Meeting Minutes

Re: Battery Condition Monitoring Workgroup Teleconference

Date: February 16, 2001

LIST OF PARTICIPANTS[†]:

Masoud Beheshti, Texas Instruments
Michael Cox, Midtronics
Dell Crouch, Delphi
Gary DesGroseilliers, MIT
Thomas Dougherty, Johnson Controls
David Freeman, Texas Instruments
Hans-Michael Graf, Siemens Automotive
David Heacock, Texas Instruments
Henry Huang, Ford
Tsuyoshi Kameda, Yuasa
Karl Keckan, Ford
Thomas Keim, MIT
Michikazu Kosuge, Furukawa Electric
Scott McCaskey, East Penn
Michael Mullin, General Motors
Paul Nicastri, Ford
Thirumalai Palanisamy, Honeywell
Hans-Peter Schöner, DaimlerChrysler
Indermohan Sethi, Siemens Automotive

PRESENTATIONS:

- Tom Dougherty proposed a set of eight battery parameters that could be used to characterize a lead acid battery. (Go to the presentation ➔). He suggested that the values of these parameters could be summarized by a standard 8-byte word (WORD 1) that would be provided on a label or electronically coded chip. These parameters would be used by an energy management system to determine "deliverable power" and "deliverable energy." In a future presentation, Dougherty will discuss the parameters of a second 8-byte word (WORD 2) that could be used to summarize the charging and life information of the battery.

- Tom Keim present the proposed "Statement-of-Purpose" and "Guidelines for Participants" for the Battery Condition Monitoring Workgroup. (Go to the document ➔).

COMMENTS:

Keckan............... Peukert's curve could be expressed either as one data point and a slope or by two data points.

† Contact information of participants is available on the web site at: http://auto.mit.edu/vei/reg.nsf under the administrative section of this workgroup (Username: "ford" and Password: "Formula1"). Documents associated with previous meetings can be found at the same site.

Crouch .... The value of the approach proposed by Dougherty's might be limited by manufacturing variations during production.

Schöner .... Agrees that manufacturing variations can occur but would still find value in the approach.

Nicastri .... Would also be satisfied with the accuracy of the information that would be available using standard battery parameters. In addition, this approach does not require that a replacement battery have the same specifications as the original battery because each vehicle can "learn" from the parameters.

Schöner .... Suggested that some of the proposed parameters should be measured in relative, rather than absolute terms.

Palanisamy........ Believes that the specific parameters proposed by Dougherty would be limited to lead-acid batteries. Other chemistries would have different set of parameters.

Schöner .... Asked if MIT might develop a software model that would use the proposed battery parameters to determine "deliverable power" and "deliverable energy."

Keim.................. MIT would require expert advice from the member organizations to effectively develop a battery model.

Crouch .... Battery model would also require extensive fleet testing under various operating conditions. Therefore, this effort would best be done by manufacturers.

Nicastri .... Agrees with the "Statement-of-Purpose" and "Guidelines for Participants" as proposed by Keim, and thinks that Dougherty's battery parameter proposal is consistent with those guidelines.

AGREEMENT TOPICS AND STATUS:

The status of topics under discussion by the BCM workgroup is summarized in the table below

Topic	Status
1. BCM Workgroup "Statement-of-Purpose" and "Guidelines for Participants"	Accepted without change
2. Battery parameters to be encoded in a "word" of one-byte per parameter.	Under discussion
3. Charging and life information of the battery would be encoded in another "word"	Under discussion
4. "Words" will be provided on a label or electronically coded chip.	Under discussion
5. Battery parameters will include:	
a. Internal resistance	Under discussion
b. Ionic/electronic ratio	Under discussion
c. Kinetics	Under discussion
d. Peukert's slope	Under discussion
e. Nominal capacity	Under discussion
f. Charged voltage	Under discussion
g. OCV/RSOC slope	Under discussion
h. Thermal constant	Under discussion

FUTURE MEETINGS:

A face-to-face meeting is scheduled for Wednesday, March 28th, from 8:00 a.m. until 12:00 noon at the **Sheraton Lisboa Hotel and Towers**, Rua Latino Coelho, 1, in Lisbon, Portugal. The agenda for this meeting will focus on a discussion of the battery parameters proposed by Tom Dougherty.

Notes:

- A block of hotel rooms has been reserved at the hotel at the rate of Esc. 30,000 (~$135 U.S.) for a single room or Esc. 33,000 (~$150 U.S.) for a double room. These rates include room charge, breakfast buffet, and applicable tax. To reserve a room, please contact the hotel directly by telephone (+351 21 312 0600) or fax (+351 21 357 5073). Please refer to the "MIT Conference" event to ensure the discounted rate.
- Non-Consortium-member participants in the are welcome to attend the BCM Workgroup meeting, and to avail themselves of the conference rate. They cannot, however, attend any Consortium-related events.
- If anyone would like to participate in this meeting by teleconference, please inform Gary DesGroseilliers before March 16th.

Proposed New Battery Terms and Parameters for Battery Simulation and Operation Part I - Battery Load Calculations (Word 1)

THIS IS A WORKING DOCUMENT

Presented by Thomas J. Dougherty
Manager of Electronic Systems
Johnson Controls, Inc.

February 16, 2001

Introduction - Objective

Our objective in developing new characteristics is to enhance the ability of the automotive industry to define the product for new applications.

Today, battery ratings are based on years of testing and data collection which define many parameters of the battery functions and performance characteristics in a vehicle. <u>We need to continue to use</u> this data since it is required in standards and rating comparisons.

Present ratings may not give enough information for proper sizing and do not easily convert over to information needed for use in system design and system models.

The goal is to add to today's standards the information that will expand terminology to encompass new system demands and requirements.

Additional Measurements

- The following ideas are being proposed for additional measurements that will allow for modeling and better understanding of battery use in a dynamic application.

- The terms presently being defined are initially being developed for the Lead Acid battery.

- The terminology is presently being discussed in an MIT subcommittee to gain general acceptance.

- A second objective is to place all the following information into a single 8 byte word. This will be defined later in the paper.

What We Are Trying to Measure?   Not just SOC

- State-of-Charge (SOC) is an idiomatic term when trying to determine the energy that a battery can deliver in a dynamic drive cycle.
- By current used terminology, SOC is a measurement of the remaining Amp Hour in a battery.
- We therefore concluded that we should only talk about State-of-Charge and State-of-Health in Relative terms which have limited application.
- Our goal is to determine the Deliverable Power and Deliverable Energy a battery can supply at any time in its use. We call this is a Deliverable Energy Unit.
- To do this we need to expand how we characterize batteries and how we measure their performance.
- Battery Condition and Aging effects will change the Deliverable Power, and methods of measuring their contribution is required.

Electrical Performance Characteristics Terminology

Internal Resistance (R) (1)	Measured in Milli ohms, it is the total DC resistance of a battery which is charged and conditioned.
Ionic/Electronic Ratio (2)	This term gives the ratio of the ionic resistive component to the electronic resistive component in a battery.This allows the model to determine the effects of temp.
Kinetics (3)	This is the voltage drop due to the reaction to form lead sulfate. It is this voltage drop plus the temperature corrected IR which will give the voltage drop of the battery under load.
Peukert's Slope (n) *(4)*	This is the measurement of the battery's ability to deliver current at different rates.
Nomimal Capacity (5)	This is the battery's ability to deliver current at the one hour rate. It also sets a data point for *Peukerts Constant* or the value of I.
Charged Voltage (6)	The open circuit voltage of a battery at equilibrium when charged and at rest with no loads.
OCV/RSOC Slope (7)	This is the slope of the curve that shows the OCV to the Relative State-of-Charge (RSOC).
Thermal Constant (8)	The ability of the battery to dissipate heat. The heat transfer co-efficient.

Note: All the above characteristics require a special test procedure to attain the proper result. See followign pages.

Total Internal Resistance Calculation - *proposed*

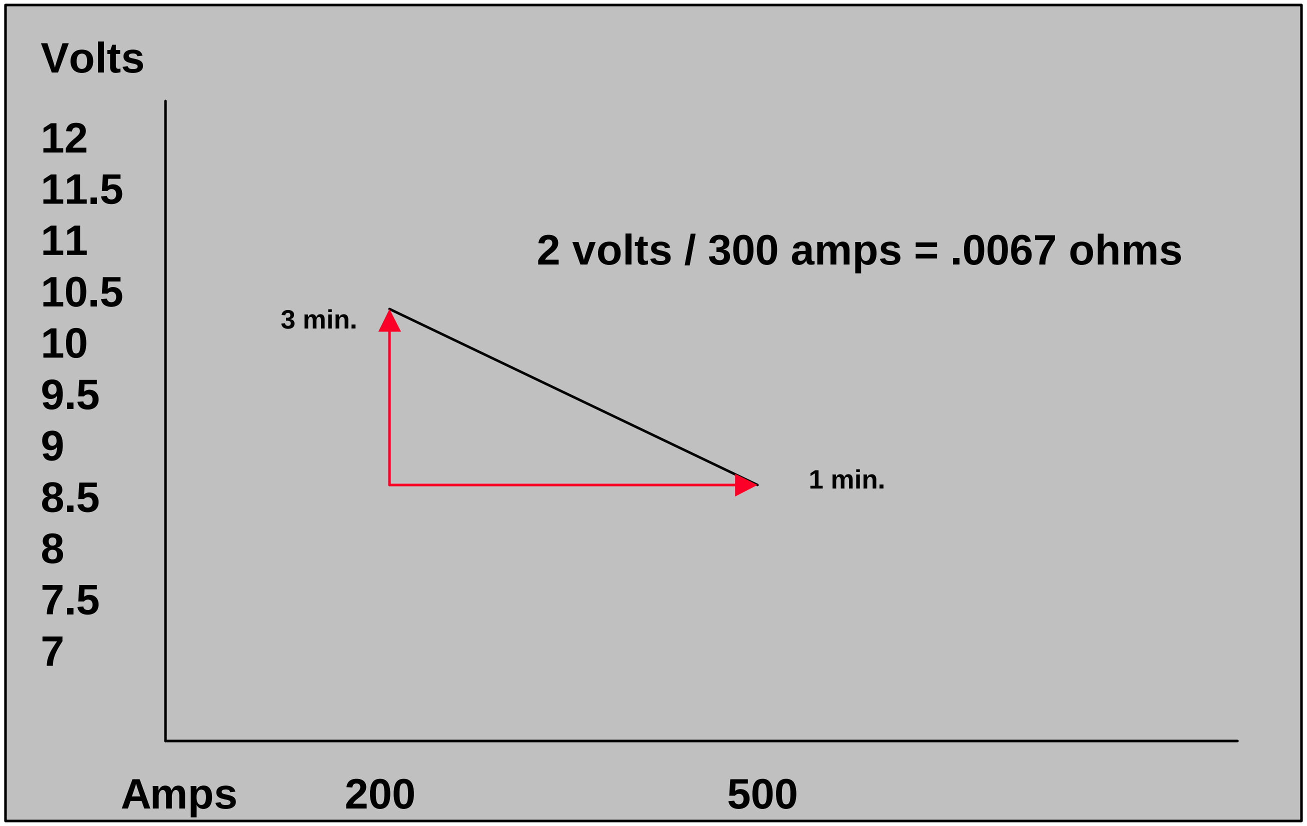
(1)

- This is the DC resistance due to the total ohmic resistive losses in the battery.
- The test is run at 25ºC and discharges the battery at the 1 min. rate for 3 sec., saving the 3 sec. voltage reading. A second test is run at the 3 min. rate, saving the 10 sec. voltage reading.
- The resistance is calculated as the dV/dI. (Voltage / Current)
- Note: IR meters,(xxx) since they have an AC component in their measurement, are not always acceptable for this test.

Total Resistance Measurement - 12 Volt Battery

(1)

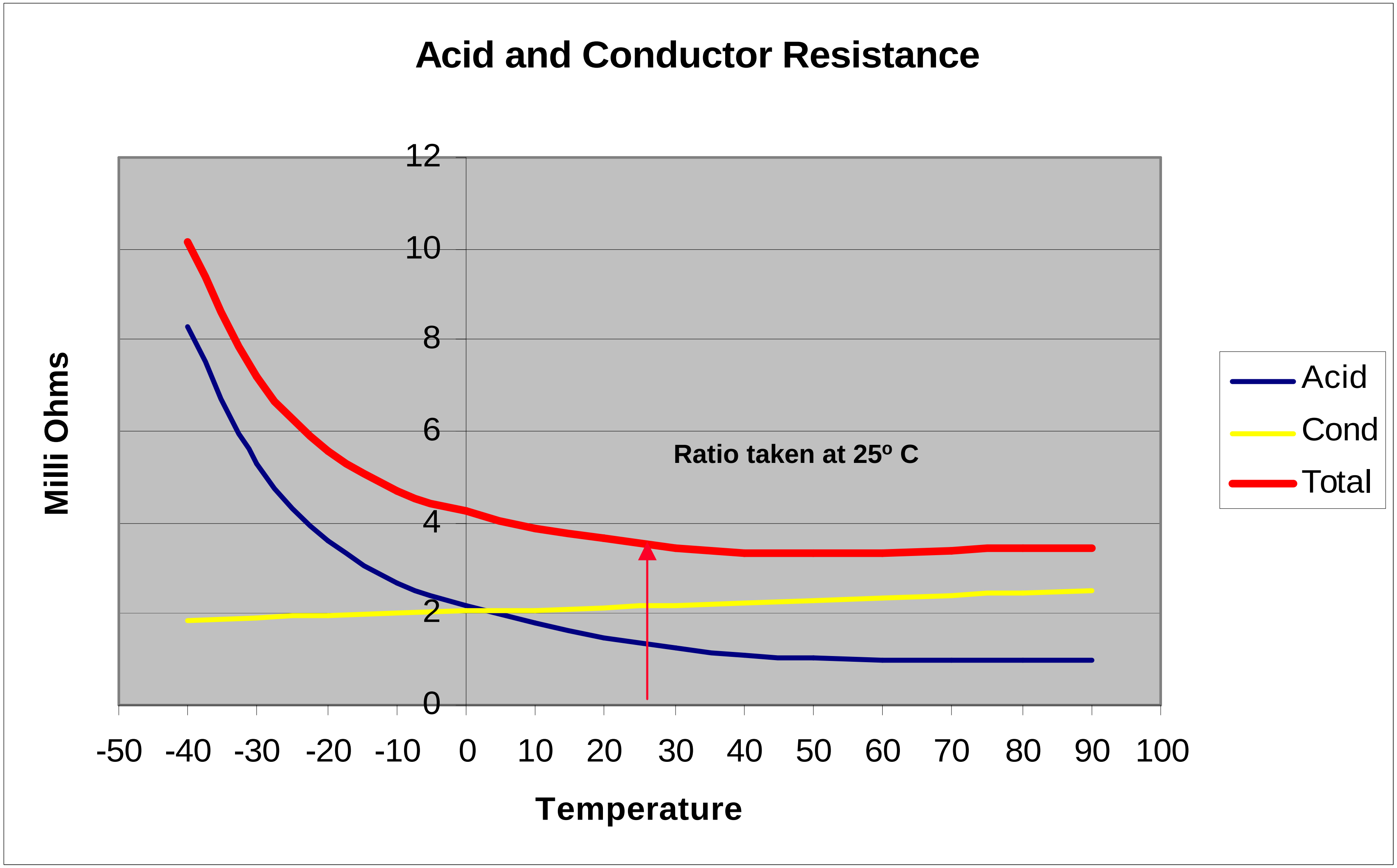
3 min. Voltage - 1 min. Voltage/ 1 min. Current - 3 min. Current



Ionic/Electronic Resistance Ratio - *proposed* (2)

- To be supplied by the battery manufacturer.
- This is the ratio @ 25ºC of the Ionic (acid resistive component) to the Electronic Resistance (conductors).
- These terms will be used by the battery model to separate the total resistance into each of its components so that temperature effects can be calculated.
- Test method needs to be developed.

Ionic/Electronic Resistance Ratio - *proposed* (2)



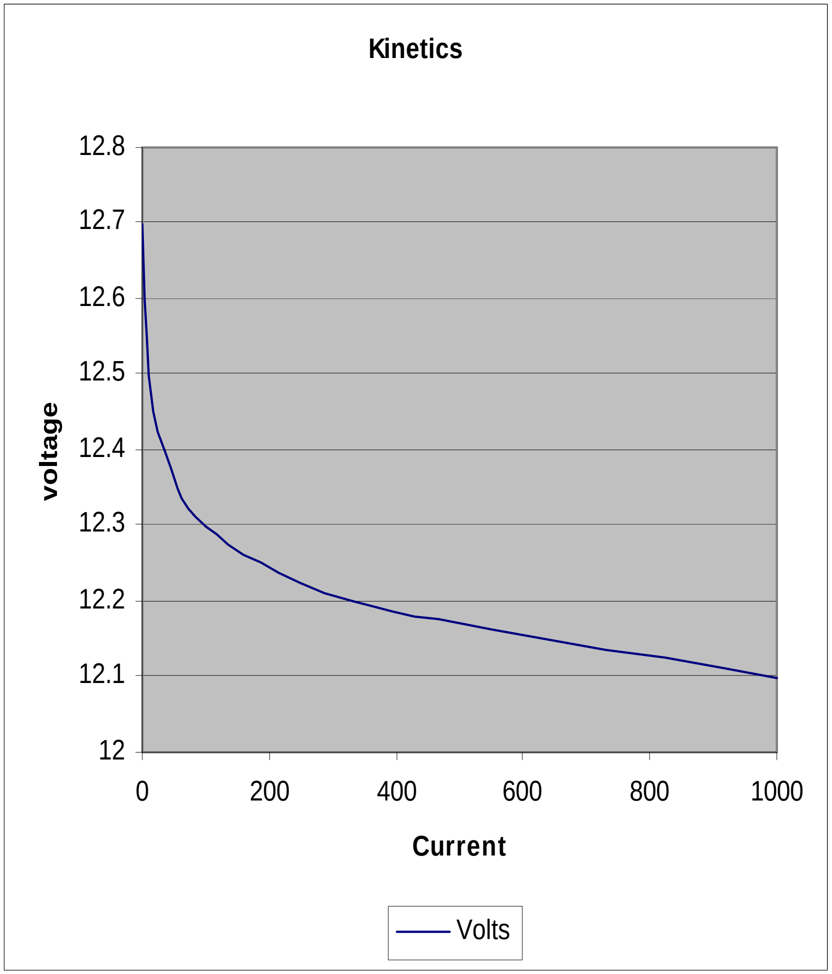
Kinetics - *proposed, needs work*

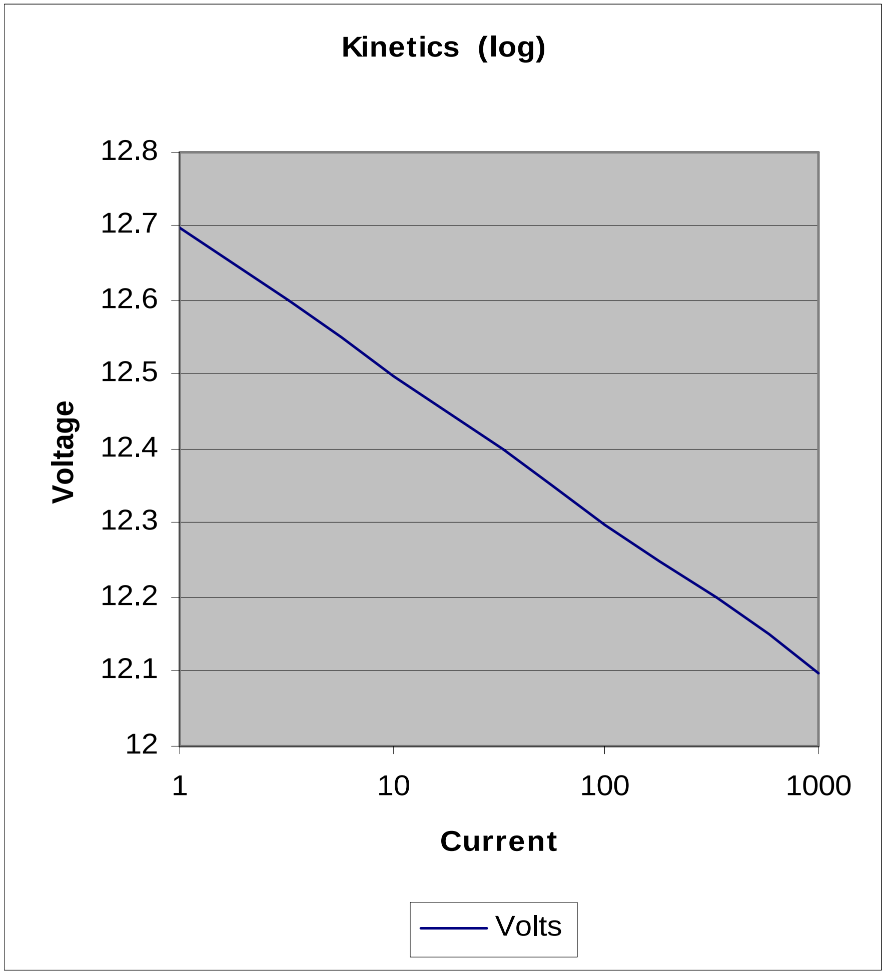
(3)

- This is the voltage drop due to the reaction that forms lead sulfate.
- The voltage drop is a logarithmic effect in relationship to current. Therefore, .1 amp and 1 amp will yield the same equivalent incremental voltage drop.
- Test is run by taking a fully charged battery that has a stable voltage and discharging it at its 20 hour rate, 3 hour rate and its .5 hour rate. Subtract from each of these their resistive component. The voltage drops are taken 5 min., 2 min and 1 min, respectively, into the discharge. Plot the dV/dI on log-log paper and determine the Kinetics Resistance (KR) function. Record the voltage dorps and plot the results.

Kinetics - *proposed*

(3)





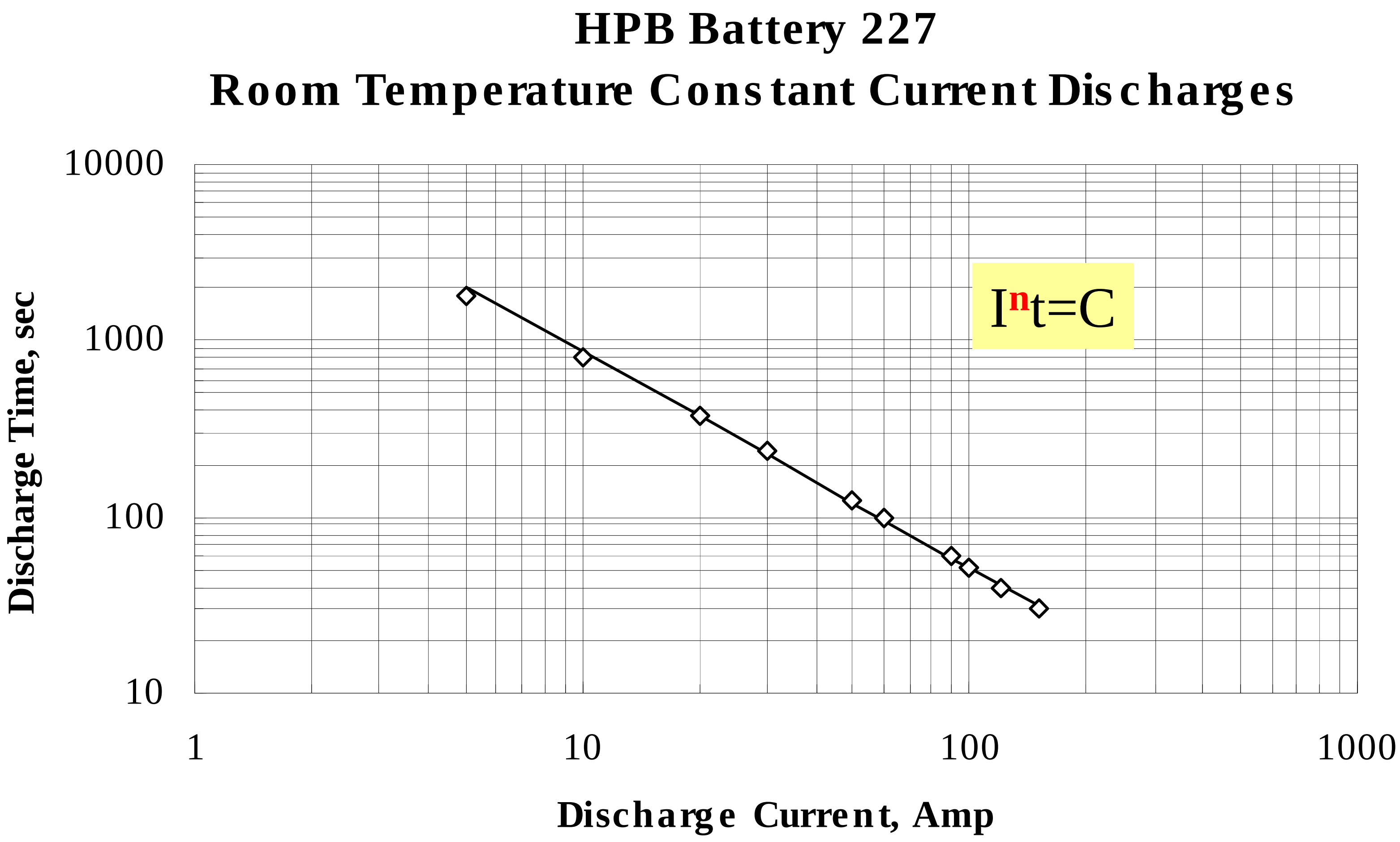
Peukert's Equation

(4,5) Capacity of a battery will be described by Peukert's Constant. $I^{n}t=C$, where **n** and C are constants for a given.

- Calculations are done as follows:
  - $I_1^{n}t_1 = I_2^{n}t_2 = C$ which equates to:
  - $$n = \frac{\log t_2 - \log t_1}{\log I_1 - \log I_2}$$
- If given the one hour rate (i.e., 60 amps) and a value of **n**=1.25 $C=(60)^{1.25} = 167$.
- The following plot for current vs. time can thus be plotted.
- Note: The end of discharge voltage is .33 volts per cell below the initial load volts. This will make Peukert's Equation a straight line over most of the discharge.

Example - Peukert's Equation

(4,5)



Charged Voltage and OCV/RSOC - Pb - working

(6,7)

- For Systems Engineers to determine Relative State-of-Charge (RSOC), two battery characteristics are needed.
  - The charged, stable Open Circuit Voltage (OCV).
  - The slope of the OCV/RSOC curve.

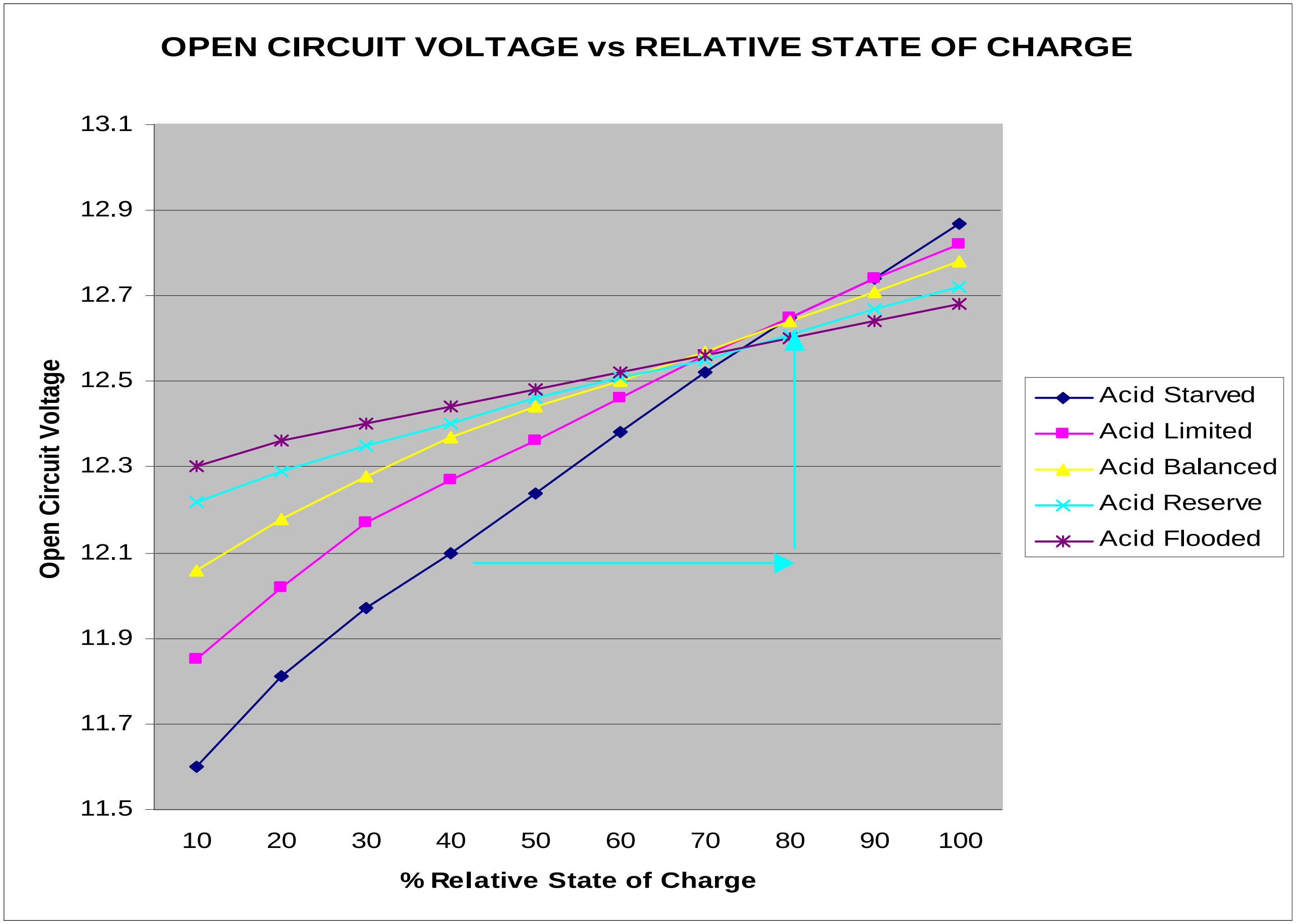
- The Charged, Stable OCV is determined by charging a battery to SAE J(537) standard. The battery is allowed to sit for 24 hours, then discharged at 25 amps for .5 min* The OCV is read after 30 min. This voltage is used for the Charged Voltage.

- The slope of the OCV vs. RSOC curve is supplied by discharging the battery at the 20 hour rate in 10% increments down to 10%. OCV are taken 1 hr. after each 10% discharge. The chart is plotted and the slope is taken between 40% and 80%.

* Battery Size dependent

RSOC Vs OCV

(6,7)



Thermal Constant - ***proposed***

(8)

- To determine how a battery heats up due to current effects on its resistance, a battery's thermal constant needs to be defined.
- Also, the effect of underhood heat needs to be defined as to how fast a battery will take on heat or cool.
- The thermal constant will be based on <u>no forced</u> air movement.
- Rating will be based on the time it takes a battery to dissipate 10ºC when the battery, @ 60ºC, is placed in a 25ºC environment. (Will have to consider the battery heat capacity)
- Convection affects on the battery are outside the scope of this document. (Temperature measurement location TBD)

Word I - ***proposed***

- The first of the two words to define the battery would have the letters A-Z and 1-0 in each digit.
- The letters and numbers would refer to a table that is found on the next page.
- The word would look like the following: **NR2TPGX4**
- The values would be agreed upon by all battery companies and all batteries would have this code in their label or electronic coded chip.

Word I - *proposed*

	1	2	3	4	5	6	7	8
	Resistance Milliohms	Ratio Ionic/ Electronic	Kinetics	Peukert's Slope	Nominal Capacity Amphour 1 Hr. rate	Charge Voltage	OCV/RSOC Slope	Thermal Constant
A	20	0.9	100	1.48	120	13.4	0.37	100
B	18	0.88	97	1.46	110	13.36	0.36	6.0
C	16	0.86	94	1.44	105	13.33	0.35	5.8
D	14	0.84	91	1.42	100	13.3	0.34	5.7
E	13	82	88	1.4	95	13.27	0.33	5.5
F	12	0.8	85	1.39	90	13.24	0.32	5.3
G	11	0.78	82	1.38	87	13.21	0.31	5.2
H	10	0.76	79	1.37	84	13.18	0.3	5.0
I	9.5	0.74	76	1.36	81	13.15	0.29	4.9
J	9	0.72	73	1.35	78	13.12	0.28	4.7
K	8.5	0.7	70	1.34	75	13.09	0.27	4.5
L	8	0.68	67	1.33	72	13.06	0.26	4.4
M	7.5	0.66	64	1.32	69	13.03	0.25	4.2
N	7	0.64	61	1.31	66	13	0.24	4.1
O	6.5	0.62	58	1.3	63	12.9	0.23	3.8
P	6	0.6	55	1.29	60	12.97	0.22	3.5
Q	5.7	0.58	52	1.28	57	12.94	0.21	3.2
R	5.3	0.56	49	1.27	54	12.91	0.2	2.9
S	5	0.54	46	1.26	51	12.88	0.19	2.6
T	4.7	0.52	43	1.25	48	12.85	0.18	2.3
U	4.3	0.5	40	1.24	45	12.82	0.17	2.0
V	4	0.48	37	1.23	42	12.79	0.16	1.8
W	3.7	0.46	34	1.22	39	12.76	0.15	1.6
X	3.5	0.44	31	1.21	36	12.73	0.14	1.4
Y	3	0.42	28	1.2	33	12.7	0.13	1.2
Z	2.8	0.4	25	1.19	30	12.67	0.12	1.0
1	2.6	0.38	22	1.18	27	12.64	0.11	0.9
2	2.4	0.36	19	1.17	24	12.61	0.1	0.8
3	2.2	0.34	16	1.16	21	12.58	0.09	0.7
4	2	0.32	13	1.15	18	12.55	0.08	0.6
5	1.8	0.3	10	1.14	15	12.52	0.07	0.5
6	1.6	0.28	7	1.23	12	12.49	0.06	0.4
7	1.4	0.26	4	1.12	9	12.46	0.05	0.3
8	1.2	0.24	L	1.11	6	12.43	0.04	0.2
9	1	0.22	N	1.1	3	12.4	0.03	0.1
0	NOP	NOP	NOP	NOP	NOP	NOP	NOP	NOP

Conclusion

- OEMs are looking for improvements in such tools as the Saber and Advisor Models to reduce design time.
- They also need simple real-time processing in vehicles to determine the ability of a battery to deliver power over its life
- Present battery criteria do not give design engineers the information they need to develop proper models or systems.
- To accomplish this goal, we should assist the OEMs in developing a set of criteria that will augment today's traditional SLI (Starting Lighting and Ignition) Battery ratings.

Word II Charging and Life Characteristics

- The second “Word” of the battery rating Characteristics has Charging and Life information. The following page shows the terms proposed.

- This subject matter will be discussed in our next paper.

Next paper and discussion (WORD II)

Performance Characteristics Terminology - Charging and Life

Note: These characteristics still need to be further refined.

Charge Acceptance (9) Ability to accept a charge when in a discharge state.

AC Impedance (10) Inductive component of a battery to an AC power source.

Condition Effect (11) History effect on capacity, conductivity and charging.

Cycling* (12) Loss of nominal capacity due to cycling.

Flat Stand * (13) Loss of nominal capacity due to flat stand.

Over Charge* (14) Effect on Electronic Resistance due to Temperature-Voltage (corrosion).

Reaction Cycle * (15) The ability to react Oxygen at the negative plate as a factor of overcharge.

Life Counts (16) This number compares one battery to other batteries by the above effects (*). (Much like the J240 measurement or fleet tests.)

Note: All the above characteristics require a special test procedure to attain the proper result.

Battery Condition Monitoring Workgroup

Statement of Purpose

The automobile electrical system of the future will incorporate some method of battery condition monitoring. A wide range of proposals has been advanced, ranging from very crude methods to the development of extensively instrumented batteries with built in microprocessors.

In the middle of this spectrum are proposals which rely on additional sensors on the vehicle (with few or no sensors on the battery), and with all digital processing done on the vehicle, not on the battery. The focus of this workgroup is on this mid-range class of battery condition monitors.

The function of such battery condition monitors can be greatly enhanced if the vehicle computer has access to information about the battery. The information required should be known to the battery manufacturer, and the battery manufacturers should be willing to provide this information with the battery.

The fundamental purpose of this workgroup is to propose the technical content of a proposed industry standard for the exchange of such information.

Matters to be agreed include:

- Definitions of the parameters to be provided
- Operational methods (tests) whereby the values of the parameters can be determined for a given battery construction
- One or more standardized methods whereby data can be communicated to the condition monitor, both during manufacture of the automobile and at the time of battery replacement.

Battery Condition Monitor Workgroup

Guidelines for Participants

The MIT/Industry Consortium on Advanced Automotive Electrical/Electronic Components and Systems will facilitate the workgroup.

Participation shall be open to all interested parties. Membership in the Consortium is not a condition of participation.

Participation in the workgroup does not convey any of the privileges of membership in the Consortium.

Participation is completely voluntary. No participant will be compensated, nor will fees be charged, other than possible fees to cover the cost of meeting room rentals and food service at meetings.

The object of this workgroup is an open standard. No participant should propose methods or standards which require the use of proprietary intellectual property unless they are prepared to provide the use of that intellectual property to all parties (not just participants) on a no-fee basis.