Duke Energy®

REGIS T. REPKO
Vice President
McGuire Nuclear Station

Duke Energy
MG01VP / 12700 Hagers Ferry Rd.
Huntersville, NC 28078

980-875-4111
980-875-4809 fax
regis.repko@duke-energy.com

September 8, 2010

U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: Document Control Desk

Subject: Duke Energy Carolinas, LLC (Duke Energy)
McGuire Nuclear Station, Units 1 and 2
Docket Nos. 50-369 and 50-370
Catawba Nuclear Station, Units 1 and 2
Docket Nos. 50-413 and 50-414

Response to Request for Additional Information Related to the License Amendment Request Applicable to Technical Specification (TS) 3.8.4, "DC Sources-Operating"

This letter provides the responses to a request for additional information (RAI) regarding the McGuire and Catawba License Amendment Request (LAR) dated December 14, 2009 applicable to Technical Specification 3.8.4 Surveillance changes. The request was conveyed by the NRC staff via letter from Jon Thompson on June 24, 2010. The NRC staff's questions and Duke Energy's responses are provided in Enclosures 1 and 2. Duke Energy's Regulatory Commitments are provided in Enclosure 3.

During the preparation of the Catawba RAI response, errors were discovered in the supporting calculations for proposed TS Table 3.8.4-1. As a result of this discovery, it is necessary to revise several of the proposed values in the table. Note that the discovered errors were in the conservative direction and this issue has been entered into Catawba's Corrective Action Program for resolution. Refer to the Question 1 response contained in Enclosure 2 for additional details. This issue is not applicable to McGuire.

The conclusions reached in the original determination that the LAR contains No Significant Hazards Considerations and the basis for the categorical exclusion from performing an Environmental/Impact Statement have not changed as a result of this request for additional information.

Please contact Lee A. Hentz at 980-875-4187 if additional questions arise regarding this LAR.

Sincerely,

Regis T. Repko

Enclosures

A001
NRR

cc: w/enclosures

L. A. Reyes
Regional Administrator, Region II
U.S. Nuclear Regulatory Commission
Marquis One Tower
245 Peachtree Center Ave., NE, Suite 1200
Atlanta, GA 30303-1257

J. H. Thompson (addressee only)
Project Manager (MNS and CNS)
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Mail Stop O-8 G9A
Rockville, MD, 20852-2738

J. B. Brady
NRC Senior Resident Inspector
McGuire Nuclear Station

G. A. Hutto III
NRC Senior Resident Inspector
Catawba Nuclear Station

W. L. Cox III, Section Chief
North Carolina Department of Environment and Natural Resources
Division of Environmental Health
Radiation Protection Section
1645 Mail Service Center
Raleigh, NC 27699-1645

S. E. Jenkins, Manager
Division of Radioactive Waste Management
Bureau of Land and Waste Management
Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201

OATH AND AFFIRMATION

Regis T. Repko affirms that he is the person who subscribed his name to the foregoing statement, and that all the matters and facts set forth herein are true and correct to the best of his knowledge.

Regis T. Repko, Site Vice President

Subscribed and sworn to me: September 8, 2010
Date

Notary Public

My commission expires: July 1, 2012
Date

Enclosure 1, McGuire's
Response to Request for Additional Information

NRC Question 1

Provide an executive summary of battery connection resistance calculations that shows how the values in proposed TS Table 3.8.4-1 were derived. Include in your response the battery design duty cycle profiles, key assumptions, any credit of margins, and supporting documentation to demonstrate that a) the batteries will perform their intended safety functions when operating within these limits and b) the safe shutdown equipment will have required minimum voltage to perform the required safety functions for the postulated design basis accident and the station blackout scenarios.

McGuire Response to Question 1

Applicable Information from McGuire (MNS) 1E 125VDC Battery Sizing Calculation:

SUMMARY:
The MNS 125VDC Instrumentation and Control Power System design basis is to supply power to nuclear safety related loads requiring an uninterruptable power source to maintain safe reactor status during the following plant conditions:

1. Normal Plant Operation (including startup and shutdown)
2. Station Blackout (SBO) or Loss of Offsite Power (LOOP)
3. Design Basis Events (DBE) including but not limited to Main Steam Line Breaks (MSLB), Steam Generator Tube Rupture Accidents, and Loss of Coolant Accidents (LOCA).
4. LOOP concurrent with the DBE.

The MNS 125VDC Battery Sizing Calculation was completed in accordance with IEEE Std 485-1997 (Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications). Each MNS 1E battery is sized to carry the continuous emergency load of its own vital buses and also assume the loads of another battery in a "backup" capacity, if required, for a period of one hour (UFSAR Section 8.3.2.1.4.2). In addition, the battery is sized such that the voltage at the battery terminals will be greater than or equal to 105VDC throughout the entire battery duty cycle under the worst case design basis scenario. A LOOP on the same train of both units yielded the worst-case current for each of the (4) DC Distribution Centers (EVCA, EVCB, EVCC, and EVCD). Train A for both units is distribution centers EVCA/EVCC and Train B is EVCB/EVDD. Since a random switchgear closing can occur any time after the first minute, a momentary load of 70 amperes was added to the worst case train loading profile (Train A). This momentary load was added during the last minute of the 1-hour duty cycle, thereby creating a third load step in the battery duty cycle.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION BY THE OFFICE OF NUCLEAR REGULATION REGARDING LICENSE AMENDMENT RELATED TO REVISION OF THE BATTERY CONNECTION RESISTANCE ACCEPTANCE CRITERIAIN THE TECHNICAL SPECIFICATIONS

KEY ASSUMPTIONS:

1. Battery room temperature is 60 degrees Fahrenheit.
2. One random switchgear closing load of 70 amperes occurring any time after the first minute of the battery duty cycle.
3. Inverter has the highest minimum operating voltage requirement (100VDC) of all DC loads.
4. Battery float voltage is 135VDC.
5. Six 4.16kV switchgear charging spring motors are at inrush simultaneously during the first minute of the duty cycle.

MARGINS:

1. Temperature Correction Factor: 1.11
2. Aging factor: 1.25
3. Load Growth Margin: 1.10

WORST CASE DUTY CYCLE (Train A):

0 - 1 minute: 941.59 amperes
1 - 59 minutes: 452.89 amperes
59 - 60 minute: 611.32 amperes

Applicable Information from MNS 1E 125VDC System Voltage Drop Calculation:

SUMMARY:

The MNS 1E 125VDC System Voltage Drop Calculation verifies that the loads powered from the 125VDC Vital I&C system will have adequate voltage available to perform their design function under the worst case voltage condition. The battery loading considered for the voltage analysis is a bounding loading for the entire battery duty cycle. The voltage drops determined bound those expected during a LOOP, LOOP/LOCA, and SBO and this calculation assumes the initial battery terminal voltage to be 105VDC with no battery charger available.

KEY ASSUMPTIONS:

1. Charging spring motors typically charge in less than 2 seconds with peak inrush current lasting approximately 10-30 milliseconds. Three charging spring motors are assumed to be starting per 4.16kV Switchgear Group during the 0 - 1 minute time period. This would be equivalent to the charging spring motors on the Emergency Diesel Generator (EDG) incoming breaker and the Load Sequencer Group 1 breakers starting simultaneously. On each train, this will result in 6 charging spring motors (3 per unit) starting simultaneously. This is a very conservative assumption since it is highly improbable that all (6) 4.16kV charging spring motors (3 per unit) would start at exactly the same time.
2. Breaker charging spring operation at a time other than the 0 - 1 minute period and the 59 - 60 minute period is not addressed. Voltage results for these two periods bound results for operation at any other time in the duty cycle.

3. During the 59 - 60 minute time period, it is assumed that one charging spring motor will be starting on each train on each unit.
4. The inverter load power factor is 1.0. This assumption will result in the maximum computed input power to the inverter.
5. The battery system is assumed to be in a cross-tied alignment (one battery supplying both channels of a train) for all duty cycle periods and without a battery charger for the entire 1-hour duty cycle period. This is conservative because for design basis events other than an SBO involving loss of AC power to the chargers, power will be restored to the chargers from the EDG during the first minute of the event. For an SBO scenario, the initial conditions of the system would be in a normal operational alignment; therefore, the DC busses would not be initially in a cross-tied alignment and each battery would only be supplying power to one DC channel for the most limiting 0 - 1 minute period of the event.
6. The inrush current to a 4.16kV breaker charging spring motor is 6 - 8 times the average run current of 10 amperes. For this calculation, the charging spring motor inrush current was assumed to be 70 amperes. This is reasonable considering the number of simultaneous inrushes (6) is being assumed.
7. Where device contact resistance was not known, the contact resistance was assumed to be equal to the contact resistance of the Cutler-Hammer D26 relay. The D26 resistance value is at the upper end of known contact resistances.
8. Resistance for circuit breakers, device terminal connections, sliding links, and internal cabinet wiring are considered to be negligible.

MARGINS:
1. A 5% margin was added to each individual panel and distribution center load amperes.

Applicable Information from MNS 1E 125VDC Vital I&C System Battery Intercell Connection Resistance Calculation:

SUMMARY:
1. To establish a battery bank intertier, interrack, terminal connections, and average intercell connection resistance TS limits for the 125 VDC Vital I & C System Batteries (EVCA, EVCB, EVCC, and EVCD) where battery operability is based on the sum total resistance of all battery connections. Results are compared to empirical testing data for validation.
2. To determine a maximum "single" intercell connector resistance TS limit for the 125 VDC Vital I & C System Batteries (EVCA, EVCB, EVCC, and EVCD) based on the battery manufacturer's allowable intercell connection I^2R losses. This limit is being calculated to determine a maximum value where connection "physical integrity" and therefore battery operability may be in question and/or personnel safety may be compromised.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION BY THE OFFICE OF NUCLEAR REGULATION REGARDING LICENSE AMENDMENT RELATED TO REVISION OF THE BATTERY CONNECTION RESISTANCE ACCEPTANCE CRITERIAIN THE TECHNICAL SPECIFICATIONS

BASIS FOR CALCULATION APPROACH:

1. Nuclear Logistics Inc. (NLI), Technical Bulletin TB-Battery-01, Rev. 1 (GNB Battery Intercell Connectors), September 2007
2. Nuclear Logistics Inc. (NLI) Letter, Duke Power Intercell Resistance, Rev. 1, May 2008 (Attachment 1)
3. IEEE Std 450-2002, Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead -Acid Batteries for Stationary Applications)
4. Nuclear Logistics Inc. (NLI) Letter dated August 10, 2009 (Attachment 2)

ANALYTICAL METHOD:

MNS Class 1E "EPL" system battery banks (EVCA, EVCB, EVCC, and EVCD) consist of 60 GNB NCN-27 (1944 Amp-Hour) flooded lead-acid battery cells. GNB is a division of Exide Corporation. Nuclear Logistics Inc. (NLI), after consulting with battery manufacturer GNB, has determined that a voltage drop of 0.05 VDC per intercell connector for the MNS Class 1E batteries is acceptable based on past performance testing data and the duty cycle load profile (Attachment 1). Additionally, NLI has determined that an acceptable resistance value for the intertier and interrack connections is 2-5 times the value for an individual intercell connector, or 0.10 – 0.25 VDC (Attachment 2). Applying these values for battery connection voltage drop, an acceptable total battery resistance can be determined, which is the basis for the values in the proposed TS Table 3.8.4-1.

KEY ASSUMPTIONS:

1. A significant amount of heat is not generated during the high rate first minute discharge due to efficient heat dissipation into the battery room atmosphere and battery electrolyte.
2. The intercell connection resistance consists of the resistance of the copper intercell connector plus the resistance of the intercell connector/battery post joints.
3. Battery room ambient temperature is 77 °F. Ambient room temperature fluctuations above and below the IEEE Standard baseline ambient temperature of 77 °F will have minimal impact on connector resistance readings.
4. EPL system load growth does not exceed 10% from the origination of the MNS 1E Vital Battery Sizing Calculation.
5. Intercell connection resistance is referring to the 56 copper connection straps between the battery jar posts.
6. Maximum intertier (2 connections) and interrack (1 connection) Technical Specification limits are set at 170.0 x 10^{-6} ohms. This conservative assumption is based on Nuclear Logistics Inc. (NLI) letter dated August 10, 2009, "Battery Cell Connection Voltage Drop" (Attachment 2). This letter documents that based on the intertier and interrack cable connections supplied by NLI for nuclear power plant applications, the voltage drop per set of cables (including terminal plates, cable lug, cable, and bolted connections) is two to five times that of the intercell connector (including connector and bolted connections) voltage drop.

7. The battery terminal connection refers to the positive and negative connections on the battery that connect to the respective distribution center and the battery test box. The battery terminal connection has 4 terminal lugs, connector plates/hardware, and associated cables attached to both the positive and negative connections. The combined parallel resistance of the 4 terminal lug connections on each of the positive and negative battery terminals is assumed not to exceed the calculated average intercell connection resistance value in this calculation.

MARGINS:

1. A 10% load growth margin was added to the duty cycle load profile. In addition, the proposed TS Table 3.8.4-1 values were calculated based on an earlier revision of the MNS 1E Battery Sizing Calculation. The most recent revision of the MNS 1E Battery Sizing Calculation dated 11/10/09 documents a worst case limiting load current of 941.59 amperes. The basis for the calculation of the proposed TS Table 3.8.4-1 values used a limiting load current of 968.0 amperes. Since the values in proposed TS Table 3.8.4-1 were based on the higher current of 968.0 amperes, additional margin above 10% exists in the proposed TS Table 3.8.4-1 values.

CALCULATION SUMMARY:

1. The maximum current for any train is the 0-1 minute rate for train A at 968.01 amps. To add additional conservatism to this calculation, a factor of 10% is added to allow margin for system load growth. NLI has analyzed the MNS class 1E battery duty cycle load profile and determined that a voltage drop of 0.05 VDC is acceptable for MNS NCN-27 class 1E battery banks (Attachment 1).

a) The limiting rate for the MNS battery load profile is calculated as follows:

$$I_{1\text{-minute}} = 968.01 \text{ amps} \times 1.10 \text{ (Design Margin)} = 1064.8 \text{ amps}$$

b) Using Ohm's Law, E=I x R, a voltage drop of 0.05 VDC and a current of 1064.8 amps yields a maximum average battery bank intercell connection resistance of 46.9×10^{-6} ohms.

Note: This could also be developed from the total allowable intercell connection resistance for the battery as well. For example, there are 56 intercell connections for the battery. That would equate to a total voltage drop for all 56 intercell connections of 2.80VDC (0.05VDC x 56). Using the same ohms law equation, the total allowable resistance for all 56 intercell connections is 2629.6×10^{-6} ohms (2.80VDC ÷ 1064.8 amps). Dividing 2629.6×10^{-6} ohms by 56 yields the average value of 46.9×10^{-6} ohms.

c) Since intertier and interrack connections are typically 2-5 times the intercell connection resistance value (Attachment 2), assumption number (6) for the MNS 1E Vital I&C System Battery Intercell Connection Resistance Calculation is validated and considered conservative considering the expected maximum could be as high as $\underline{234.5 \times 10^{-6}}$ ohms [5 x (46.9 x 10^{-6} ohms)] using the average intercell connection resistance value calculated in 1(b).

2. To establish a maximum intercell connection resistance for any "single" connector, the maximum power dissipation can be calculated based on the manufacturer's published data. Since the manufacturer's 1-minute rate for the GNB NCN-27 battery cell is 1840.0 amps, the intercell connectors must be sized to adequately dissipate the generated heat produced by the I^2R losses.

$$P = I \times E = 1840.0 \text{ amps} \times 0.05 \text{ VDC} = 92.0 \text{ Watts}$$

Using the $P = I^2R$ version of the power equation, a current of 1064.8 amps and a maximum power dissipation of 92.0 watts:

$$\text{Maximum Single Intercell Connection Resistance} = P \div I^2 = 92.0 \div (1064.8)^2$$
$$\text{Maximum Single Intercell Connection Resistance} = \underline{81.1 \times 10^{-6} \text{ ohms}}$$

This provides a bounding upper operability limit for a single "intercell" connection as long as the average intercell connection resistance is less than $\underline{46.9 \times 10^{-6} \text{ ohms}}$.

3. The battery terminal connection consists of 4 terminal lugs connected to the actual battery posts. Since these connections are in parallel, a connection resistance can be calculated such that each of the terminal connections will not exceed the average connection resistance value of 46.9 x 10^{-6} ohms. The following equation applies to resistance in parallel:

$$R_{\text{Term Conn}} = 1 \div (1/R_{\text{Lug}} + 1/R_{\text{Lug}} + 1/R_{\text{Lug}} + 1/R_{\text{Lug}})$$
$$R_{\text{Lug}} = 4 \times R_{\text{Term Conn}}$$
$$R_{\text{Lug}} = 4 \times 46.9 \times 10^{-6} \text{ ohms} = \underline{187.6 \times 10^{-6} \text{ ohms}}$$

CONCLUSION:

The above approach provides conservative Technical Specification limits for vital batteries MNS 1E Vital Batteries EVCA, EVCB, EVCC, and EVCD where battery operability can be clearly established:

1. Average intercell connection resistance $\leq$ 46.9 x 10^{-6} ohms.
2. Any single intercell connection resistance $\leq$ 81.1 x 10^{-6} ohms.
3. Intertier and Interrack Connection Resistance $\leq$ 170.0 x 10^{-6} ohms.
4. Single terminal connection (Single Lug-Post) $\leq$ 187.6 x 10^{-6} ohms.

NRC Question 2

The licensee proposed to include a new parameter "Average Intercell Connection" in TS Table 3.8.4-1 and in the associated TS Bases sections. However, the NRC staff did not find any definition or details of this proposed parameter in the LAR or the TS Bases. Lack of any definition or details in the TS Bases could create confusion in future. Discuss in detail the proposed parameter "average intercell connection" including the definition and provide a Regulatory Commitment to include a definition and details of this parameter in the TS Bases.

McGuire Response to Question 2

DEFINITION:
Average intercell connection resistance is defined as the battery manufacturer's maximum allowed intercell connection voltage drop divided by the maximum battery duty cycle load current. The maximum allowable battery total intercell connection resistance can then be defined as the average intercell connection resistance times the total number of intercell connectors in the battery string. Intercell connection is referring to the (56) copper connection straps between the battery jar posts and the battery terminal connections.

Enclosure 3 contains McGuire's Commitment to add the above definition and details to the Bases for SR 3.8.4.4 and SR 3.8.4.5

DISCUSSION:
When MNS craft personnel conduct the applicable TS surveillance requirement (TSSR) 3.8.4.5 to check resistance values, they are required per MNS procedure to add each intercell connection resistance measurement value to get a total "as-found" battery intercell connection resistance value, and then divide by the number of connections (56) to calculate the average "as-found" intercell connection resistance. In essence, they are verifying that the total allowable intercell connection resistance is not exceeded, just on an individual connection basis.

This methodology is effective in that instead of just looking at battery total resistance for acceptance criteria, the actual average intercell connection resistance value can be used as a conservative limit where maintenance action must be taken, but battery operability is not in question.

For example (scenario): If one <u>single</u> intercell connection measurement reads 51.0×10^{-6} ohms and the battery bank average intercell connection resistance is 34.3×10^{-6} ohms, the TSSR is satisfied based on the proposed Table 3.8.4-1 values and battery operability is not in question. However, craft can quickly determine that this particular connection has degraded because it has exceeded the administrative limit of 46.9×10^{-6} ohms and a work request will be written per

MNS procedure for cleaning or connector replacement. It simplifies the interpretation of the data.

NRC Question 3

Provide a chart of the past five years surveillance test results for Surveillance Requirements 3.8.4.6 (Catawba 1 and 2) and 3.8.4.5 (McGuire 1 and 2) for "As Found" and "As Left" battery intercell, intertier, interrack and terminal connection resistances.

McGuire Response to Question 3

When MNS craft personnel perform the procedure that satisfies the requirements for TSSR 3.8.4.5, the "As Found" and "As Left" values are the same. By procedure, craft personnel are directed to take all measurements and then compare values to the established TS and administrative acceptance criteria documented in the procedure.

If any acceptance criteria are not met, the procedure directs applicable notifications and actions to enter the deficiency into the site corrective action program and work management program by generating a work request. Once the work order is completed, the connection resistance values are again reviewed by craft and engineering for acceptance.

The following attachments are provided for the past five years:

Attachment 3: 1E Battery EVCA Resistance Totals per Connection Category
Attachment 4: 1E Battery EVCB Resistance Totals per Connection Category
Attachment 5: 1E Battery EVCC Resistance Totals per Connection Category
Attachment 6: 1E Battery EVCD Resistance Totals per Connection Category
Attachment 7: Maximum 1E Battery Intercell Connection Resistance Value
Attachment 8: Maximum 1E Battery Intertier Connection Resistance Value
Attachment 9: Maximum 1E Battery Interrack Connection Resistance Value
Attachment 10: Maximum 1E Battery Terminal Connection Resistance Value

It should be noted that Attachment 9 documents a maximum individual interrack connection resistance value of 170.0×10^{-6} ohms for 1E battery EVCC, which is above the current TSSR limit of 150×10^{-6} ohms. This was reported to the NRC in MNS LER 369/2007-01 dated March 16, 2007 (NRC ADAMS ML 070860761), "The Completion Time of TS 3.8.4 Condition A was Exceeded on May 12, 2005."

NRC Question 4

Battery manufacturers typically recommend correcting any battery connection that has a resistance value of more than 20% above the benchmark values. Provide the benchmark resistance values for each connection in proposed TS Table 3.8.4-1. Provide justifications for any connection resistance value in proposed TS Table 3.8.4-1 that is higher than 20% of the benchmark value and is contrary to the battery manufacturer's recommendations.

McGuire Response to Question 4

Baseline data taken following battery installation in 1997:

PARAMETER	BASELINE VALUE	BASELINE PLUS 20%
Average Intercell Resistance	22.8 micro-ohms	27.4 micro-ohms
Individual Intercell Connection	81.1 micro-ohms	Not Applicable
Intertier Connection	70.1 micro-ohms	84.2 micro-ohms
Interrack Connection	113.0 micro-ohms	135.6 micro-ohms
Terminal Lug Connection	22.1 micro-ohms	26.5 micro-ohms

In late 2006 when MNS became aware of the non-conservative TSSR value of 150.0 micro-ohms and entered the operability evaluation process, a comprehensive review of all 1E Vital Battery connection resistance values since battery installation was conducted. The results of this review indicated that many battery connection resistance measurements had been erratic and highly variable from one year to the next. This review also identified many of the 1E Vital Battery connections were already greater than the baseline value plus 20% documented in the above Table; however, 1E Vital Battery operability was not in question based on an extensive review of the past battery service test voltage profiles. The service tests, which include all connector resistance values as well as each battery cell's internal resistance, clearly demonstrated significant margin available. This was validated in a comprehensive operability evaluation which determined that based on the 1E battery duty cycle load profile; significant margin still existed using the present resistance measurements.

When taking resistance measurements in the micro-ohm range, readings can be inconsistent as a result of many variables such as specific Digital Low Resistance Ohmmeter (DLRO) used, test contact point on battery post, test equipment inability to "lock in" on a specific value which leads to visual interpolation of meter swings by technicians, and human factors just to name a few. For example, several readings one year after battery installation already exceeded the baseline measurement plus 20% even though it is highly unlikely that any connection had degraded that much in one year on a new battery. In 2007, MNS engineering recognized this inconsistency, researched the DLRO technology available by various vendors, and selected a better type instrument for the application, thus eliminating the inaccuracies associated with the previously used instrument reading variability and human interpolation of a rapidly changing (cycling) digital readout. New measuring and test equipment was procured and data values obtained since 2008 have been much more consistent and trendable; however, the test equipment change displayed an average step increase in the connection resistance values of approximately 8.0 micro-ohms. This step increase can be recognized in the attached graphs. In analyzing the data over the past 5 years and prior to using the new test equipment in 2008, the average percentage change in readings from one year to the next was $\pm$ 36%. Readings taken with the new DLRO have reduced this variability in readings down to a percentage change of only $\pm$ 5%.

The Following Justification Supports This Conclusion:

The MNS 1E Vital Battery connections consist of (56) intercell, (2) intertier, (1) interrack, and the battery terminal connection. The battery terminal connection consists of (4) terminal lugs connected in parallel.

1. Total Battery **Allowable** Technical Specification Resistance Limit Using Proposed TS Table 3.8.4-1 Values:

Note: Since the battery positive and negative connections have two current carrying conductors each at any given time (2 used for system loads and 2 for battery load testing), the resistance at the battery positive and negative terminal will be 93.8 x 10^{-6} ohms each. So the combined resistance of both the positive and negative battery terminals will be 187.6 x 10^{-6} ohms (2 x 93.8 x 10^{-6} ohms).

(56 Intercell connections) x (46.9 x 10^{-6} ohms) = 2626.4 x 10^{-6} ohms
(Battery Terminal Connections) = 187.6 x 10^{-6} ohms
(3 Intertier/Interrack connections) x (170.0 x 10^{-6} ohms) = 510.0 x 10^{-6} ohms.

Total Allowable Battery Resistance = (2626.4 x 10^{-6} ohms) + (187.6 x 10^{-6} ohms) + (510.0 x 10^{-6} ohms) = 3324.0 x 10^{-6} ohms

2. The Total Calculated Connection Resistances from the Most Recent Completion of TSSR 3.8.4.5:

Battery	Date	WO	Intercell (μΩ)	Intertier (μΩ)	Interrack (μΩ)	Terminal Lug (μΩ)	Total (μΩ)
EVCA	1/5/09	1814721	1673.1	162.1	117.4	13.3	**1965.9**
EVCB	6/20/09	1845684	1751.6	110.2	93.0	14.8	**1969.6**
EVCC	6/15/09	1847050	1894.9	199.3	135.4	15.7	**2245.3**
EVCD	5/21/09	1842632	1712.8	165.4	123.4	12.1	**2013.7**

The worst case recorded TSSR 3.8.4.5 1E Vital Battery total resistance is 2245.3 x 10^{-6} ohms on battery EVCC.

3. The lowest battery terminal voltage recorded during the most limiting portion of the battery duty cycle:

The limiting period of the MNS Vital battery 1-hour duty cycle is during the first minute where the load demand is the highest. This voltage dip during the first minute is exacerbated by the coup-de-fouet effect, which is primarily observed on stationary lead-acid batteries that have been maintained on a long-term float charge. During the initial moments of discharge, the chemical reaction is slightly less efficient which results in an additional voltage dip during the first few minutes of discharge, followed by a recovery to a slightly higher voltage during this initial discharge period. The following Table documents the lowest first minute voltage during the most recent Battery Service Test. It should be noted that the first minute current used in these battery service tests was 1182.0 amperes, which is 200.0 amps more than the actual worst case first minute duty cycle amperage of 941.59 amperes documented in the 1E Vital Battery sizing calculation, which was completed in accordance with IEEE Std. 485 in March 2010. This additional current adds significant conservatism to this analysis.

Battery	Date	0-1 Min Lowest Voltage (VDC)	Current (Amps)
EVCA	3/30/09	109.0	1184.9
EVCB	8/11/08	108.9	1185.1
EVCC	08/18/09	108.2	1191.3
EVCD	6/16/09	108.4	1192.4

The worst case minimum voltage (lowest) is 108.2 VDC on battery EVCC.

The discharge voltage profile during the battery test includes all intercell, intertier, interrack, terminal, and battery cell internal resistances. From the above Tables, it can be concluded that battery EVCC is most limiting from both a voltage and connection resistance standpoint, so the margin associated with EVCC will be used to validate the values in the proposed TS Table 3.8.4-1.

4. ANALYSIS:

Assume that battery EVCC reached the TS limit on all intercell, intertier, interrack, and terminal connections. The total connection resistance for battery EVCC would be 3324.0×10^{-6} ohms. The minimum EVCC voltage of 108.2 VDC already includes the EVCC total connection resistance value of 2245.3×10^{-6} ohms (actual empirical load test data), so it must be subtracted from the total allowable proposed TS Table 3.8.4-1 resistance to determine the resistance margin.

Note: The limiting battery current of 941.59 amperes will be used based on the most current revision of the MNS 1E Vital Battery sizing calculation.

Resistance Margin (RM) = (Total Allowable Connection Resistance) – (Actual Connection Resistance)

$$RM = 3324.0 \times 10^{-6} \text{ ohms} - 2245.3 \times 10^{-6} \text{ ohms} = 1078.7 \times 10^{-6} \text{ ohms}$$

If battery total resistance increased to 3324.0×10^{-6} ohms, this would cause the following additional voltage drop below the minimum voltage for EVCC (108.2 VDC) with an additional 10% load addition margin factored in:

$$E = IR$$
$$E = (941.59 \text{ amps}) \times (1.11) \times (1078.7 \times 10^{-6} \text{ ohms}) = 1.12 \text{ VDC}$$

So if the worst case battery (EVCC) reached the total allowable combined resistance value of 3324.0×10^{-6} ohms per proposed TS Table 3.8.4-1, the expected minimum battery terminal voltage would be 107.1 VDC (108.2 – 1.12), which is still 2.1 VDC above the minimum allowable battery terminal voltage of 105.0 VDC.

Note: MNS has tested one battery (EVCB) since the revision of the 1E Vital Battery Sizing Calculation completed. The minimum battery terminal voltage recorded during the first minute using the new duty cycle load profile was 110.1 VDC. This is 1.2 VDC higher than the worst case voltage recorded in the previous service test on battery EVCB using the higher current in the superseded calculation. The same results are expected to occur on all vital batteries during their next scheduled service test based on the revised duty cycle load amperages.

This analysis concludes that if every single connection reached the average resistance value, there would still be significant operating margin based on the cumulative conservative elements of the vital battery calculations. Since a baseline could not be accurately determined from available data, the MNS maintenance procedure requires action to be taken if **ANY** connection reaches 46.9 x 10^{-6} ohms or **ANY** intertier/interrack/terminal lug connection reaches 145 x 10^{-6} ohms. These administrative limits are conservative and battery operability and safety are not in question based on this calculation methodology.

NRC Question 5

Battery manufacturers typically require that a benchmark value for all similar connections should be no greater than 10% or 5 micro ohms, whichever is greater, above the average resistance of all such connections in the battery. On page 3.8.4-4 of the McGuire 1 and 2 LAR, (Attachment 2, TS Table 3.8.4-1), the proposed value of "Single Intercell Connection" resistance is approximately 72.9% or 34.2 micro ohms above the "Average Intercell Connection" resistance. Provide justification for exceeding the manufacturer's recommendation.

McGuire Response to Question 5

The battery manufacturer recommendation of 10% or 5 micro-ohms, whichever is greater, above the average connection resistance of such connection is to establish a consistent benchmark value that can be used for connection resistance trending following battery installation. The TS Table 3.8.4-1 value is for battery operability and is not a value that would be used in the maintenance and monitoring program. It provides a bounding upper limit on any single intercell connector. When looking at battery operability, meeting all of the values in the proposed TS Table 3.8.4-1 must be considered at any given time.

The basis for the maximum single intercell connection resistance is based on the battery manufacturer's discharge curves. The most limiting power dissipation calculation is the A train 1- minute rate. Using the power equation P=IE and the manufacturer's sizing data, a maximum design power dissipation at each connection can be established. Since the manufacturer's 1-minute rate for the GNB NCN-27 battery cell is 1840.0 amps, the intercell connectors must be sized to adequately dissipate the generated heat produced by the I^2R losses.

$$P = I \times E = 1840.0 \text{ amps} \times 0.05 \text{ VDC} = 92.0 \text{ Watts}$$

The maximum duty cycle 1-minute load current for the EPL system duty cycle is 968.01 amps (Note: this has now changed to **941.59** amps based on the recent calculation update. This adds additional conservatism to the current value proposed in TS Table 3.8.4-1). Using a 10% load growth margin results in the following 1-minute load current:

$$I_{1\text{-minute}} = 968.0 \times 1.10 = 1064.8 \text{ amps}$$

Using the $P = I^2R$ version of the power equation, a current of 1064.8 amps and a maximum power dissipation of 92.0 watts:

Maximum Single Intercell Connection Resistance = $P / I^2 = 92.0 / (1064.8)^2$
Maximum Single Intercell Connection Resistance = 81.1×10^{-6} ohms

This provides a bounding operability upper limit for a single connection so long as the average of all intercell connections is less than or equal to 46.9×10^{-6} ohms. This value is based on battery **operability** due to the design heat transfer capabilities of the connectors themselves. This is not a value that is used in the battery maintenance and monitoring program.

Scenario: If craft is performing a TSSR 3.8.4.5 on a 1E Vital Battery and one intercell connection for some reason (connection bolt loosened) measures 69.0×10^{-6} ohms while the actual bank intercell average resistance is 32.0×10^{-6} ohms, one can quickly ascertain that action must be taken on that one particular connection, however, battery operability and safety is not in question. Without a calculation and basis for a bounding upper limit, the site could unnecessarily enter the operability process. Per MNS procedure, action must be taken if any SINGLE connection exceeds 46.9×10^{-6} ohms.

NRC Question 6

Discuss why average connection resistance values for intertier, interrack, and terminal connection limits were not included in proposed TS Table 3.8.4-1 for McGuire 1 and 2 and Catawba 1 and 2.

McGuire Response to Question 6

The average intercell connection limit of 46.9×10^{-6} ohms also includes the terminal connections. The value in proposed TS Table 3.8.4-1 is based on (4) terminal connections in parallel on the battery terminal posts such that no individual combined terminal connection resistance will exceed the average intercell connection limit of 46.9×10^{-6} ohms. (Reference Q1, calculation summary, Para 3).

The intertier and interrack resistance values are based on the manufacturer's recommended range of 2 to 5 times the allowable intercell connection resistance value. Since there are only 3 of these connections in the battery, a reasonably conservative value was assumed within that recommended range for these connections when calculating the battery total resistance.

NUCLEAR LOGISTICS INC

Evaluation of Intercell Connection Resistances for GNB NCN-27 Battery for Duke Power

Issue Definition

Duke Power provided the following information to NLI:

- NLI bulletin TB-BATTERY-001 was reviewed and the calculated allowable intercell connection resistance was 16.9 μohm, based on the first minute rate of 1182 amps. The measured resistances were in the approximate range of 25-45μohm.
- Verbal information was provided that the batteries are configured with one ¼" thick intercell connector per connection.

Evaluation

The following evaluation is provided:

- The information in NLI technical bulletin TB-BATTERY-001, rev. 1 has been reviewed and is applicable.
- Voltage drop:
  - Using the allowable intercell connection voltage drop of (0.020v/connection)(59 connections) = 1.2 volts drop.
  - If the measure voltage drop is approximately (0.050v/connection), the total voltage drop would be approximately 3.0 volts. The added voltage drop due to the increased intercell connection resistance is 1.8 volts.
  - The added voltage drop can be shown to be acceptable based on the plant specific load profile and the tested capacity of the battery. Additional information is presented below.

Battery Operability

The following information is provided concerning the operability of the battery:

- The increased intercell connection resistances are only a possible concern during the high first 1 minute discharge rate.
- Duke Power has performed a service test or a modified performance test on the battery. The battery demonstrated that the plant load profile can be met with the higher intercell connection resistances. A connector voltage drop of up to 50mv is acceptable, provided that the battery passed the service or modified performance test.
- Batteries are sized with significant margin (25% aging margin + plant specified design margin). If the battery capacity is still well above 80%, the added voltage drop from the higher intercell connection resistance is not significant.

7450 Whitehall Street • Fort Worth, Texas 76118 • 817.284.0077 • Fax 817.590.0484 • 800.448.4124 • generalinfo@nuclearlogistics.com
www.nuclearlogistics.com

Attachment (1)

- As stated above, the higher intercell connection resistances are only a potential concern during the first 1 minute high discharge rate. The higher resistances may cause a slight increase in the temperature of the connectors, but it is not significant. The heat would be dissipated by the air and electrolyte.
- There is no risk of damage to the battery, overheating or fire.

The battery is considered operable.

NLI Recommendations

The following recommendations are made:

- Review the previously collected data on the intercell connection resistances. If the resistances have increased significantly, the connections should be cleaned.
- Add one ¼" intercell connector to each side of the battery posts for a total of 2 x ¼" thick connectors on each side.

Prepared by: 5/15/08

Reviewed by: 5/15/08

Approved by: 5/15/08

Attachment (1)

NUCLEAR LOGISTICS INC

August 10, 2009

Attention: Howard Nudi
POWER Engineering
Duke Energy, McGuire Nuclear Station

Subject: Battery Cell Connection Voltage Drop

Dear Sir;

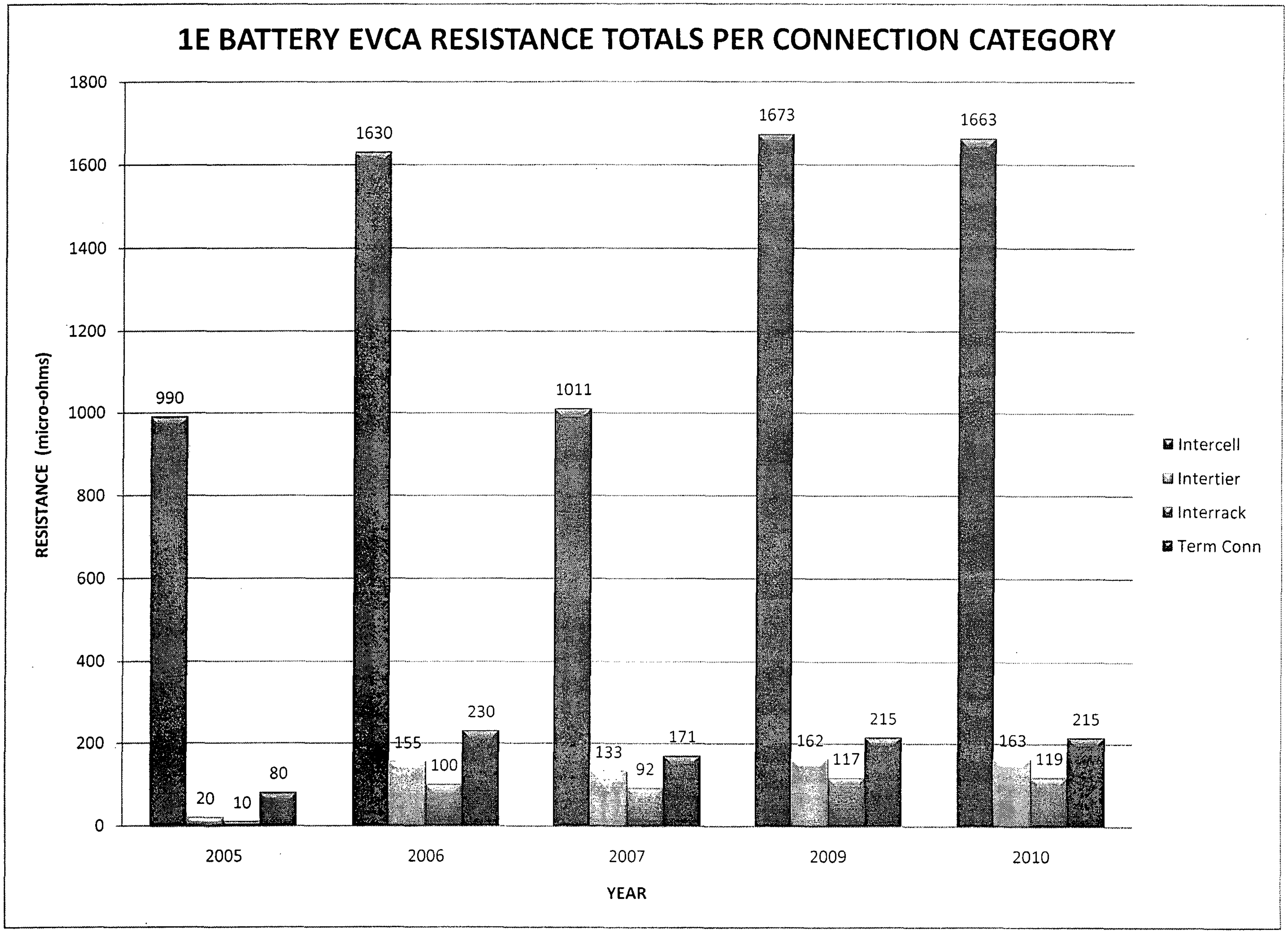
We have reviewed the GNB sizing requirements for cable connections and performed additional evaluations. Based on the inter-tier and inter-rack cable configurations supplied by NLI for nuclear power plant applications, the voltage drop per set of cables (including terminal plates, cable lug, cable, and bolted connections) is two to five times that of the inter-cell connector (including connector and bolted connections) voltage drop.

All practices in installation, operation and maintenance of a battery should be in accordance with the GNB Installation and Operating Instructions.

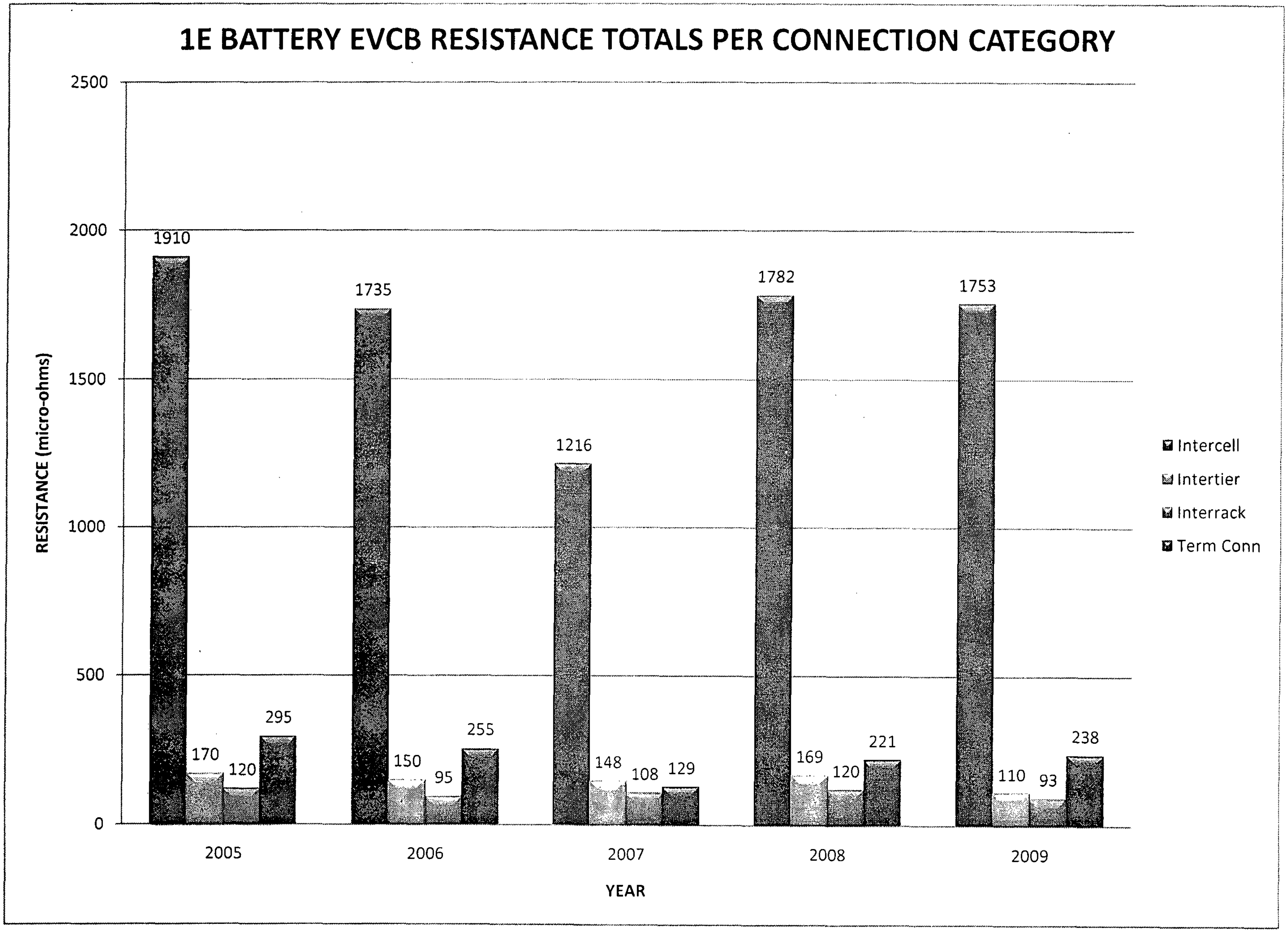
Sincerely,

David Phillips
Project Engineer
Nuclear Logistics Inc.

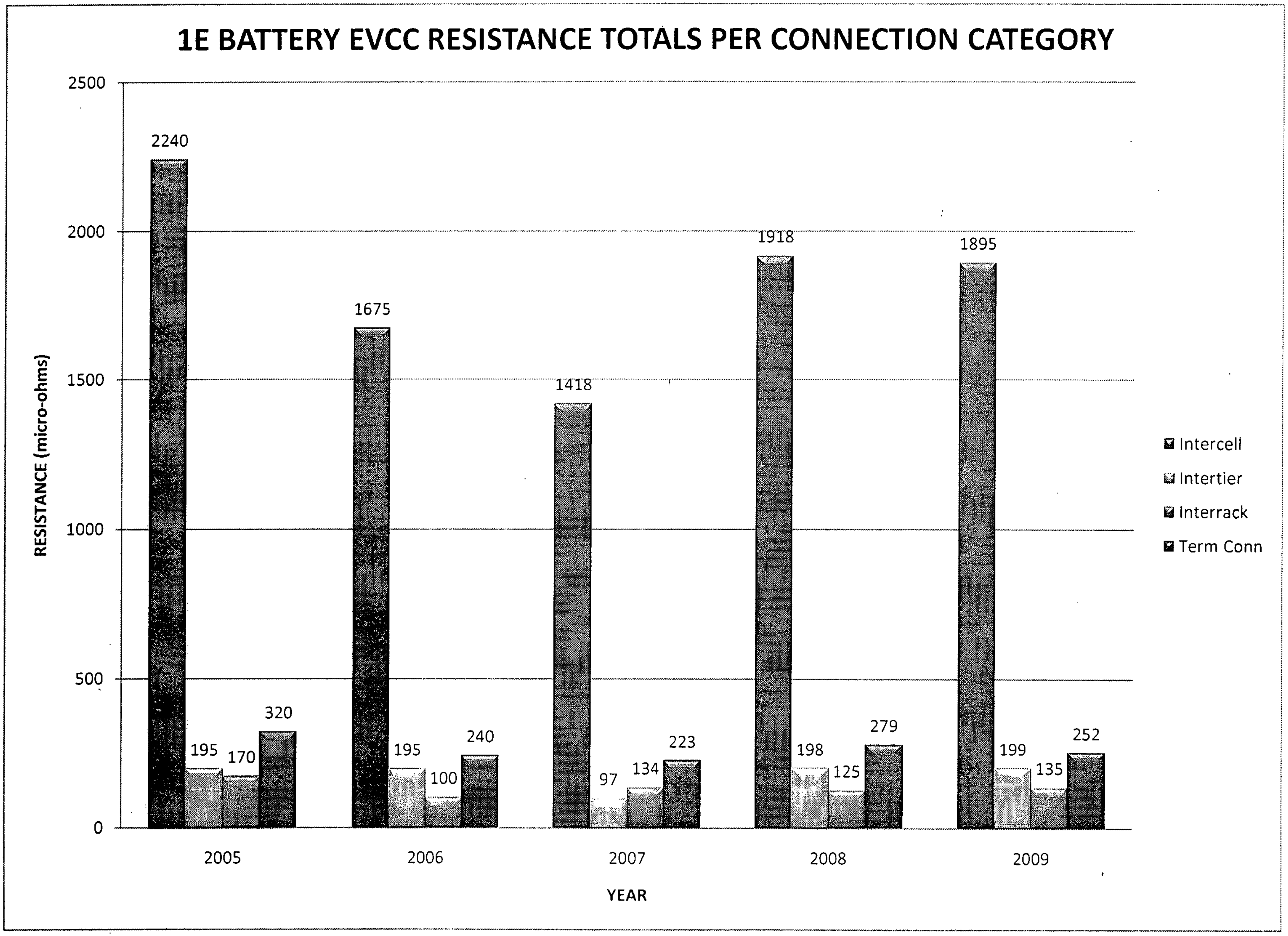
Attachment (2)



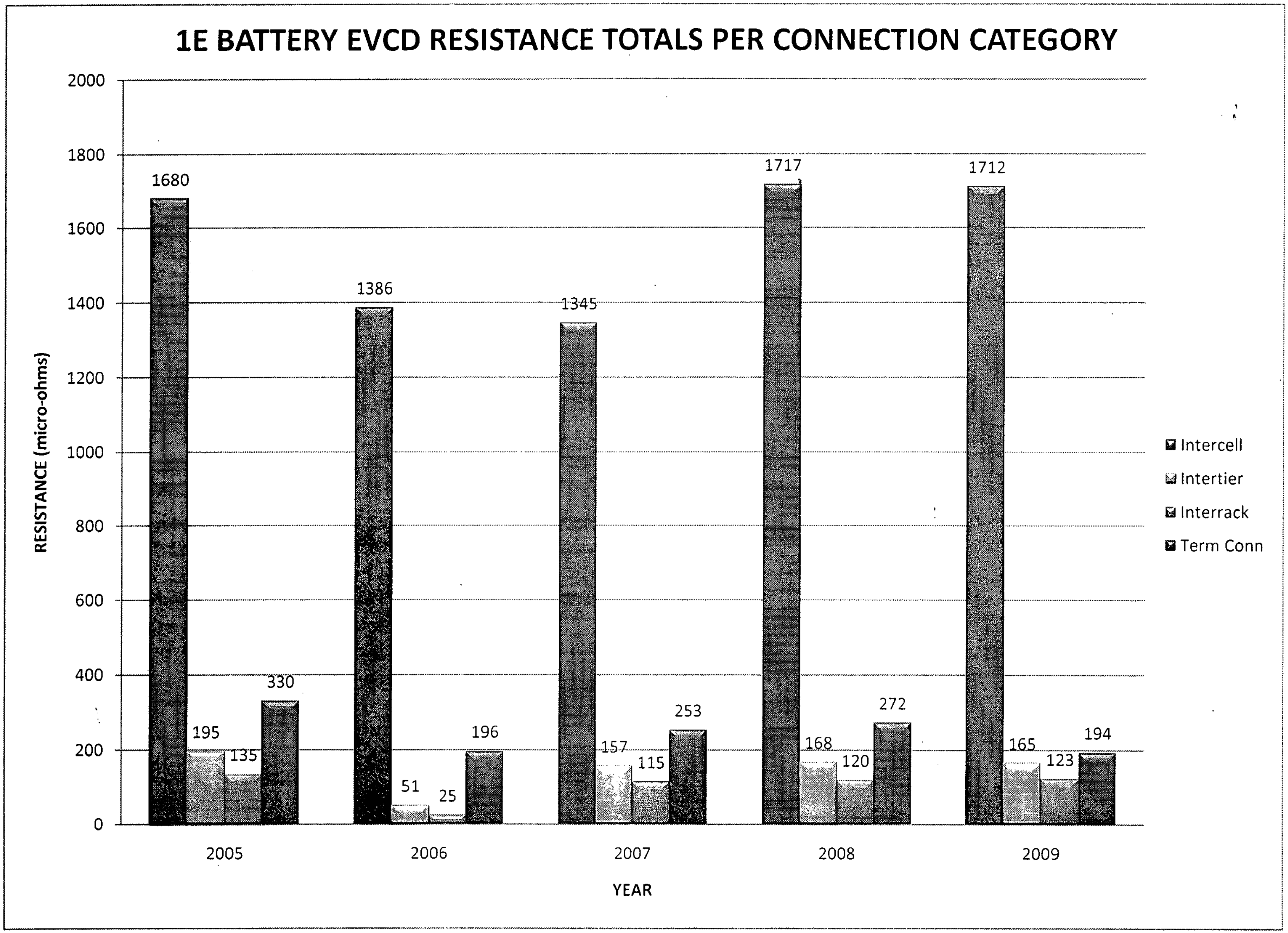
Attachment (3)

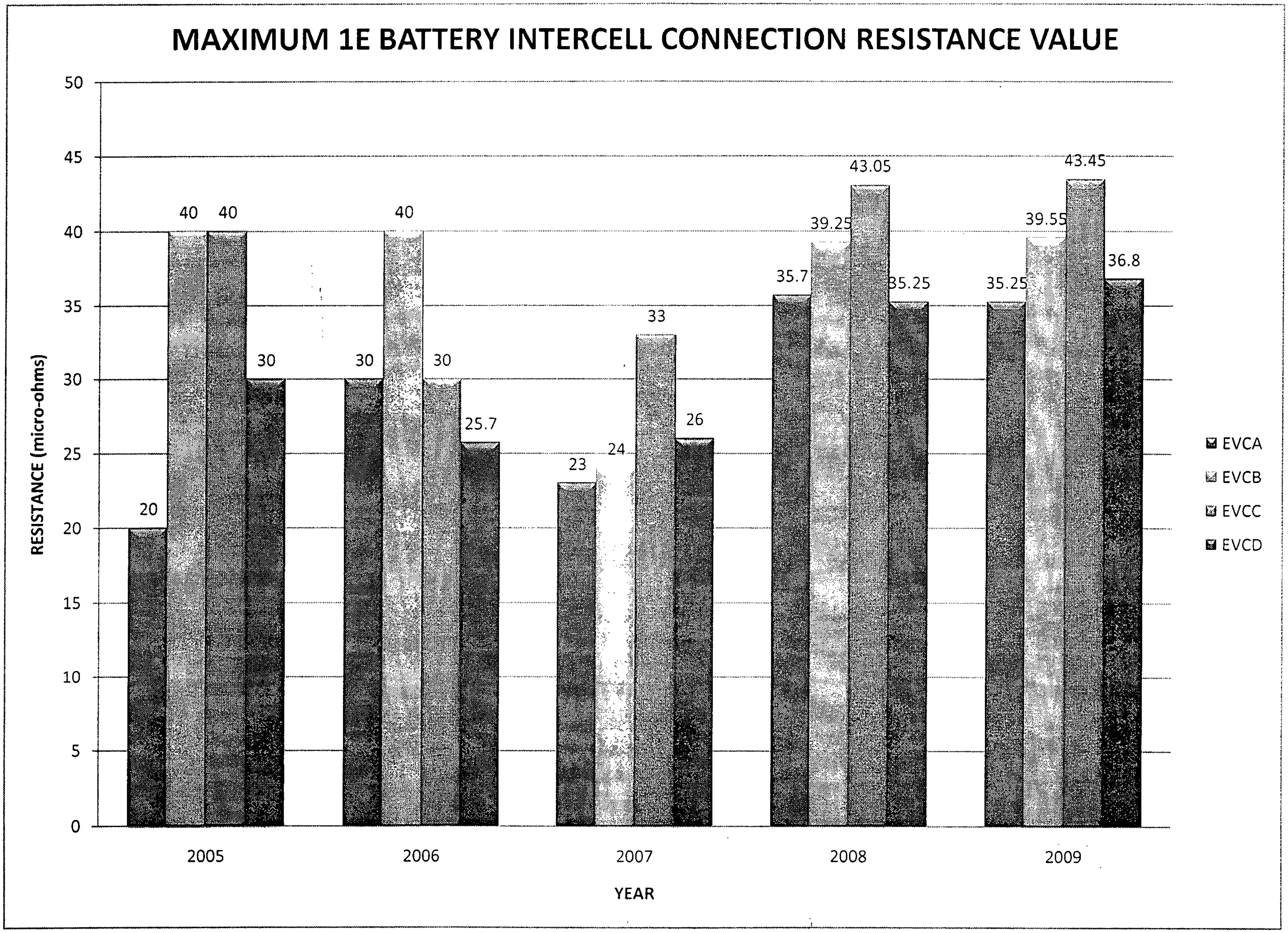


Attachment (4)

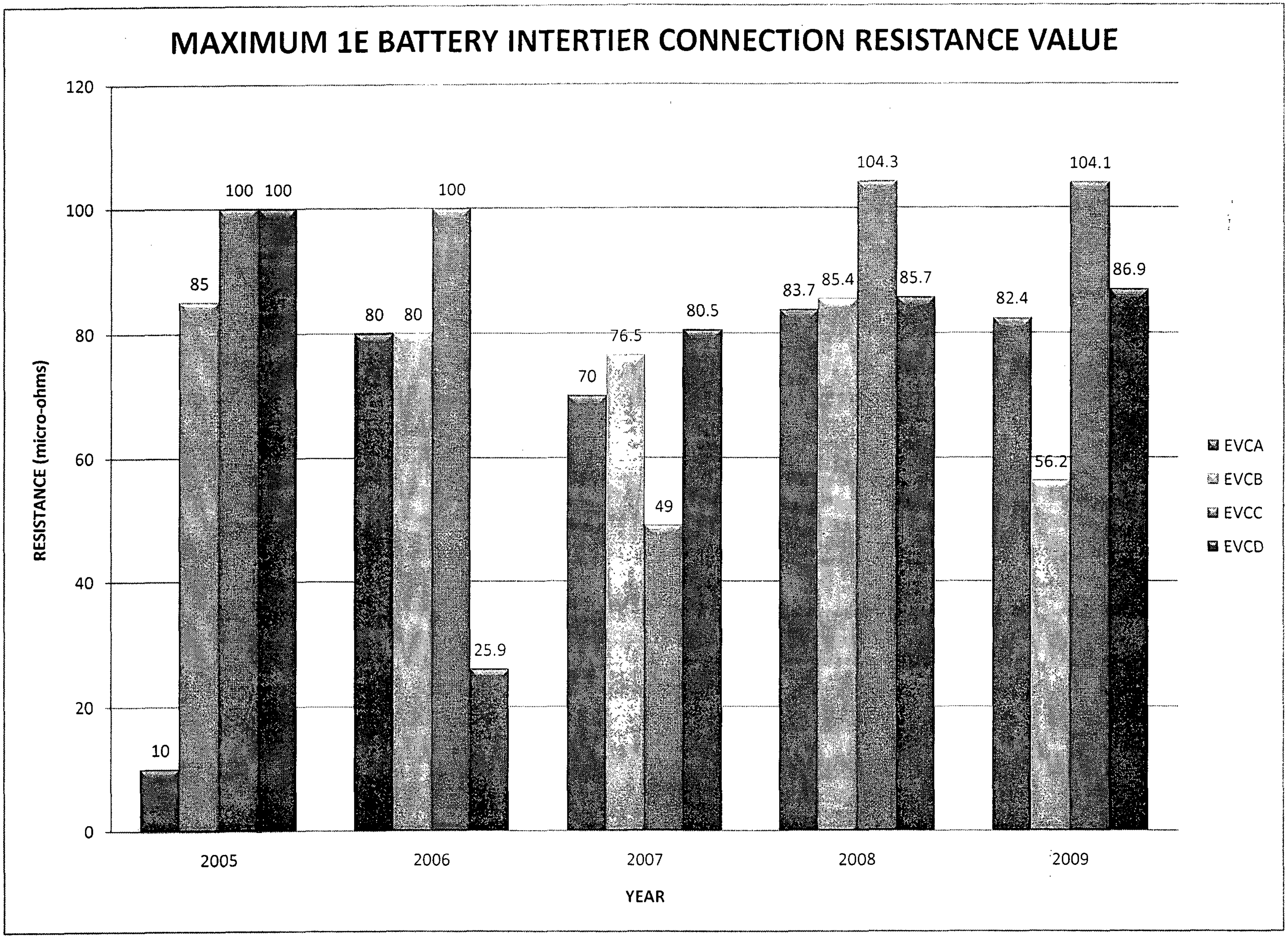


Attachment (5)

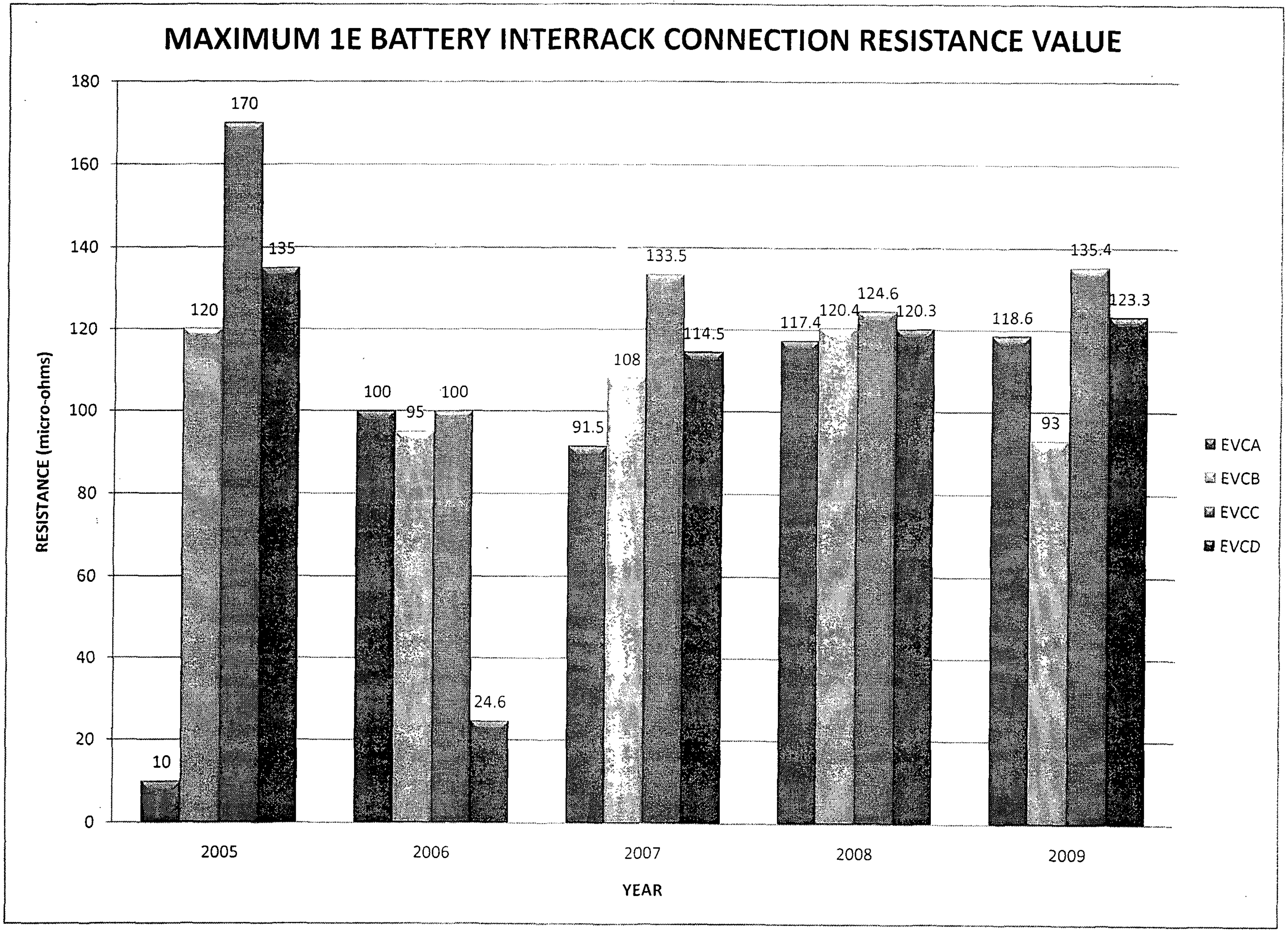

1E BATTERY EVCD RESISTANCE TOTALS PER CONNECTION CATEGORY
RESISTANCE (micro-ohms)
YEAR
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2005
2006
2007
2008
2009
1680
195
135
330
1386
51
25
196
1345
157
115
253
1717
168
120
272
1712
165
123
194
Intercell
Intertier
Interrack
Term Conn



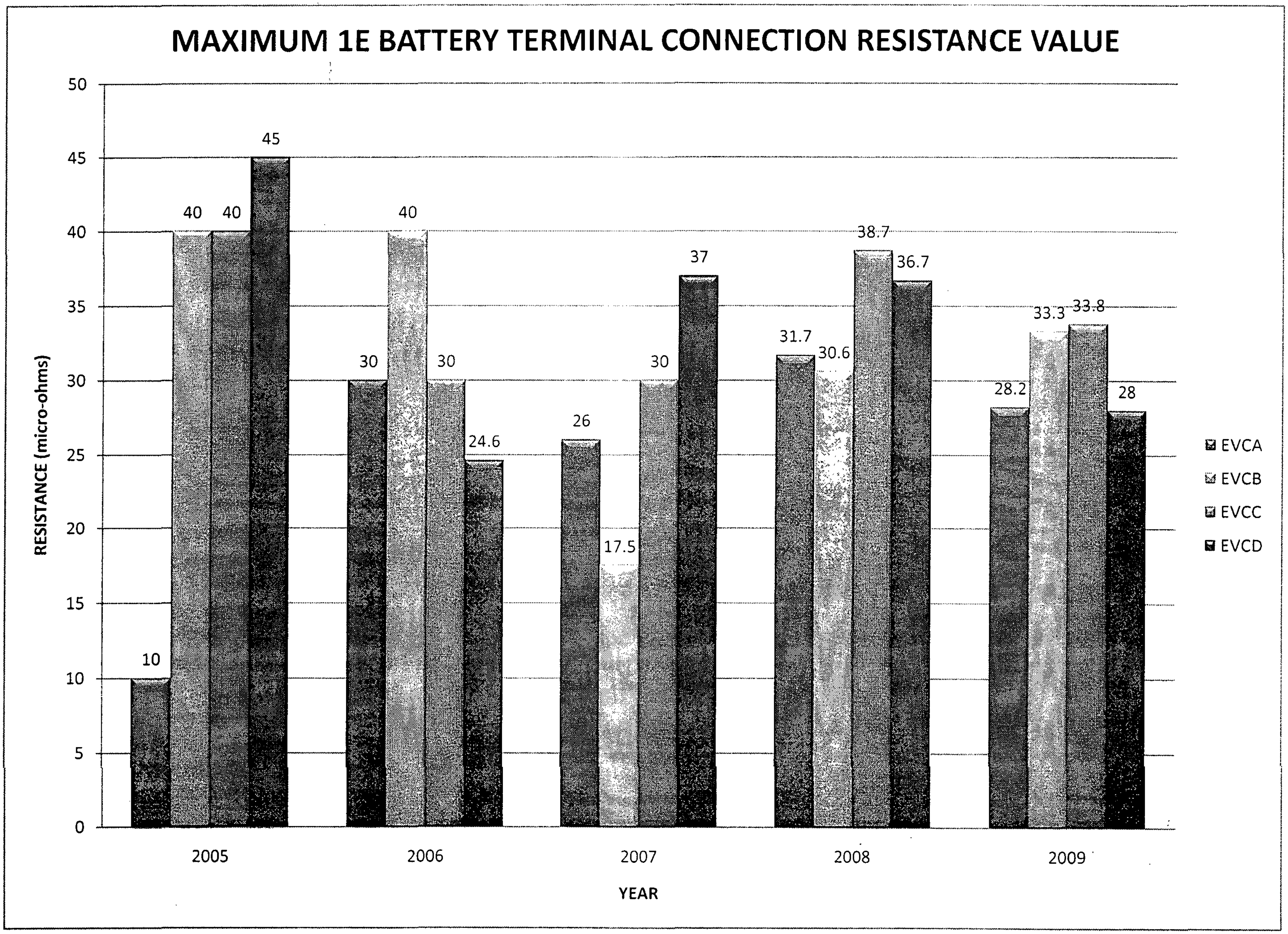
Attachment (7)



Attachment (8)



MAXIMUM 1E BATTERY INTERRACK CONNECTION RESISTANCE VALUE
RESISTANCE (micro-ohms)
180
160
140
120
100
80
60
40
20
0
10
120
170
135
100
95
100
24.6
91.5
108
133.5
114.5
117.4
120.4
124.6
120.3
118.6
93
135.4
123.3
2005
2006
2007
2008
2009
YEAR
EVCA
EVCB
EVCC
EVCD



MAXIMUM 1E BATTERY TERMINAL CONNECTION RESISTANCE VALUE
RESISTANCE (micro-ohms)
50
45
40
35
30
25
20
15
10
5
0
10
40
40
45
30
40
30
24.6
26
17.5
30
37
31.7
30.6
38.7
36.7
28.2
33.3
33.8
28
2005
2006
2007
2008
2009
YEAR
EVCA
EVCB
EVCC
EVCD

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION BY THE OFFICE OF NUCLEAR REGULATION REGARDING LICENSE AMENDMENT RELATED TO REVISION OF THE BATTERY CONNECTION RESISTANCE ACCEPTANCE CRITERIA IN THE TECHNICAL SPECIFICATIONS

Enclosure 2, Catawba's

Response to Request for Additional Information

NRC QUESTION 1:

1. Provide an executive summary of battery connection resistance calculations that shows how the values in proposed TS Table 3.8.4-1 were derived. Include in your response the battery design duty cycle profiles, key assumptions, any credit of margins, and supporting documentation to demonstrate that a) the batteries will perform their intended safety functions when operating within these limits and b) the safe shutdown equipment will have required minimum voltage to perform the required safety functions for the postulated design basis accident and the station blackout scenarios.

CATAWBA'S RESPONSE TO QUESTION 1:

a. Applicable Information from CNS 1E 125VDC Battery Sizing Calculation:

i. SUMMARY:

1. The CNS 125 VDC Vital Instrumentation and Control Power (EPL) System is designed to provide a reliable and continuous source of power to a select group of Class 1E instrumentation and control equipment required for startup, normal operation, and orderly shutdown of each unit. Should a loss of offsite power (LOOP), blackout (no voltage or a degraded voltage condition on the 4KV Essential Bus ETA (ETB)), or other D.B.E occur, this class 1E equipment would be required to safely shutdown the reactor.
2. During normal operation, each battery is paralleled with its respective charger and connected to a 125 VDC Vital I&C distribution center; therefore, it is ready to assume the loads assigned to it without interruption upon loss of the battery charger. Each battery has adequate capacity, at the minimum battery electrolyte temperature of 60°F and the end of battery service life, to carry its own load group plus its "train associated" load group for two hours. Note that batteries EBA and EBC on channels A and C, respectively, are A-Train related; batteries EBB and EBD on channels B and D, respectively, are B-Train related.
3. A battery Service Test is used to verify that each 125 VDC Vital Battery is capable of carrying emergency loads for 120 minutes while maintaining acceptable voltage. During 120 minutes of test period, battery terminal voltage must be maintained $\geq$ 110.4 VDC. Individual battery cell voltages are monitored before, during, and after testing to verify proper battery

performance. The battery service test is performed once every 18 months during the Unit shutdown on each Vital Battery.

ii. KEY ASSUMPTIONS:
1. The Batteries will be sized to carry their assigned loads and the associated channel's loads for a period of 2 hours.
2. Inverter power losses are assumed to be a linear function of inverter output current.
3. The inverter load power factor is assumed to be 0.98, this is a conservative assumption.
4. Total Battery terminal voltage is greater than equal to 125 volts on float charge.
5. Minimum anticipated battery electrolyte temperature of 60°F

iii. MARGINS:
1. Temperature Correction Factor: 1.11
2. Aging factor: 1.25
3. Load Growth Margin: 1.15
4. WORST CASE DUTY CYCLE (Train 1A):
    a. 0 - 1 minute: 420.24 amperes
    b. 1 - 10 minutes: 219.02 amperes
    c. 10 - 20 minutes: 303.96 amperes
    d. 20 - 60 minutes: 230.19 amperes
    e. 60 - 120 minutes: 230.19 amperes

b. Applicable Information from Intercell Resistance Calculation:

i. SUMMARY:
1. To establish battery bank connection resistance administrative limits for the 125 VDC Vital I & C System Batteries (EBA, EBB, EBC, and EBD) and 125 VDC Emergency Diesel Generator Auxiliary Power System Batteries (DGBA and DGBB).
2. To determine a maximum "single" intercell connector resistance TS limit for the 125 VDC Vital I & C System Batteries (EBA, EBB, EBC, and EBD) and the 125 VDC Emergency Diesel Generator Auxiliary Power System Batteries (DGBA and DGBB).

ii. BASIS FOR CALCULATION APPROACH:
1. Nuclear Logistics Inc. (NLI), Technical Bulletin TB-Battery-01, Rev. 1 (GNB Battery Intercell Connectors), September 2007
2. Nuclear Logistics Inc. (NLI) Letter "Evaluation of Intercell Connection Resistances for GNB NCN-9 and NCN-21" dated July 15, 2008 (Attachment 1)

3. IEEE Std 450-2002, Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead -Acid Batteries for Stationary Applications
4. Nuclear Logistics Inc. (NLI) Letter dated August 10, 2009 (Attachment 2)

iii. ANALYTICAL METHOD:

1. CNS Class 1E "EPL" system battery banks (EBA, EBB, EBC, and EBD) consist of 60 GNB NCN-21 (1495 Amp-Hour) flooded lead-acid battery cells. The "EPQ" system battery banks (DGBA and DGBB) consist of 60 GNB NCN-9 (690 Amp-Hour) flooded lead-acid battery cells. GNB and IEEE 450 use a voltage drop of 0.02 VDC per connection in the battery sizing data provided to the industry, and this value was implemented into the calculation for the EPQ batteries. Nuclear Logistics Inc. (NLI), after consulting with battery manufacturer GNB, has determined that a voltage drop of 0.05 VDC per connector for the CNS EPL Class 1E batteries is acceptable based on past performance testing data. Using the values provided by NLI for connector voltage drop, an average battery bank inter-cell connection resistance and a maximum single connector resistance can be calculated.

iv. KEY ASSUMPTIONS:

1. A significant amount of heat is NOT generated during the high rate first minute discharge due to efficient heat dissipation into the battery room atmosphere and battery electrolyte.
2. The inter-cell connection resistance consists of the resistance of the copper inter-cell connector plus the resistance of the inter-cell connector/battery post joints.
3. Battery room ambient temperature is 77 °F. Ambient room temperature fluctuations above and below the IEEE Standard baseline ambient temperature of 77 °F will have minimal impact on connector resistance readings.
4. EPL system load growth does not exceed 15% from the origination of the CNS 1E Vital Battery Sizing Calculation.
5. Maximum Inter-Tier (2 connections) and Inter-Rack (1 connection) Technical Specification limits are set at 200.0x10-6 ohms. This conservative assumption is based on Nuclear Logistics Inc. (NLI) letter dated August 10, 2009, 'Battery Cell Connection Voltage Drop". This letter documents that based on the inter-tier and inter-rack cable connections supplied by NLI for nuclear power plant applications, the voltage drop per set of cables (including terminal plates, cable lug, cable, and bolted connections) is two to five times that of the inter-cell connector (including connector and bolted connections) voltage drop.
6. "Single terminal connection" is defined in proposed T.S. Table 3.8.4-1 as "This measurement is from each individual load cable lug to the battery

cell post". The battery terminal connection refers to the positive post of cell #1 and negative post of cell #60 on the battery that connect to the respective distribution center and the battery test box.

v. MARGINS:

1. Credit of Margins: A 15% load growth margin was added to the duty cycle load profile.

c. CALCULATIONS:

1. EPL Vital Battery Calculations:
   i. The maximum current for any train is the 0-1 minute rate for train A at 420.24 amps. To add additional conservatism to this calculation, a factor of 15% is added to allow margin for system load growth. NLI has analyzed the EPL CNS class 1E battery duty cycle load profile and determined that a voltage drop of 0.05 Vdc is acceptable for CNS NCN-21 class 1E battery banks.
   ii. The limiting rate for the CNS battery load profile is calculated as follows:
      1. $I_{1\text{-minute}}$ = 420.24 amps x 1.15 (Design Margin) = 483.28 amps
   iii. Using Ohm's Law, E=I x R, a voltage drop of 0.05 Vdc and a current of 483.28 amps yields a maximum average battery bank inter-cell connection resistance of: 103.46 x 10-6 ohms.
   iv. Since inter-tier and inter-rack connections are typically 2-5 times the inter-cell connection resistance value, the proposed maximum inter-tier (2 connections) and inter-rack (1 connection) technical specification limits of 200.0 x 10-6 ohms , assumption (6) above, are considered conservative considering the expected maximum could be as high as 517.3 x10-6 ohms [5 x (103.46 x 10-6 ohms)] using the value calculated in 1(iii) above.
2. EPQ DG Battery Calculations:
   i. The maximum current for any train is the 0-1 minute rate for train A at 178.84 amps. To add additional conservatism to this calculation, a factor of 15% is added to allow margin for system load growth. CNS class 1E battery duty cycle load profile uses IEEE-450 standard to determine that a voltage drop of 0.02 Vdc is acceptable for CNS NCN-9 class 1E battery banks.
   ii. The limiting rate for the CNS battery load profile is calculated as follows:
      1. I1-minute = 178.84 amps x 1.15 (Design Margin) = 205.67 amps

        2. Using Ohm's Law, E=I x R, a voltage drop of 0.02 Vdc and a current of 205.67 amps yields a maximum average battery bank inter-cell connection resistance of: <u>97.24 x 10-6 ohms</u>.
        3. Since inter-tier and inter-rack connections are typically 2-5 times the inter-cell connection resistance value, the proposed maximum inter-tier (2 connections) and inter-rack (1 connection) technical specification limits of <u>200.0 x 10-6 ohms</u>, assumption (6) above, are considered conservative considering the expected maximum could be as high as 486.2 x10-6 ohms [5 x (97.24 x 10-6 ohms)] using the value calculated in 2(ii) above.

3. To establish a maximum inter-cell connection resistance for any "single" connector, the maximum power dissipation can be calculated based on the manufacturer's published data. Since the manufacturer's 1-minute rate for the GNB NCN-21 battery cell is 820.0 amps, and for GNB NCN-9 battery cell is 315.0 amps, the inter-cell connectors must be sized to adequately dissipate the generated heat produced by the I^2R losses.
    i. <u>EPL Vital Battery Calculations:</u>
        1. P = I x E = 820.0 amps x 0.05 Vdc = 41.0 Watts
        2. Using the P = I^2R version of the power equation, a current of 483.28 amps and a maximum power dissipation of 41.0 watts:
            1. Maximum Single Inter-Cell Connection Resistance
               = P ÷ I^2 = 41.0 ÷ $(483.28)^2$ = <u>175.54 x 10-6 ohms</u>
        3. This provides a bounding upper operability limit for a single connection as long as the average inter-cell connection resistance is less than 103.46 x 10-6 ohms.
    ii. <u>EPQ DG Battery Calculations:</u>
        1. P = I x E = 315.0 amps x 0.02 Vdc = 6.30 Watts
        2. Using the P = I^2R version of the power equation, a current of 205.67 amps and a maximum power dissipation of 6.30 watts:
           Maximum Single Inter-Cell Connection Resistance
           = P ÷ I^2 = 6.30 ÷ $(205.67)^2$ = <u>148.94 x 10-6 ohms</u>
        3. This provides a bounding upper operability limit for a single connection as long as the average inter-cell connection resistance is less than 97.24 x 10-6 ohms.

4. Each positive and negative battery terminal connection consists of 2 load terminal lugs for EPL vital batteries, and 1 load terminal lug for EPQ DG batteries. The 2 EPL load connections are in parallel, therefore a maximum lug/plate/post connection resistance can be calculated such that it will not exceed the maximum average connection resistance value of <u>103.46 x 10-6 ohms</u>.

5.

i. EPL Vital Battery Calculations

   The following equation applies to resistance in parallel:

   1. RTOT = 1 ÷ (1/RLug + 1/RLug)
   2. RLug = 2 x RTOT
   3. RLug = 2 x 103.46 x 10-6 ohms = 206.92 x 10-6 ohms

ii. EPQ DG Battery Calculations:

   1. RLug = 97.24 x 10-6 ohms

d. CONCLUSION:

i. The above approach provides conservative Technical Specification limits for CNS 1E Vital Batteries EBA, EBB, EBC, EBD, DGBA, and DGBB where battery operability can be clearly established:

   1. EPL Vital Batteries Calculations:
      i. Average inter-cell connection resistance ≤ 103.46 x 10-6 ohms.
      ii. Any single inter-cell connection resistance ≤ 175.54 x 10-6 ohms
      iii. Inter-Tier and Inter-Rack Connection Resistance ≤ 200.0 x 10-6 ohms.
      iv. Any single battery positive or negative terminal connection ≤ 206.92 x 10-6 ohms.

   2. EPQ DG Batteries Calculations:
      i. Average inter-cell connection resistance ≤ 97.24 x 10-6 ohms.
      ii. Any single inter-cell connection resistance ≤ 148.94 x 10-6 ohms.
      iii. Inter-Tier and Inter-Rack Connection Resistance ≤ 200.0 x 10-6 ohms.
      iv. Any single battery positive or negative terminal connection ≤ 97.24 x 10-6 ohms.

   3. In conclusion, if the worst case battery reached the total allowable combined resistance value from the figures above, the expected minimum battery terminal voltage would still be above the minimum allowable battery terminal voltage required to perform its intended safety function. Refer to the response to Question 4 for further details.
   4. During the RAI review, errors were noted in some of the values used during the initial submittal for the Tech Spec change. These incorrect values were used during the original calculation work, and the calculation has since been corrected through the Catawba's corrective action program. The errors mainly involved use of a more conservative value for both the EPL and EPQ maximum single inter-cell connection resistance in proposed T.S. Table 3.8.4-1 due to a miscalculation that used the 1-hour rate instead of the 1-minute rate found in the GNB flooded batteries amp data.

e. The following table contains the corrected single intercell connection resistance values and DG terminal connection value for the new CNS TS Table 3.8.4-1 proposed in the December 14, 2009 License Amendment Request.

New Catawba TS Table 3.8.4-1
Battery Connection Resistance Limits

PARAMETER	DC CHANNEL LIMIT (micro-ohms)	DG BATTERY LIMIT (micro-ohms)
Single intercell connection	≤ 175.54 x 10-6 ohms	≤ 148.94 x 10-6 ohms
Single interrack connection	≤ 200.0 x 10-6 ohms	≤ 200.0 x 10-6 ohms
Single intertier connection	≤ 200.0 x 10-6 ohms	≤ 200.0 x 10-6 ohms
Single terminal connection	≤ 206.92 x 10-6 ohms	≤ 97.24 x 10-6 ohms
Average intercell Connection	≤ 103.46 x 10-6 ohms	≤ 97.24 x 10-6 ohms

NRC QUESTION 2:

2. The licensee proposed to include a new parameter "Average Intercell Connection" in TS Table 3.8.4-1 and in the associated TS Bases sections. However, the NRC staff did not find any definition or details of this proposed parameter in the LAR or the TS Bases. Lack of any definition or details in the TS Bases could create confusion in future. Discuss in detail the proposed parameter "average intercell connection" including the definition and provide a Regulatory Commitment to include a definition and details of this parameter in the TS Bases.

CATAWBA'S RESPONSE TO QUESTION 2:

a. DEFINITION:
   i. "Intercell connection" is referring to the (56) copper connection straps between the battery jar posts.
   ii. "Average intercell connection resistance" is defined as the battery manufacturer's maximum allowed intercell connection voltage drop divided by the maximum battery duty cycle load current, and includes the battery post to intercell connection resistance.
   iii. "Maximum allowable battery total intercell connection resistance" can then be defined as the "average intercell connection resistance" multiplied by the total number of "intercell connectors" in the battery string.

b. DISCUSSION:
   i. When CNS craft personnel conduct the applicable TS surveillance requirement (TSSR) 3.8.4.6 to check resistance values, they are required to add each intercell connection resistance measurement value to get a total "as-found" battery intercell connection resistance value, and then divide by the number of connections (samples) to calculate the average "as-found" intercell connection resistance.
   ii. This methodology is effective in that instead of just looking at battery total connection resistance for acceptance criteria, the actual average intercell connection resistance value can be used as a conservative limit where maintenance action must be taken, but battery operability is not in question.

c. Enclosure 3 contains Catawba's Commitment to add the above definition and details to the Bases for SR 3.8.4.5 and SR 3.8.4.6

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION BY THE OFFICE OF NUCLEAR REGULATION REGARDING LICENSE AMENDMENT RELATED TO REVISION OF THE BATTERY CONNECTION RESISTANCE ACCEPTANCE CRITERIA IN THE TECHNICAL SPECIFICATIONS

NRC QUESTION 3:

3. Provide a chart of the past five years surveillance test results for Surveillance Requirements 3.8.4.6 (Catawba 1 and 2) and 3.8.4.5 (McGuire 1 and 2) for "As Found" and "As Left" battery intercell, inter-tier, inter-rack and terminal connection resistances.

CATAWBA'S RESPONSE TO QUESTION 3:

a. When CNS craft personnel perform the procedure that satisfies the requirements for TSSR 3.8.4.6, the "As Found" and "As Left" values are the same. By procedure, craft personnel are directed to take all measurements and then compare values to the established TS and administrative acceptance criteria documented in the procedure. If any acceptance criteria are not met, the procedure directs applicable notifications and actions to enter the deficiency into the site corrective action-program and work management program by generating a work request. Once the work order is completed, the connection resistance values are again reviewed by craft and engineering for acceptance. In the past five years of data, CNS has not exceeded any of the proposed T.S. connection resistance values.

The following attachments are provided for the past five years:

Attachment 3: 1E Battery 1EBA Resistance Totals
Attachment 4: 1E Battery 1EBB Resistance Totals
Attachment 5: 1E Battery 1EBC Resistance Totals
Attachment 6: 1E Battery 1EBD Resistance Totals
Attachment 7: 1E Battery 2EBA Resistance Totals
Attachment 8: 1E Battery 2EBB Resistance Totals
Attachment 9: 1E Battery 2EBC Resistance Totals
Attachment 10: 1E Battery 2EBD Resistance Totals
Attachment 11: 1E Battery 1DGBA Resistance Totals
Attachment 12: 1E Battery 1DGBB Resistance Totals
Attachment 13: 1E Battery 2DGBA Resistance Totals
Attachment 14: 1E Battery 2DGBB Resistance Totals
Attachment 15: Maximum 1E EPL Battery Intercell Connection Resistance Value
Attachment 16: Maximum 1E EPL Battery Intertier Connection Resistance Value
Attachment 17: Maximum 1E EPL Battery Interrack Connection Resistance Value
Attachment 18: Maximum 1E EPL Battery Terminal Connection Resistance Value
Attachment 19: Maximum 1E EPQ Battery Intercell Connection Resistance Value
Attachment 20: Maximum 1E EPQ Battery Intertier Connection Resistance Value
Attachment 21: Maximum 1E EPQ Battery Interrack Connection Resistance Value
Attachment 22: Maximum 1E EPQ Battery Terminal Connection Resistance Value

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION BY THE OFFICE OF NUCLEAR REGULATION REGARDING LICENSE AMENDMENT RELATED TO REVISION OF THE BATTERY CONNECTION RESISTANCE ACCEPTANCE CRITERIA IN THE TECHNICAL SPECIFICATIONS

NRC QUESTION 4:

4. Battery manufacturers typically recommend correcting any battery connection that has a resistance value of more than 20% above the benchmark values. Provide the benchmark resistance values for each connection in proposed TS Table 3.8.4-1. Provide justifications for any connection resistance value in proposed TS Table 3.8.4-1 that is higher than 20% above the benchmark value and is contrary to the battery manufacturer's recommendations.

CATAWBA'S RESPONSE TO QUESTION 4:

EPL VITAL BATTERY BENCHMARK VALUES

PARAMETER	BENCHMARK VALUE	BENCHMARK PLUS 20%
Average Intercell Resistance (04'-10' All EPL Batteries)	43.10 micro-ohms	51.72 micro-ohms
Maximum Intercell Connection (1EBA)	65.00 micro-ohms	78.00 micro-ohms
Maximum Intertier Connection (1EBD)	85.00 micro-ohms	102.00 micro-ohms
Maximum Interrack Connection (1EBD)	69.00 micro-ohms	82.80 micro-ohms
Maximum Single Terminal Connection (1EBC)	55.00 micro-ohms	66.00 micro-ohms

EPQ DG BATTERY BENCHMARK VALUES

PARAMETER	BENCHMARK VALUE	BENCHMARK PLUS 20%
Average Intercell Resistance (04'-10' All EPQ Batteries)	24.28 micro-ohms	29.14 micro-ohms
Maximum Intercell Connection (1DGBA)	28.00 micro-ohms	33.60 micro-ohms
Maximum Intertier Connection (1DGBB)	95.00 micro-ohms	114.00 micro-ohms
Maximum Interrack Connection (1DGBB)	96.00 micro-ohms	115.20 micro-ohms
Maximum Single Terminal Connection (1DGBB)	30.0 micro-ohms	36.00 micro-ohms

a. Many battery connection resistance measurements had been erratic and highly variable from one year to the next (see attached graphs). After further review, some of the 1E Vital Battery and 1E DG Battery connections were already greater than the baseline value plus 20% documented in the above table; however, 1E Vital Battery and 1E DG Battery operability was not in question based on an extensive review of the past battery service test voltage profiles.

The service tests, which include all connector resistance values as well as each battery cell's internal resistance, clearly demonstrated significant margin available. This was validated in a comprehensive operability evaluation which determined that based on the 1E battery and 1E DG Battery duty cycle load profile; significant margin still existed using the present resistance measurements.

b. When taking resistance measurements in the micro-ohm range, readings can be inconsistent as a result of many variables, such as Digital Low Resistance Ohmmeter (DLRO) used, test contact point on battery post, test equipment inability to "lock in" on a specific value which leads to visual interpolation of meter swings by technicians, and human factors just to name a few. For example, several readings one year after battery installation already exceeded the baseline measurement plus 20% even though it is highly unlikely that any connection had degraded that much in one year on a new battery.

The Following Justification Supports This Conclusion:

c. The CNS 1E Vital Battery and 1E DG Battery connections consist of (56) intercell, (2) intertier, (1) interrack, and (2) battery terminals. Each positive and negative battery terminal connection consists of (2) load terminal lugs for the EPL Vital Batteries in parallel and (1) load terminal lug for the EPQ DG Batteries.

Total Battery **Allowable** Technical Specification Resistance Limit Using Proposed TS Table 3.8.4-1 Values:

TABLE J-1

Total Battery Allowable Technical Specification Resistance Limit (EPL)

Connection	Calculated Value (μΩ)	Connections	Total (μΩ)
Inter-Cell	103.46	56	5793.76
Inter-Tier	200.00	2	400.00
Inter-Rack	200.00	1	200.00
Lug	206.92 (2 in parallel = 103.46)	2	206.92
TOTAL ALLOWABLE CONNECTION RESISTANCE			6600.68

Note: The proposed TS Table 3.8.4-1 value for an "individual" Terminal Connection resistance is 206.92×10^{-6} ohms for EPL, but with (2) load terminal connections in parallel on both the battery positive and negative connections, the combined parallel resistance for the battery positive and negative connection is determined using the equation $R_{TOT} = 1 \div (1/R_{Term} + 1/R_{Term})$. Using the value of 206.92×10^{-6} ohms for each R_{Term} in the equation yields total terminal connection resistance value for both the positive and negative battery terminal connection of 103.46×10^{-6} ohms. This is NOT the case with the 1E EPQ DG Batteries, the proposed TS Table 3.8.4-1 value for an "individual" Terminal Connection resistance for EPQ is 97.24×10^{-6} ohms with (1) load terminal connection.

TABLE J-2

Total Battery Allowable Technical Specification Resistance Limit (EPQ)

Connection	Calculated Value (μΩ)	Connections	Total (μΩ)
Inter-Cell	97.24	56	5445.4
Inter-Tier	200.00	2	400.00
Inter-Rack	200.00	1	200.00
Lug	97.24	2	194.5
TOTAL ALLOWABLE CONNECTION RESISTANCE			6239.9

The total allowable connection resistance for any CNS 1E Vital Battery (EPL) is 6600.68 x 10-6 ohms.

The total allowable connection resistance for any CNS 1E DG Battery (EPQ) is 6239.9 x 10-6 ohms.

The Total Calculated Connection Resistances from the Most Recent Completion of TSSR 3.8.4.6:

TABLE J-3

Battery	Date	56-Intercell (μΩ)	2-Intertier (μΩ)	1-Interrack (μΩ)	2-Terminal Lug (μΩ)	Total (μΩ)
1EBA	12/16/2008	2560	257	105	78	**3000**
1EBB	12/30/2008	2540	245	94	110	**2989**
1EBC	06/22/2010	2471	232	105	113	**2921**
1EBD	01/20/2009	2575	219	88	100	**2982**
Battery	**Date**	**Intercell (μΩ)**	**Intertier (μΩ)**	**Interrack (μΩ)**	**Terminal Lug (μΩ)**	**Total (μΩ)**
2EBA	07/28/2009	2892	246	119	96	**3353**
2EBB	11/04/2009	2984	235	109	82	**3410**
2EBC	03/02/2010	2770	251	119	93	**3233**
2EBD	10/27/2009	2937	244	112	94	**3387**
Battery	**Date**	**Intercell (μΩ)**	**Intertier (μΩ)**	**Interrack (μΩ)**	**Terminal Lug (μΩ)**	**Total (μΩ)**
1DGBA	11/26/2009	1389	216	107	43	**1755**
1DGBB	11/182009	1424	187	93	42	**1746**
2DGBA	03/18/2009	1387	182	93	52	**1714**
2DGBB	03/25/2009	1411	184	86	53	**1734**

The worst case recorded TSSR 3.8.4.6 1E Vital EPL Battery total resistance is 3648 x 10-6 ohms on battery 2EBA, 8/31/2004.

The worst case recorded TSSR 3.8.4.6 1E DG EPQ Battery total resistance is 1755 x 10-6 ohms on battery 1DGBA, 11/26/2009.

d. The limiting period of the CNS Vital battery and D/G battery duty cycle is during the first minute where the load demand is the highest. This voltage dip during the first minute is exacerbated by the coup-de-fouet effect, which is primarily observed on stationary lead-acid batteries that have been maintained on a long-term float charge. During the initial moments of discharge, the chemical reaction is slightly less efficient which results in an additional voltage dip during the first few minutes of discharge, followed by a recovery to a slightly higher voltage during this initial discharge period. The following table (J-4) documents the lowest first minute voltage during the most recent Service Test for both the EPL and EPQ batteries. **It should be noted that the first minute current used during these test were 522.14 amps for EPL and 228.00 amps for EPQ, which are 38.86 amps and 6.30 amps more than the actual first minute duty cycle amperage value used in the calculation. These numbers include a 10-15% load growth margin and an 11% temperature correction factor. This additional current adds significant conservatism to this analysis.**

TABLE J-4

Battery	Date	1-Min Lowest Voltage (VDC)	Current (Amps)
1EBA	12/16/08	112.90	522.14
2DGBA	03/18/09	113.91	228.00

The worst case minimum voltage (lowest) is 112.90 VDC on battery 1EBA for the EPL Vital Batteries.

e. The discharge voltage profile during the battery test includes all intercell, intertier, interrack, terminal-lug, and battery cell internal resistances. From the above Tables, it can be concluded that battery 1EBA is most limiting from the combination of voltage and connection resistance standpoint, so the margin associated with 1EBA will be used to validate the values in the proposed TS Table 3.8.4-1.

f. Assume that battery 1EBA reached the TS limit on all inter-cell, inter-tier, inter-rack, and terminal-lug connections. The total resistance for battery 1EBA would be 6600.68 x 10-6 ohms (TABLE J-1). Since the 1EBA voltage in TABLE J-4 (112.9 VDC) includes the 1EBA total resistance value in TABLE J-3 (3000 x 10-6 ohms), it must be subtracted from the total allowable resistance value to determine the margin:

   a. Resistance Margin = 6600.68 x 10-6 ohms – 3000 x 10-6 ohms = 3600.68 x 10-6 ohms

g. If battery total resistance increased to 6600.68 x 10-6 ohms, this would cause the following additional voltage drop below the minimum voltage in TABLE J-4 (112.9 VDC):

   a. E = IR = (483.28 amps) x (3600.68 x 10-6 ohms) = 1.74 VDC

h. So if the worst case battery (1EBA) reached to total allowable combined resistance value of 6600.68 x 10-6 ohms, the expected minimum battery terminal voltage would be 111.16 VDC (112.9 – 1.74), which is still 0.76 VDC above the minimum allowable battery terminal voltage of 110.4 VDC.

The worst case minimum voltage (lowest) is 113.91 VDC on battery 2DGBA for the EPQ DG Batteries.

i. The discharge voltage profile during the battery test includes all intercell, intertier, interrack, terminal-lug, and battery cell internal resistances. From the above Tables, it can be concluded that battery 2DGBA is most limiting from the combination of voltage and connection resistance standpoint, so the margin associated with 2DGBA will be used to validate the values in the proposed TS Table 3.8.4-1.

j. Assume that battery 2DGBA reached the TS limit on all inter-cell, inter-tier, inter-rack, and terminal-lug connections. The total resistance for battery 2DGBA 6239.9 x 10-6 ohms (TABLE J-2). Since the 2DGBA voltage in TABLE J-4 (113.91 VDC) includes the 2DGBA total resistance value in TABLE J-3 (1714.00 x 10-6 ohms), it must be subtracted from the total allowable resistance value to determine the margin:

   a. Resistance Margin = 6239.9 x 10-6 ohms – 1714.00 x 10-6 ohms = 4525.9 x 10-6 ohms

k. If battery total resistance increased to 6239.9 x 10-6 ohms, this would cause the following additional voltage drop below the minimum voltage in TABLE J-4 (113.91 VDC):

   a. E = IR = (205.67 amps) x (4525.9 x 10-6 ohms) = 0.93 VDC

l. So if the worst case battery (2DGBA) reached to total allowable combined resistance value of 6239.9 x 10-6 ohms, the expected minimum battery terminal voltage would be 112.98 VDC (113.91 – 0.93), which is still 2.13 VDC above the minimum allowable battery terminal voltage of 110.85 VDC.

This analysis concludes that if every single intercell connection reached the average resistance value, there would still be significant operating margin based on the cumulative conservative elements of the vital calculations. Since a baseline could not be accurately determined from available data, the CNS maintenance procedure will require action to be taken if **ANY** connection reaches 175.54 x 10^{-6} ohms for EPL/148.94 x 10^{-6} ohms for EPQ or **ANY** intertier/interrack connection reaches 200 x 10^{-6} ohms. These values are conservative and battery operability and safety are not in question.

NRC QUESTION 5:

5. Battery manufacturers typically require that a benchmark value for all similar connections should be no greater than 10% or 5 micro ohms, whichever is greater, above the average resistance of all such connections in the battery. On page 3.8.4-4 of the McGuire 1 and 2 LAR, (Attachment 2, TS Table 3.8.4-1), the proposed value of "Single Intercell Connection" resistance is approximately 72.9% or 34.2 micro ohms above the "Average Intercell Connection" resistance. Provide justification for exceeding the manufacturer's recommendation.

Duke Energy Response to Question 5:

a. The battery manufacturer recommendation of 10% or 5 micro-ohms, whichever is greater, above the average connection resistance of such connection is to establish a consistent benchmark value that can be used for connection resistance trending following battery installation. The TS Table 3.8.4-1 value is for battery operability and is not a value that would be used in the maintenance and monitoring program. It provides a bounding upper limit on any single intercell connector. When looking at battery operability, meeting all of the values in the proposed TS Table 3.8.4-1 must be considered at any given time.

b. EPL:
The basis for the maximum single intercell connection resistance is based on the battery manufacturer's discharge curves. The most limiting power dissipation calculation is the A train 1- minute rate. Using the power equation P=IE and the manufacturer's sizing data, a maximum design power dissipation at each connection can be established. Since the manufacturer's 1-minute rate for the GNB NCN-21 battery cell is 820.0 amps, the intercell connectors must be sized to adequately dissipate the generated heat produced by the I^2R losses.

   i. P = I x E = 820.0 amps x 0.05 VDC = 41.0 Watts

   ii. The maximum duty cycle 1-minute load current for the EPL system duty cycle is 420.24 amps. Using a 15% load growth margin results in the following 1-minute load current:

      1. $I_{1\text{-minute}}$ = 420.24 x 1.15 = 483.28 amps

   iii. Using the $P = I^2R$ version of the power equation, a current of 483.28 amps and a maximum power dissipation of 41.0 watts:

      1. Maximum Single Intercell Connection Resistance = $P / I^2 = 41.0 / (483.28)^2$

2. Maximum Single Intercell Connection Resistance = <u>175.54×10^{-6} ohms</u>

c. EPQ:
The basis for the maximum single intercell connection resistance is based on the battery manufacturer's discharge curves. The most limiting power dissipation calculation is the A train 1- minute rate. Using the power equation P=IE and the manufacturer's sizing data, a maximum design power dissipation at each connection can be established. Since the manufacturer's 1-minute rate for the GNB NCN-9 battery cell is 315.0 amps, the intercell connectors must be sized to adequately dissipate the generated heat produced by the I^2R losses.

   i. P = I x E = 315.0 amps x 0.02 VDC = 6.30 Watts

   ii. The maximum duty cycle 1-minute load current for the EPL system duty cycle is 178.84 amps. Using a 15% load growth margin results in the following 1-minute load current:

      1. $I_{1\text{-minute}}$ = 178.84 x 1.15 = 205.67 amps

   iii. Using the $P = I^2R$ version of the power equation, a current of 205.67 amps and a maximum power dissipation of 6.30 watts:
      1. Maximum Single Intercell Connection Resistance = $P / I^2 = 6.30 / (205.67)^2$
      2. Maximum Single Intercell Connection Resistance = <u>148.94×10^{-6} ohms</u>

d. This provides a bounding operability upper limit for a <u>single</u> connection so long as the <u>average</u> of all intercell connections is less than or equal to 103.46×10^{-6} ohms for EPL and 97.24×10^{-6} ohms for EPQ. This value is based on battery operability due to the design heat transfer capabilities of the connectors themselves. This is not a value that is used in the battery maintenance and monitoring program.

NRC QUESTION 6:

6. Discuss why average connection resistance values for inter-tier, inter-rack, and terminal connection limits were not included in proposed TS Table 3.8.4-1 for McGuire 1 and 2 and Catawba 1 and 2.

Duke Energy Response to Question 6:

a. The average intercell connection limit of 103.46 x 10-6 ohms also includes the terminal connections. The actual value in proposed TS Table 3.8.4-1 for the 1E EPL Vital Batteries is based on (2) load terminal connections in parallel on the battery string positive connection and (2) load terminal connections in parallel on the battery string negative connection with a combined parallel resistance on each not exceeding the average connection value of 103.46 x 10-6 ohms. The actual value in proposed TS Table 3.8.4-1 for the 1E EPQ DG Batteries is based on (1) load terminal connection on the battery string positive connection and (1) load terminal connection on the battery string negative connection with a combined resistance on each not exceeding the average connection value of 97.24 x 10-6 ohms for the 1E EPQ Vital Batteries.

b. The intertier and interrack resistance values are based on the manufacturer's recommended range of 2 to 5 times the allowable intercell connection resistance value. Since there are only 3 of these connections in the battery, a reasonably conservative value was assumed within that recommended range for these connections when calculating the battery total resistance.

NUCLEAR LOGISTICS INC

Evaluation of Intercell Connection Resistances for GNB NCN-9 and NCN-21 Batteries for the Catawba Nuclear Plant

Issue Definition

NLI bulletin TB-BATTERY-001 identified a method to calculate the allowable resistance of the battery intercell connectors.

Catawba Nuclear Plant personnel provided the following information to NLI:

- NCN-21 batteries are installed with one 1/8" connector on each side of the battery post. The first minute of the duty cycle is 534 amps.
- NCN-9 batteries are installed with one ¼" connector on each side of the battery post. The first minute of the duty cycle is 228 amps.
- The resistances reading for the NCN-21 batteries were approximately 45 micro-ohms when the batteries were received in 1996/1997 and are approximately 55 micro-ohms currently.
- The last performance tests demonstrated over 100% capacity.

Evaluation

The following evaluation is provided:

- The information in NLI technical bulletin TB-BATTERY-001, rev. 1 has been reviewed and is applicable.
- NCN-21 battery:
  - The GNB design intercell connection voltage drop is 0.020v/connection.
  - At the maximum current of 534amps, the design intercell connection resistance is 0.02volts/534amps = 37 micro-ohms.
  - The voltage drop with plant reported 55 micro-ohm resistance/connection is calculated as follows:
    - The GNB design intercell connection voltage drop is (0.020v/connection)(59 connections) = 1.2 volts drop.
    - With a connection resistance of 55micro-volts/connection, the voltage drop per connection is (55micro-ohm)(534amps) = 0.03v/connection. The total battery voltage drop = (0.03v/connection)(59 connections) = 1.77 volts.
    - The added voltage drop due to the increased intercell connection resistance is (1.77-1.2) = 0.57 volts.

- NCN-9 battery:
  - The GNB design intercell connection voltage drop is 0.020v/connection.
  - At the maximum current of 228amps, the design intercell connection resistance is 0.02volts/228amps = 88 micro-ohms.
- If the average voltage drop is (0.050v/connection), the total voltage drop would be approximately 3.0 volts (0.05 x 59 connections). The added voltage drop due to the increased intercell connection resistances is (3.0-1.2 = 1.8volts). The additional voltage drop can be show to be acceptable based on the plant specific load profile and the tested capacity of the battery. See the information below.
  - NCN-21 battery: The voltage drop of 0.050v/connection is equivalent to (0.05/534 = 94 micro-ohms/connection).
  - NCN-9 battery: The voltage drop of 0.050v/connection is equivalent to (0.05/228 = 219 micro-ohm/connection).

Battery Operability

If the measured intercell connection resistances are greater than the GNB design values specified above, the operability of the battery can be evaluated as follows:

- The increased intercell connection resistances are only a possible concern during the high first 1 minute discharge rate.
- Duke Power performs service tests or modified performance tests on the batteries in accordance with plant procedures. The tests demonstrate that the plant load profile can be met with the higher intercell connection resistances.
- Batteries are sized with significant margin (25% aging margin + plant specified design margin). If the battery capacity is still well above 80%, the added voltage drop from the higher intercell connection resistance is not significant.
- As stated above, the higher intercell connection resistances are only a potential concern during the first 1 minute high discharge rate. The higher resistances may cause a slight increase in the temperature of the connectors, but it is not significant. The heat would be dissipated by the air and electrolyte.
- There is no risk of damage to the battery, overheating or fire.

NLI Recommendations

The following recommendations are made:

- Add one ¼" intercell connector to each side of the NCN-21 battery posts for a total of one 1/8" + one ¼" thick connectors on each side.
- The GNB maintenance manual contains recommendations on cleaning the intercell connections based on increases in the resistance. These recommendations should be followed.

Prepared by: [signature] 7/14/08

Reviewed by: [signature] 7/15/08

Approved by: [signature] 7/15/08

Attachment 2
Sheet 1 of 1

NLI
NUCLEAR LOGISTICS INC

August 10, 2009

Attention: Howard Nudi
POWER Engineering
Duke Energy, McGuire Nuclear Station

Subject: Battery Cell Connection Voltage Drop

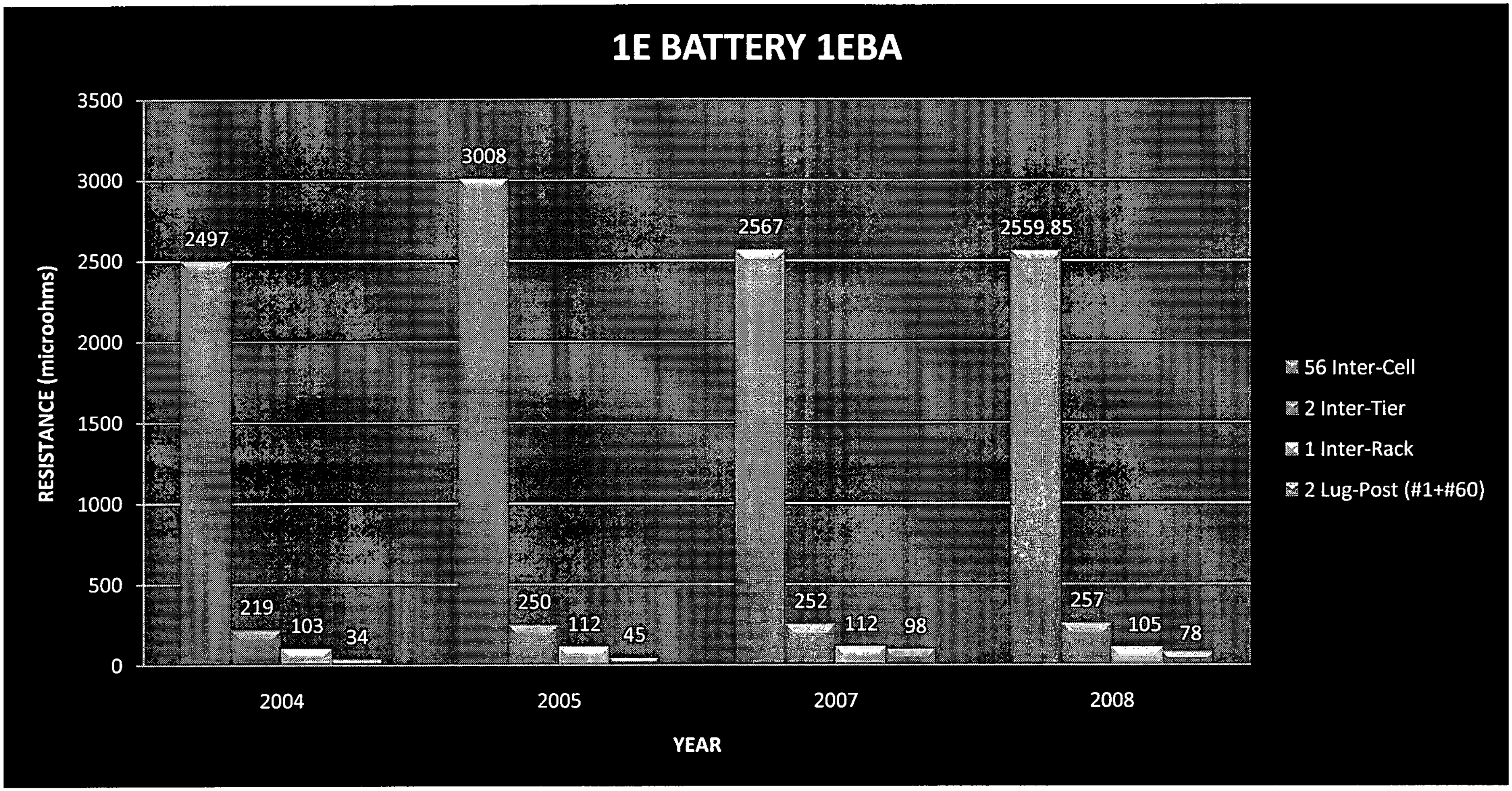
Dear Sir;

We have reviewed the GNB sizing requirements for cable connections and performed additional evaluations. Based on the inter-tier and inter-rack cable configurations supplied by NLI for nuclear power plant applications, the voltage drop per set of cables (including terminal plates, cable lug, cable, and bolted connections) is two to five times that of the inter-cell connector (including connector and bolted connections) voltage drop.

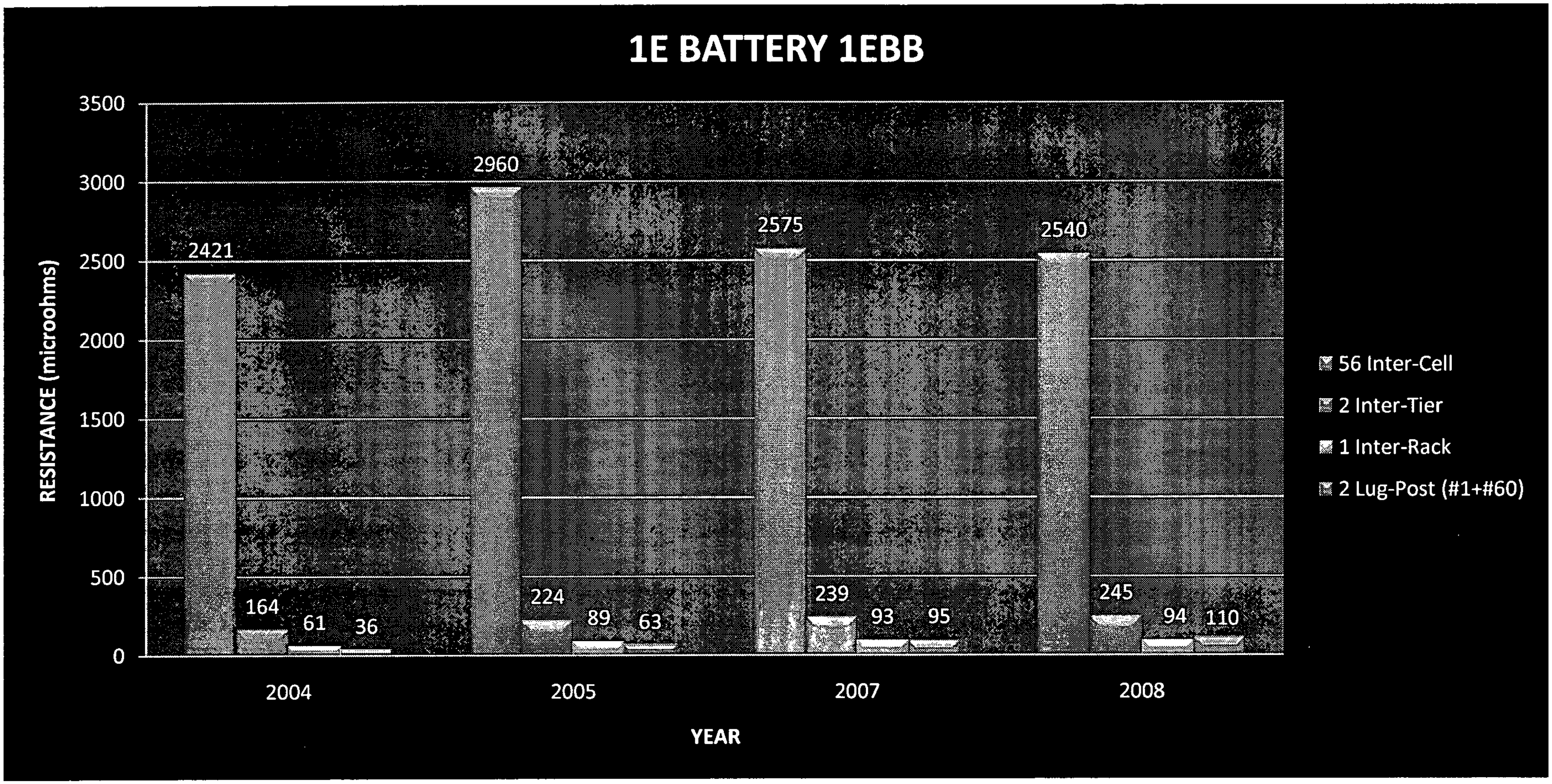
All practices in installation, operation and maintenance of a battery should be in accordance with the GNB Installation and Operating Instructions.

Sincerely,

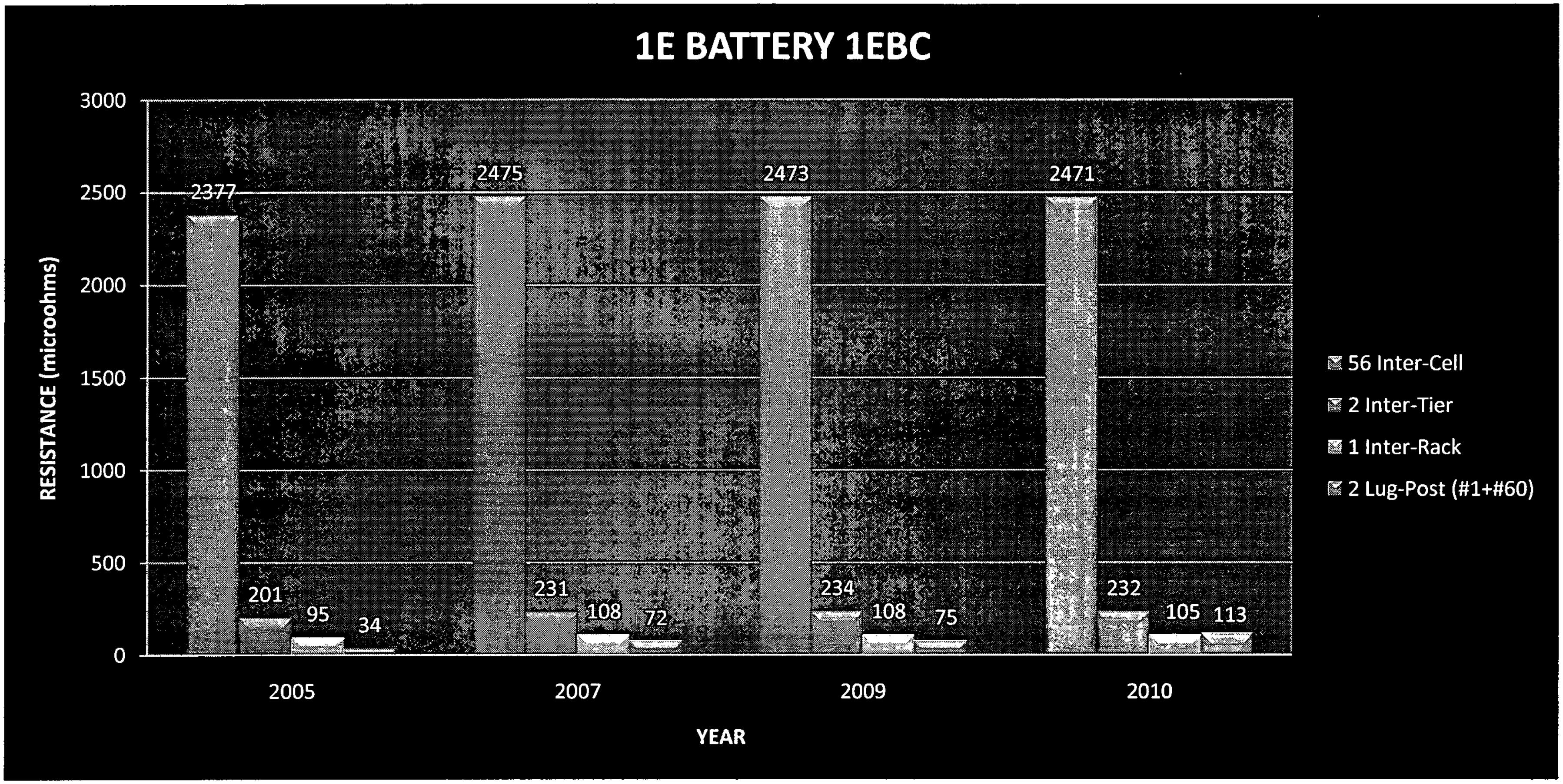
David Phillips
Project Engineer
Nuclear Logistics Inc.



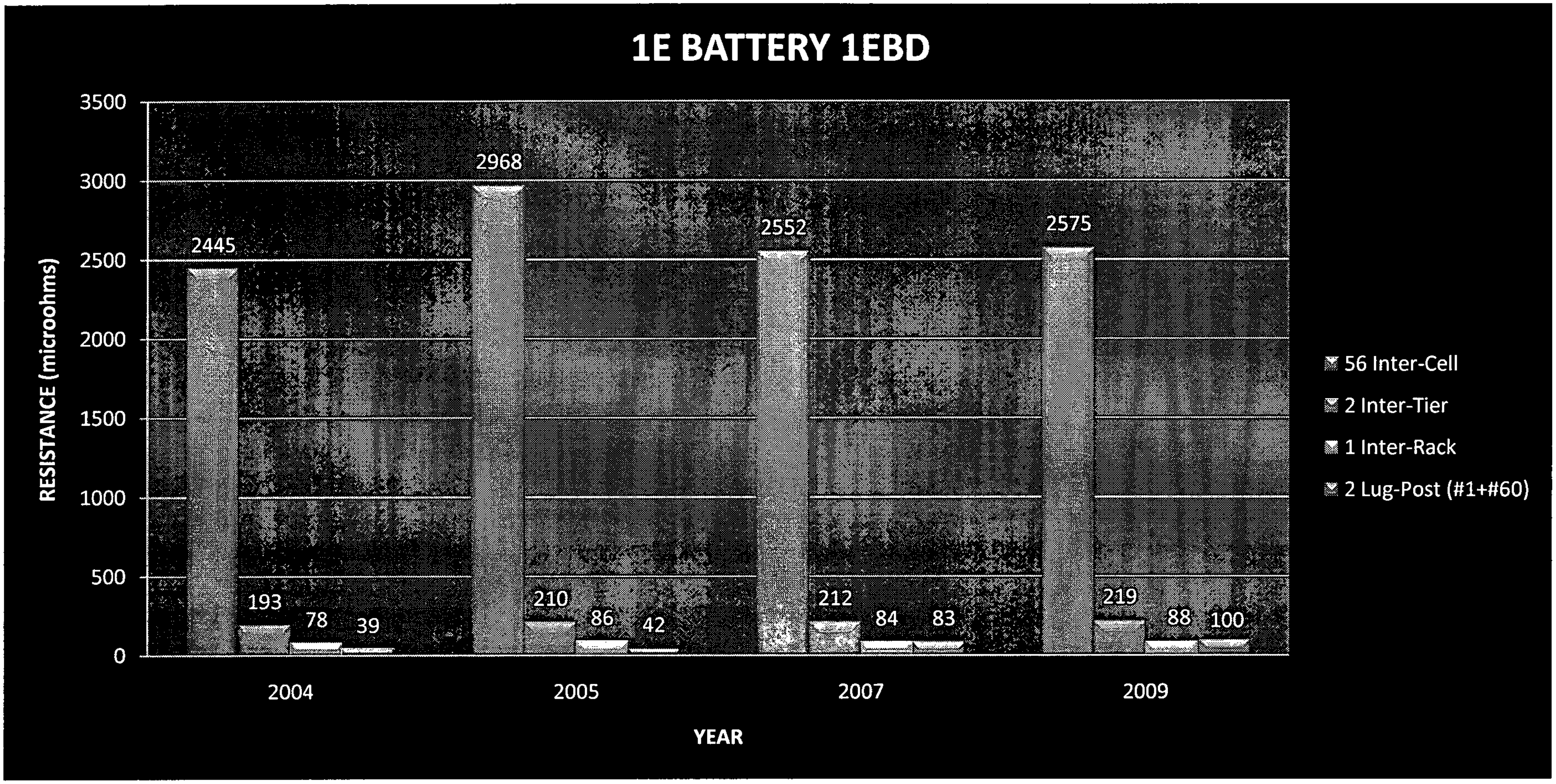
Attachment 3



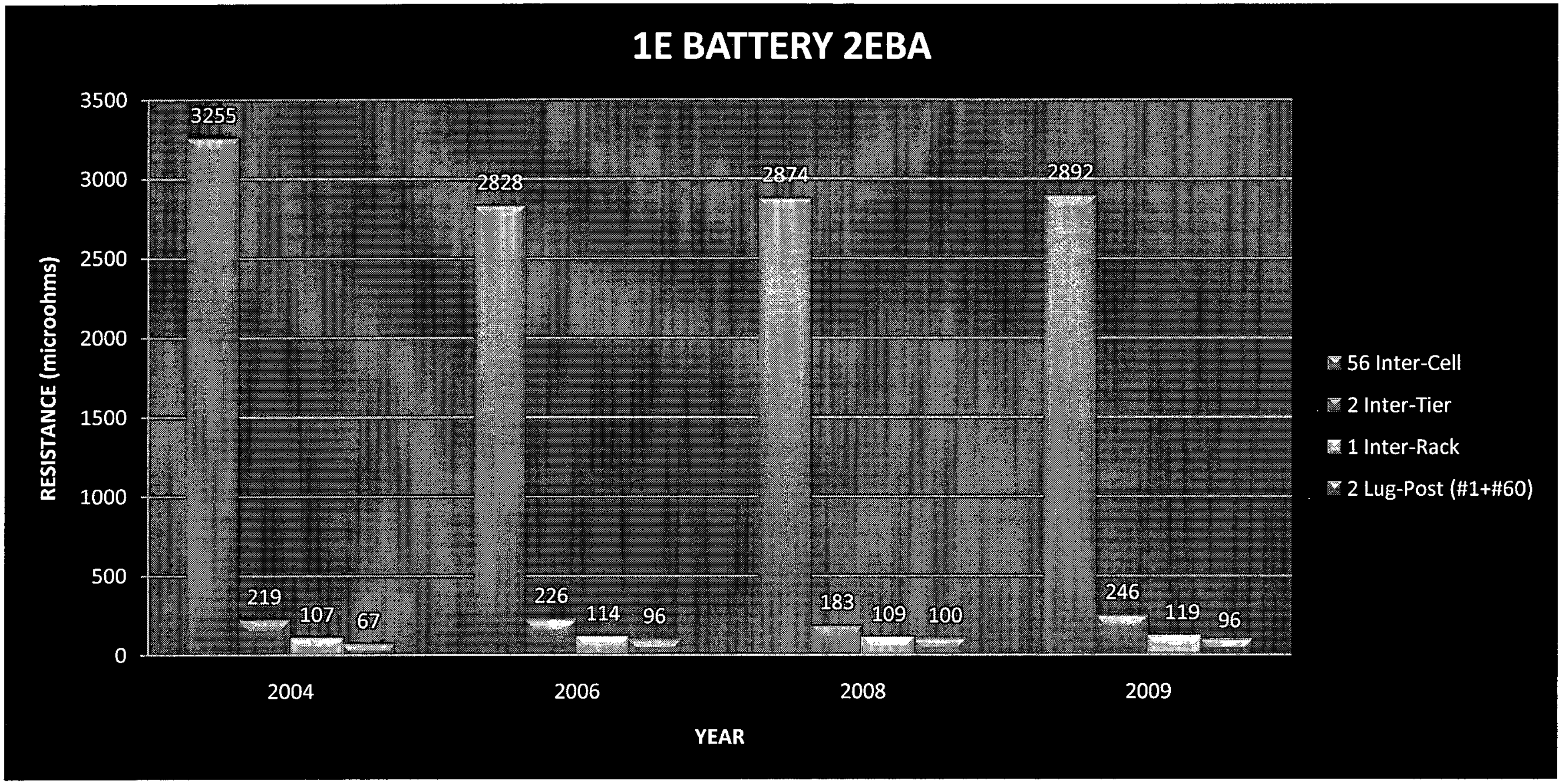
Attachment 4



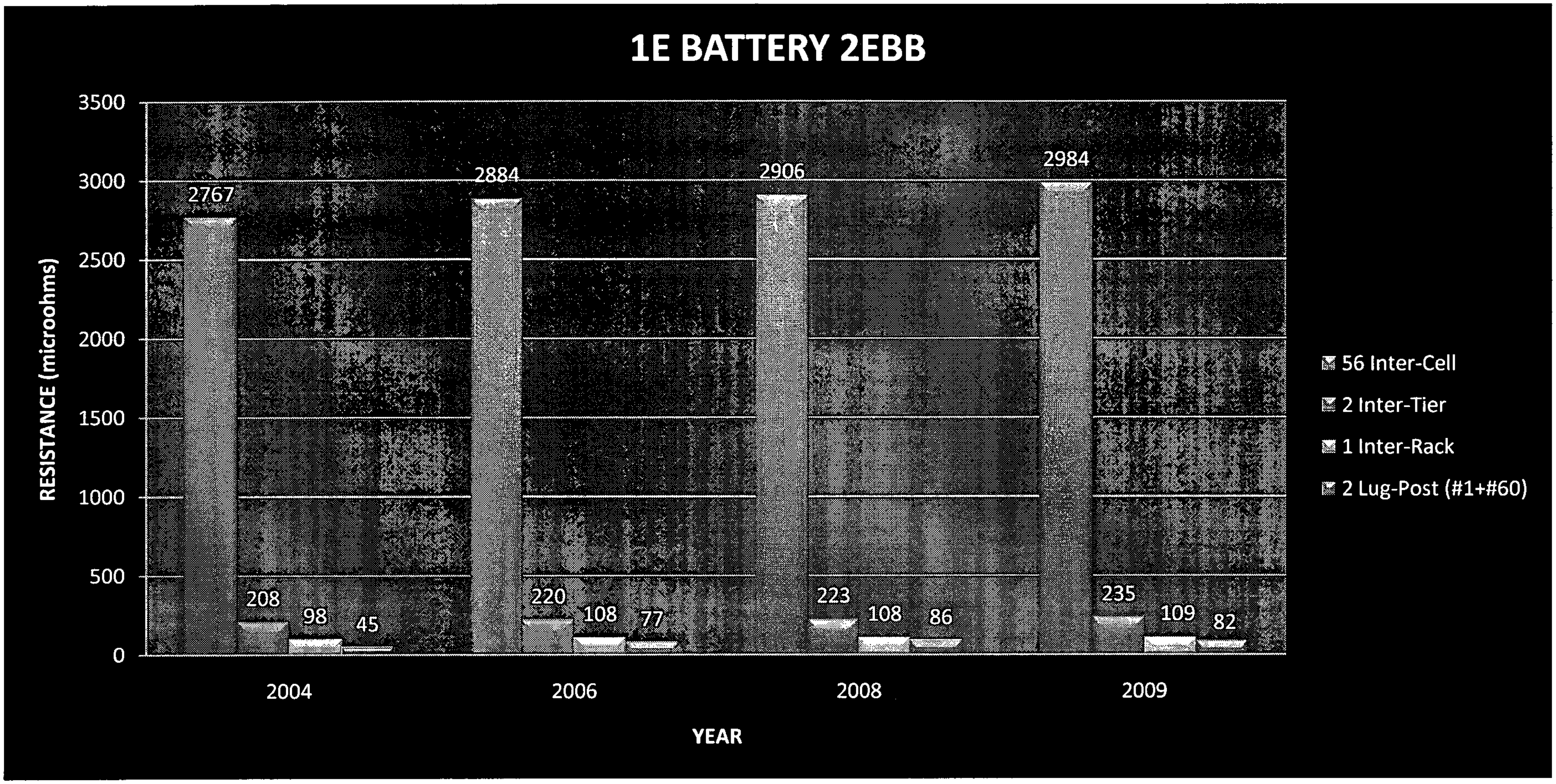
Attachment 5



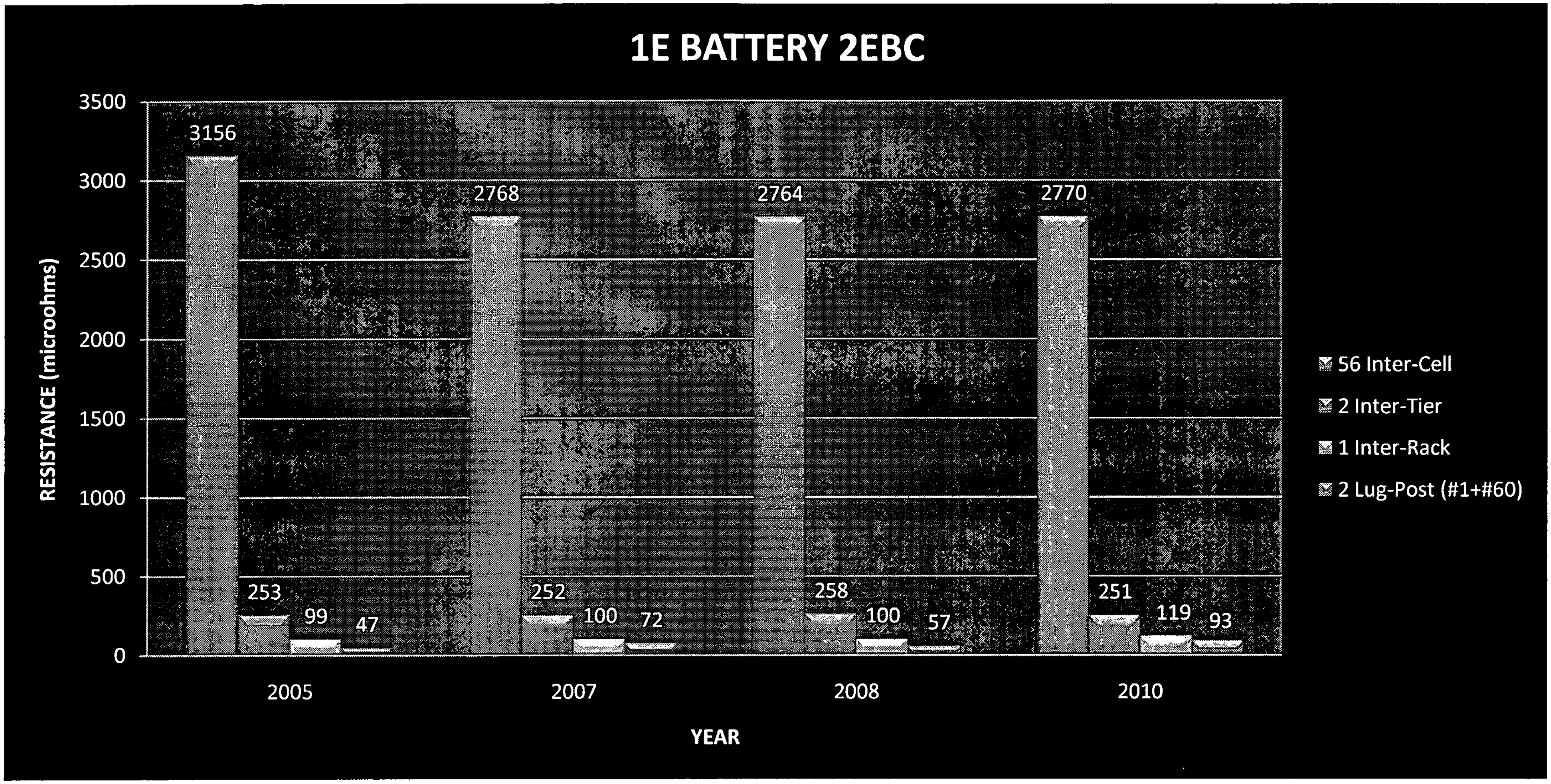
Attachment 6



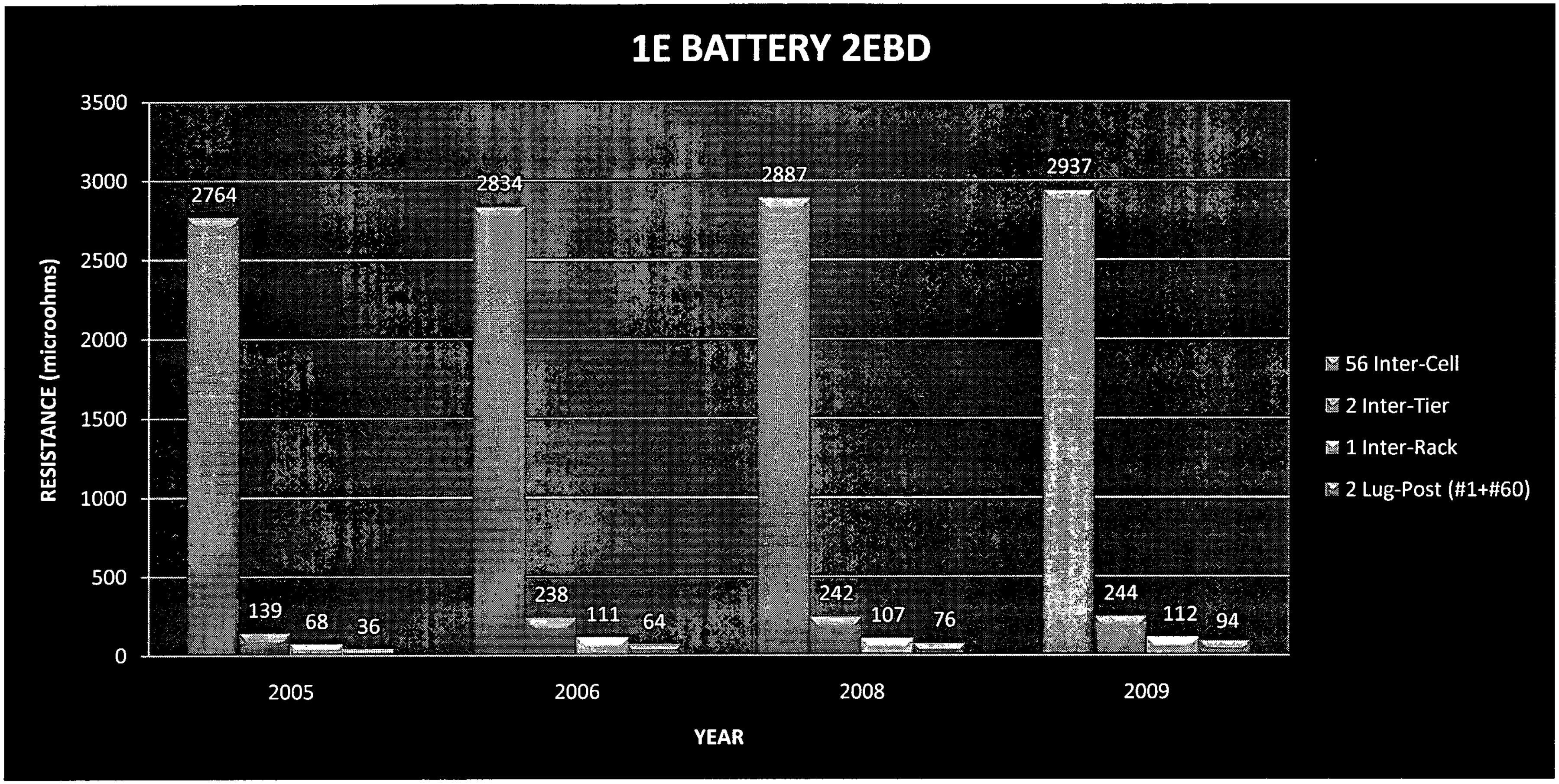
Attachment 7



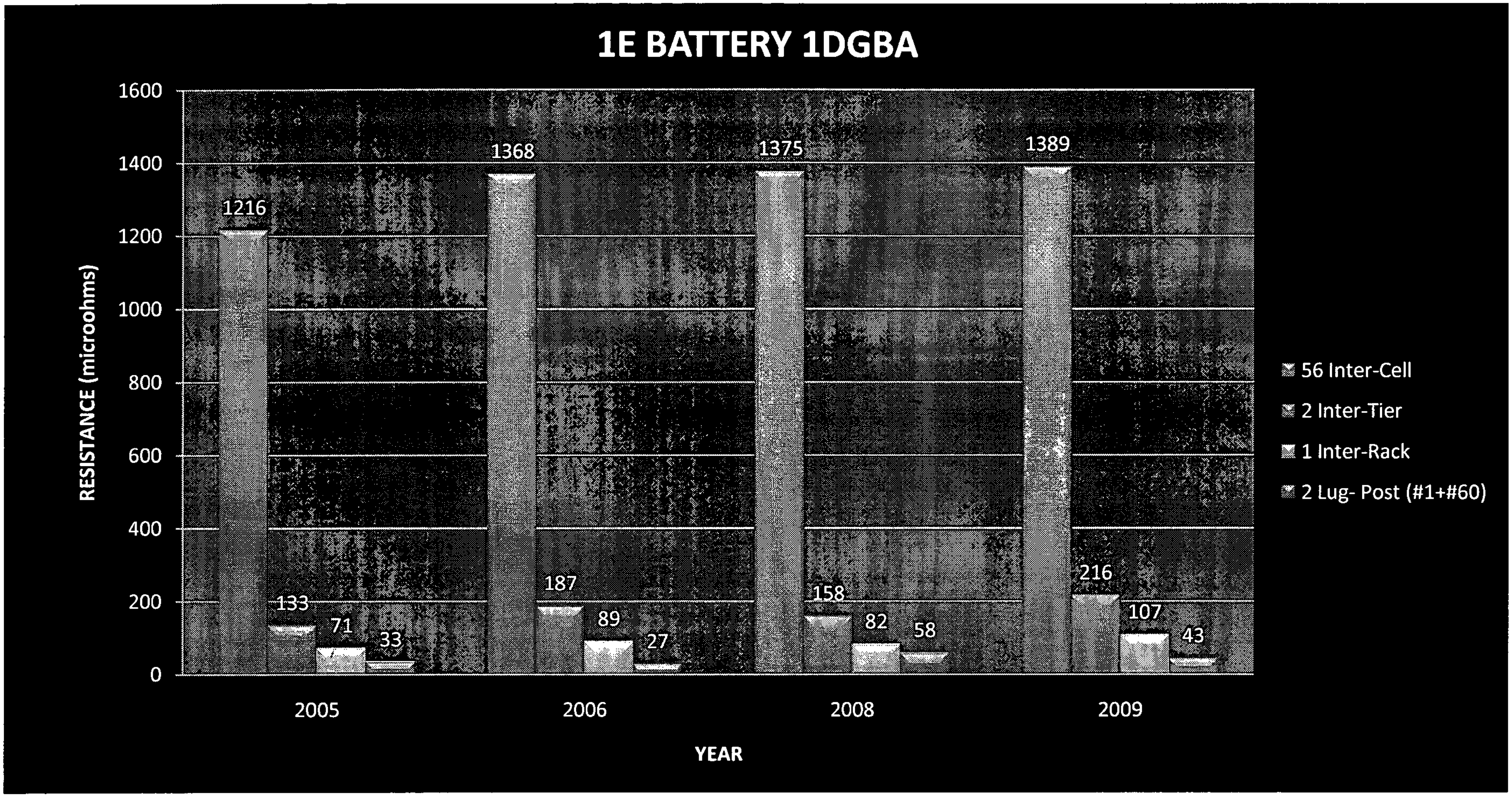
Attachment 8



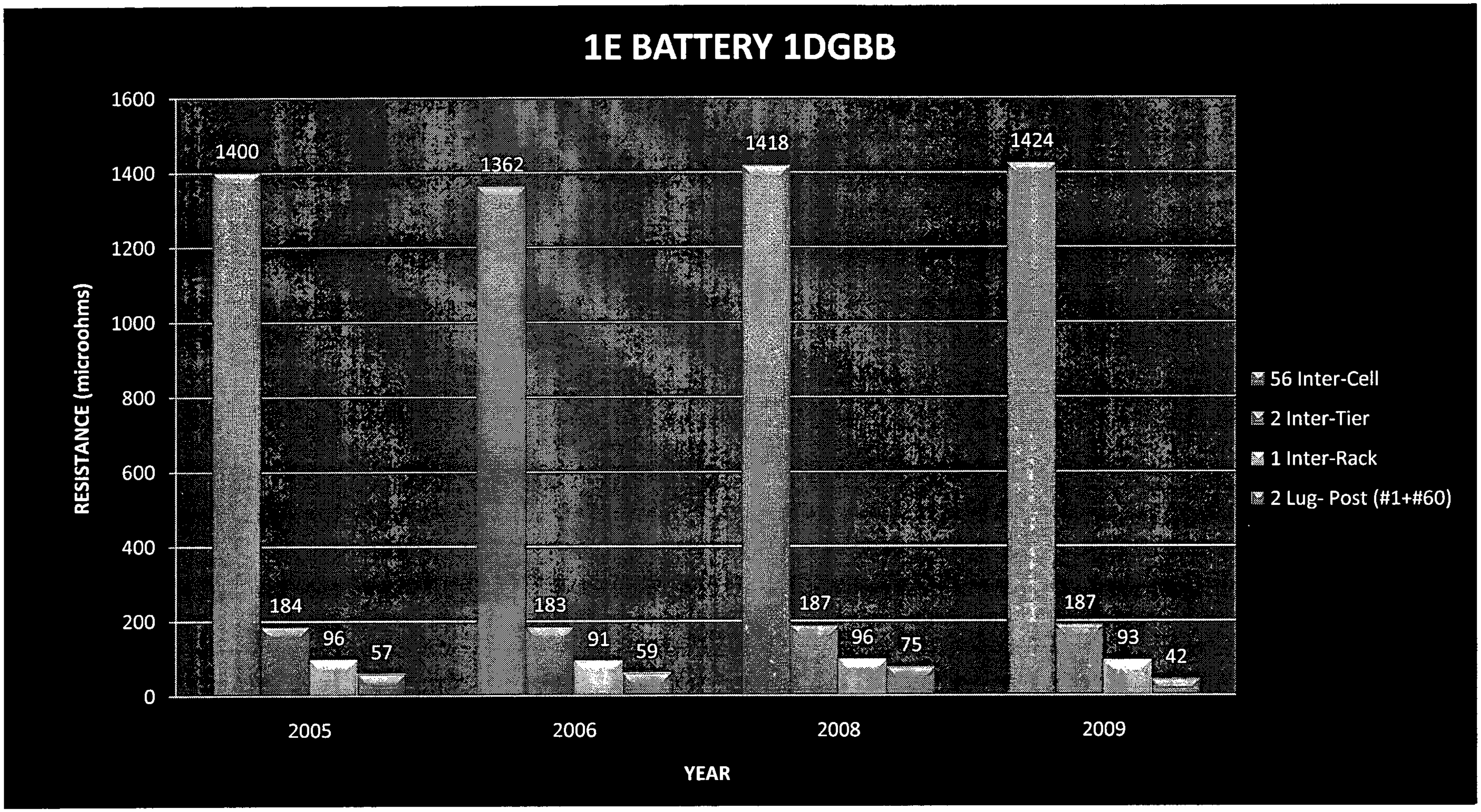
Attachment 9



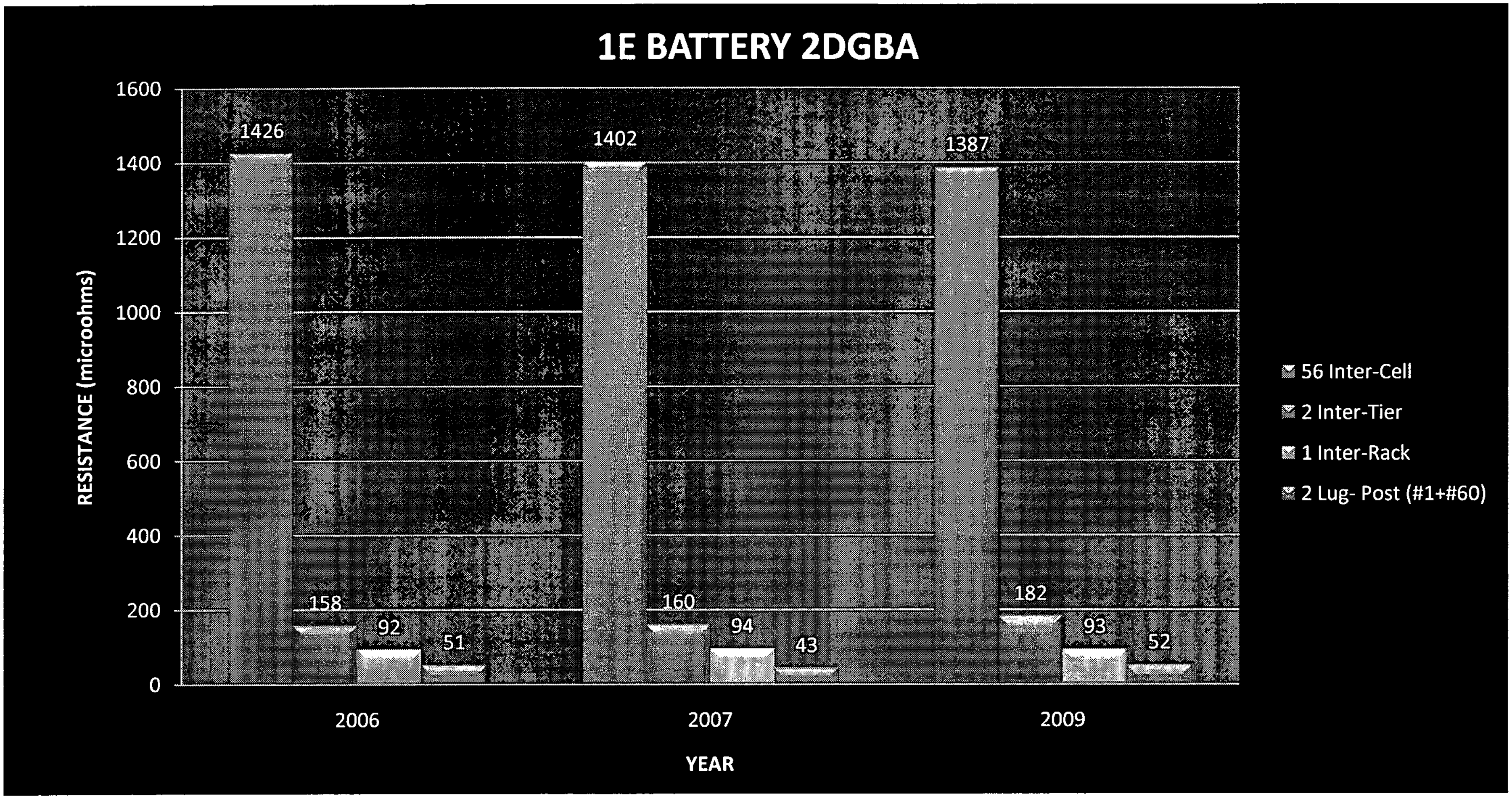
Attachment 10



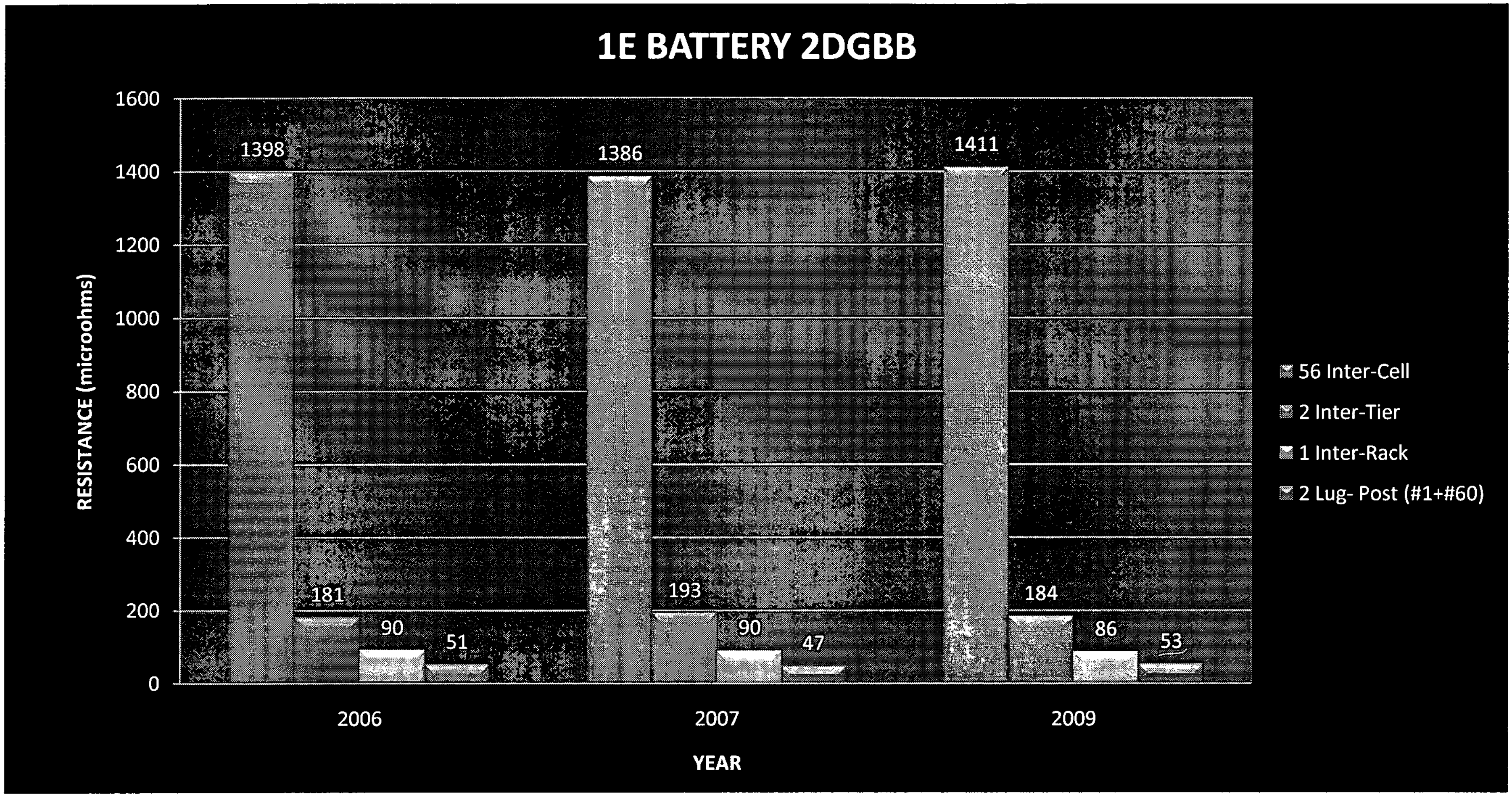
Attachment 11



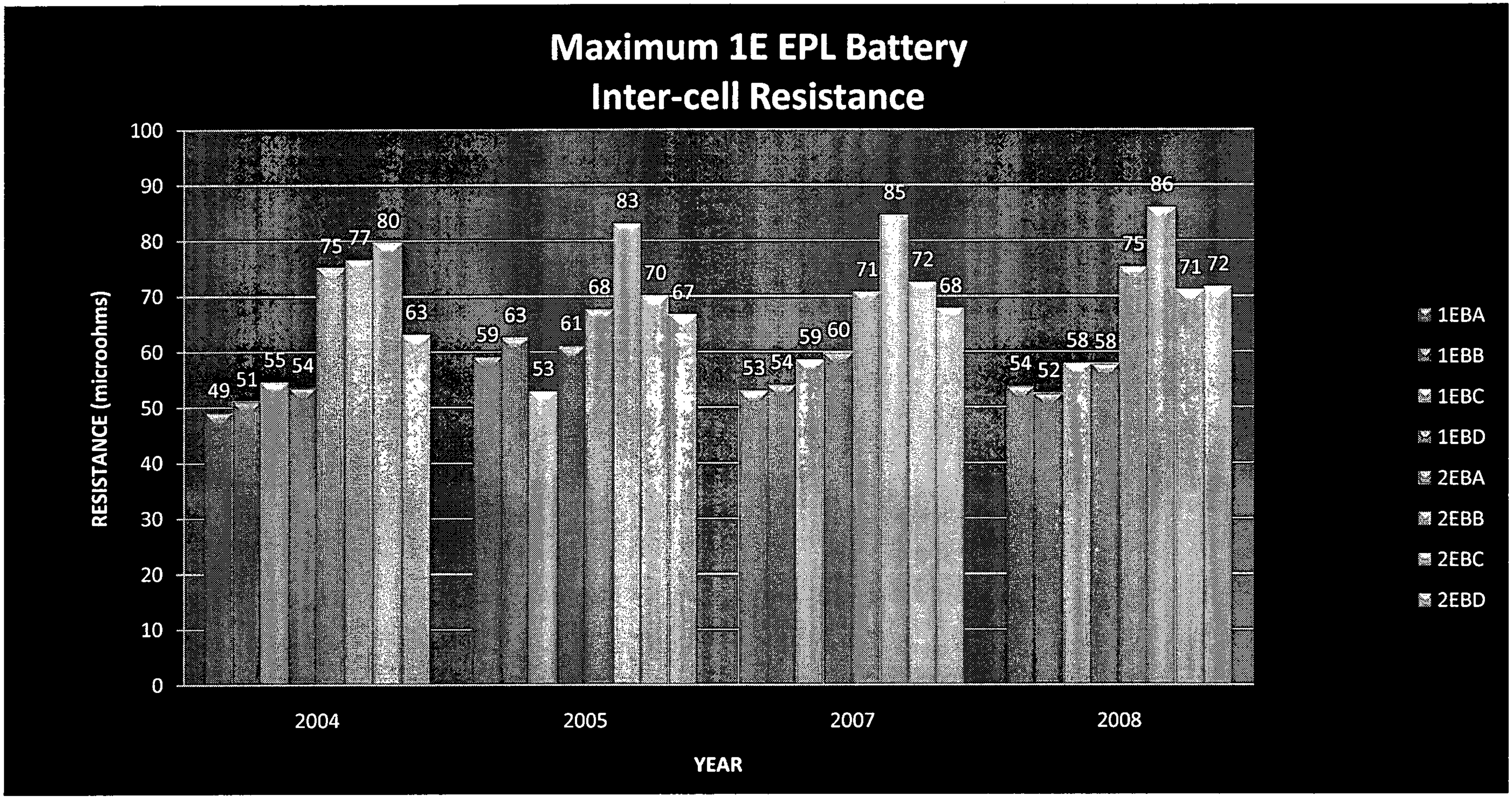
Attachment 12



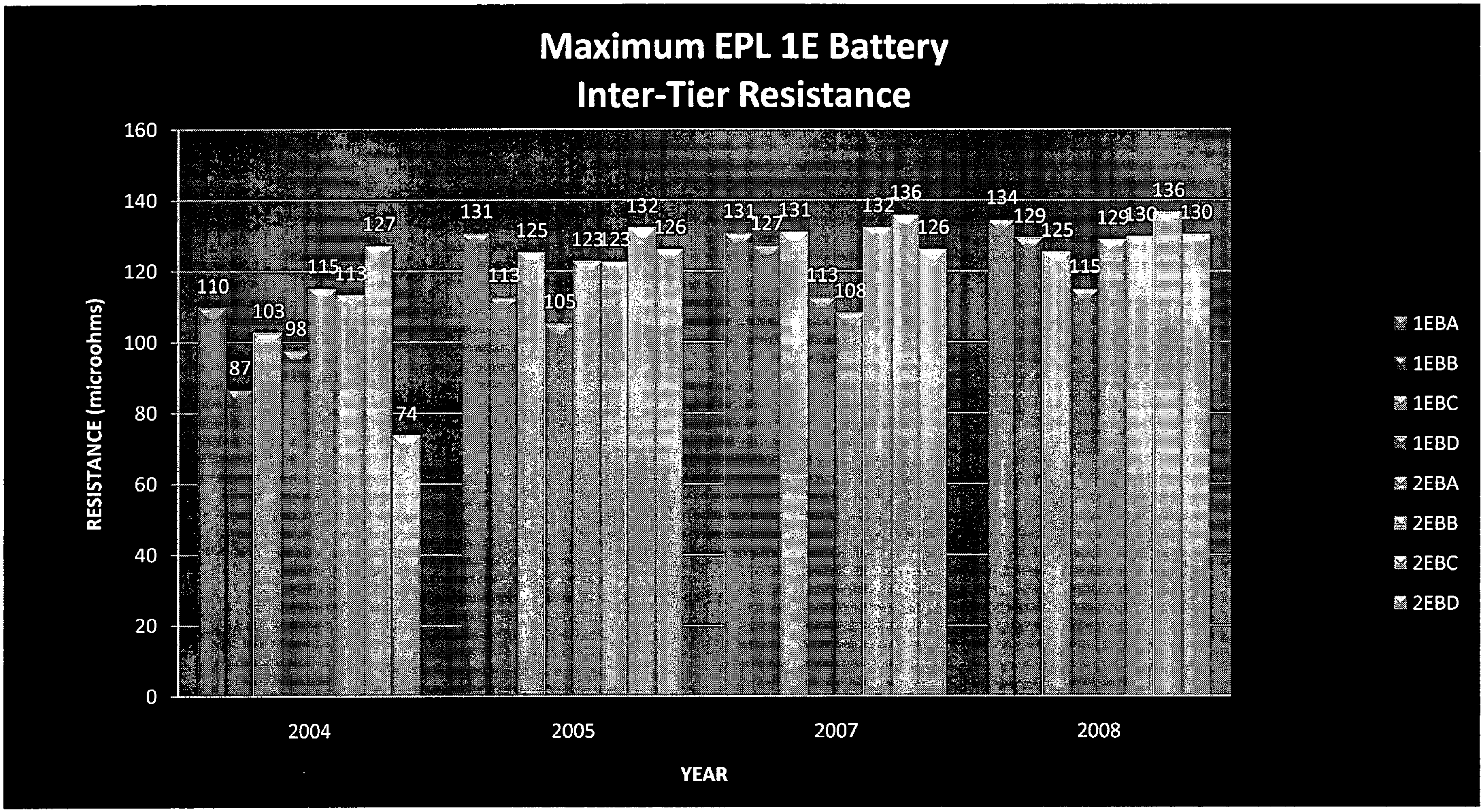
Attachment 13



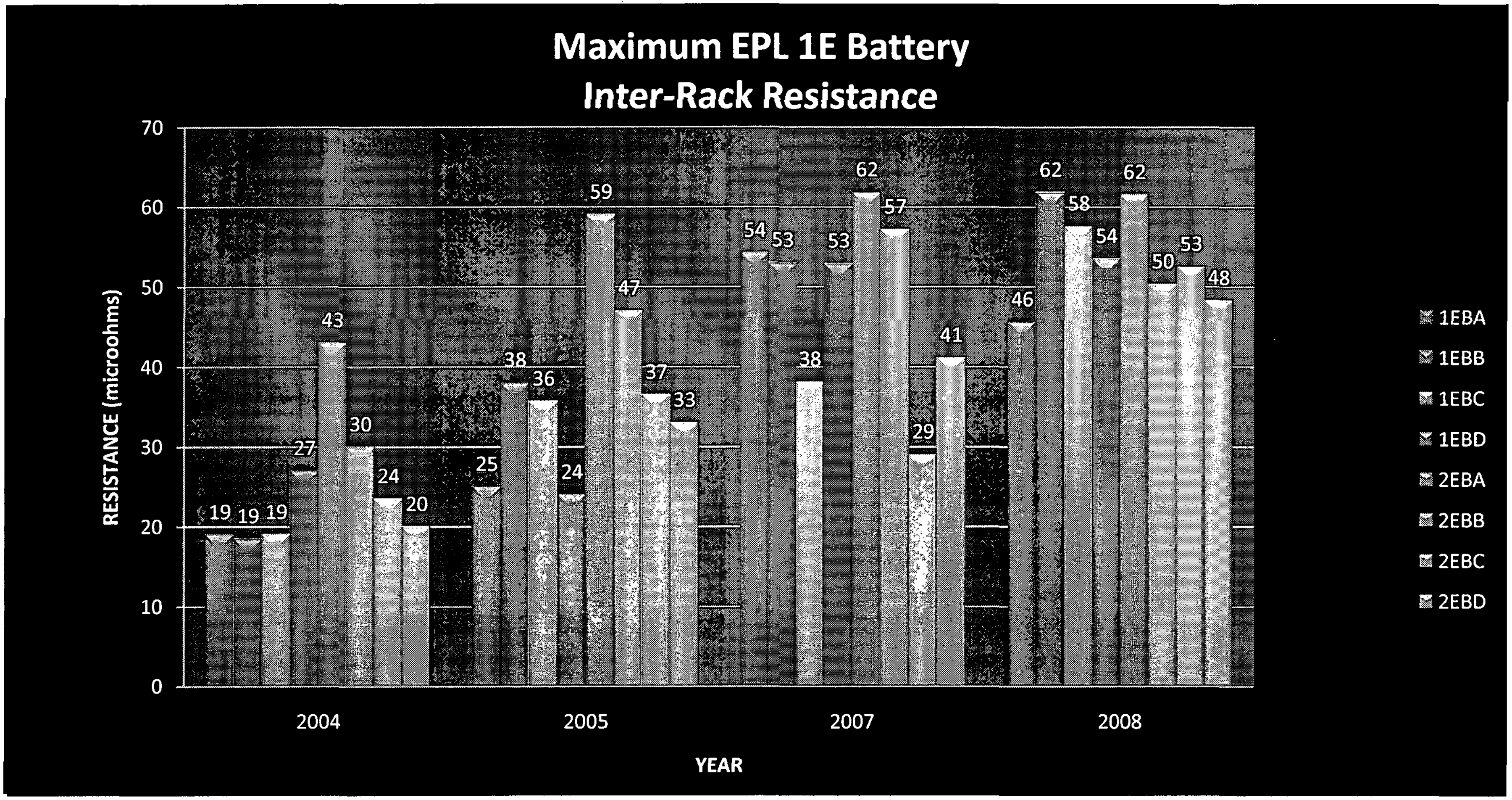
Attachment 14



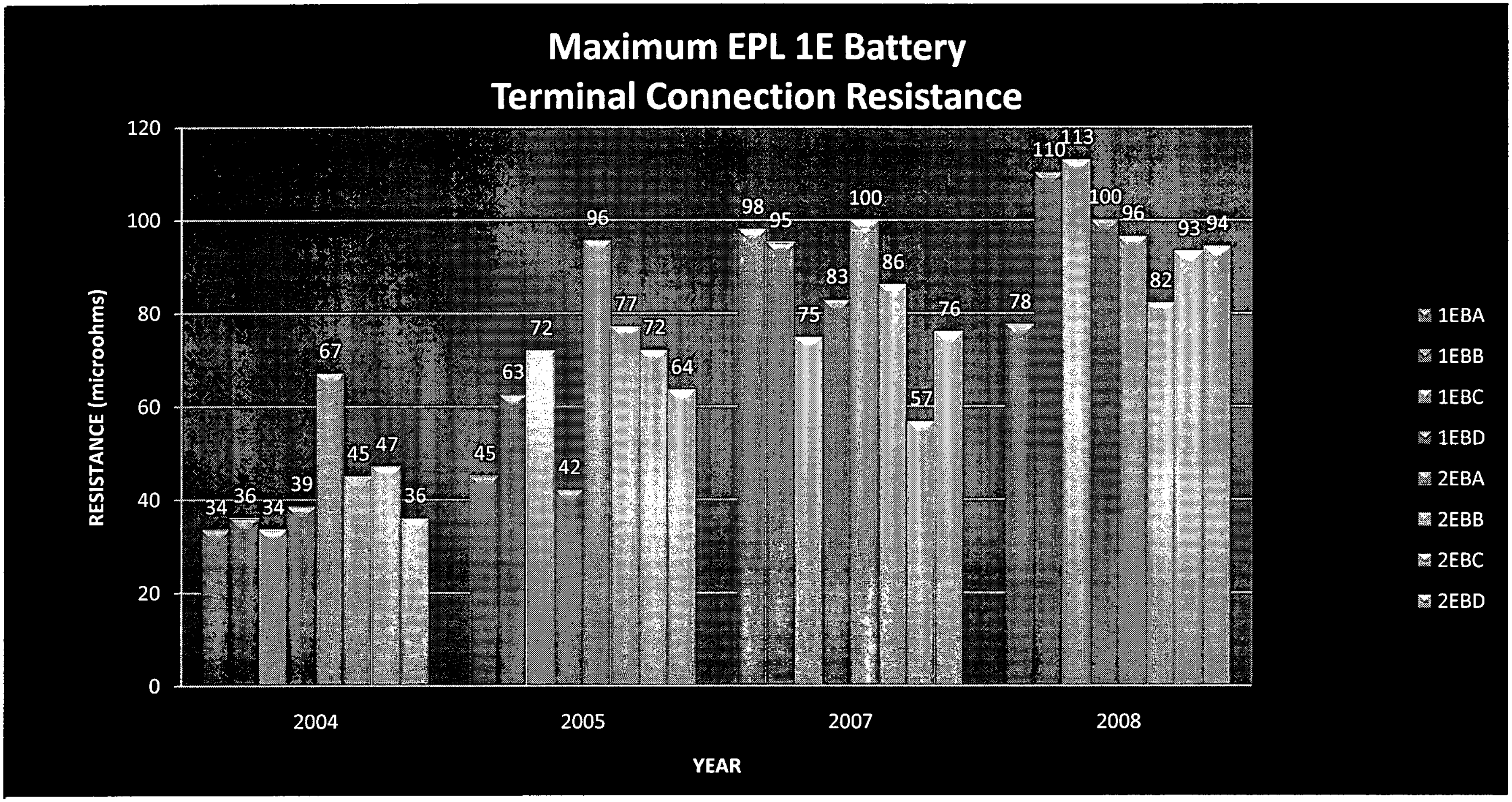
Attachment 15



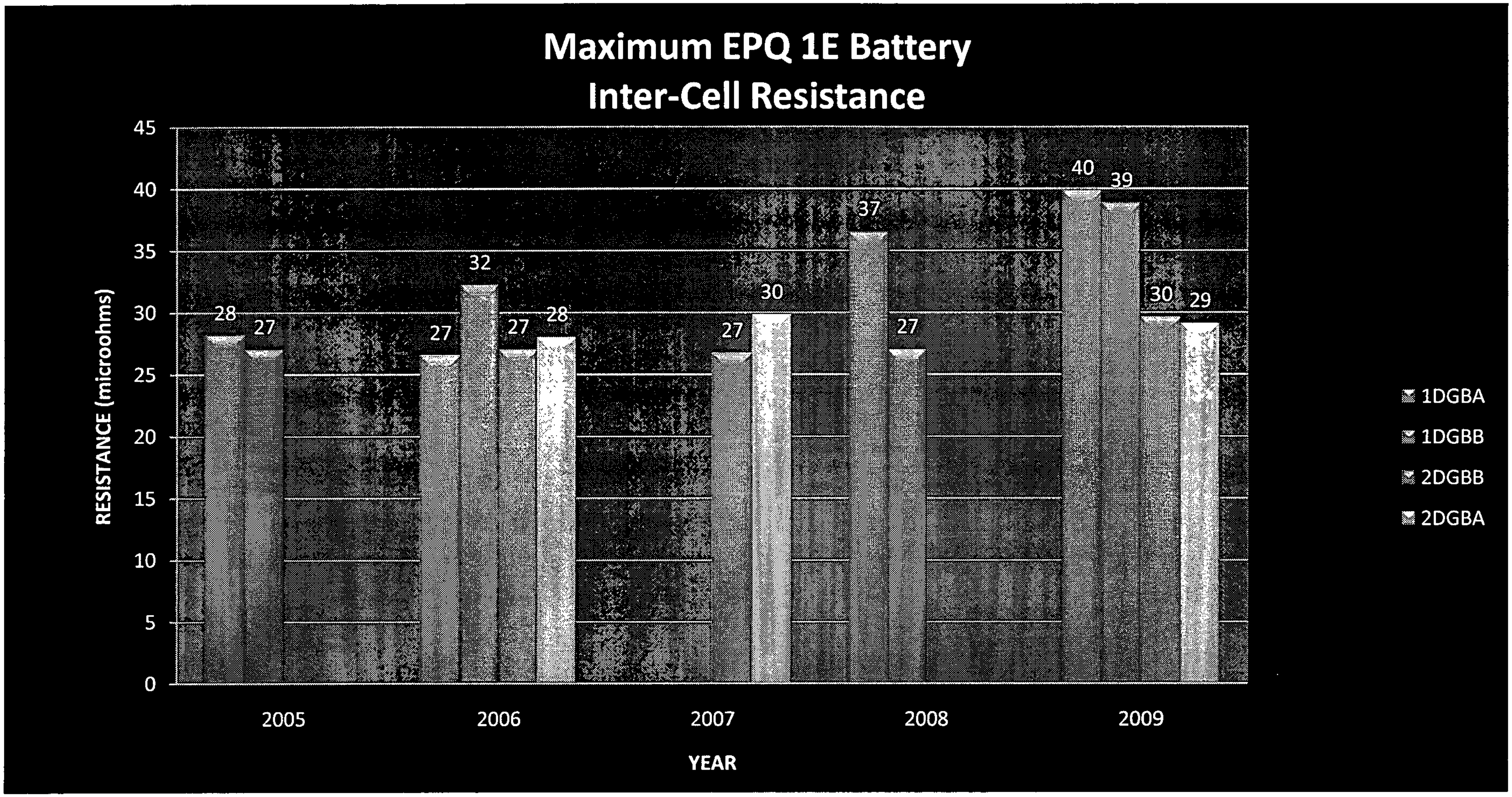
Attachment 16



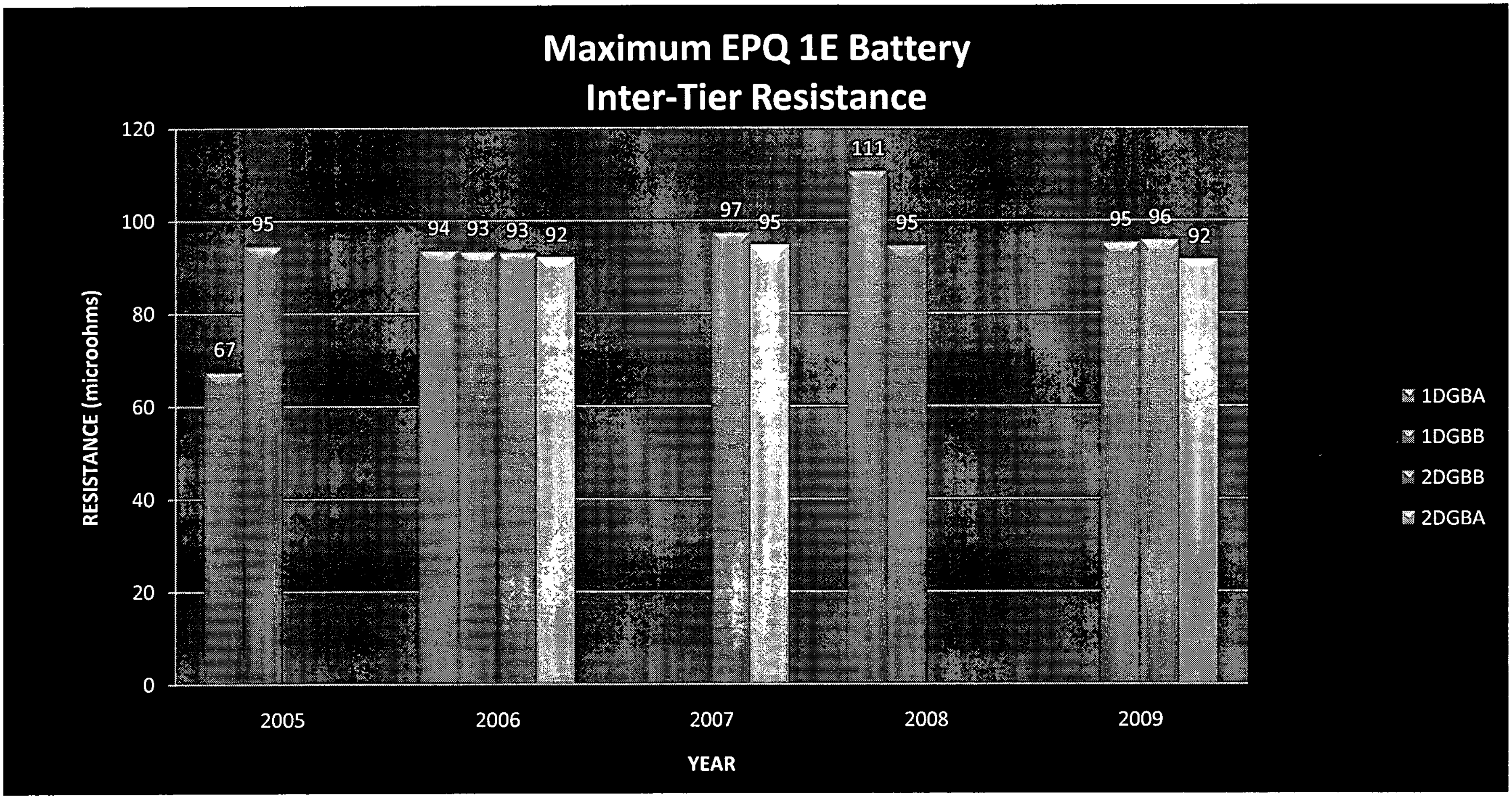
Attachment 17



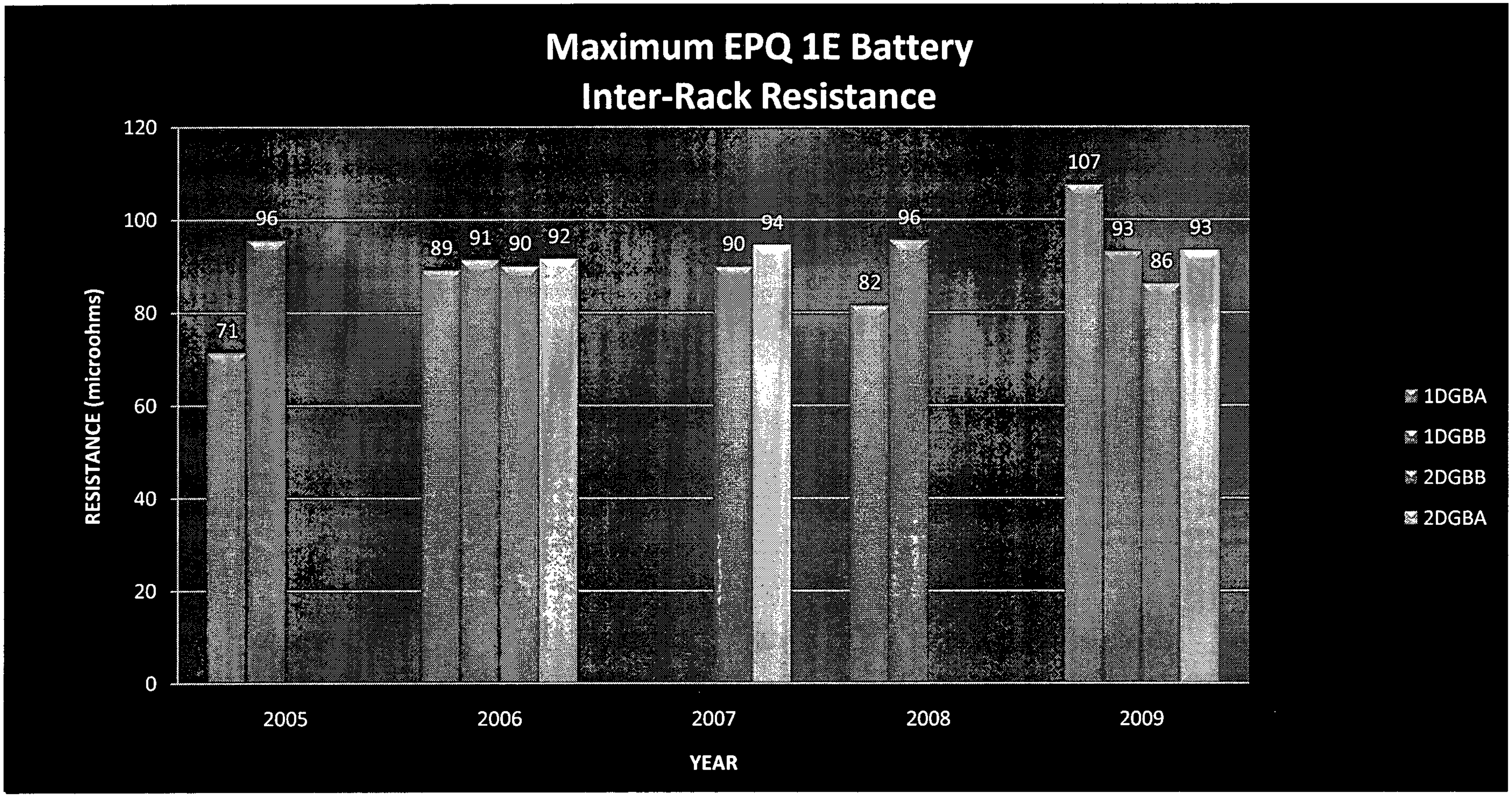
Attachment 18



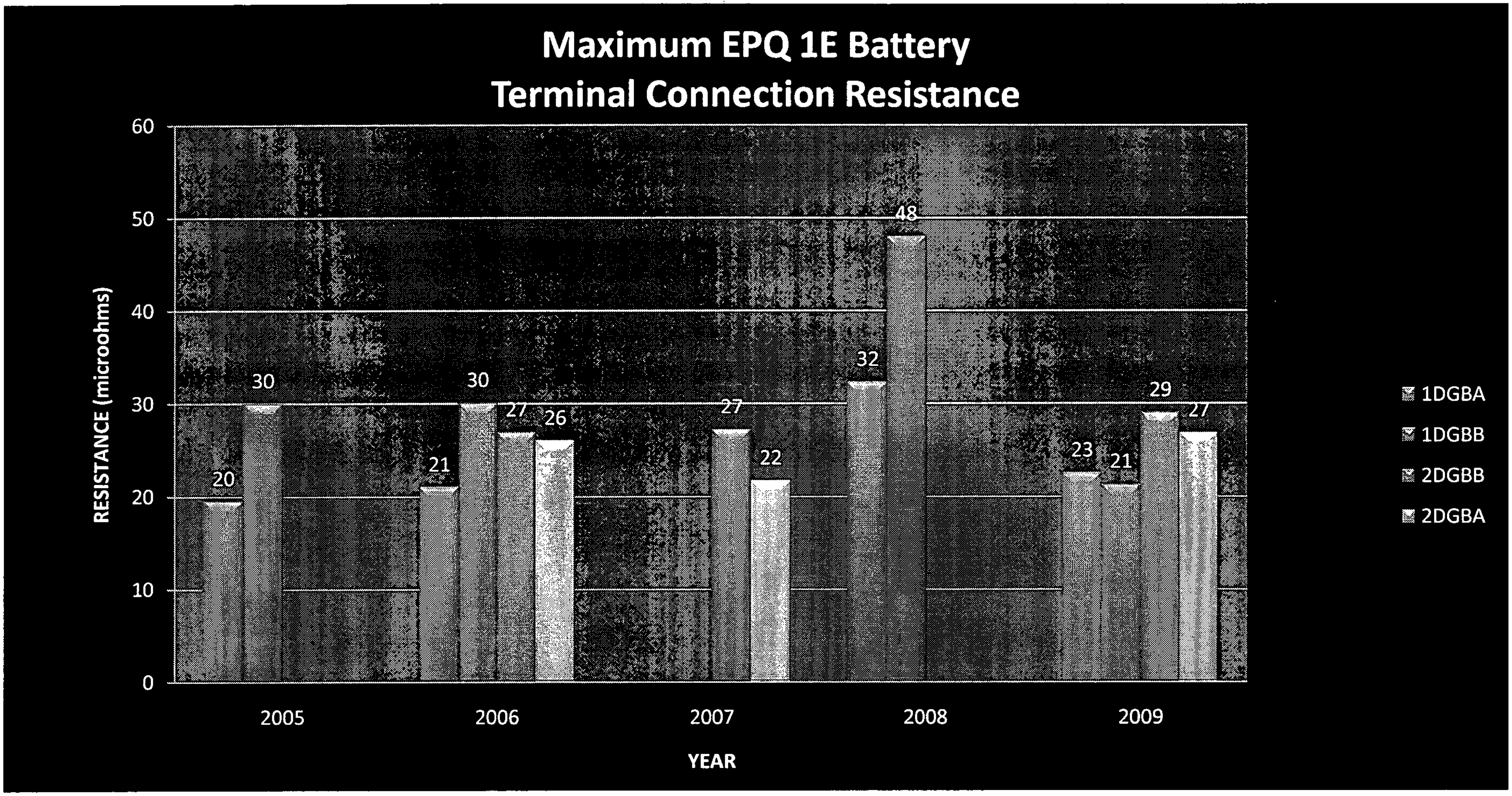
Attachment 19



Attachment 20



Attachment 21



Attachment 22

Enclosure 3

LAR Applicable to TS 3.8.4
For MNS and CNS

List of Commitments

Commitment	Commitment Date
McGuire will include a definition and details for new parameter "Average Intercell Connection Resistance Limit" from TS Table 3.8.4-1 in the TS Bases for SRs 3.8.4.4 and 3.8.4.5.	Upon implementation of the NRC approved License Amendment to revise TS 3.8.4 dated December 14, 2009.
Catawba will include a definition and details for new parameter "Average Intercell Connection Resistance Limit" from new TS Table 3.8.4-1 in the TS Bases for SRs 3.8.4.5 and 3.8.4.6.	Upon implementation of the NRC approved License Amendment to revise TS 3.8.4 dated December 14, 2009.