph, back at point "a", whereat the required force will have returned to 100 lbs, or with drive train loses, 10.2 hp. This decay may also require several seconds. During this time the motor supplies no torque and no horsepower.

Hence for every full cycle the motor will be powered by a duty cycle given by the time the motor is powered divided by the sum of the powered and un-powered times.

This four-step cycle can then be repeated to sustain an average velocity but as the battery discharges, say to the hypothetical 60% state of charge, and loses open-circuit voltage and gains internal resistance, the character of the cycles will need to change. Since the battery provides less torque and power as it discharges, it would take longer to accelerate from 35 to 55 mph and so the "on" chop times would have to be longer, if indeed the battery pack is able to produce the final velocity at all. If a constant cycle period were desired, then the width (the velocity change) of the cycle would have to be reduced. (shown at the middle-cycle curve ("efgh") on Figure B-1. Assume you must now do the manual switching (the chopping) at 40 and 50 mph in order to reduce the acceleration times. When the battery has discharged to the hypothetical intermediate level, the four cycle-steps will be around the loop "efgh" (shown for chopping between plus or minus 5 mph on velocity). Further, the time required to accelerate from point "f" to "g" might be longer than the time that was required before to accelerate from point "b" to "c". However, the time to coast down from point "h" to "e" will also be shorter than the time to coast down from point "d" to "a". So the overall cycle time may be similar, but the duty cycle (the fractional "on" time) would be greater.

Ultimately when the battery has discharged to its arbitrary end-point (~20% state of charge) at the 45 mph velocity which is at the lowest performance cycle shown ("ij"), the power will have to be continuously applied, the duty cycle would be 100% (continuous connection). This is the end of the range at constant-average velocity, v, but it does not mean the vehicle must stop moving (that is, it still has a decaying-velocity range). Any further motion, however, must be at a progressively decaying velocity, and (if the battery really were at a true 20% state of charge[B2] [it might not have to be *that* low!]) would drain the battery to po-

[B2] Remember from Appendix A, the battery may stop delivering current and voltage far before it falls to a 20% state of charge when current draws are high., perhaps even protecting itself from excessive discharge.

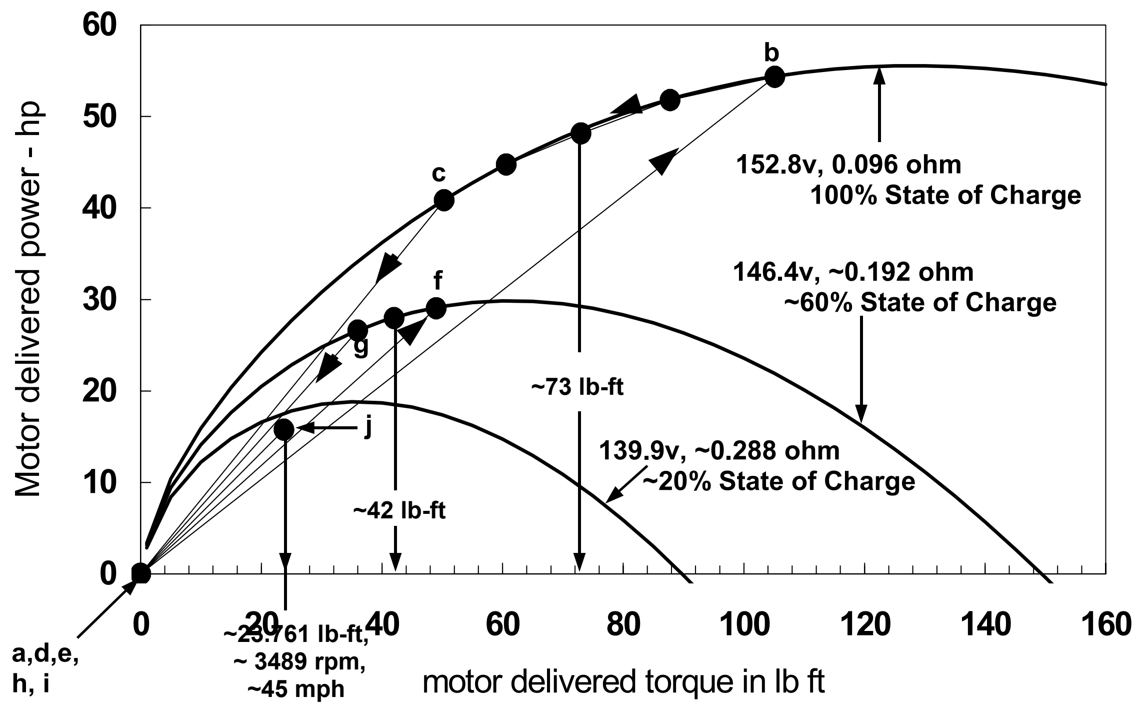

Figure B-2—*Motor cycles for three states of battery-pack charge.*

tentially damaging levels (if conventional battery wisdom is correct).

It is not only the relationship of torque and motor speed that varies during this electro-mechanical cycle. Figures B-2 and B-3 exhibit how the relationship between torque and horsepower and between torque and efficiency vary, and indicates how the three electro-mechanical cycles of Figure B-1 might appear. Note that the efficiency of the energy conversion decays as the battery discharges, respectively, in this hypothetical example, losing a third of its energy at the end point to nonproductive heating within the battery. *Obsess over internal resistance.*

Figure B-4 exhibits various parameters for the manually chopped hypothetical EV for the cycles exhibited in Figures B-1 to B-3. Notice how the inertia of the vehicle serves to smooth the velocity curve by storing kinetic energy ($MV^2/2$) in its momentum and using it to sustain velocity (and to circulate the free-wheeling current in the motor) when the power is off.

To the extent that this contrived example adequately estimates battery and motor performance, it illustrates a realistic mechanism. One could operate a vehicle this way with a manual switch, and the illustrated chopping might be at a very low frequency if one operated the manual switch slowly to apply the power. However, it would tend to be “jerky” with the chops being noticeable every time the vehicle lurched to accelerate or coast. Currently electronic switching is done very rapidly (15,000+ cycles per second is a typically cited rate) intended to get the “lurches” at a frequency so high and of such small amount that they are not

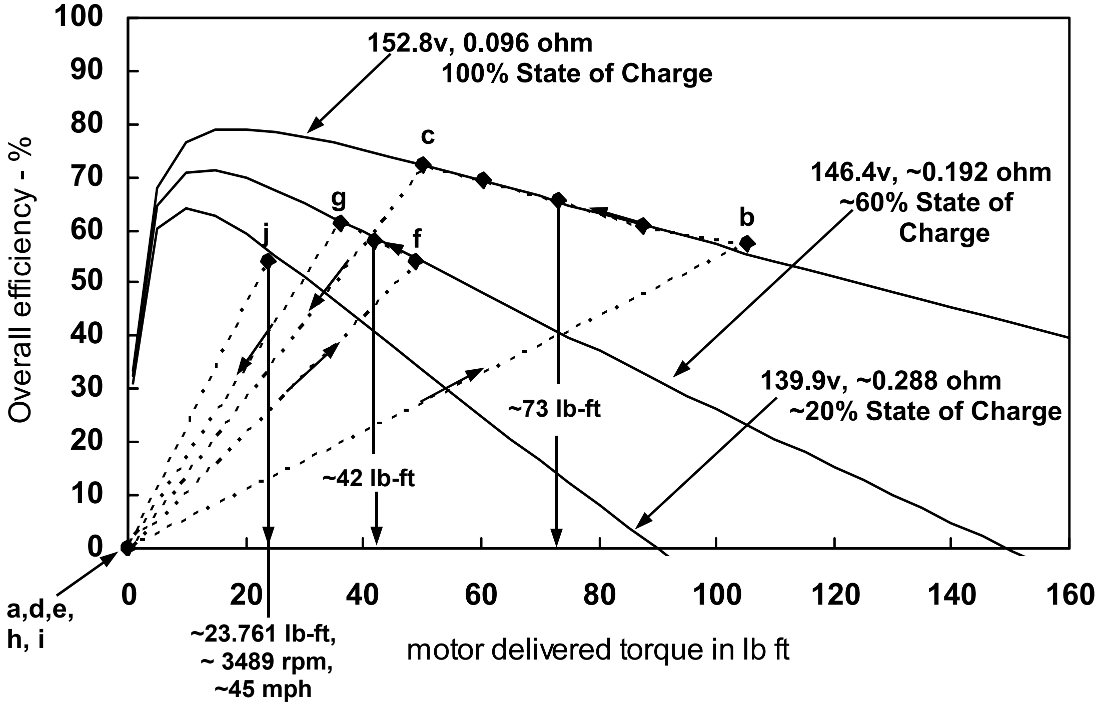

Figure B-3—*Motor cycles for three hypothetical states of battery-pack charge.*

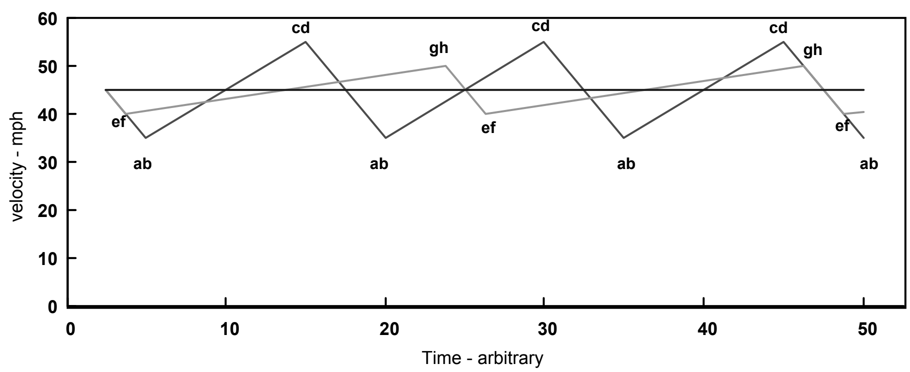

Figure B-4—*Acceleration and coasting during chopping.*

only not felt, but are not even heard (except perhaps by some musicians, young children, bats and dogs).

At such high frequencies, the width of the cycles (the changes in speed, power and efficiency) shown in Figures B1 to B-4 are so narrow their width could not be illustrated on these figures, and yet even these mini-widths would nonetheless still shrink further as the duty cycle grew larger and approached 100%.

Popular literature on electric vehicles seem to attribute the smoothing effect of rapid chopping to the inductance of the motor (or to added capacitors) and the way inductors resist

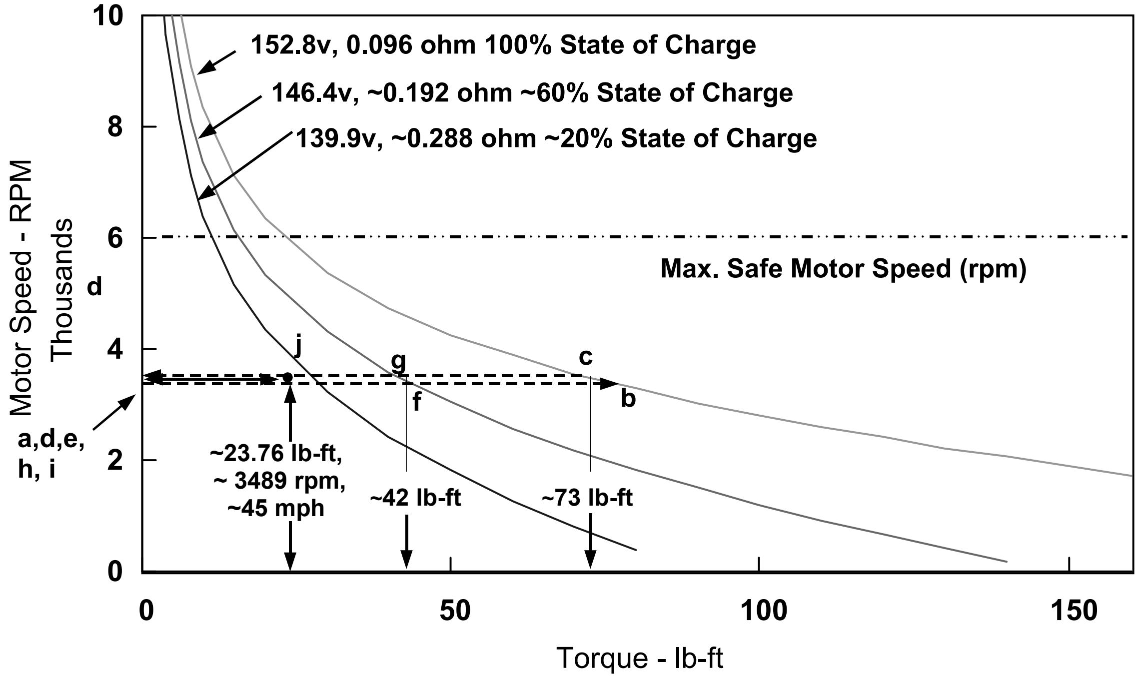

Figure B-5—*Motor cycles for three states of battery pack charge at high chopping frequency.*

changes in current flow (and capacitors resist change in voltage levels). That may be a contributing factor and has been ignored in this treatment. However, this analysis has argued there is massive "smoothing" as a result of the relatively huge inertia of the vehicle itself, because the energy storage in this inertia dwarfs the energy that can be stored in practical inductors or capacitors. However although the model presented above explains how power to the vehicle can be controlled, notice that as the fully charged battery discharges, the efficiency of the power application (points "b" to "c", "f" to "g" and finally at single point "j" actually decreases.

Consider the cycle "abcd" back on Figure B-1 but with a 15,000+ hertz chopping frequency as is approximated on Figure B-5. In this case the entire cycle is completed in about 1/15,000th of a second. So the power "on" portion from points "b" to "c" occur at a motor speed of perhaps 3488.99896 rpm and the power off change from "d" to "a" occurs at about 3489.00104 rpm[B3]. These two motor speeds are so close that the torque available at point "b" would be negligibly different than at point "c". Both are at very nearly 73 lb-ft of torque. This ratio is (73/23.76 = 3.07) more than three times the torque required for constant speed. Hence when the coast occurs for Δt_1 losing $P\Delta t_1$ of kinetic energy, it can be made up with $\Delta t_2 = \Delta t_1/3.07$ as much time during acceleration. Hence the duty cycle for the chopper would be $\Delta t_1/(\Delta t_1 + \Delta t_2) = \Delta t_1/(\Delta t1 + (\Delta t_1/3.07)] = 1/[1 + (1/3.07)] \sim 75\%$, and electronic choppers can do this quite nicely. As the ratio of required torques approach unity, at "ij", so too does the duty cycle.

In the popular literature, it is assumed that at the high chopping frequencies, changes in the torque and speed and power are so small that they are treated as approximate constants

[B3] The repetitious change in velocity per cycle is approximately : $\Delta v = P\Delta t/mv$

within a chop. Yet, in internal combustion engines, there is much more severe and dramatic "jerkiness" (to wit, referred to in the industry as noise, vibration and harshness [NVH]) and yet at high speeds engines can seem to be very smooth, and only reveal their jerkiness to electronic instrumentation. There again, much of the filtering is accomplished by the vehicle mass when cruising, and if the clutch is released, the inertia of the flywheel (if present) does some filtering of vibration. In motors, the vibration within and between motor chops can also be "filtered" with the reactivity of the motor's reactive inductance, and with added reactive capacitance, but first and foremost with the vehicle's own inherent inertia. The role of reactive capacitance and inductance will be left for a future effort, or to someone else, if ever needed, however, the prospect of using lower frequency on practical vehicles like the Cockroach (where it might provide alternative practicality benefits to be examined later at some loss in "smoothness") needs to be re-considered.

Constant Power vs. Constant Current

At constant speed, the power and torque requirements to propel an EV are constant. In a chopped motor, at constant "average" speed the "average" power and average torque to propel it are also cyclically "constant".

Peukert's Failings

Appendix A argued that traditional Peukert's Law is seriously flawed for EV analysis in two ways:

- With typically available commercial battery data, one may extrapolate discharge time beyond the range of available data, where it is known that these data are not linear in log-log representations (but exhibit a bend), nor are they good fits to a single polytropic equation.
- The load requirement of an EV at constant speed is not dependent only upon constant current as measured with a decreasing load resistance. The cycle analysis here has shown the peak cyclic current decreases, the duty cycle increases, and load resistance increases. Hence, with increasing internal battery resistance and decreasing internal battery voltage, there *must* be increasing duty cycle to the load.

Nonetheless, at constant speed, the power and force to propel an EV *is* constant. Hence, one would be better served to have a tabulation of time-to-discharge based on constant power draw rates for as Arendt indicates (his page 85 [***13***]), "Not only is the ampere-hour [capacity of constant current withdrawal] capacity reduced at high rates, but the watt-hours [that is, the energy] obtainable are also reduced, *and to a greater degree*." Furthermore, although chopping of the power allows for variable control, the higher chopped currents can alter resistive losses and efficiency.

Hence, in pursuing a better formula for predicting time-to-discharge (actually situational discharge) one must specify *both* a minimum current *and* a power delivery per cell. Three methods of testing and modeling LAB discharge performance were exhibited in Figure A-2: Peukert's constant current, constant load resistance, and constant power delivery.

Notice that Peukert's constant current approach (which involves a decreasing load) is

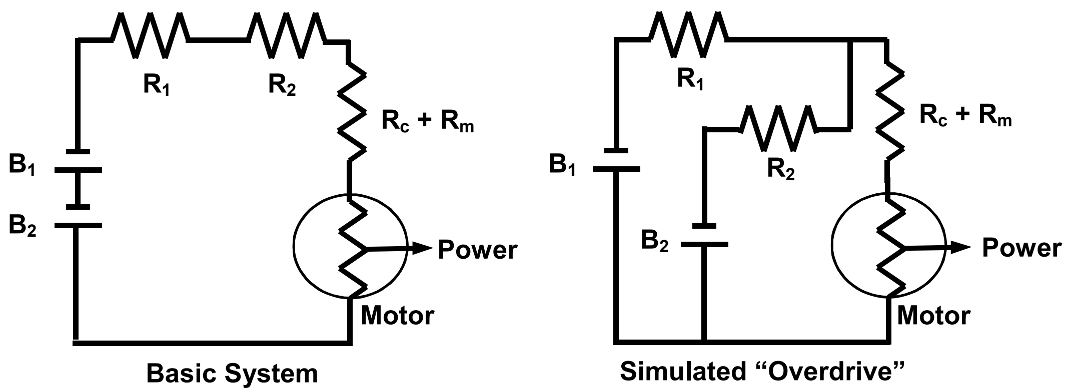

Figure B-6—*Simulated "overdrive" function in battery/motor system.*

too optimistic while the constant load resistance and constant power estimates (which involve a slightly increasing load resistance) were similar. Since it is much easier to provide a constant load resistance experimentally than to simultaneously adjust both the lost resistance and duty cycle, Appendix D will attempt to present some example internal resistance and internal voltage relationships for constant load resistance discharge. A robust equation of state for these parameters will not be attempted nor especially useful in comparison to the potential rewards if the re-engineered FLA battery of Appendix C proves valid.

Simulating "Overdrive"

Internal combustion engine technology has sought improvements by controlling the way the engine operates in terms of its speed and other considerations. An early approach was to operate the engine in a high performance mode until cruising speed was achieved, and then to change the drive train gear-ratios to strain the engine, forcing it to run with a high manifold pressure and thereby cut pumping loses. The drive-shaft operated at a higher speed than the engine leading to the description: "Overdrive." This mechanism in early cars produced a jump in gas mileage but produced a sluggish response, and so a stomp on the throttle produced a solenoid activated "downshift" or "kick-down" gear change.

After the gas crisis in the 1970s, it became common to just make the top gear ratio (or in some case top two gears) in the transmission as overdrive ratios. In this, it took more than a stomp on the pedal, it also required a manual gear change to improve acceleration.

Similar thinking can be applied to the Cockroach EV math and if proven useful, might similarly increase range and yield other benefits. The math has been explored with the companion spreadsheet using the techniques that follow. Indeed the step numbers 26, 26A, 26B and 26C suggest that overdrive-like hardware might theoretically increase range by as much as 30% with this method. An error may be lurking in this math but it does make sense. Here is why…

Figures B-5, B-1, B-2 and B-3, estimated how motor speed, motor power, and vehicle efficiency change, respectively, as a battery pack discharges and the internal voltage decays and internal resistance increases. Figure B-6 illustrates how a series-connected battery pack behaves when operated in series and when split into two parallel strings of batteries

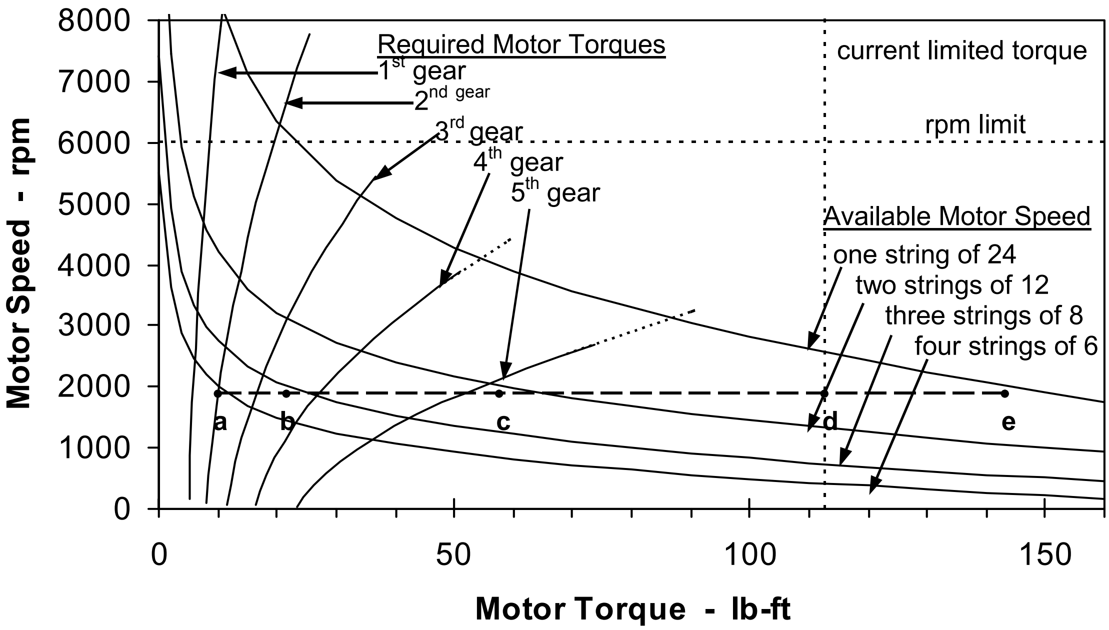

Figure B-7—*Motor speed curves vs, motor torque for four battery pack connection schemes compared with required motor torque in gear.*

with half the voltage and one-fourth the equivalent internal resistance, and the reader can visualize a similar situation occurs when split into three parallel strings with a third of the maximum voltage respectively, and one-ninth the internal resistance, respectively. Figures B-7, B-8 and B-9 show the performance estimates for the signature Cockroach of page 149.

Battery internal resistance was seen to initially decrease with increasing current, especially at very low currents, and this would partially offset the benefits (the parallel resistance would not drop all the way down to one fourth the series resistance), but it appears that because EVs do not operate at low current levels, the increase should be small compared to any elevation of internal resistance increase resulting from being discharged. Practical testing would be a priority future goal.

When an EV is cruising at constant speed, there is a required drive-wheel torque needed to sustain the motion. This driving torque (per Chapter 6) dictates the required constant motor torque which in turn dictates a required constant applied voltage. However, in a typical power-chopped EV, the battery pack provides a voltage significantly greater and sometimes much greater than the required amount. As this Appendix has examined, this is dealt with by direct connection of the battery pack to the motor but with intermittent (chopped) timing. A battery pack that supplies just the right amount of voltage is more efficient than chopping a higher voltage pack even though it is often, perhaps too casually, assumed that the motor and other components will "average' out the difference. In the example resistive system averaging is not the case and although a motor introduces inductive reactance that might alter the equation, this analysis (if valid) suggests the reality is closer to the resistive model than to a true "averaging" situation. Figures B-7 to B-9 exemplify why Chapter 6 and the associated spread sheet estimate such a significant difference.

Figure B-7 includes curves for the required motor torque versus motor speed

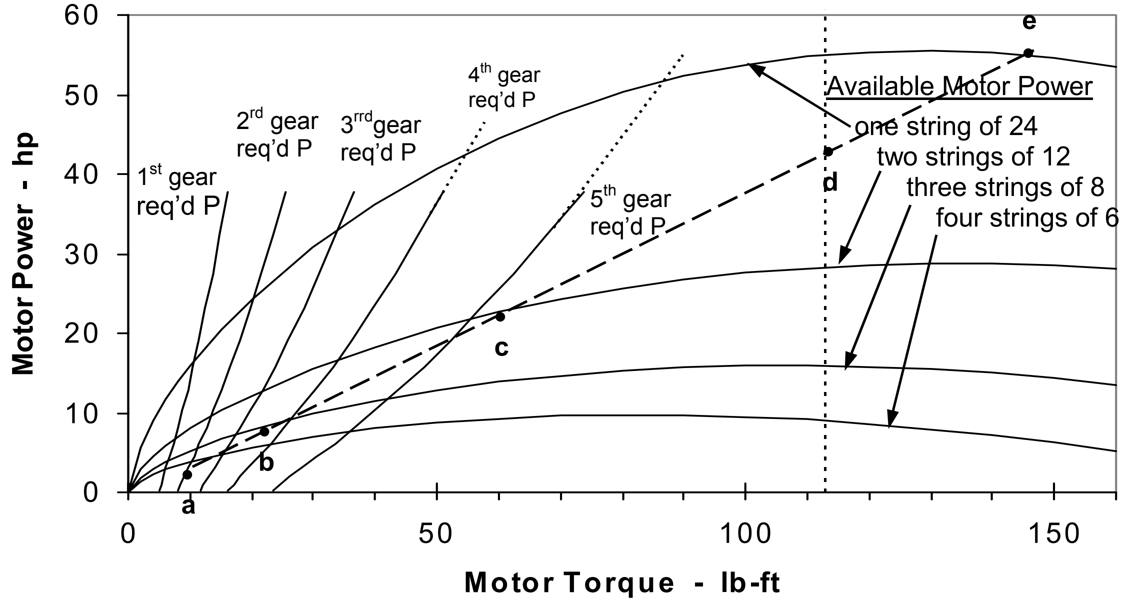

Figure B-8—*Motor power curves vs, motor torque for four battery pack connection schemes compared with required motor power in gear.*

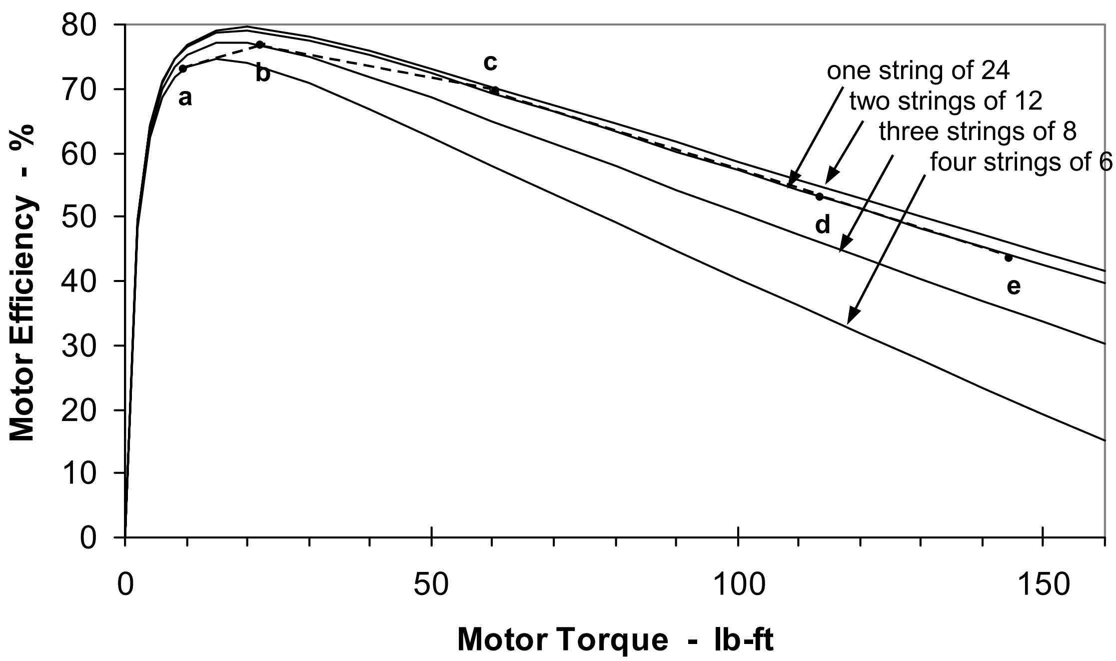

Figure B-9—*Motor efficiency curves vs, motor torque for four battery pack connection schemes compared with required motor efficiency r in gear.*

(converted from vehicle speed for the gears in the Signature Cockroach transmission). For any vehicle velocity, therefore, the equivalent motor speed on this curve, the battery scheme will provide sufficient torque if the available performance curve lies to the right (is greater than) the required torque for that velocity.

For example, Point “a” on all three curves is at a motor speed of ~2000 rpm and a motor torque of ~10 lb-ft which are equivalent to a top vehicle velocity of ~18 mph in first gear with four parallel strings of six batteries yielding 36 volts max. Points “b”, “c”, “d”, and “e”, are also at ~2000 rpm, therefore also ~18 mph in first gear, but at higher torques that would be available with differing connection schemes of three stings of eight batteries (48 volts max.), two strings of twelve batteries (72 volts max.) and one string of 24 batteries (144 volts max). Note point “d” is where the controller current limit of 500 amperes, limits torque to about 110+ lb-ft.

For these conditions, points “b”, “c”, “d”, and “e”, must be chopped in progressively smaller duty cycles. Figures B-8 and B-9 exhibit the motor power and efficiency that result for each of these points. Figure B-9 in particular shows how running continuously at point “a” should yield greater range than chopping the lower efficiency point “e”.

Indeed, for operation at point “a”, the efficiency of about 72% means that 28% (100%-72%) of the power is lost in heating the batteries, the controller and the motor. In comparison at point “e”, or about 44% efficiency, about 56% (100% - 44%) of the energy is wasted heating those same components. In still other words, at point “a”, 39% (28%/72% - 0.389) as much energy as it takes to push the car goes to heating the parts, and at point “e”, 127% as much power as it takes to push the car (56%/44% - 1.27) goes to heating parts. That is bad for the batteries, the controller and the motor.

There may be some problems with intermittently connecting potentially unbalanced batteries in parallel. Depending upon whether they have discharged equivalently, one string may try to charge the other string. However even in this case a hybrid approach may be possible: Instead of chopping the high voltage one could chop the two strings separately. This would eliminate the current for each string passing through the other string’s internal resistance and cross-charging, but it would double the equivalent parallel resistance and would sacrifice a fraction of the range improvement.

Indeed, if all this math has been done correctly, this suggests a 24 battery pack would provide more range if connected in two parallel strings whenever 72 volts can provide adequate performance, and then a heavy-duty switch is used to change the connection to provide a “passing-gear” performance when needed. Indeed, the three and four parallel strings should provide still better range whenever able to meet the driving demands. The associated spread sheet includes as Steps 26, 26A, 26B, and 26C, theoretical estimates based on this analysis. And if only a portion of the gains suggested were to be realized it would be a significant step forward. It would be quite analogous to the overdrive strategy of years bygone, and yet even more important because range extension in an EV is much more desirable than a few more miles were from a tank of gas in the 1950s and 1970s.

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Appendix C

Re-Engineering an EV Battery

The previous sections have indicated a huge breach exists between what real batteries can do under high draws and what their theoretical, their chemical, potential is. This section is intended to explore potential ways that today's EV "deep draw" FLA batteries might possibly be improved. Some of these, perhaps all of these items may prove unworkable, but if any are workable it would be a boon to the Cockroach EV paradigm and to EV converters everywhere. That would still leave some way needed to get them produced.

There are five areas cited so far in which present EV FLA batteries seem most flawed. Very limited testing will be cited to make the case for some of them, but the writer is not a research laboratory and so many of them can only be represented as speculation and in an anecdotal format. These are explained here and tabulated in terse detail in Chapter 5.

Different Case Design. FLA batteries tend to be manufactured in clusters of three, four or six cells ganged together. In testing of six volt batteries and especially in high power, high current, draw tests, the writer noticed that the center cell of even just a three-cell battery (USB 2200XC2) gets appreciably warmer than the outer cells. At a 60-amp draw, this happened after about two hours when the current draw collapsed, and yet if this battery were optimum it would have to continue heating itself for about another two hours. Heat is variously criticized as destructive to FLA batteries in several ways especially during charging. Indeed any heating leads to higher local voltage which means some areas of the battery are going to try to charge other areas, some areas are going to try to produce a greater fraction of the current flow, and during charging some areas will try to charge faster, all of which may be destructive. Figure C-1 exhibits the approximate case details for each of the cells of the most common GC2 battery with internal dimensions of roughly 10 in. long x 7 in. wide x 9.5 in. high.

Note on figure C-1 that the end cells both have one side panel (~7x9.5 in., 66.5 in^2) plus two end panels (3.3x9.5 in., 62.7 in^2) and a bottom panel (3.3x 7 in., 23.1 in^2) to yield a total of about 152 in^2 of surface area in contact with the liquid to transfer heat from the cell. The center cell lacks the side panel (both its sides insulated against the other two cells) and has about 85.5 in^2 of heat transfer area (about half as much as the end cells). Individual cells would increase the end cell area by 43% and the center cell by 156%. This situation is much

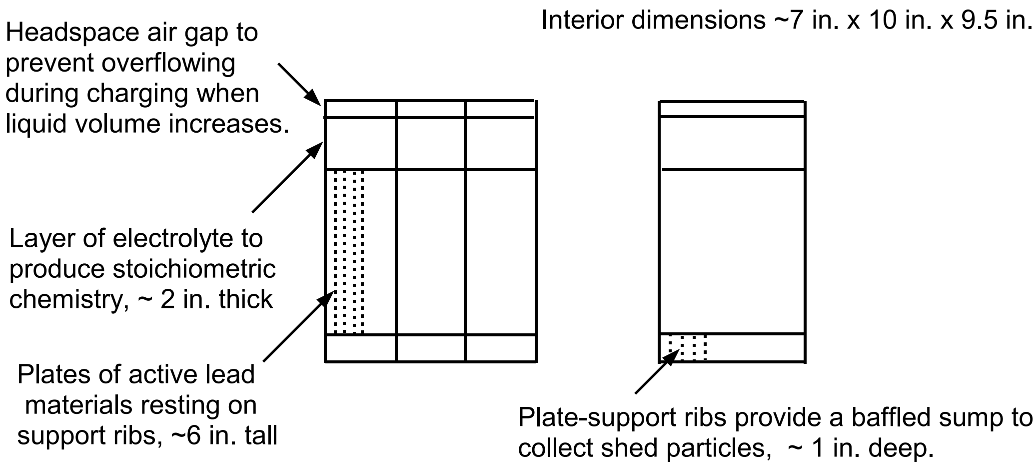

Figure C-1—*Coarse standard deep-draw GC2 battery details.*

worse in cases that hold four and six cells. Clearly these cases need to allow for better heat transfer, either by providing an air gap between the cells, packing one cell at a time, or making the cases long and thin. Lithium batteries appear to be packed one cell at a time, possibly due to numerous incidents of their overheating.

Furthermore, the external and perhaps internal surfaces should all be textured or finned to provide for better heat transfer to air or liquid whether in stagnant or forced flow (preferred) configurations. The resulting decease in temperature would be of benefit not only in keeping temperature down during discharge but especially in keeping it down when recharging where heating is especially destructive.

Curiously, numerous EV conversions will close-pack their batteries and then insulate the box in which they are contained to help keep their temperatures up in cold weather. Under high draw rates the geometric center of these cells may be at elevated risk. The box is insulated, and the batteries insulate each other and the end cells insulate the inner cells and the outer plates insulate the inner plates and the perimeter of the plates insulate the plate centers. Hence, the geometric center of the pack/battery/cell/plate may be prone to excessive battery-killing heat during high draw/charge rates.

Reduce electrolyte stratification. Stratification on either a large or small scale can limit the availability of acid for reaction. Batteries typically contain stoichiometric amounts of acid[C1] and the combined lead in both sets of plates to produce power. If any one of these is in short supply, that will limit the overall battery capacity.

Acid can be limited because it is remote to the plates in bulk or because there is a thin depleted layer that separates it from the plates or because it has been completely reacted. All can occur in current batteries.

[C1] It appears that many FLA batteries for starting and lighting these days are shorting the amount of acid in the electrolyte (calling them “starved-acid”) by about 50% to allow a semi-sealed battery with less electrolysis and no maintenance even though they are not technically called “sealed” batteries in the “Valve Regulated” context that is applied to AGM or GEL batteries.

Vinal [***15***] indicates typical FLA batteries will contain 1.0 liters of electrolyte per 128.5 ampere hours of ultimate capacity per cell. Hence for a ~258 AH battery with the dimensions of Figure C-1, about 2 liters of liquid are present in each fully charged cell. Notice that for the rough 9.5 inch height of the subject battery there is about one inch of liquid below the plates and about two inches above the plates.

In the sump there are risers that support the plates that act as superb baffles to interfere with mixing of the liquid. Similarly in the head space the liquid is again unlikely to mix readily with that in the tight inter-plate spacing. Very interestingly, these two isolated volumes of electrolyte (~3.44 liters in volume) represent about 57% of the full-6-liter acid charge in the three cells. And since these cells tend to be stoichiometric as to both amount of acid in the electrolyte, and the amount of lead in both the positive and negative plates, if the sump and head space liquid do not mix in with the remaining liquid they will represent a 57% reduction in the "apparent" ampere-hour capacity of the battery.

When this battery is tested at a very low draw rate (a so-called 100-hour rate), it is specified for 250-258 ampere hours of delivery. In 100 hours (~ four days) normal diffusion can produce a significant circulation (perhaps even equilibrium) of the liquid. However when these batteries are discharged rapidly, for example, at the one-hour rate, there is little or no circulation of the liquid in these two isolated volumes. Interestingly the US 2200 XC battery is rated for 133 Ampere hours at the one hour rate (51% or a 49% reduction in the 100-hour rate).

The writer can verify this failure to mix, as he has discharged this model battery several times at high rate, and measured its terminal voltage and head space specific gravity (by the methods of Appendix D), and found that upon agitating the battery mechanically (rotating it head-over-heels), it produced a significant change in these parameters. The SG after collapse of delivery (not just a drop in voltage to 5.25 volts but to more like 3 volts) was little different than its starting value. It changed significantly along with voltage and current capability. Similarly when this battery power delivery collapsed in testing, and it was allowed to sit and its ullage specific gravity was tracked, it took several days (approaching the 100 hour point) to approximate equilibrium.

Notice that after a one hour discharge, isolated volume would prevent the battery from delivering more than about half of its full ultimate capacity, and this is likely due to localized stratification between the plates themselves. Since electrolyte acid content is just one of three necessary and sufficient ingredients for battery operation, other mechanisms can and almost certainly are also reducing the capacity in parallel,...and the first to fall short will dictate when power collapse occurs. And EVs usually need to draw high currents.

In order to get more acid between the plates, the plates could be moved further apart, but this would increase the electrolyte and battery internal resistance and heating and kill efficiency.

In this case, to ensure all electrolyte has access to react, deliberate agitation (as introduced in German electric boats during WWII, see footnote page 176) is desirable. Air lift pumps (see Appendix E) can pump electrolyte from the sump of the battery to the head space and cause it to mix with the inter-plate liquid. This agitation is especially useful during re-charging because it should reduce the acidity between the plates and lower the battery voltage making it easier and more efficient to charge the battery and resolve sulfation, *provided it does not become so intense that it affects shedding and crystalline sulfate remedia-*

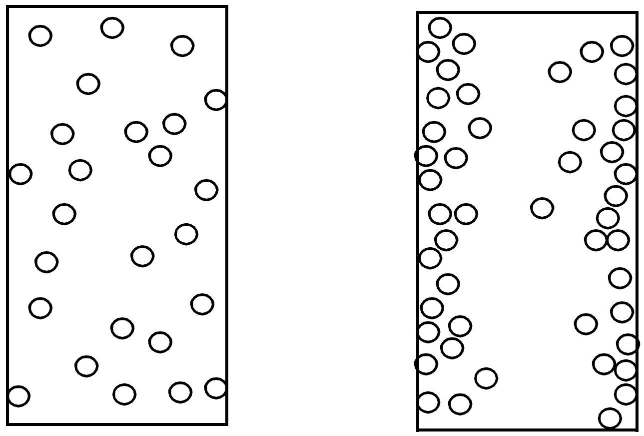

Figure C-2—*Sulfate clusters distribution in plates under high and low current draw rates.*

tion.

Finally agitation can serve to transfer heat from the insulated center of the cells to provide a more uniform temperature therefore a more uniform current flow in either direction as well.

Note that if plate thicknesses are reduced as suggested below, and the number of liquid layers are increased, a greater fraction of the presently stratified liquid would be rapidly accessible to the plate surfaces and should increase the measurable capacity of the battery. Double the number of liquid layers, should double the available acid and significantly reduce this stratification effect, *even without electrolyte agitation*.

However do not forget that stratification is not the only mechanism that can limit measurable amp-hour capacity. Three mechanisms tend to operate in parallel, and the capacity can become choked off whenever any one of them takes effect. Hence even if more electrolyte is made accessible (as this writer discovered) the surface may clog or be shielded, or erode to yield a similar result.

Reduce plate surface clogging. Surface clogging was not mentioned in most texts consulted, but is thoroughly described in Bode [***20***] and Rand et al. [***19***]. Clogging clearly interrupts (collapses) battery operation the same as acid depletion does.

While much of the discussion of FLA operation appears to describe sulfate that comes to the plate and gloms onto it, apparently it is much more complex than that with the plate dissolving into the acid, reacting with the sulfate, and then re-depositing itself onto the surface in a new form. In the case of the negative plate (apparently most vulnerable to surface clogging) new lead-sulfate is deposited onto the plate surface and it diffuses into the plate mass while at the same time the interior lead migrates to the surface. Here again, when the discharge rate is low, there is plenty of time for the two materials to exchange places, but in high current draws, the lead sulfate forms on the surface much faster than it can diffuse into the plate. As long as there is a goodly amount of lead on the surface, the acid and lead can combine with at most an increase in internal resistance and if the surface sulfate is localized, an increase in electrolyte stratification.

Figure C-2 monkeys a figure from Rand et al [***19***], their page 556, showing how the

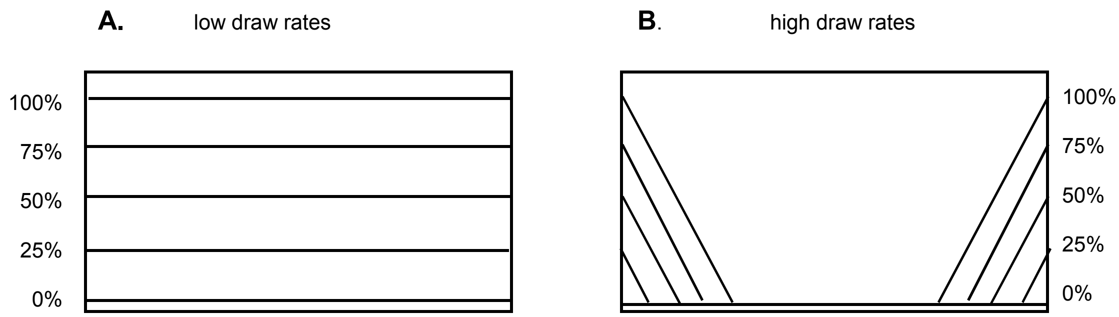

Figure C-3—*Sulfate clusters concentration distribution in plates under high and low current draw rates. based on Bode [20] but with liberties taken.*

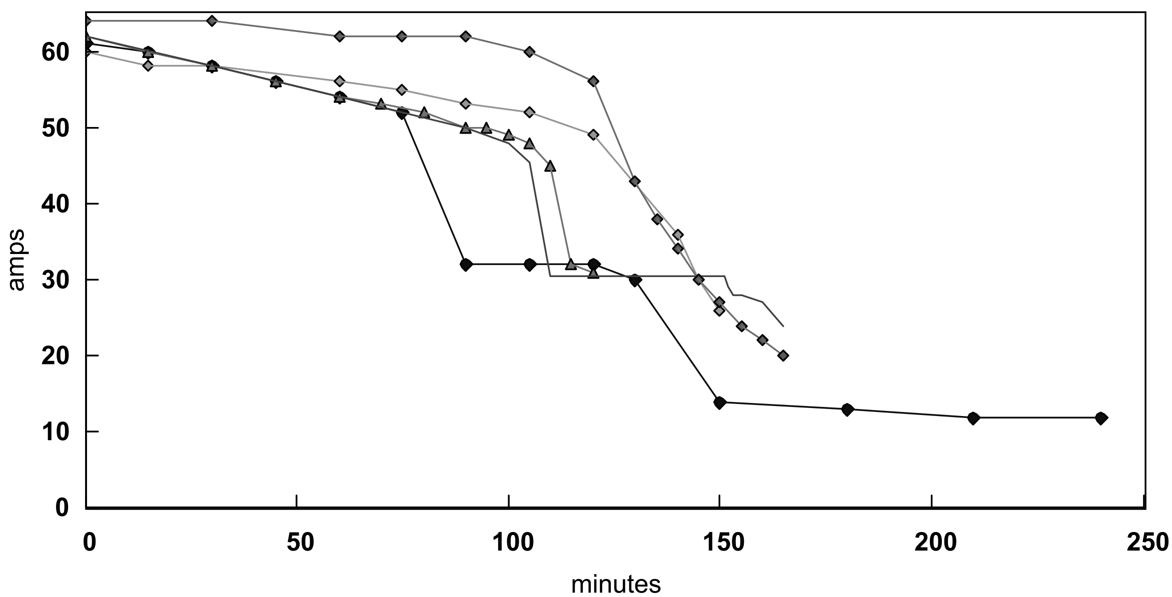

Figure C-4—*Writer's discharge curves under constant resistive load.*

surface concentration of sulfate forms under low and high current draws. When the surface is fully coated, the battery is no longer a lead acid battery, it has become a lead-sulfate/lead-peroxide/acid battery apparently of increased internal resistance and reduced cell voltage.

Figure C-3 monkeys Bode [***20***], his pages 156, 157, showing how the density of sulfate in the plates might concentrate under low and high discharge currents.

Figure C-4 shows the writer's test results which he "believes" may include surface clogging in which a constant-load battery drawing an initial 60 amps suddenly undergoes a decay in both current and internal voltage. These figures are for an abused battery that may be heavily hard-sulfated as well that is also contributing to the deterioration. In a very real sense, the interior lead in these plates may have become "stratified" and as unavailable for reaction as is the remote bulk acid in the baffled sump described in the prior section.

It matters little if a new battery design makes more acid available if surface clogging prevents lead from reacting instead. And indeed it may be difficult to detect from a battery's output whether acid stratification or surface clogging is the limiting factor.

Here again, if the interior of the plate were to be excised and placed as a new plate, it would provide two new surfaces to react and the new liquid gaps that result would allow stratified acid to be made more available to those surfaces. So once again thinner deep-cycle plates would improve deep-cycle battery performance (perhaps doubling it or more in some cases). But this gain would require thin plates that we are told can not handle deep-cycle discharging (but for which the writer is skeptical).

Indeed plates half as thick might approximately double the discharge time before surface clogging takes place. But here again, even if the thin plates doubled both the time to deplete acid and to surface-clog both plates, any other limiting mechanism (like hard sulfate surface shielding, or who knows what?) might still kick in and limit the draw time and in addition, therefore, useful capacity.

Reduce hard sulfate formation. Negative plate surface sulfation apparently "hardens" (that is to say, grows into a crystal layer) (1) if the battery is allowed to stand in even so much as partially discharged condition for any amount of time and (2) if the battery is not fully (and they do mean *fully*) recharged when it is recharged. This risk is apparently greatest when a deep-discharged battery is allowed to stand for even fairly small periods of time.

Hard sulfate can be distributed but apparently most often forms as a white (other colors are possible) layer (a sheet) over the central portion of the negative disk where it can block access of acid with the lead. In effect it reduces the available surface area of the plate (except perhaps to very low current draws) and hence can permanently reduce the capacity of the battery. In other words, if half the plate surface is coated, then it will take only half the normal time to surface-clog the remaining half. This can apparently result from a remarkably thin layer of hard sulfate even though the sulfate can become quite thick also.

Apparently the hard sulfate crystal is more stable (requires more energy to convert) than amorphous sulfate (or whatever wimpy crystal forms instead) and is the last to resolve back into acid and lead during recharge. This final conversion occurs when the battery voltage is near its final voltage value (about 2.3-2.4 v./cell). It also occurs when the battery is electrolyzing the water in the liquid. Many charging regimens call for charging to this high voltage and holding that voltage constant for hours while the hard sulfate slowly resolves but also while the water electrolyzes. Unfortunately when the water electrolyzes it forms bubbles of oxygen and hydrogen that are apparently destructive, especially to the positive plates (addressed in the next section).

Numerous texts describe a "water treatment" to remove hard sulfate. The electrolyte is replaced with water and the battery is charged at a low initial current and voltage and the voltage is never allowed to exceed 2.3 V per cell. The lower acidity of the water helps to dissolve the sulfate. It begs to question whether a lower acidity in the battery electrolyte itself might also make the end stage hard sulfate resolution more effective even if the acidity is just a few tenths of a point lower. However, a specific gravity of 2.5 would also result in a lower native battery voltage and so any applied voltage below the electrolysis value might be more effective. This is perhaps worth testing and yet inferring the health of a deep-cycle battery is apparently very difficult to do.

Therefore, it may also be desirable to prevent as much hard sulfate creation as possi-

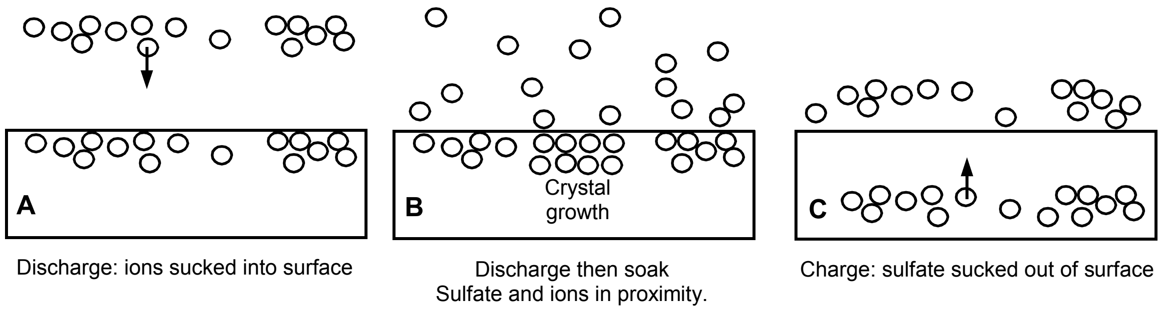

Figure C-5—Possibly s*peculative mechanism for "hard" sulfation growth.*

ble and a few pretty speculative suggestions are offered here. Crystals (for example silicon crystals in the semiconductor industry) are typically grown from an unstable liquid, (such as a cooling melt) by introducing a seed crystal and then slowing retracting and cooling it. Perhaps a similar mechanism is operating on negative plates when they grow sulfate crystals.

Numerous references caution, some vociferously, about the risk of deep discharge and the urgent need to re-charge such a battery ASAP. Indeed many indicate it is much less problematic to allow a full-charge battery to stand for long periods than to allow a deeply discharged battery to stand for even just hours.

This is itself quite a problem, because the nature of a Cockroach EV it that of use for errands. It needs to be able to go to the supermarket and sit on the lot, partially discharged, until one's shopping is done, and yet if the discharge is deep, this might tend to grow destructive hard sulfate, perhaps quite quickly.

Indeed, in planning tests for this book, a US 2200 XC2 battery was purchased and allowed to stand unattended except for one or two brief partial chargings for years. It should have grown massive hard sulfate which as was expected, intended and planned. It did not. Its internal resistance increased a bit but not massively. However, when it was being deep discharged in testing and then allowed to stand overnight to achieve equilibrium (so that final state of charge could be determined), its capacity deteriorated by about half in just a few months and perhaps less than a dozen discharge cycles.

This leads the writer to wonder if when deep discharging occurs, surface clogging of amorphous sulfate occurs as described in the prior section. This would force sulfate regions to be close packed, an unstable condition where sulfate from the liquid layer/phase might be able to glue these pieces together into a crystal. This apparently does not happen during discharge,...for during discharge the liquid layer nearest the surface is depleted in sulfate "glue". However when the battery is disconnected and allowed to stand, sulfate ions would quickly diffuse to the surface where they might start to bind. Immediate re-charging may serve to prevent this by drawing the sulfate out of the surface to reform liquid acid. Hence, as Figure C-5 supposes, perhaps during discharge there is less or no "glue" sulfate in the liquid interface and during charge there is plenty of glue-sulfate but no surface sulfate on the interface to glue. Perhaps the battery that stood for four years and passed slowly through this same state of charge did not crystallize because there was no surface clogging present—it was always in both liquid and solid equilibrium.

Hence the writer is considering a future test of two identical batteries (perhaps starting variety) wherein one would be rapidly discharged and allowed to stand overnight, while the other would be deep discharged (perhaps more slowly or not) and immediately slow-charged at the end of the draw. If this tactic proved very destructive to the soaked battery, it might suggest a way to prevent formation of most hard sulfate, ...by always keeping the battery in a stage of discharge or charge (constant activity as described in Appendix G),.. thereby making abusive recharging less necessary,...thereby also reducing or eliminating positive plate erosion: win, win, win?

Reduce (or eliminate) shedding from positive plates. A scrubbing action is attributed to the gas bubbles that sweeps away loose particles and breaks loosely held particles of $PbSO_4$ and PbO_2 from the positive plate and permanently reduces battery capacity. Indeed, part (if not all) of the bases for the use of thick plates in deep-cycle cells is so that this erosion mechanism can not eat all the way through the plate and reduce its surface area to zero, which reduces the current delivery capability. Nonetheless, every lost particle is a lost micro-fraction of the battery capacity.

The writer's observations, like some mentioned in the literature also, have been that FLA batteries that are significantly discharged can begin charging even at rather high current levels with a very calm liquid electrolyte until the end stages of charging. At this point, when the cell voltage is quite high (greater than it will be when it equilibrates after the charging ceases, the liquid begins bubbling and a very fine black powder is then distributed throughout the battery ullage. The writer knows this because in several tests a white witness paper (paper towel) was placed over open cell ports. The paper remained clean and white until this bubbling began. Then a circular darkening black region formed on the paper at each port. However, after a while the darkening of the region ceased and a fresh witness could be placed on the ports and with the battery already near maximum specific gravity would bubble for hours with no appreciable additional darkening of the new paper.

Based on the literature, the writer took this as a possible indicator that the erosion occurs only after electrolysis begins and until the bulk battery is charged and then there is no more erosion taking place, because there is no longer a liquid layer of lead sulfate/peroxide in which the bubbles form.

In other words, it appears that during initial charge, there is no bubbling to scrub the particles, then once electrolysis begins and bubbles form, they can erode the surface until there is no more lead peroxide being formed, at which time the surface appears stable and continued electrolysis does not remove particles while any final hard sulfate (on the other plate) is being remedied.

Another speculative mechanism will be suggested that is apparently neither cited in the literature nor disputed there. Without offering proof, the writer offers the following guess. The literature reports a fragile liquid solution of lead sulfate forms in a thin layer near the plate surface. This thin layer is where the lead peroxide grows as the battery charges, and it is also where aggressive bubbling of [oxygen or hydrogen] begins that can wash away this liquid or perhaps even break off flimsy structures that form within it.

What if a portion this thin liquid layer (perhaps it is even a different liquid phase) is captured by surface tension within the [oxygen or hydrogen] bubbles as they form within the layer, as in Figure C-6? From this layer, re-deposition of the lead peroxide grows, and within this layer, the gas bubbles could grow trapping some liquid lead sulfate/oxide within their

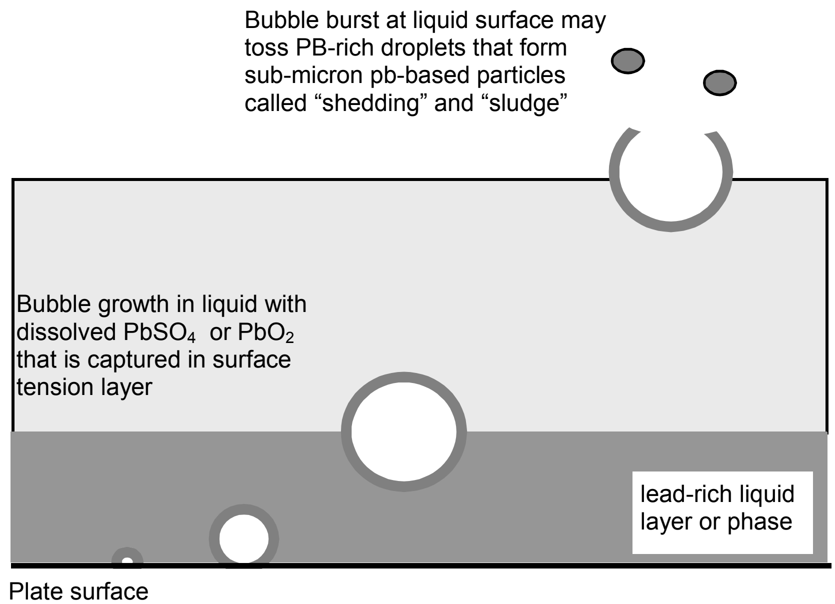

Figure C-6—*Speculative mechanism for electrolysis to create lead peroxide particles.*

surface tension layer. These bubbles that form ultimately break free and can be carried to the surface where they are seen rupturing ("popping") and flinging micro-droplets of the bubble surface liquid into the ullage some of which land on the filter paper and apparently form black particles from the trapped lead sulfate/peroxide. Bulk liquid placed on such paper does not produce these black deposits.

When the battery is fully charged (except for the hard sulfate on either plate), the thin liquid layer is no longer present and the bubbles that form can not trap the lead peroxide. Bubbling then did not deposit black circles.

When the GC2 battery is charged slowly (at 2 amperes or less) and limited to ~7.1 volts, (a process taking a number of days), it appears the full- charge condition is approached so slowly that erosion may be largely reduced or avoided entirely. However it is not clear whether this eliminates any hard sulfate, or whether more charging at higher voltages is still needed when the range for erosion is passed. But it begs for more study.

However in this observation, (dare I arrogantly call it a model?) may lay a way to achieve some or all of the desired hard sulfate reversion with less damage to the positive plates. Consider yet another possibility. Suppose the battery is operated with a slightly lower maximum specific gravity say 1.23-1.25 but with a larger inventory of liquid so that the total acid content would be the same. This would allow full reaction of the plates but the battery would deliver less total energy because of its slightly reduced terminal voltage. Figure C-7 shows the terminal voltages that might be expected (based on an assumption that battery voltage is a function only of electrolyte pH therefore specific gravity) and the loss of energy would be less than the reduction in specific gravity. However the reduced voltage might make it easier to fully and more quickly charge the battery before reaching the gassing level (most especially if electrolyte agitation were also present), thereby potentially reducing the

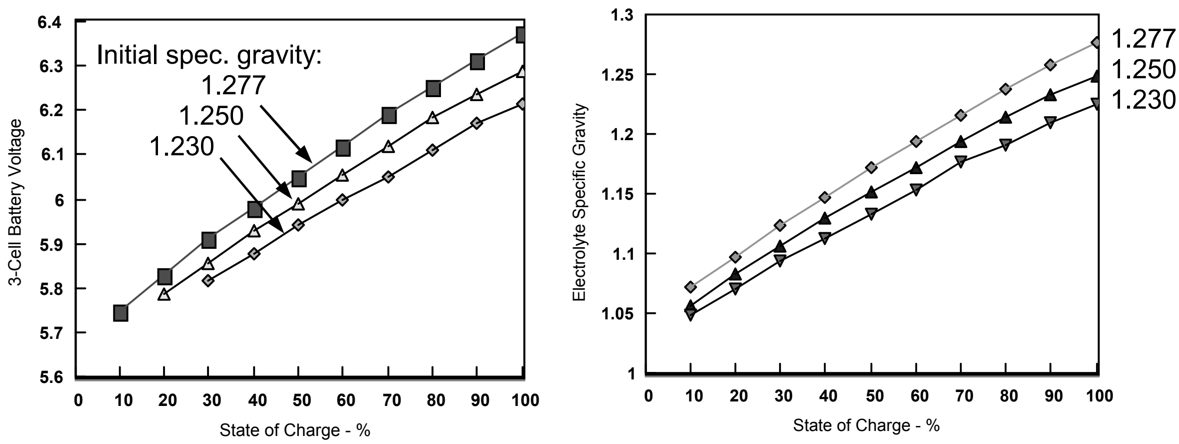

Figure C-7—*Battery Voltage and Electrolyte Specific Gravity Dependence on State of Charge. (For three starting acid concentrations).*

tendency to shed particles and saving the positive plates. Rapid charging to the gassing level might thus shorten the safe charge time greatly, unless electrolysis does not depend on voltage

The additional liquid volume would help slightly reduce any heating effect and water loss rate (which would already be low if electrolysis loss is minimized). And the lower specific gravity is also reported to reduce positive grid corrosion. Indeed the greater differential voltage, below the "electrolysis voltage", that would act on any hard sulfate might be more effective at remedying hard sulfate. Several charge-cycles were performed by the writer on a battery with electrolyte removed (perhaps 10%) and replaced with water and it did indeed appear to charge with less production of black deposits on witness paper (or was it wishful thinking). It was then charged at a low electrolysis loss point but much more testing would be needed to determine if it was effective at resolving hard sulfate. *Do Not Forget*: on charging, acid is pushed into the liquid between the plates decreasing the pH (more acidic) especially near the plate surface and making higher voltages necessary to effect charging.

Electrolyte agitation as mentioned earlier should help to similarly reduce the acidity during charging keeping the voltage down and reducing electrolysis. Electrolyte flow through the plate as demonstrated by Liebenow over a hundred years ago works in both directions as described by Morse [***16***]: "to keep acid concentration up during discharge and down during charge." Hence on that basis, reducing bulk acidity might help also.

These five tactics seek (perhaps in vain) to remedy known issues with present FLA batteries. If any are effective, a better FLA battery for EV use may be possible; If all of them can be realized a really good FLA battery (with like twice the high draw capacity) might result. An FLA battery twice as good as the present design (twice the range at high speeds, little or no maintenance, easier faster charging, and long life) would be akin to miraculous. And yet, that prospect may not be out of the question,...because FLA batteries today perform to such a low fraction of their theoretical potential.

A PC can monitor all of this and optimize each effect for the EV's driving patterns. When an EV stops for errands, the PC can decide whether to sustain a low discharge (perhaps by charging the accessory battery) to fight sulfation, or to reversibly draw from half the battery pack through a small DC-to-DC inverter to charge the other half of the pack and then at regular intervals to reverse the discharge and charge sources.

Indeed, Appendix F discusses the use of a small lithium battery pack to supplement the FLA pack and compensate for its greater deterioration in power delivery, or to act as a power-pack. This supplemental pack could also be used with an inverter to charge the FLA battery pack, or be charged by it, to again maintain it in a constant discharge or charge condition to fight sulfate formation.

All of these measures in this appendix may be realistic (or not), some are established technology, some are highly promising, some may be much more speculative (perhaps the use of thin plates being the most speculative among them), but the net benefit of any is uncertain at present. If all of them were viable, the combined gain could be impressive. If they are only partly successful or if other factors can collapse current delivery, their benefit could range from marginal to null.

However, if all paid out, the result might be a reliable, bulletproof, maintenance-free battery pack for a decade or more in Cockroach EV service. That seems well worth determining.

Are Thin plates such a paradox, a bugaboo?

With the potentially incomplete knowledge of battery technology now at hand, one can ask if the industry disdain of thin deep-draw FLA battery plates is an imaginary fear? The warnings are certainly dire. **Do not discharge a starting battery more than half way or you may destroy it in as little as one cycle**. Do not discharge a deep-draw battery more than 80% or you will at least wound it. Leitman and Brant [***1***] on their page 191, say about starting batteries with their thin plates:

> "Used in an EV, it would give you only the shortest deep-cycle discharge life—you'd be lucky to get 100 cycles out of it. Even on a brief trip, if you stomped down too hard (or for too long) on the accelerator pedal, you'd be lucky to make it back to your own driveway."

Buchman [***18***], his page 42, is more statistical. He cites typical life spans of 100% discharged starter batteries as only 12-15 cycles, and that of thick plate deep cycle batteries as 150-200 cycles. He further offers that use of a starter battery in deep-cycle wheelchair use would find its thin plates "would quickly dissolve with repeated cycling".

This final section will question and try to make the case to disprove, reject, and clarify this myth/commandment. Indeed, thin plates may be highly beneficial for the Cockroach EV—if they can be made to work.

Why are thin plates condemned for deep draw? Why have there been so many bad experiences with them? The writer has found no detailed analysis. We have the L&B assertion that a single overload may trash them. The Buchman assertion that they will "dissolve" over several cycles. Furthermore the limited testing, capital equipment, and time available to write this book may not be nearly enough to answer the questions properly. But some data that have been found are fascinating.

First some speculation as to why thin plates may be vulnerable in deep-draw service.

1. Because they are thin, so-called surface shedding may eat its way through the plate material faster (say twice as thin, twice as fast) and once perforated the individual blocks of active material may fall out. Twice as thick might last twice as long. or longer.
2. Thicker means more heat capacity to absorb transient Joule heating in the battery.
3. Thicker plates may have more rigidity to withstand mechanical forces in the battery.

However the following things also appear to be "known":

1. There are deep draw batteries sold of the absorptive glass mats (AGM) variety which have thin plates that are claimed to exhibit reliability similar to deep-cycle FLA lead acid batteries. *TILT!*
2. Starting batteries which have thin plates are sold that profess reserve capacities (of 90-120 minutes for the BCI Size 24) which are actually rather impressive when compared to deep-cycle batteries on a apples-to-apples basis.

First consider deep-draw AGM batteries and this will focus on the Odyssey PC1350 which is within a half pound of the typical GC 2 battery weight. The manufacturer claims its plates are typically about half as thick as the GC2 US Battery and Trojan batteries (of apparently ~0.07 inches), being about 0.040 inches which is also a commonly cited thickness of starting battery plates.

Battery nomenclature sucks. It is often near impossible to know what one is saying when they talk about batteries. Three areas need to be clarified here. Capacity, discharge and state-of-charge. The distinction is important here and is the same as that stressed in chapters 5 and Appendix A, the distinction between best and real-case battery performance.

To repeat, lead-acid batteries contain three necessary and sufficient chemicals; positive plates, negative plates and electrolyte. If all are present in the exact right proportions, a battery will provide a fixed number of electrons when all of the plate materials and all of the acid in the electrolyte is reacted. This can be called the battery capacity, and when all are gone the battery can be said to be discharged (dead) and its state of charge can be called zero. However if a battery is drained at a high rate, for the reasons cited elsewhere, it may stop delivering electrons prematurely, and will also be called discharged (and dead) and its capacity will be called the amount that was delivered (even though possibly less than half of the chemical potential) and the state of charge may even be called zero.

When you are told to avoid more than an 80% *discharge*, the quantity of electrons you can receive may range from 80% of the chemical equivalent to zero. Yes, at sufficiently high current rates, current test criteria can define a fully charged battery as "dead". Yes clearly a battery will not be damaged by discharging 80% of zero electrons.

Also clearly there is a lot of issues related to the nondestructive discharging of lead acid batteries. As a result, the writer has surmised that the problem with deep discharge of lead acid batteries may not be mechanical damage to the plates resulting from too much conversion to "healthy" sulfate. Instead the thesis here is that the hazard of deep discharge results from *overheating* of the battery.

Here again the nomenclature sucks. "*Do not charge to higher than 130°F*" the books say. But they do not say where the temperature must be measured. On the case? In the electrolyte? At the center of the center plate where the insulation effect and heating should be greatest?

Note that as a battery discharges, its internal resistance increases (triples or more) and for a given current the power transferred to the internal battery (I^2R) would also triple [on top of any earlier heating that occurred). Hence the longer a discharge, the more chemistry is reacted, but perhaps more importantly, the greater will be the temperature produced. The higher the power, the less time there will be for the heat to dissipate before the electrolyte starts boiling or the paste or even plates start melting.

L&B [***1***] say don't stomp down too hard. High speed and high acceleration cause high current draw (and high heating rates). Again, perhaps that is the hazard.

Let us consider the two thin-plate example batteries cited. First the Odyssey PC 1350. This is a 12 volt AGM battery rated for 400 each 80% discharge cycles while providing much higher current ability (cranking amps) through a lower internal resistance. It is rated for a Reserve Capacity of 195 minutes (it will provide 25 amperes of current for 195 minutes). But this is a capacity that can be compared apples-to-apples with GC2 batteries. Perform one of Einstein's thought experiments in which this (Odyssey) battery is cut in half into two six volt batteries that are then connected in parallel. Then we have a six volt battery and we can run a 50 ampere reserve capacity test and would expect 195 minutes to result. However this can be compared to "capacity" data for the GC 2 battery that we can pluck from the (Peukert- like) equation developed in Appendix A

$$[\text{For} \quad I > 7.5 \text{ amps}, \ t = 405.77/(I^{1.228}).]$$

or 199.6 minutes. And herein we see the two batteries would provide very similar ranges.

The Odyssey battery is an AGM style and therefore may have been electrolyte starved, hence there might be far more plate material available than electrolyte and so an 80% discharge may be indeterminate (80% of the electrolyte, 80% of the plates, 80% of the in-situ capacity, or what?).

This suggests to the writer both batteries experience current collapse at similar times. Since the AGM battery has many more thin plates, negative plate surface clogging should not be the cause. However, if the space between plates must contain enough fibrous glass to sponge up the electrolyte, the spacing would have to be larger and therefore of higher resistance than for the GC 2 battery, however because there are more plates, their parallel resistance can nonetheless fall. However the resistance would not be nearly as low as one would predict for closer spacing with a greater density of electrolyte that a thin-plate flooded-battery could provide.

Hence even this AGM battery would withhold half of its best-case capacity from the EV. We can discharge more than 80% of its "effective" or "in-situ" capacity but perhaps not 80% of its best case or ultimate capacity, if indeed, it has the same quantity of the three key materials as the GC2 battery (but if a starved electrolyte or other design, it will not!). The consequence is loss of nearly half of its potential EV range. And if it could provide the other half, we can not be sure if even its heat situation would not prove destructive. But this may argue thin plates are do-able in deep cycle.

Next we conduct the same thought experiment with some inexpensive starting batteries obtained from Auto-Zone ($69.95 plus core charge for BCI Size 24). The 24F/E

Econocraft batteries weigh 37 pounds and have a 90 minute Reserve Capacity. Hence they weigh about two-thirds as much as the typical GC2 deep draw batteries. Their rating of 675 cranking amps and 550 cold cranking amps indicates the presence of thin-plates.

However, these are again 12-volt batteries. Hence for the thought experiment, consider two of them being cut in half to yield four 6-volt batteries. Next consider three of the halves connected in parallel weighing (3 times 37/2) or ~55.5 pounds, or a little less than the same as a standard GC2 battery. In this case each segment would provide 25 amps, 75 amps total for 115 minutes. This compares to a predicted ~121 minutes for the GC2 battery. Here again, even though there are thin plates that should reduce the surface clogging effect, the effective capacity of the two configurations is very close. Hence one must surmise that electrolyte stratification is inhibiting the capacity. And this battery is rated for this performance.

The writer drew down one of these batteries at a low current of 2 amperes, to avoid surface clogging and it collapsed at about 25 hours (50 ampere-hours). It appeared to be a starved electrolyte battery deprived of enough acid to fully react its plate materials.

Here again, this starting battery would withhold about half of its potential best-case capacity from the EV. We can discharge more than 80% of its “effective” or “in-situ” capacity but not 80% of its best case or potential capacity. The consequence is loss of nearly half of its potential EV range. And if it could provide the other half, we again can not be sure if even its heat situation would not prove destructive. But again this may argue thin plates are do-able in deep cycle *if heat can be managed*.

Let’s do one more thought experiment. Regardless of how EV converters who have tried to use starting batteries came to grief, it is likely they tried to substitute 12-volt forty pound batteries for two series six-volt sixty-pound batteries. Forty pounds substituting for 120 pound of lead. But on the basis of the above analysis, and on the basis of heat capacity, they should have substituted three forty pound batteries in parallel for every two sixty-pound batteries. At that point they would have had a lower internal resistance to generate less heat per ampere, but they would have had the ability to supply many many more amperes and heat is proportional to amperes squared. Indeed, the little starting batteries are able to work their hearts out, delivering much more drive than deep-draw batteries.

The writer is tempted to surmise from these analyses that thin plates may perform as well as thick plates if the user employs limits on the maximum amount of average current that is drawn to limit heating. Current PWM controllers are apparently not designed to do this.

However, while the thin plates may eliminate surface clogging and lower internal resistance, the Cockroach EV needs to exploit the energy in the other half of the traction batteries that is internally limited by these various mechanisms, And here again it is worth noting that if the center cell of a GC 2 battery shows disproportional heating after two hours of discharging (which the writer witnessed) when the current collapses, that heating will be much greater if the internal resistance is allowed to continue to increase and the same current is sustained for another two hours.

Clearly if one prevents electrolyte stratification from collapsing the current in time, then one must manage the potential heat transfer situation. Appendix C addresses this issue with increased cell case surface area, and improved heat transfer fins, plus electrolyte agitation to serve as an internal cooling system. Whether these measures would be enough can not be known until a meaningful test can be designed. The writer hopes to attempt such testing but has decided not to hold up this publication till methods are found.

Appendix D

Internal Resistance and Internal Voltage Testing

In Appendix A, a generalized equation was derived for predicting the effective capacity of the BCI GC2-style deep-draw battery under high *and* deep draws. Appendix B considered how to apply "constant" (albeit recurrently cyclically constant) power to constant loads by chopping the connection. However, in order to make best use of these materials, one would need to know at least approximately how the battery internal resistance and internal voltage depends on current draw, state of charge (SoC), and, ultimately, battery age.

Although there appears to be few internal resistance and voltage data published, there are numerous ways to measure resistance described [***18***]. None of the references consulted appear to address dynamic measurement *in-situ*. There are good reasons why *in-situ* testing may be the best way to measure both properties. In general when a voltage source is producing, V, volts at current, I, the power being delivered is simply V x I in a resistive system. Hence the apparent resistance and voltage and current and power must in fact be THE resistance and voltage and power. If the battery acts like its resistance is X, then its effective resistance at that moment, there and then, ***is*** X.

Figure D-1 presents the equivalent circuit of Figure A-3, and a chopper has been added. When the circuit is in operation and the chopper is interrupting the current flow, and if it has enough time (to wit, a low enough chop frequency) then upon opening (breaking the circuit) it will exhibit an apparently stable transient semi-equilibrium that will indicate its operational open circuit voltage. This voltage will be less than or equal to its equilibrium open-circuit voltage. During this time the battery will think it is open-circuited but should tend to approximate the chemical conditions present when running.

When the chopper switch circuit is closed, and again if there is enough time, the voltage will reflect the voltage drop that the current, I, is producing inside the battery. This would ideally be a square wave function like that of Figure D-1 part B. However if there are reactive components in the circuit (like an inductive motor) it may distort the wave-shape significantly.

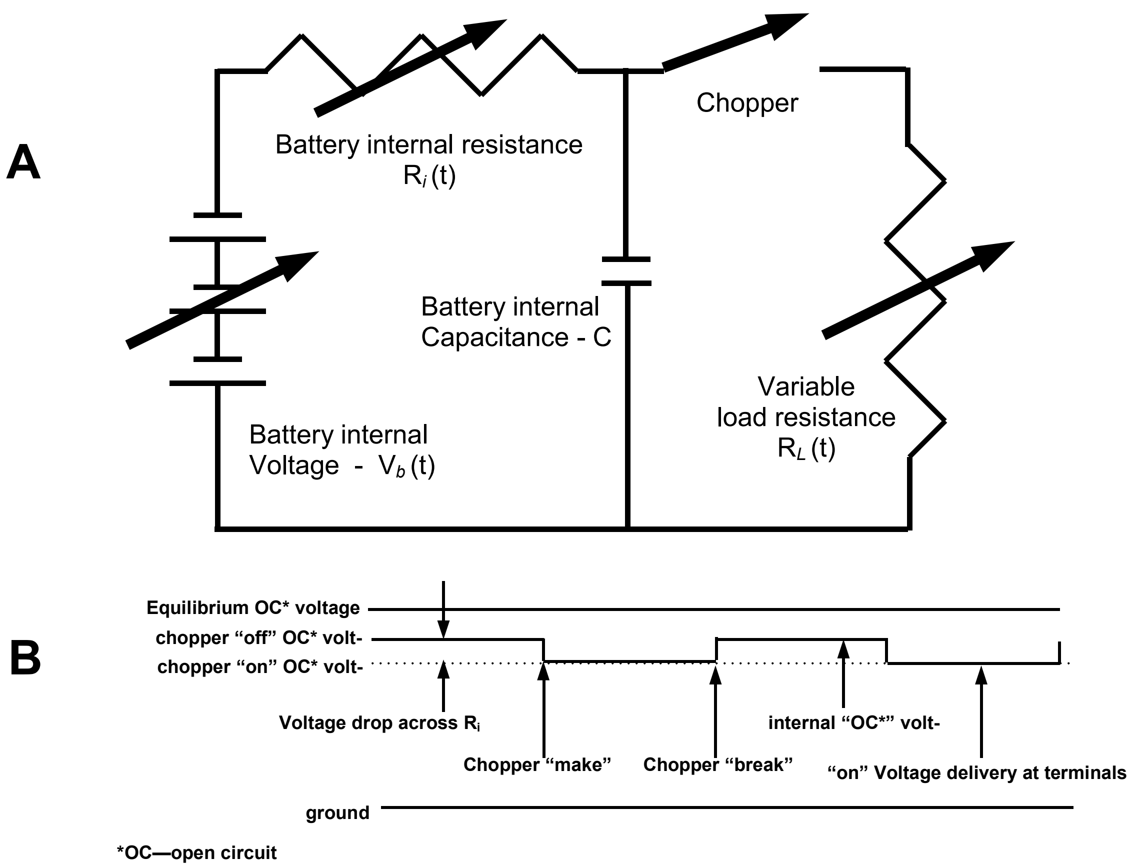

Figure D-1—*Equivalent circuit with chopper and internal battery capacitance.*

Testing done for this effort, like traditional testing for constant-current battery capacity (Appendix A), employed resistive loads to avoid or at least minimize reactive distortion, however there is one reactive component that is unavoidable. An FLA battery like the BCI GC2 has an electrical capacitance, and it is an enormous electrolytic capacitance at that. The parallel plates provide an accommodating geometry and the electrolyte between the plates contains ions that can and do segregate (polarize) in the electric field to store energy therefore provide capacitance. Hence, we must consider the presence of an equivalent capacitor function, "C", across the battery terminals as indicated in Figure D-1 Part A. This capacitance can distort the waveform and must be reconciled in interpreting the circuit's behavior. This is the model, for good or for bad, that will be used here to estimate battery, motor and therefore EV performance.

Capacitance Effect

Chopper Contacts "Break". Since a battery contains a large inherent capacitance, it can effect the waveforms used to interpret internal resistance and internal voltage during a current draw. For the assumed model, if the circuit chopper contacts are made and current is equilibrated (then there is no further current in the capacitor branch and its voltage matches that across the load) and if the chopper then breaks the load connection, then current flow

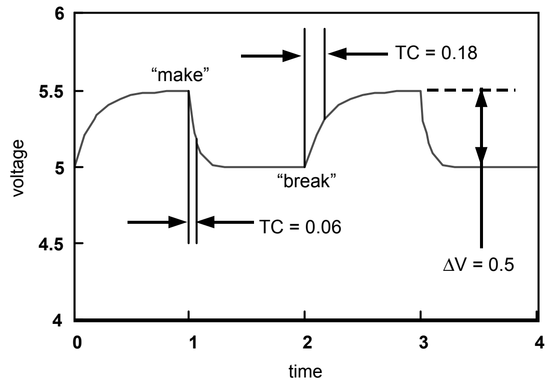

Figure D-2—*Reactive effect of battery capacitance.*

through R_L and R*i* will both cease. Then the voltage drop across R*i* will decrease, hence the voltage across the capacitor will seek to increase. Then the capacitance will need to charge to match the new open-circuit voltage, [V_B(t)].

The switching transient of the voltage/current behavior of a capacitor at an initial voltage (in this case the initial stabilized voltage of $V_{chopper\text{-}on}$) in series with a resistor and higher voltage source (in this case $V_{chopper\text{-}off}$) is a traditional instructional example used in teaching RC circuits widely and the math is cited variously as:

$$V_c = V_{\text{chopper-off}} + (V_{\text{chopper- off}} - V_{\text{chopper-on}})(1\text{-}e^{(-t/R_i C)})$$

Where t is the time in seconds after the chopper "breaks" the circuit. Other properties are shown on Figure D-1. The transient effect expected from this is shown in Figure D-2 where TC = 0.06, and is a standard time constant curve in which the increase in the V_c is ~66% of the remaining way to $V_{chopper\text{-}break}$ (namely the open circuit battery voltage) for every RC time constant.

Chopper "Make". The switching transient that applies to the stabilized circuit of Figure D-1 when the chopper "makes" (connects the load) appears to be tabulated less commonly. However, the differential equation that covers this example for the node is

$$C\ dV/dt + V_c/R_L + (V_c\text{-}V_B)/R_i = 0$$

This can be algebraically manipulated to the differential equation:

$$dVc\ /[(-V_c/Tc) + (V_B/CR_i)]$$

Where $Tc = CR_L Ri/(R_L + Ri)$.

If one lets: $a = (V_B/CR_i)$, and $b = (-V_c/Tc)$, the differential equation takes on the form:

$$dV/(aV + b)$$

and the tabulated solution (per Dwight's solution 90.1 [*27*] on his page 22) is

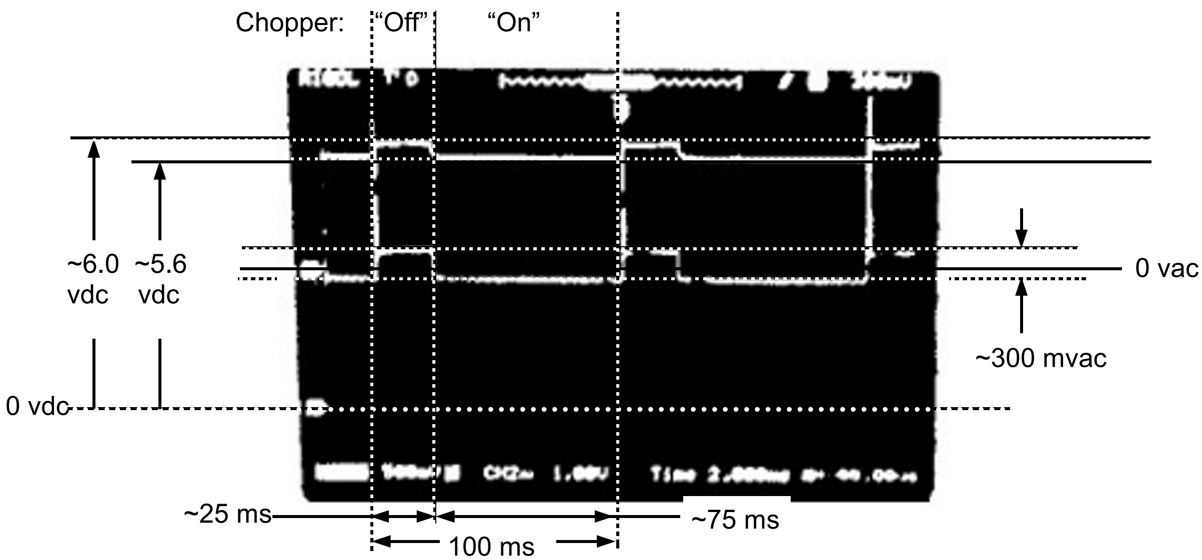

Figure D-3—*Oscilloscope trace.*

$$Vc = [1/(-V_c/Tc)] \log \left| (V_B/CR_i)V + (-V_c/Tc) \right|$$

This is an exponential curve akin to the exponential rise upon break but with an associated shorter time constant given by the equivalent resistance of both resistances in the circuit as if connected in parallel:

$$T_C = CR_iR_L/(R_i + R_L)$$

Since this time constant is inherently smaller than the "break" time constant (because it has the same capacitance and a parallel resistance across the previous resistor), the voltage should fall to its steady-state value faster upon "make" than its rises to battery voltage upon "break" as shown in Figure D-2. Figure D-3 exhibits an actual oscilloscope trace (Rigol DS1102E dual-trace scope) for a fully charged GC2 (US 2200 XC2) battery being switched at ~80 amperes and 100 Hertz. In this case there is sufficient time for both rise and fall times to achieve their final states quickly enough (yielding a "square" waveform) to allow the closed circuit voltage drop and semi-open-circuit voltage rise to be measured. However as this battery discharges the internal resistance increases until ultimately a saw-tooth waveform is seen and the voltage neither rises to a steady state nor falls to a steady state in the available-time interval...even though voltage and current collapse occur well before the battery reaches a 20% state of charge.

Oscilloscope Results. In Figure D-3 notice that these hypothetical time constants are both negligible. Hence to measure the delta voltage and obtain a valid internal resistance measurement and open-circuit voltage drop, each phase time must be sufficient for the trace to equilibrate. In some cases this may mean altering the chop frequency and/or varying the duty cycle to get a measurement.

Note that if one is chopping at the currently common 15,700 hertz rate, then the circuit has only 66μs before the contacts close again, regardless of duty cycle. Indeed, the writer has observed that as the GC-2 battery discharges, its internal voltage falls appreciably and its internal resistance rises (and due to the depletion of acidic ions in the electrolyte, its capacitance may change also). As a result the time constants for both make and break increase and a point is reached where even at a slow 100 Hertz (150+ times slower), one does not achieve voltage equilibrations during a phase and a saw-tooth trace representing only partial transition is witnessed as is depicted in.

Therefore to obtain meaningful internal resistance measurements herein, the much lower 100 Hertz chop rate was used than that which is common in EVs. Too high a frequency, even with a resistive load, and all you get to see is part of the build-up and decay curves, a "saw-tooth waveform", of the exponential effects from the battery capacitance. Indeed, in a EV application the capacitance and inductances of the motor might produce vastly different waveforms that might also affect the ATSR (acceleration, top speed, and range) behavior. While that might be more accurate and realistic, and either might be more or less efficient, to typical high-frequency motor controller systems, that scenario requires much heavier duty math that is reserved for the future or, hopefully for others.

However, keep in mind that the high frequency chopping is not required and was not always standard. It is apparently used to maximize the smoothness of the resulting power flow that is already far smoother than the NVH (noise, vibration and harshness) performance of internal combustion engines and smoother than would be required of a practical Cockroach exemplar. I don't mind the shaking in my Subaru boxer four-cylinder and I would not mind similar shaking in an EV. Hence, if lower frequency made for better (more economical, or more effective, or more convenient) systems, that would be my preference, so perhaps lower frequency systems need to be revisited for the Cockroach paradigm. Indeed, low frequency might also facilitate monitoring of battery internal resistance and voltage. An LCD screen and a basic oscilloscope application, would allow one to see the changing rise-time as the battery internal resistance builds and help to signal state of charge or at least available capacity.

Finally, and this may be most important of all, when one consider the operation of solid state switching devices (such as the MOSFETs in the user's controller), they exhibit very low closed resistance and very high open resistance. Neither produces much heat. Perhaps their heating comes mostly during the switching. Fewer switches might equate to less heating and more robust and reliable controller performance and, therefore best of all, more EV range. In addition, as cited on pages 232/233 , if the motors experience higher electrical resistance due to "skin effect', lower frequency should reduce the effect and resistance and improve motor performance significantly. Unless the writer has blown this analysis, he would therefore welcome and even wants a little more shake in his own E-car.

Physics, Chemistry, Electronics and Apparatus

As a reminder, an FLA battery contains an acid that produces an electric potential between two parallel sets of plates. The electrical potential establishes an electrical field between the plates, and the field causes many of the ions in the electrolyte to collect near the plates in what Helmholtz labeled a double layer, while many other ions continue to circulate Brownian style in likely accordance with a statistical velocity distribution perhaps as the

Maxwell-Boltzman or Gaussian distribution equations predict. Any change in the composition changes the voltage developed which changes the chemical distribution and so forth and so on.

In equilibrium and in the absence of a current flow, the battery terminals exhibit a voltage which when measured with a high impedance meter is the "open circuit voltage" indicated in Figure D-1 Part A. However, when a load resistance is connected to the battery, and a current is allowed to flow, the current flow in the external circuit is matched by a redistribution and flow of ions between the plates and also a change in the chemistry near the plates.

The redistribution of ions represents a change in chemistry (a reduction in concentration) near the plate surfaces and the voltage measured transiently during open circuit is reduced. Similarly, when the battery discharges the acid concentration decreases and the transient open circuit voltage is decreased. Both of these conditions are diagrammed in Figure D-1 as the "chopper off" voltage).

This current must flow through the electrolyte which exhibits an electrical resistance. Published data shown in Figure A-5 exhibit measurements of the resistivity of battery electrolyte as cited in Arendt [***13***] which may not be exact for the battery geometry of interest here but are not irrelevant either. These provide a first approximation of what the resistance of the electrolyte is, except that in the battery there is a potentially differing ion separation caused by the electric field that varies the composition of the fluid. Near the plates the ion density is increased and the resistivity is reduced but in between these two concentrations the concentration is reduced and the resistivity is increased. This changes things but the degree of change is for more lettered workers to explain. Nonetheless, the passage of current through this resistance results in an internal voltage drop that also subtracts from the open circuit equilibrium value to allow measurement of the "chopper-"on" voltage.

The internal resistance of the battery may be best surmised from the difference between the chopper-off and chopper-on voltages (ΔV) divided by the current: $R_i = \Delta V/I$ with the current being the instantaneous current and not the average current that a common analog meter would measure. Oscilloscopic measurements of these properties were made in 2017 on two US Batteries US 200XC2, 6-volt 258 amp-hour batteries manufactured about a year apart (~2014 & 2015), Figure D-4, Part A. A new battery manufactured in 2017, produced the discharge curve shown in Figure D-4. Part B.

Apparatus: The modest apparatus arrangement for these coarse tests is shown in Figures D-5 through D-7. Voltage measurements were made with either a Rigol DS1102E 100 mhz dual-trace oscilloscope or a Tekpower 9602R digital multimeter. The load resistances were either series 0.5 ohm, 100 watt resistors (up to 10) or a variable length up to 25 ft of 0.25 inch 304 stainless steel, 0.010 inch wall, tubing (about 0.568 ohm max) through which cooling tap water was flowed (no elevation in tubing temperature was noted in even the highest current tests). Current was measured with any of three 75 mv shunts of 50, 100 or 300 amp range (resistances of 0.0015, 0.00075, and 0.00025 ohms respectively).

Chopping was accomplished with a Canakit UK1133, 0-50 amp digital DC PWM (Pulse Width Modulation) motor controller kit (factory assembled) driving the high-current stage of an OpenRevolt Cougar 500 ampere MOSFET motor controller. The Open Revolt's Cougar front end was not used due to the many options that were not adjustable and because

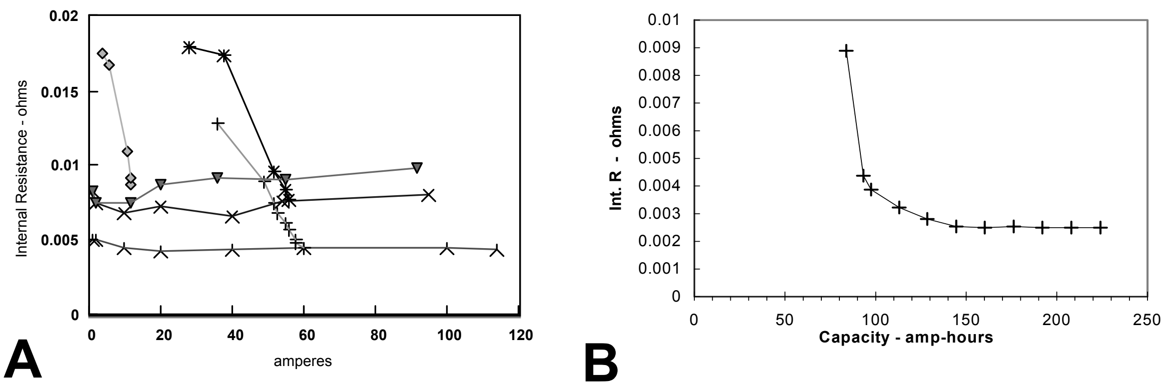

Figure D-4—*Internal Resistance curves.*

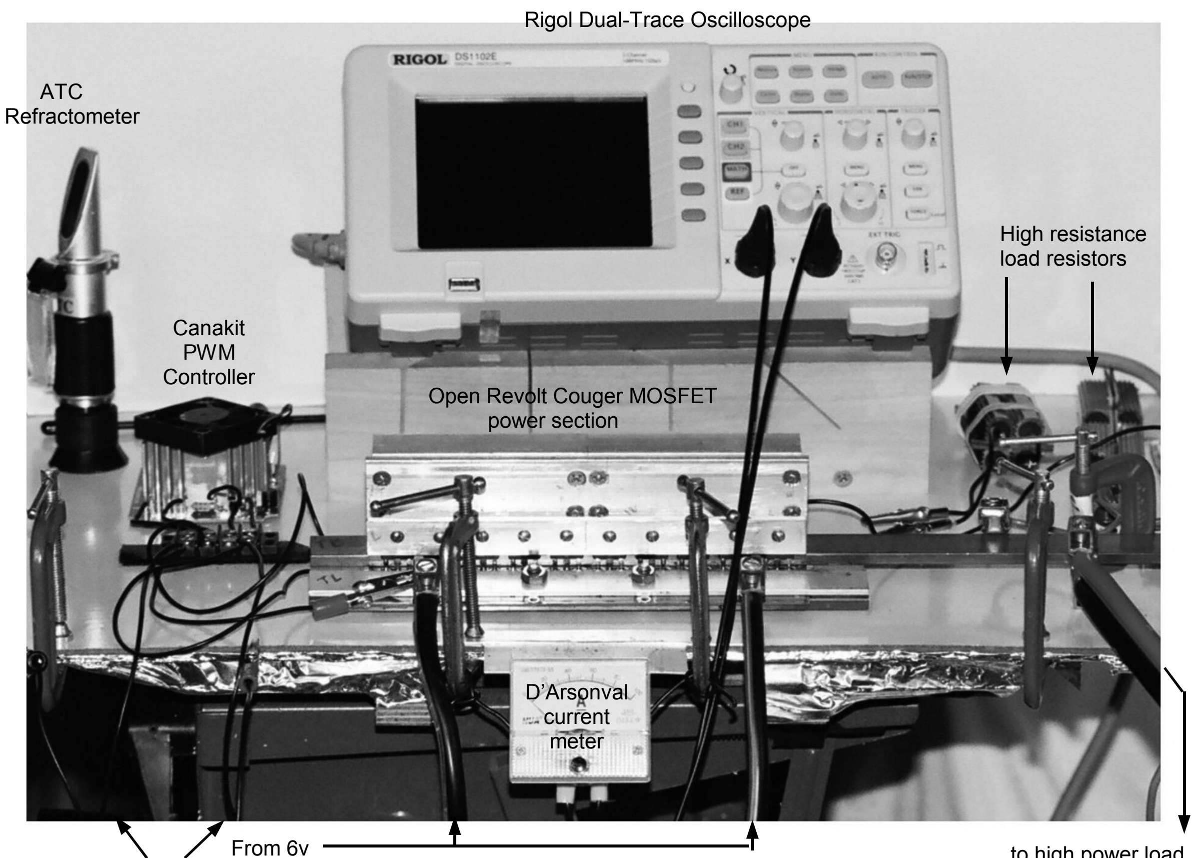

Figure D-5—*Hardware.*

the chopping frequency which was fixed at ~15 khz. The Canakit allowed full manual adjustability of frequency from 100 hertz to 3.1 kilohertz. and duty cycle from 0-100% and was powered with a 12 volt AutoZone Econocraft battery. Indeed as the battery discharges, the resistance grew to levels such that the 100 hertz chopping frequency no longer produced a semblance of a nice square wave but had stretched into a saw-tooth wave. And it was too

Figure D-6—*Hardware.*

Figure D-7—*Hardware.*

quick to allow for a good steady-state measurement of ΔV. Hence internal resistance measurements near full discharge were not made.

US Batteries BCI-GC2 Batteries (US 2200XC2, 6 volt 258 amp-hour) were purchased in 2013, 2015, and 2017 and used only sparingly during start up and apparatus preparation. In 2017 the batteries were partially formatted with about five-ten charge/discharge test-cycles. During these, various measurements of R_i and V_B were made as a function of approximate SoC.

The batteries were initially recharged with a Pro-Logix Model 2320 (apparently switching) battery charger operated in standard, 6 volt mode, at 20 amperes. Electrolyte specific gravity was measured with either an American Optical or ATC refractometer. Later on a couple of Dr. Meter constant-current/constant-voltage 0-30 ampere power supplies were used for charging.

Measuring State of Charge

The SoC of a battery under test is crucial to most of the battery testing planned and, as also noted elsewhere herein, it is hard to measure. When you charge and discharge an FLA battery you experience false “overcharge” and “discharge” conditions. Many years ago “overcharge” used to be called “surface charge”. The battery voltage can exceed its rated delivery, but if allowed to stand over time will appear to discharge (indeed its internal capacitance is probably discharging through its low internal resistance) and drop to a level consistent with it state of charge. Similarly when a false discharge state is allowed to stand over time, the state of charge will appear to increase (however in this process apparently severe hard sulfate can also form that is very damaging to battery capacity which the writer believes he witnessed). Hence when you discharge an FLA battery you can experience a false mortality. Indeed, Peukert’s equation and the preferable equation of Appendix A predict when an FLA battery will appear mortal (dead) but as many EV hobbyists know: when FLAs appear to die, one can resurrect them with a little (albeit harmful) rest and relaxation.

Both of these bogus conditions, appear to result from localized stratification (of both the sulfate in the electrolyte and the sulfate in the plates). During charging, sulfate and hydrogen are released on the plate surfaces and produce an erroneously concentrated layer that jacks the voltage up and as the local transient stratification mixes in, the voltage drops to indicate a true SoC. When you discharge, water is released on the plate surface jacking up internal resistance and artificially reducing the voltage to what can appear to be “mortal” levels, but which after time this opposite local transient stratification will dissipate to bring the battery back to life.

This process is why electrolyte agitation can be so helpful in keeping the acid concentration near the plates up during discharge (desirable) and keeping it down during charge (also desirable) and keeping resistance down during both charge and discharge improving the efficiency and very, very, importantly reducing battery heating and consequential damage.

Both of these local and transient stratification mechanisms can not be surmised from specific gravity measurements because the actual amount of acid or water in the thin layer is too small to affect the bulk concentration. However over long periods of time, a severe stratification in the bulk acid density in the battery sump is apparently possible (at least in starting batteries) that can form and persist indefinitely.

The writer has found that over a period of a few days that specific gravity measurements and battery open-circuit voltage measurements tend to converge to agreement that has been consistent with what the batteries states of charge should have been.

Constant Load Testing

Constant load testing was easiest to accomplish. A fixed Ohmic resistance was used to establish a draw on a battery in equilibrium and at known starting SoC, and the load was maintained until the battery was drawn down to a target level (often collapse of voltage and current) estimated on the basis of integrated current flow from the battery. Then the battery was allowed to equilibrate (apparently being damaged in the process) and the final SoC was determined from open circuit voltage. The circuit included a shunt for measuring average current and the PWM controller based upon ten MOSFET switches in parallel. During draw the PWM controller was maintained at 100% duty cycle and both probes of the dual trace oscilloscope were connected across the battery terminals. One trace was set to measure 0-6+ VDC the other was set to magnify the differential VAC voltage during switching. .

At regular intervals, the duty cycle would be briefly reduced far enough to allow "settled" differential voltage to be measured on the one trace and the internal open-circuit voltage would be measured on the other trace from plots like those of Figure D-4.

And other similar approaches were also used.

Constant Current Testing

Constant current testing is the traditional standard. Battery specifications that cite capacity apparently refer to constant variable resistive load testing. As a result since the internal battery resistance increases during discharge and the internal voltage decreases, the load resistance must be continually decreased and since power is current squared times resistance, the power of the constant current is constantly decreasing. Hence it implies a constantly decreasing EV velocity would result. However, it was quite surprising to the writer that while this scenario is scary and led him to believe constant power discharge would be far more rapid than constant current, the variations were much less than expected. Nonetheless the estimates throughout this text and doubtless most if not all similar tests are probably optimistic but Figure A-2 suggests perhaps only by a few percent or one or two tens of percent. Not irrelevant but not massive either.

Constant Power Testing

Constant load testing shows that as a battery discharges, its internal voltage falls, its internal resistance increases, and therefore, a constant Ohmic load will experience decreasing power and current. However, chopping the power allows the load to experience a greater power for an interval followed by a lesser power for a second interval. At the same time it will experience a greater current and power than the necessary average during the first while a lesser current and power during the second period. Although a motor load will circulate "free-wheeling" current during the second period, this chopping can allow the average power or average current (but not necessarily both) to match the respective required constant-power levels.

In an EV, when the vehicle is above its average need, its efficiency may be different (and lesser) than when it is at the specific need. Hence, its losses may be greater also. Hence chopping allows smooth variable average power application but at a probable cost in efficiency and exacerbation of heating in the batteries and controller.

To roughly and crudely measure constant power discharge, a constant initial load was applied and since the applied power waveform was square its RMS power and average power were both the same. Hence the power was

$$P = I_{peak}^2 \text{ x R x Duty Cycle}$$

The average current was set using an analog D'Arsonval meter (pre-tested to verify it provided true average-current readings. However, the peak current and duty cycle values were read with the Rigol oscilloscope. At internals, when the meter reading had fallen slightly, the duty cycle was increased to return the average current and therefore power average to the constant crudely average value. The duty cycle reading was read to verify the average power value. Not precise but better than nothing. And the constant-power curves of Figure A-2 were obtained for an average 60 amp trial.

Measuring Internal Resistance

An equation of state for internal battery resistance would be much preferable to an assumed constant value (for example, 0.004 ohms for a T-105 GC-2 battery) as is often used including in EV Calculator and in the spreadsheet associated with this text.

This text argues the highest priority is delaying voltage and current collapse through quantum reduction in internal resistance. However, good internal resistance data would be very helpful for subsequent fine-tuning of EV designs. Internal resistance is something we should obsess over. Any reductions in internal resistance may improve range, and acceleration and top speed, and very importantly, perhaps most importantly, ...reduce battery heating. If as Appendix C surmises, FLA batteries can be operated with thin plates, then the prospect looms of halving the battery internal resistance with massive benefits compared to the benefits of more precise measurements of present batteries during the bulk of their discharge or even during their end-game behavior.

Nonetheless, one assertion in this analysis is that internal resistance may be more dependent upon the nature of charge and discharge history than upon state of charge. We have seen that internal resistance shoots up when battery power collapses and that collapse is largely a function of current draw rate. We may need to treat it with gross approximations just to make the math tenable. Hence we need to be able to surmise how much battery resistance we must confront in our calculations.

For many of the example calculations herein, a discharging BCI GC2 battery is taken as providing a resistance profile linear in SoC. But it is not. By virtue of the long known resistivity measurements for battery electrolyte (Figure A-5) even though acting through potentially much different geometries, we can assume that the midpoint resistance should indeed be much closer to the fully charged value that to the fully charged value. Hence the use of an assumed constant value is not necessarily a bad call to make.

As a result, although the calculations in Chapter 7 and the associated spreadsheet use the hypothetical/traditional values, the reader must apply his own judgment in assigning these values. Earlier, as an aid, Figure D-4 showed *in-situ* measurements of the BCI GC2 batteries tested for this analysis and how they behaved at various draw rates and SoCs. Some were on a four-year-old battery that had been in stored condition and allowed to self-discharge and soak. These figures show that for these test conditions, the resistance was fairly flat until the battery approached the point where its delivery "collapsed" with a surge in resistance and a plunge in internal voltage.

Internal voltage was monitored and was important to know in estimating internal resistance. A small change in internal voltage can produce a large error in internal resistance measurements. However, up to the point where both the internal voltage and current flow collapsed and internal resistance surged, the changes seen in internal voltage were modest and incremental. The reader can make of this what he will when using the associated spreadsheet or making the reader's own independent calculations.

Appendix E

Electrolyte Agitation Devices

When *The Cockroach EV Volume 1*, was nearly finished, key words were stumbled upon when seeking to find some confirmation that the circulation of the electrolyte in lead-acid batteries would be of significant benefit in combating electrolyte stratification. Ultimately searching for “agitated electrolyte” with “battery” yielded numerous patents to achieve a more uniform electrolyte mixture. Old patents that have long-ago expired described electrolyte agitation systems that appear to have been in use for decades but do not appear to be sold today for use in EVs. Hence, Volume 1 was published with a future goal to further explore agitation in this performance-math related Volume 2. Several important references are reviewed here and the key words enable your own further study. At present it appears that agitation is one really important part, among several really important parts (see Chapter 5), of the game changer one would hope it to be, a critical part, but one part among several hitherto unheralded and yet equally important parts.

Benefits of Agitation

This volume has considered how current deep-draw batteries and theoretical “ideal” or “perfect” batteries would perform to serve as upper and lower bounds on what one could hope for from agitated batteries. Agitation can remedy stratification of electrolyte to the extent that is possible. There appears to be at least three kinds or characters of stratification that upset the homogeneity in an FLA battery.

Thin-film and pore stratification. Appendix C noted that when a battery in equilibrium was either charged or discharged slightly, even just as little as 15 amp-seconds, the open circuit voltage changed significantly (up to several percent or more). Charging and discharging both release or extract, respectively, acids at the surface of the plates. Such small changes could not possibly affect the overall average specific gravity of the bulk electrolyte. Some liquid may be trapped in pores and some will be very close to the surface where any low-flow velocity would be zero even in a moving electrolyte stream. It is unlikely that realistic electrolyte agitation schemes would be effective at sweeping away this thin surface film or trapped liquid of altered acidity. Therefore agitation should have relatively less effect on voltage than on internal resistance.

Thick film stratification. When charging or discharging has proceeded for a period or when its production rate is high (high current flow either way), the altered acidity will diffuse out into or be taken away from the bulk regions of the liquid space between the plates. This altered electrolyte can quite effectively be swept away with a moving agitation stream and should have a big effect on internal resistance but should also somewhat change the internal voltage of the battery which is likely established more so by the acid-to-plate interface.

Bulk stratification. When the pure dense acid produced during charging trickles down to the bottom of the battery or when the water produced during discharge buoys up to the ullage and builds to a significant size, two different systems are formed and the density differences can be large. The higher density section is at the bottom and the lower density section is at the top. The molecular velocities in these two sections will be different (whether Maxwell-Boltzmanian,. Gaussian or other distributions apply). This layering is more likely to persist for at least a protracted time (days to weeks) unless agitation is used and agitation should be extremely effective at mixing it back into the bulk electrolyte.

Note that when a battery is being discharged, starting from an equilibrium high specific gravity in the electrolyte, then lighter water is replacing heavier sulfuric acid in the plate interstices. The upper and lower layers are heavier. So there is a natural mechanism for the water to buoy up and the acid to percolate down. This same density difference acts to prevent mixing of the bottom layer. When charging the battery the electrolyte is all of low density and the light water fraction is being replaced with dense acid. In this case there is a natural mechanism for the inter-plate electrolyte to percolate down into the lower section and for the lighter electrolyte there to buoy up.

As a result repeated charge-discharge cycles act to move water into the top layer while tending to percolate acid into the sump which has less natural tendency to equilibrate with the upper regions. Therefore agitation of the electrolyte can be more important during discharging (in cases where the discharge takes an hour or less) than during charging which will take several hours at a minimum.

Hence the promise of agitation is great but is not perfect, and until some EV-sized deep draw batteries are cobbled together and tested (or some cognoscenti releases their data or finds them in the literature) this writer can only surmise great, but not perfect, benefit is possible. However, it does seem realistic to note that while the charge/discharge behavior of these batteries may improve a little or a lot, there is every reason to suspect the reliability (cycle and term life-spans) of these batteries should be extended (due to a less damaging charge process), perhaps by several times, and that alone is a game changer.

Example Battery Stratification

Deep-draw batteries (BCI Group Size GC2 which apparently stands for Golf Cart #2, e.g. U.S. Battery US 2200 XC2) were examined and properties important to stratification were shown earlier in Figure C-1 and are expanded upon in Figure D-1). Based on a 258 amp-hour rating, Vinal [***15***] (his page 117) , indicates that an electrolyte charge of about two

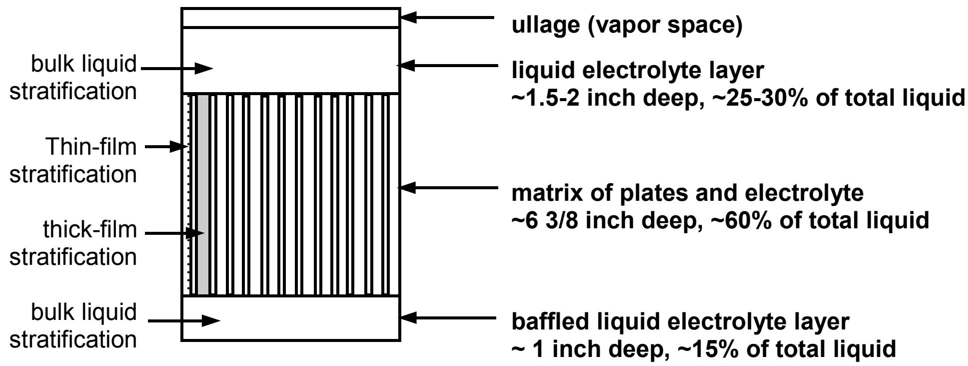

Figure D-1—*Battery configuration for US Battery US 2200 XC2 258 AH battery.*

liters (122 cubic inches) is required per cell. Therefore with a one inch layer of electrolyte below and up to a 2 inch layer above, approximately half of the electrolyte is outside the plate access regions.

If the battery is placed on a low-current draw there will be plenty of time (100 hours or more) for the electrolyte to mix (presuming that any heavy layers more likely to resist diffusion have not formed in the sump) and all 258 ampere-hours will be available.

However as the current draw increases, the time needed for the electrolyte to mix (which may be hours) will not allow all of the electrolyte to access the plate. Remember a EV current rate of 500 amperes would allow only 30 minutes for complete discharge and this is less time than it takes for the battery to come back to equilibrium after even a small discharge.

When an equilibrated battery was at 6.21 volts (~75% SoC, ~194 amp-hour capacity) and about 0.1 ohms of load resistance was applied, a current of ~62 amps was established. After the extraction of about 106 ampere hours of current at current levels above ~50 amperes, the current flow and voltage collapsed (<2.8 volts open circuit) indicating <10% SoC. After allowing the battery to re-equilibrate overnight, its open-circuit voltage indicated a 30% SoC (about 77 AH residual). In other words, the collapse in current flow occurred after about 106 amp-hours were drawn, and this corresponds to about 55% of the initial capacity that should be available, suggesting the 40% or so of the electrolyte that was not between the plates may not have been able to get to the plates fast enough to do its thing.….but this is not the only mechanism that may have been causing the current to collapse.

However, it does mean, stratification remediation is badly needed in FLA EVs.

Some Literature on Agitation Mechanisms

Whereas most conversion EVs run for as little as two or three years with flooded lead acid batteries, and are then seriously degraded, one web site indicated their electric boat batteries (too large for EV use) with built-in electrolyte agitation (and who knows what other technology), operate for up to ten years (and even much longer) apparently with little or no appreciable degradation in capacity. Is this a joke? Submarine battery use should be much more severe than EV use. And some information sites that were skimmed cited use of agitation in EB (electric boat) batteries for more than six decades.

Despite the surmise of Chapter 5 to the effect that thin deep-draw plates (if possible to deploy) might produce a large chunk of stratification-avoidance benefits, why isn't this, potentially grail, technology being described and pursued in the conversion EV literature?

There are a lot of ways liquids can be circulated:

Mechanical pump (piston, turbo pump)
Inertial splashing during acceleration and braking
Gravity feed systems
Ultrasound
Stirring
Shaking or manipulating the entire battery
Magnetic circulation (Yes, GM has such a patent [***28***])
"Air Lift" Pumping (ALP)

Who knows how many more creative ways there may be to mix or relocate the water released from the plates that buoys up slowly on discharge and similarly mix or relocate the acid released from the plates that slowly sinks during recharging of a lead acid battery.

Many patents are written to deliberately obscure what they are saying, and so the writer wonders what a more skilful/literate patent search than he is capable of would reveal in terms of electrolyte agitation schemes. Nonetheless, even with this approach, the purpose of this section is to argue that a practical method of circulation (agitating) electrolyte in small batteries for the Cockroach and other EVs is realistic and obvious and could be accomplished without major modification to the batteries. Hence this is intended to speculate on a few possibilities.

The writer considered whether it would be worthwhile to design a battery case that would include passages to install a driven shaft to spin a fan blade in each cell, or to install tubing to pump liquids, and to arrange for molded cases to be made in hopes of getting them loaded with commercial plates. For indeed the potential benefits of such motorized circulation were well-argued in Volume 1. However, as of now, it appears that a majority of the benefits of agitation can be secured with only slight changes to current battery manufacture.

A brief history of electrolyte agitation with no intent to be rigorous or complete will provide context. In 1897, if not before, Liebenow's magnificent experiment (*TCEV Volume 1*, pages 127-130) suggested the benefits that electrolyte agitation could provide. It was probably submarine warfare in World War II that led to agitation systems in German Sargo 2 class submarines, monkeyed by the United States in our Guppy 2 class submarines.

Early systems pumped air into the bottom of batteries so that the bubbling could mix the liquid (ala Figure D-2 Part A). This worked and the same physical principle is used today in "equalization charging" in which a fully charged FLA battery is abusively overcharged to deliberately produce electrolysis of the liquid so that the hydrogen and oxygen bubbles produced will provide some stirring action. As harmful as this should be, and as much maintenance (watering) as it requires, its benefits apparently outweigh the expected harm, and equalization chargers sell for a price premium.

Bubbling air into the electrolyte in large volume tended to evaporate the water and required sailors whose main job on a sub was to just keep the batteries watered. Later the air was humidified so that water loss would be reduced and drying of solids that could plug the tubing was reduced. Instead the main humidifier vessel then had to kept full of pure water.

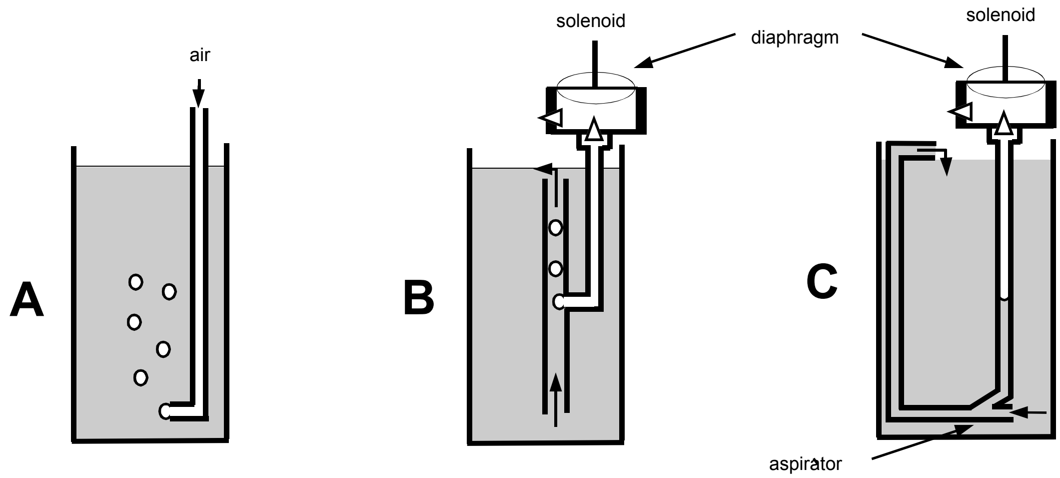

Figure D-2—*Electrolyte agitation systems based upon saturated-air-Lift pumps.*

Apparently the state-of-the-art for agitation ultimately became the air lift pump (ALP). Several old patents [***29-30***] describe this mechanism, and it has real appeal for EVs. A really nicely configured example is described in the patent by Sundberg [***29***] which lists the use of individual motors or solenoids for each cell. Sundberg's ALP is pretty simple with each cell containing a piping arrangement like that shown in Figure D-2, Part B

In Sundberg's example, a solenoid deflects a diaphragm at the top displacing a slug of gas from the cell ullage into a tube through a check valve. The tube size is important so that the bubble produced is capable of supporting the column of liquid above it with its meniscus. Since the bubble is of low density, the weight of the column of liquid above the bubble produces a pressure that is lower at the bubble than the pressure in the bulk liquid head outside the column. Hence the bulk liquid will push, will "lift", the entire column of liquid upward, displacing some liquid out of the tube and shifting the point of differential pressure upward. This proceeds until the bubble is released from the top of the tube. Hence that bubble produces a pumping action on the entire column of liquid out the top of the tube. Further, the column of liquid has in a sense been lifted by the bubble, hence the moniker "air lift pump".

When the solenoid is released, the diaphragm returns and its chamber is refilled by gas from the cell ullage through a second check valve. Hence the pumped gas is not only fixed in volume for each cell, and humidified, it is saturated and in equilibrium with the electrolyte. Liquid loss through evaporation should be nil.

However, there are "issues". In an EV which might have nearly a hundred cells, a hundred individual solenoids could present a significant reliability issue, could draw appreciable power to run, and the clattering several times a second could be offensive to passengers in the same compartment. However, the solenoids can be replaced with a single compressed air system, Figure D-3, with one solenoid valve that pressurizes all of the diaphragms at once. There are reports the pressure head used in air lift pumps is only about 1.5 psig.

Figure D-2, Part C, illustrates a higher volume pump. In this case, the slug of driving air pushes down on electrolyte that has filled the tubing of the pump. It flows downward tru-

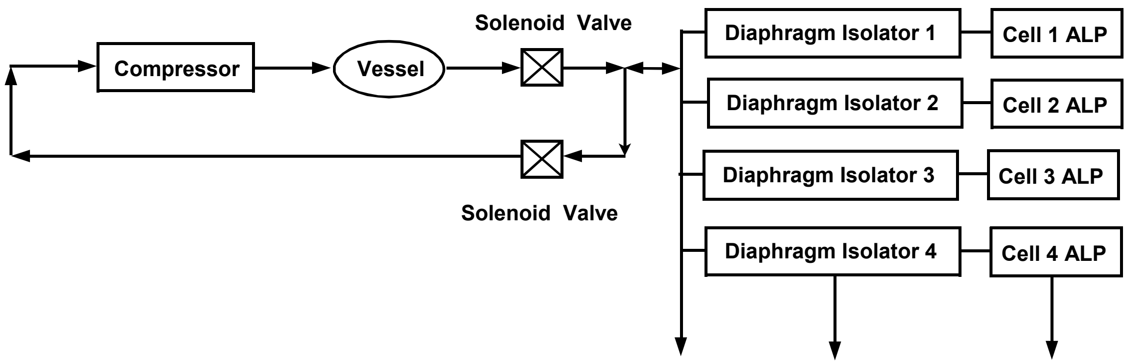

Figure D-3—*System for pulsing multiple ALPs (Air Lift Pumps).*

ing the corner at the bottom and passing through an aspirator or actual venturi mixing device. Upon passing through the aspirator or venturi it sucks additional liquid from the bottom of the cell into the tubing and positively displaces it into the ullage of the cell. When the driving gas is halted and the diaphragm retracts, the electrolyte from the bottom of the cell backfills the tubing automatically. Makers of industrial mixing venturis/eductors/ejectors claim they can entrain twenty to forty times the driving fluid volume and so a significant throughput is possible with this system.

Indeed, the driving fluid can be a liquid much like hydraulic fluid is used to operate the car brake cylinders. In real world brake systems as many as at least six similar circuits have been used.

Aspects of these variations and comments herein may or may not have been patented in the past or might be new, and if so, this publication is intended as a patent-barring public disclosure.

However in this case, the simplicity of ALP circulation is intriguing. It involves no rotating or moving hardware machinery inside the battery itself. All the power for a collection of batteries can come from one compressed gas source. Since this appears to have become standard in electric boats, it may well have established itself to be the most practical.

Hypothetical Design

Figure D-4 exhibits the writer's current speculation. He wants to see FLA batteries tested like this moved to market quickly if they prove as viable as they promise to be. In order to get to a testing phase under way ASAP, this speculation is based on cobbling ALPs into batteries of present designs as much as possible.

Hence, the writer envisions using the present case and plates, and top cover from existing designs such as the Trojan T-105 and T-115. From the middle of the plate assembly, a few plates (one or two pairs of positive and negative) would be removed and replaced with an ALP which would install with the tube for the gas entry centered in the ordinary filler cap opening. Can any of today's battery vendors (Trojan, US Battery, Deka, Exide, etc.) be convinced to hand-assemble some prototypes for testing? Can battery-build shops as described by Hurly [*22*] be convinced?

Inserted in the space provided by the deletion of plates would be the molded plastic

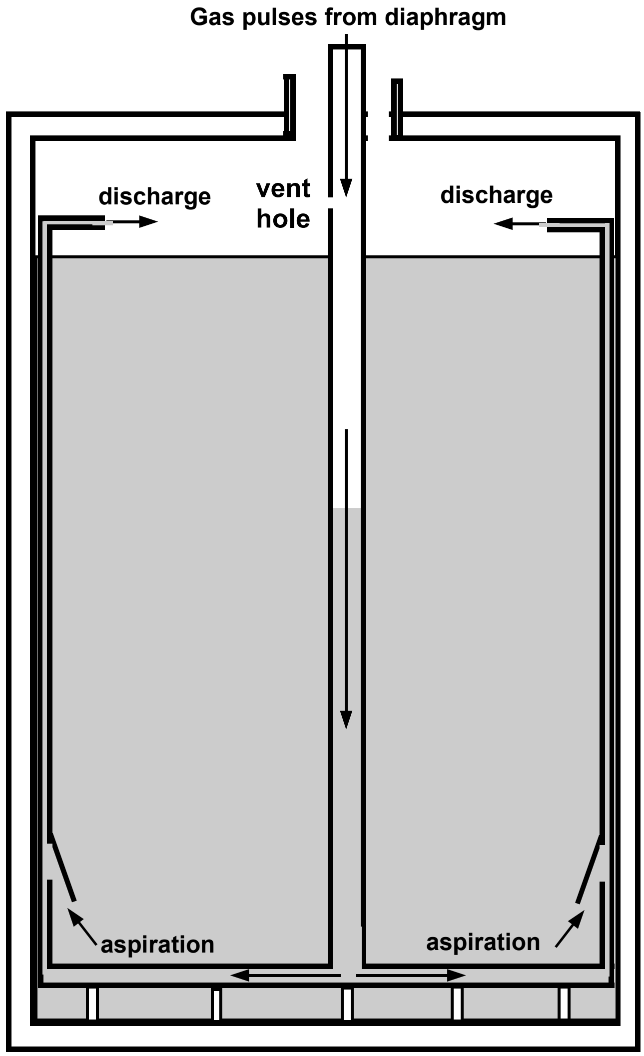

Figure D-4—*Split-flow agitation system centered in filler- cap opening.*

ALP of Figure D-4. When air is injected into the inlet from the diaphragm assembly it pushes the electrolyte straight down to the bottom where it splits into two streams, flowing in opposite directions. Each stream turns the corner at the opposite sides of the battery and moves upward passing through a flow enhancement device (aspirator, eductor, ejector or full venturi tube) where is pulls in additional electrolyte that is pushed upward and sprays out into the ullage (vapor space at the top of the battery). When the pressure slug stops flowing and starts to retract, a check valve (possibly not needed) ala Sundberg allows vapor space gas to back-fill the diaphragm device. In addition, electrolyte from the bottom of the battery will back fill the ALP through the open enhancement devices. Some care may be needed to prevent debris from the battery bottom from sucking into the ALP.

Eductors/ejectors/venturis can be very sophisticated high-precision and expensive instruments but even cheap simple molded/3D-printed aspirator versions should provide significant benefit. This may be very useful because when one is accelerating, one needs a constant supply of power, and pulsing of the agitator might lead to surging in vehicle velocity. As a result, the performance math of Chapter 6 assumes the best-case-battery pack contains eductor-agitated electrolyte that provides a complete homogeneity of the fluid.

Consider also a Trojan T-145, or US Batteries 145 XC2, or similar battery that has a case that is about one inch taller than the T-105 (11.91 vs. 11.07 in.) or US 2200 XC2 ($11^{7}/_{8}$-in. versus 11.25 in), but apparently have the same width and length. If they can be loaded with plates from the T-105 or 2200 XC2 designs, then this in addition to the gap provided by the deleted four plates, would increase the void and the head space to increase the amount of electrolyte that is present (and allow for stoichiometric reduced specific gravity electrolyte as described in Appendix C).

The extra inch of space on the top of the battery and the ten percent gap will be assumed to provide about 12% percent more electrolyte and slightly lower open-circuit voltage, but as the acid is consumed, the specific gravity will decrease from an initial average of about 1.25 to a final average of about 1.15 when the battery active materials are 80% reacted (although with homogeneous electrolyte the maximum safe discharge level may be still lower). And since we assume the electrolyte circulation will provide homogeneity of the fluid, the specific gravity at the top is equal to the average value throughout. Perhaps the plate spacing can be reduced to yield a proportionally smaller battery internal resistance. Perhaps the maximum specific gravity could also be reduced if the benefits obtain in charging as speculated in Appendix C. We can surmise the performance of this battery simply as follows:

-Its open cell voltage will fall from 2.122 volts when fully charged to about 1.943 volts when 80% discharged, regardless of the discharge rate.

-Its internal resistance might be as low as 0.002 ohms (50% less than for the T105 class battery with half-thick plates and when 80% discharged might increase to only about 0.006 ohms.

Would any of these work? Apparently some of them already have. Done deal! However, it is not possible to say how close they could approach theoretical best-case predictions here. There is no way to say without actual testing, and that may or may not be possible in the future by this writer? However, these predictions are the very best performance one could theoretically hope for. Maybe some conversion hobbyists will take interest. Perhaps many could take political interest and help support the development of the Cockroach as a public service.

However, to the extent that such modification did not result in a best-case battery performance, the next section considers how any remaining shortfall might be offset with supplemental high-tech cubic money batteries.

Appendix F

Supplemented Battery Systems

We have seen that lead-acid batteries (LABs) are way more economical than lithium-ion batteries (LIBs). Someday that may change and LIBs may supplant LABs in cost. However, at present, LIBs have two principal advantages, they are much lighter (perhaps 500 pounds lighter per car or more) and they do not deteriorate in performance as much as LA batteries as they discharge and/or age (their Peukert's exponent is closer to 1.0). As Li-ion batteries discharge, they apparently provide performance close to what they did when they were fully charged. Their claims would suggest they are close to best-case battery performance...in other words they have much less internal resistance to obsess over.

The weight of FLA batteries is not a fatal issue in a "practical" niche vehicle (a vehicle that is by its nature a "dog" when compared to "muscle-cars" and even ordinary cars) that are targeted to serve retired people, poor people, students and for niche errand "city car" service.[F1] Cars for which good enough performance is good enough. However batteries that lose half their acceleration, top speed and range (ATSR) when they discharge, that lose half their ATSR when they age two years, that lose half their ATSR when they get cold, can suddenly find themselves unable to do even a good-enough job.

We have seen that five redesign thrusts including agitated electrolyte hold promise to solve a large portion of these ills. We can hope all of the ATSR degradation of FLA batteries during discharge will resolve but lacking specific hard data we do not know how much better lithium batteries might still be, beyond of course, providing better acceleration due to lower weight and more persistent power delivery.

This section intends to suggest that if upgraded LABs do not totally erase the discharge-performance deficits, or if any of the target audience requires a tad better performance, that LABs can be supplemented with a small number of lithium cells to largely com-

[F1]City cars used just for short trips have been a legend. The Pontiac Fiero maybe the most recent major attempt at a "city car" but its price was too high to convince people to forego the benefits of having two identical cars for just a small marginal increase in purchase and operating expense. The much, much , much lower cost of a Cockroach EV and its reliability and operating cost edge might just change the calculus.

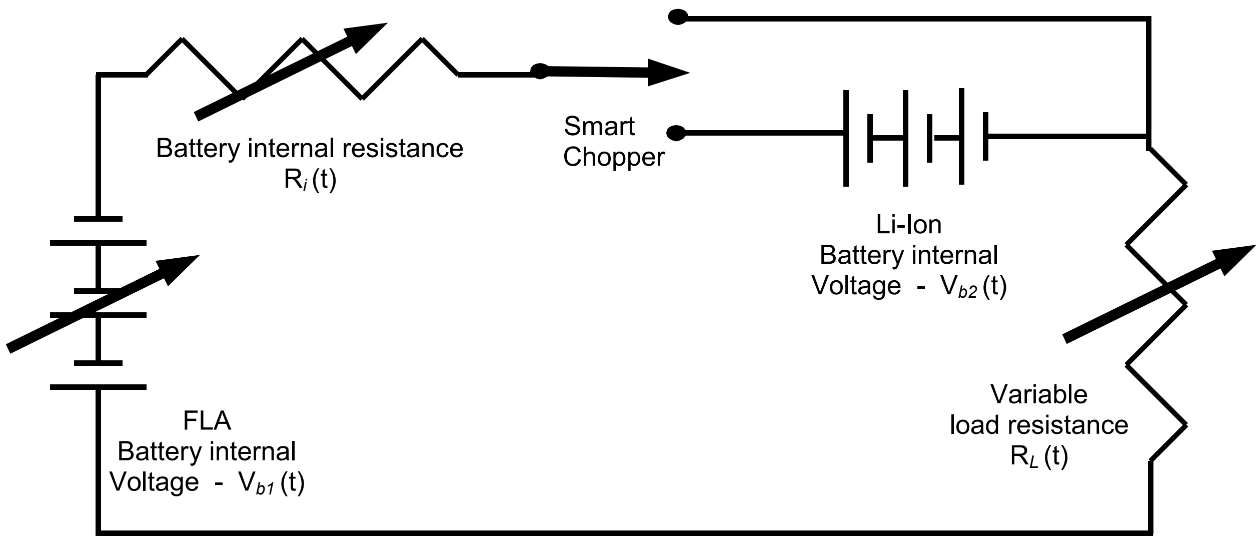

Figure E-1—*Supplemented EV power system.*

pensate for the last of the worst deficits. Indeed, it may be theoretically possible to compensate for some (but not nearly all) of even current FLA battery shortfalls.

It has been previously inferred (well! at least surmised) that if one can add voltage to a LA battery pack, that, despite its elevated internal resistance and reduced internal voltage, it would act a bit more like the original pack did before it developed the additional internal resistance that shifted operation from a higher performance curve of Figure 5 to a lower performance curve.

Indeed, one can envision an arrangement where a variable number of FLA and lithium batteries can be combined ranging from all-FLA to all-LIB to tailor vehicle performance to specific performance needs.

As LAB battery performance declines, a smart controller can gradually chop in gradually increasing amounts of voltage from a supplemental Lithium battery pack, as illustrated in Figure E-1, and because that pack does not deteriorate in performance like FLA batteries, it can back-fill the gap between LAB real and best-case performance to provide better-case performance. And since only a few LIBs are required, the major cost benefits of LABs may continue to render them a much more practical choice for EVs for a bigger chunk of the target audiences.

Indeed, such lithium supplemental batteries can also be viewed as a reserve gasoline tank was viewed in the original VW Beetles, and finally, it can also be used as a “passing gear” that can upgrade even fully charged LABs by providing a kick-down switch on the accelerator pedal.

Since there are data for current batteries (scant as they may be) this analysis will examine the prospects for minimizing the performance deficit of even current (un-agitated) LABS. Since there are fewer data for LI batteries than for FLABs, the math treatment herein will treat them as having zero internal resistance (best case) and zero voltage decay during discharge. Testing of a few may be accomplished for Volume 3 of this series (if there ever is one).

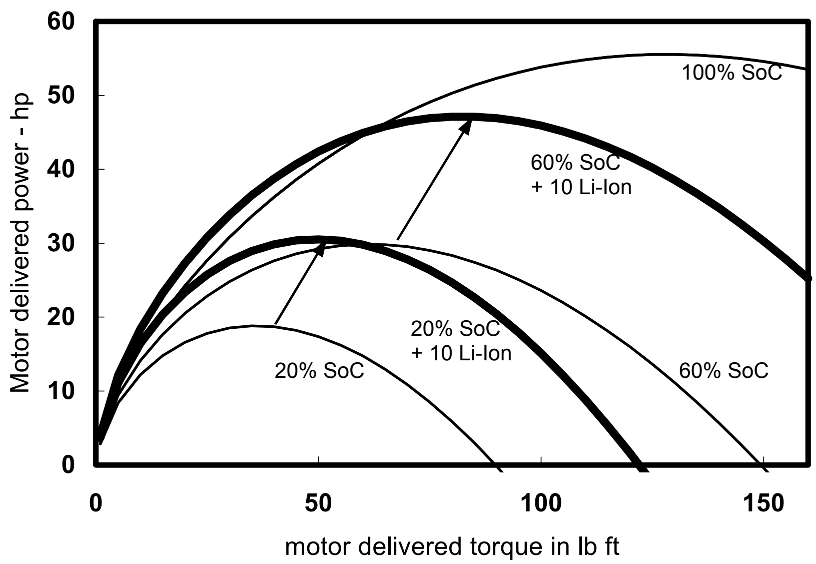

Figure E-2—*Default system power plus 10 Lithium ion supplements at 60% and 20% SoC.*

This treatment (right or wrong) indicates the power curves of Figure B-2, page 259, would become the curves of Figure E-2. The related open source spread sheet was used to generate these data. Notice that the addition of just ten lithium ion cells to the standard 24 battery, 144 volt pack can significantly increase power available at reduced states of charge (SoC). This can allow one to better maintain speed when nearing end-of-range. And similarly they would help parallel connections of lead acid packs to be used in “over-drive” mode at higher velocities better exploiting the apparent greater range possible there. And yet ten lithium-ion batteries would increase the battery pack cost by about $1500. All of these can greatly narrow the difference between expensive lithium ion and lead acid.

However, the better the performance of any FLA battery pack, or the less harsh the driving scenarios, then the fewer lithium batteries that would be needed, and the greater would be the amount of supplementation that could be provided.

However, because the charge and discharge histories of both sets of batteries differ, they would have to be recharged with separate independent chargers.

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Appendix G

Constant Activity Battery Systems

Among the five tactics cited in Appendix C to re-engineer FLA batteries is the possibly wild speculation that hard, unhealthy, sulfation may be most likely to form when the battery has been significantly discharged producing a dense layer of lead sulfate in its plate surfaces and stripping the sulfate ions from the electrolyte layer next to the plate surface. And then that perhaps it will only harden if current flow is ceased and sulfate ions in the liquid are allowed to diffuse near to the plate surface again resulting in exposure of the surface to sulfate ions to serve as a ”glue” material and grow the crystals. This can apparently be prevented if charging is immediately initiated (but only at a low level to prevent overheating).

This is surmised because an FLA battery that was slowly discharged over a period of hours, days, weeks and months did not appear to grow a lot of hard sulfate, nor apparently do batteries discharged rapidly so long as charging at least at a low level is quickly begun. Hence it suggests the battery should always be kept either fully charged ...or in a state of constant activity (either discharge or charge).

Alas, when an FLA powered EV is taken on an errand, it is discharged, maybe a little maybe a lot, then typically parked while the errand is completed, a time during which any dense surface sulfate may have been formed and is still diffusing into the plate. But the discharge mechanism that strips sulfate from the liquid layer right next to the plate can then become filled with sulfate ions. And if this theory or anything like it applies, it may grow hard sulfate crystals.

When it is being charged, the lead sulfate is being removed from the surface and converted back into acid ions. But that depletes the surface of sulfate and perhaps again thwarts hard sulfate from growing.

So how can an FLA battery pack that has been partially discharged, perhaps at a high surface clogging rate, and has been parked somewhere during an errand preserve either of the presumed safe states A or C of Figure C-5. Several ways may be feasible.

Many conversion EVs employ both a high voltage battery pack and a small accessory battery. The battery pack converts its voltage into a lower level (via a reverse inverter) and continuously charges the accessory battery. If that battery is not charged during the early

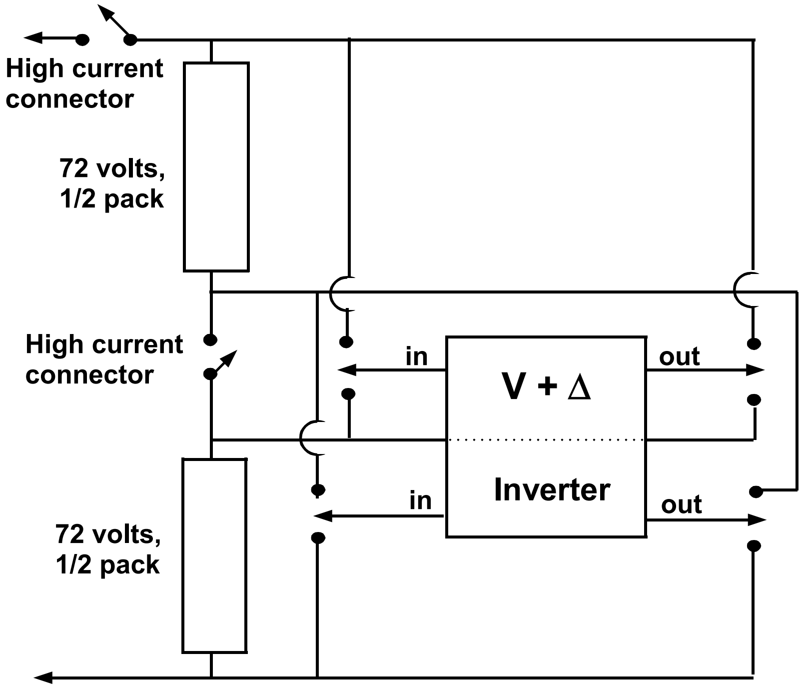

Figure F-1—*Charge-swapping example.*

portion of a trip, then when the EV is parked, the battery pack can continue to charge the accessory battery. That would sustain a low-level discharge and perhaps preserve the depleted layer of electrolyte next to the plate. When the accessory battery has been fully charged, the roles can be reversed and it can be used to re-charge the battery pack through an inverter. The battery pack can be split into sections that can be made to swap back and forth (Figure F-1). If these speculated low levels of charge and discharge currents can be shown to prevent hard sulfate formation, the small inefficiency of the charge-swapping would be a good use of energy, provided the EV was not going to be parked for days or weeks.

If larger charge or discharge currents are needed, then the battery pack can be split in two and an inverter used to charge half the pack from the other half and to swap their roles at regular periods.

Here again as is the case with lithium supplementation (Appendix F) and simulated overdrive operation (pages 264-267), when the batteries are later re-charged, they will need to be charged with separate chargers for each of the sections that are allowed to operate independently to avoid "balance" issues.

Of course this prospect hangs totally on whether the mechanics of hard sulfate formation has been correctly surmised. At the moment that is mere conjecture despite the favorable supporting materials that have been identified.

References

[**1**] Leitman, S and Brant, B., *Build Your Own Electric Vehicle*, Second edition, McGraw-Hill, New York, 2009, 329 pages.

[**2**] Leitman, S and Brant, B., *Build Your Own Electric Vehicle*, Third edition, McGraw-Hill, New York, 2013, 388 pages.

[**3**] Brant, B., *Build Your Own Electric Vehicle*, First edition, McGraw-Hill, New York, 1994, 310 pages.

[**4**] Brown, M. P., with Prange, S., *Convert It*, Third Edition, Business With Pleasure, 1993, 128 pages.

[**5**] Warner, M., P.E., *The Electric Vehicle Conversion Handbook*, First Edition, HP Books, New York, 2011, 170 pages.

[**6**] Boxwell, M., *The 2011 Electric Car Guide*, Third Edition, Gulfstream Publishing, United Kingdom, 2011, 181 pages.

[**7**] Leitman, S., *Build You Own Plug-In Hybrid Electric Vehicle*, McGraw-Hill, New York, 2009, 281 pages.

[**8**] Shacket, S. R., *The Complete Book of Electric Vehicles*, Domus Books, Northbrook, Ill, 1981, 224 pages.

[**9**] Shnayerson, M., *The Car That Could: The Inside Story of GM's Revolutionary Electric Vehicle*, Random House, New York, 1996, 295 pages.

[**10**] Hughes, A., *Electric Motors and Drives*, Elsevier/Newnes, Amsterdam, etc., Third Edition, 2006-2011, 410 pages.

[**11**] Gottlieb, I. M., *Electric Motors and Control Techniques*, McGraw-Hill/TAB Books, New York, etc., 1994, 294 pages.

[**12**] Watson, A. E., *Storage Batteries, Their Theory, Construction and Use*, Second Edition, Bubier Publishing Company, Lynn, Mass, 1911, 166 pages

[**13**] Arendt, M., E., *Storage Batteries: Theory, Manufacture, Care and Application*, D. Van Nostrand Company, Inc., New York, 1928, 285 pages.

[**14**] Pagé, V. W., *Storage Batteries Simplified*, Lindsay Publication, Inc., Bradley IL, 1986, Original copyright Norman W. Henley Publishing CO., New York, 1917, 208 pages.

[**15**] Vinal, G. W., Sc.D, *Storage Batteries: A General Treatise on the Physics and Chemistry of Secondary Batteries and their Engineering Applications*, Fourth Edition, John Wiley and Sons, Inc., New York, 1955, 446 pages.

[**16**] Morse, H. W., *Storage Batteries, The Chemistry and Physics of the Lead Accumulator*, The Macmillan Company, 1912, 266 pages.

[**17**] *Rechargeable Batteries*, Books LLC, Memphis TN, USA, 170 pages.

[**18**] Buchman, I**,** *Batteries in a Portable World, A Handbook on Rechargeable Batteries for Non-Engineers***,** Third Edition, Cadex Electronics, British Columbia, Canada, 2011, 328 pages.

[**19**] Rand, D. A. J., Mosley, P. T., Garche, J., and Parker, C. D., *Valve-Regulated Lead-Acid Batteries*, Elsevier, B. v., The Netherlands, 2004, 575 pages.

[**20**] Bode, H., *Lead-Acid Batteries*, John Wiley & Sons, New York, etc., 1977, 387 pages.

[**21**] Barre, H., *Managing 12 Volts*, Summer Breeze Publishing, Redwood City, California, 1996, 214 pages.

[**22**] Hurley, P., *The Battery Builders Guide*, Wheelock Mountain Publications, Wheelock VT, 2008

[**23**] Rowlette, J. J., *Lead Acid Battery*, United States Patent 4,405,697, U.S Patent and Trademark Office, 20 September 1981, Assignee: California Institute of Technology, Under contract to the National Aeronautics and Space Administration

[**24**] *Corvair—A Complete Guide*, A Car Life Special Edition, Bond Publishing Company, Newport Beach CA, 1963.

[**25**] United States Senate Budget Committee, CRS Report: Welfare Spending The Largest Item In The Federal Budget, 18 October, 2012, Internet Access.

[**26**] Drum, K., "How Much Do We Spend on the Nonworking Poor?, in *Mother Jones* magazine, 13 February 2012, Internet access.

[**27**] Dwight, H. B., *Tables of Integrals and Other Mathematical Data*, Fourth Edition, The Macmillan Company, New York, 1961.

[**28**] Newill, W. J., U.S. Patent 4469759 A, *Magnetic electrolyte destratification*, Assigned: General Motors, 04 September 1984.

[**29**] Sundberg, E. G., U.S. Patent 3083253 A, *Method and apparatus for electrolyte circulation*, Assignee: Tudor Ab., 26 March 1963.

[**30**] Gauvin, R. J., U.S. Patent 3040116 A, *Battery Charging system for submarines*, 19 June 1962.

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