INSULATION RESISTANCE TESTING

IES AVIATION LIGHTING COMMITTEE
85TH ANNUAL FALL CONFERENCE - 2014

PRESENTED BY: CARL JOHNSON ©
2014

IES ALC
ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE

AVCON


Megger
A Guide To Diagnostic Insulation Testing Above 1 kV
IES
AVIATION LIGHTING COMMITTEE
"A Stitch in Time..."
The Complete Guide to Electrical Insulation Testing
Featuring
MEGGER®
Insulation Testers
"A Stitch in Time..."
The Complete Guide to Electrical Insulation Testing
Megger
Fluke Education Partnership Program

INSULATION RESISTANCE TESTING RESOURCES

A STITCH IN TIME - A COMPREHENSIVE GUIDE TO ELECTRICAL INSULATION TESTING - CONTAINS HELPFUL DIAGRAMS, TABLES AND APPLICATIONS.

A GUIDE TO DIAGNOSTIC INSULATION TESTING ABOVE 1KV - A BOOKLET CONTAINING GUIDELINES FOR INSULATION TESTING ABOVE 1 KV.

http://www.biddlemegger.com/cgi-bin/webshop.cgi?config=ent-apps

WHY TEST?

AC 150/5340-26C PART 5.1.3.1 STATES

“PERFORMING REGULAR PREVENTATIVE MAINTENANCE CHECKS ON AIRFIELD LIGHTING CIRCUITS IS ABSOLUTELY NECESSARY FOR RELIABLE OPERATION OF THE SYSTEM

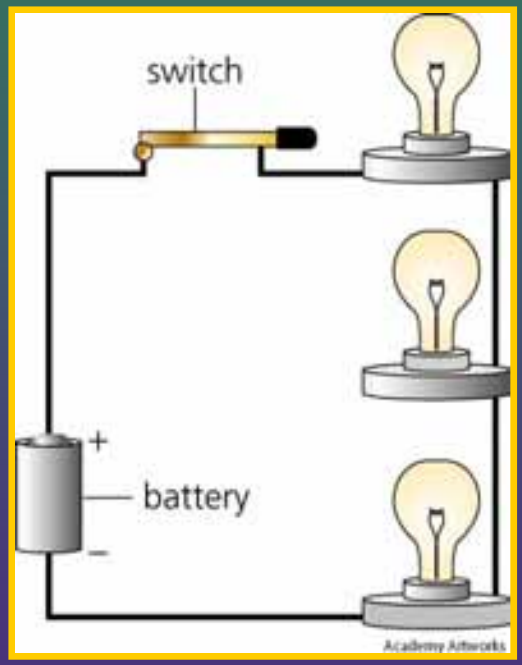
…… goes on to say….

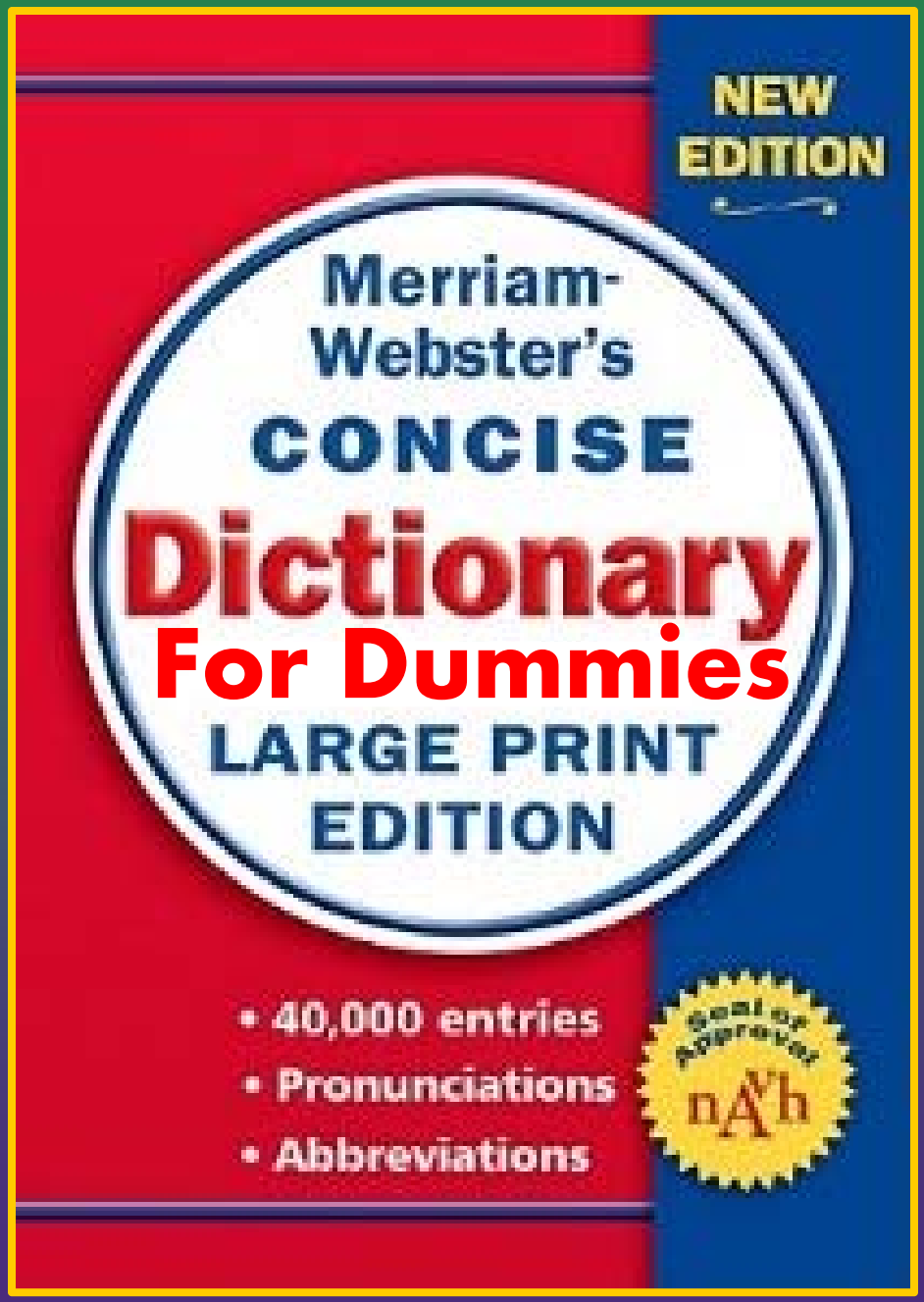
PERFORM INSULATION RESISTANCE TESTS ON ALL AIRFIELD CIRCUITS ON A MONTHLY BASIS AS A MINIMUM.” MORE OFTEN AS NEEDED.

MANY POTENTIAL FAILURES CAN BE FOUND DURING DAYLIGHT HOURS BY PERFORMING PM.

BACK TO THE BASICS

- RESISTANCE.
- OHM'S LAW.
- INSULATION.
- CAPACITANCE.




NEW EDITION
Merriam-Webster's
CONCISE
Dictionary
For Dummies
LARGE PRINT EDITION
• 40,000 entries
• Pronunciations
• Abbreviations
seal of approval
nAVh

MERRIAM WEBSTER CONCISE DICTIONARY FOR DUMMIES

DEFINITION 1

LOVE IS OUR RESISTANCE?

MERRIAM WEBSTER CONCISE DICTIONARY FOR DUMMIES

DEFINITION 2

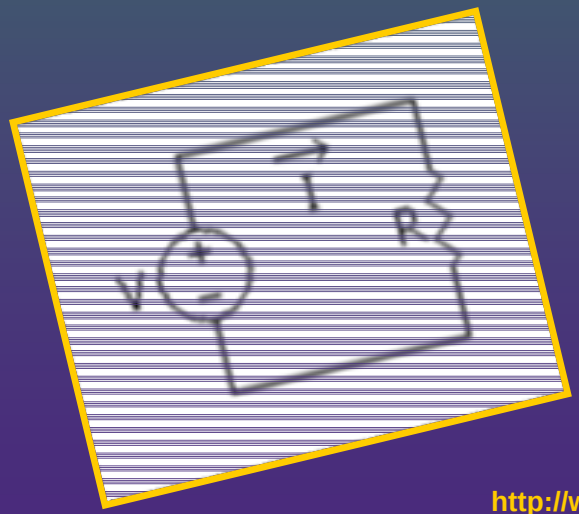
RESISTANCE IS FUTILE

MERRIAM WEBSTER CONCISE DICTIONARY FOR DUMMIES

DEFINITION 3

NOUN 3. ELECTRICAL RESISTANCE

A MATERIAL'S OPPOSITION TO THE FLOW OF ELECTRIC CURRENT; MEASURED IN OHMS.

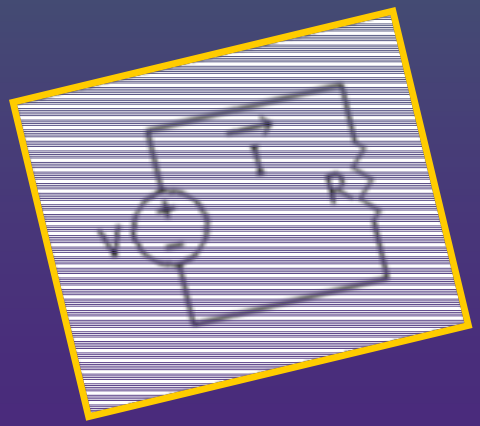


http://www.thefreedictionary.com/Resistance+(electricity)

MERRIAM WEBSTER CONCISE DICTIONARY FOR DUMMIES

Definition 3

THE OHM IS EQUAL TO THE RESISTANCE OF A CIRCUIT IN WHICH IN WHICH A POTENTIAL DIFFERENCE OF ONE VOLT PRODUCES A CURRENT OF ONE AMPERE.



MERRIAM WEBSTER CONCISE DICTIONARY FOR DUMMIES

Definition 3

- RESISTANCE IS USED TO CONTROL THE AMOUNT OF CURRENT FLOWING IN A CIRCUIT.
- ALSO TO KEEP THE CURRENT CONTAINED WITHIN THE CONDUCTOR.
- THE UNIT OF RESISTANCE IS THE OHM.
- THE SYMBOL USED TO REPRESENT RESISTANCE IS THE GREEK LETTER OMEGA: Ω

INSULATION 101

NFPA 70B

RECOMMENDED PRACTICE FOR ELECTRICAL EQUIPMENT MAINTENANCE, 2013

Part 11.9.1.1 states: "INSULATION is the material between points of different potential in an electrical system that prevents the flow of electricity between those points."

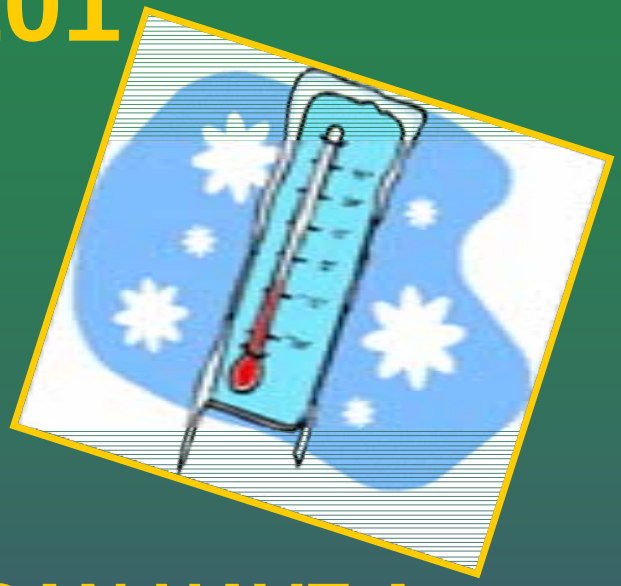
INSULATION 101

- THERE ARE NO PERFECT INSULATIONS / INSULATORS.
- HIGH VOLTAGES PRODUCE CURRENTS IN INSULATORS.
- ALL INSULATORS LEAK, BECAUSE ALL INSULATING MATERIALS CONDUCT SOME CURRENT, HOWEVER SMALL.

INSULATION 101

- **THE AMOUNT OF LEAKAGE CURRENT DEPENDS ON:**
  - **APPLIED VOLTAGE (OHM'S LAW).**
  - **SYSTEM CAPACITANCE.**
  - **TOTAL RESISTANCE.**
  - **TEMPERATURE OF MATERIAL.**

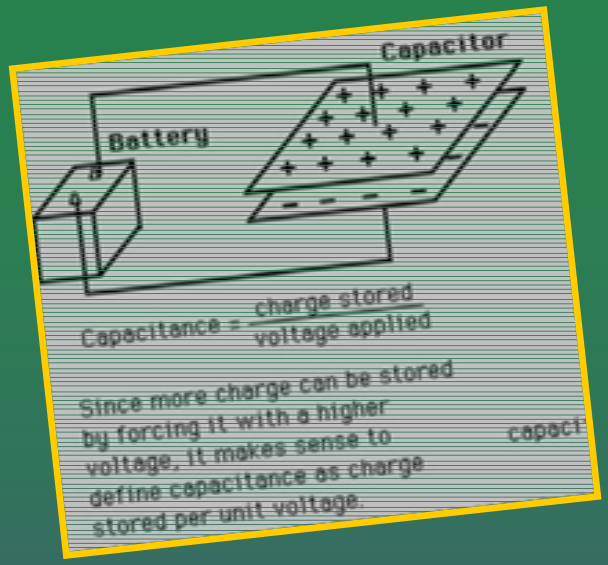
INSULATION 101



- TEMPERATURE VARIATIONS CAN HAVE A SIGNIFICANT EFFECT ON INSULATION RESISTANCE READINGS.
- EACH TYPE OF INSULATING MATERIAL HAS A DIFFERENT DEGREE OF RESISTANCE CHANGE WITH TEMPERATURE.

INSULATION 101

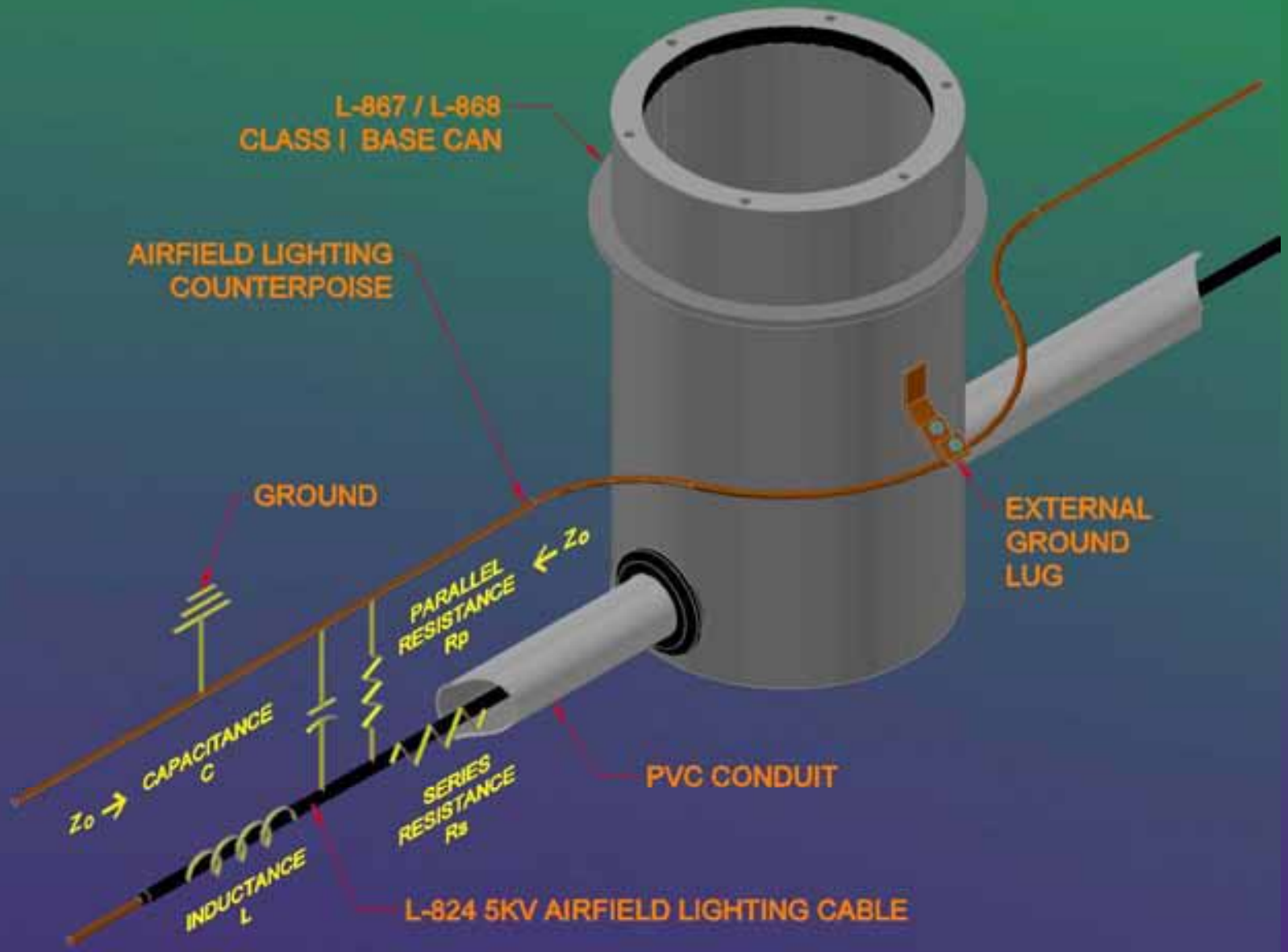
- TEMPERATURE CORRECTION TABLES HAVE BEEN DEVELOPED FOR THE VARIOUS INSULATION TYPES.
- "RULE OF THUMB"
  - FOR EVERY 10^0C INCREASE IN TEMPERATURE HALF THE RESISTANCE.
  - FOR EVERY 10^0C DECREASE IN TEMPERATURE DOUBLE THE RESISTANCE.
- TEMPERATURE AND INSULATION RESISTANCE ARE INVERSELY PROPORTIONAL.



CAPACITANCE 101

- THE ABILITY TO ACCUMULATE / RECEIVE CHARGE FROM THE CIRCUIT AND TO GIVE IT BACK TO THE CIRCUIT.
- NEGATIVE CHARGE – EXCESS OF ELECTRONS.
- POSITIVE CHARGE – DEFICIENCY OR LACK OF ELECTRONS.

EQUIVALENT CIRCUIT OF A GOOD CABLE

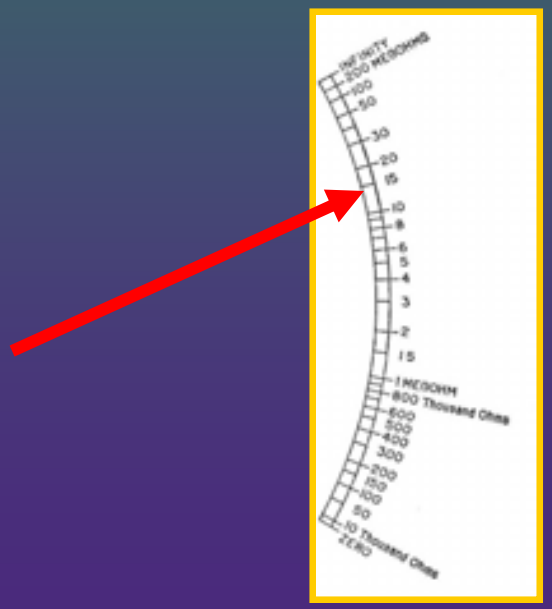


WHAT IS AN INSULATION TESTER?

- AN INSULATION TESTER IS A PORTABLE INSTRUMENT THAT PROVIDES A DIRECT READING OF INSULATION RESISTANCE IN OHMS, KILOHMS, MEGOHMS, GIGAOHMS OR TERAOHMS.
  - KILOHMS (KΩ) = 1,000 or 10^3 OHMS.
  - MEGOHMS (MΩ) = 1,000,000 or 10^6 OHMS.
  - GIGAOHMS (GΩ) = 1,000,000,000 or 10^9 OHMS.
  - TERAOHMS (TΩ) = 1,000,000,000,000 or 10^{12} OHMS.
- BASICALLY IT IS A VERY HIGH-RANGE OHMMETER.

WHAT IS THE PURPOSE OF AN INSULATION RESISTANCE TEST?

THE PURPOSE OF AN INSULATION RESISTANCE TEST IS TO EVALUATE THE CONDITION OF THE INSULATION BETWEEN CONDUCTORS OR BETWEEN CONDUCTORS AND GROUND.



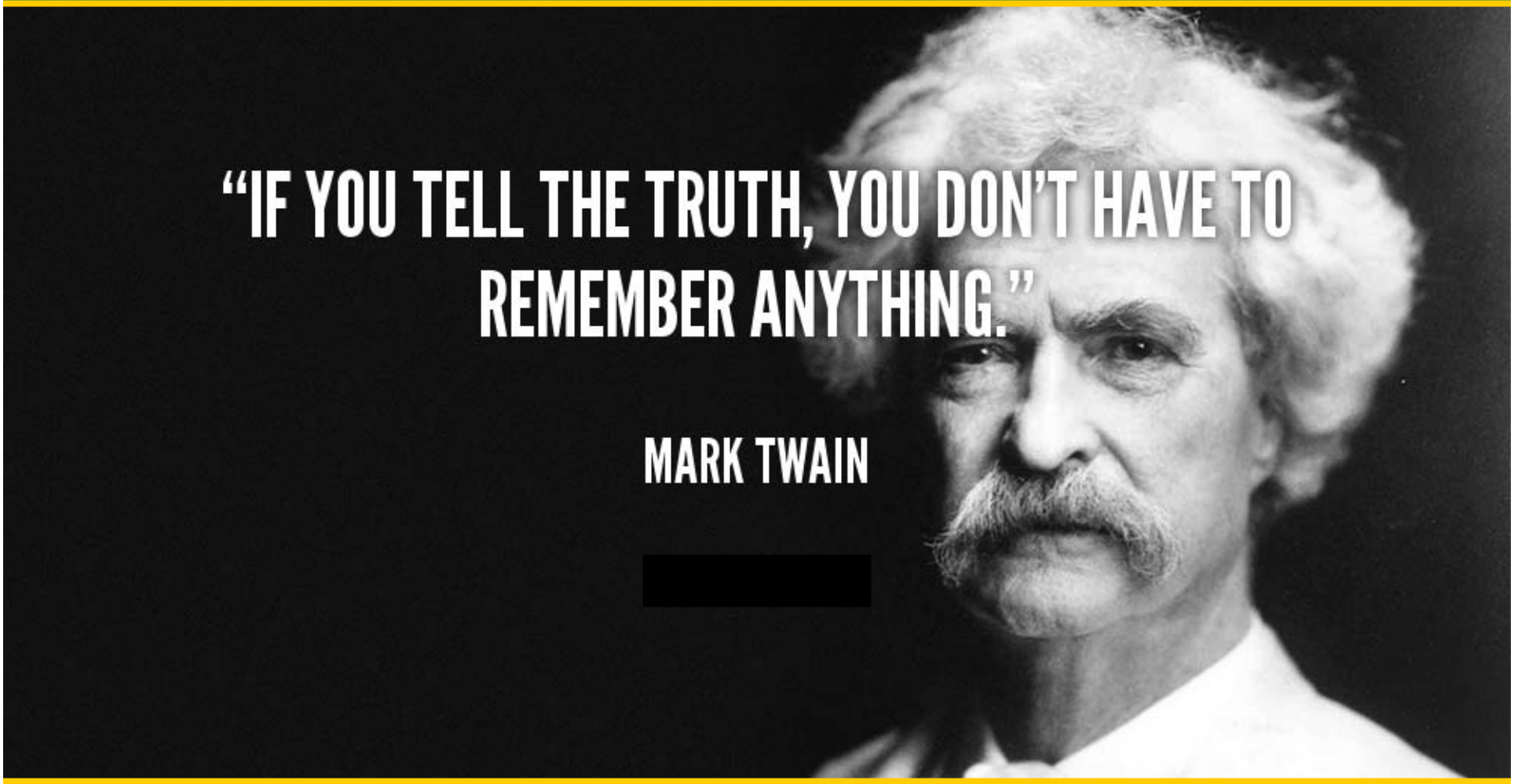
IN SUMMARY, THE INSULATION RESISTANCE TESTER USES THE APPLIED DC VOLTAGE (V_{DC}) DIVIDED BY THE TOTAL CURRENT (I_T) AND PROVIDES A DIRECT READOUT IN OHMS, KILOHMS, MEGOHMS OR GIGAOHMS.

TYPICAL IR TEST

- SIMPLE TEST.
- TEST VOLTAGE APPLIED FOR A SHORT SPECIFIC TIME PERIOD.
  - TYPICALLY 60 TO 120 SECONDS.
- RESULTS COMPARED TO MINIMUM ACCEPTABLE VALUES.
- RECORDED RESULTS USED FOR TRENDING.

TYPICAL IR TEST

- PROS -
  - QUICKLY AND EASILY PERFORMED.
  - BEST WHEN TRENDED AGAINST OTHER PREVIOUSLY OBTAINED VALUES.
- CONS –
  - BY ITSELF THE READING IS NOT VERY USEFUL (unless troubleshooting).
  - TEMPERATURE AND HUMIDITY EFFECT READINGS.
  - VALUE MUST BE TEMPERATURE CORRECTED.


“IF YOU TELL THE TRUTH, YOU DON’T HAVE TO REMEMBER ANYTHING.”
MARK TWAIN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DEODORANT
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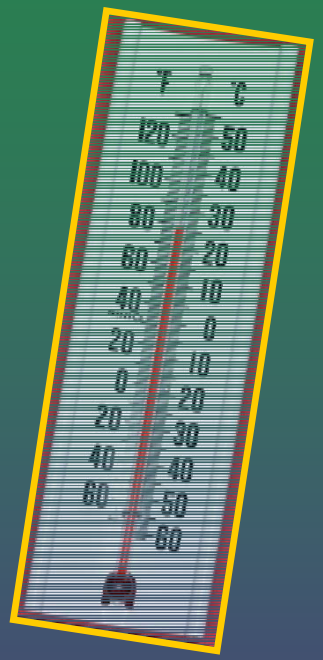
EFFECTS OF TEMPERATURE

TEMPERATURE AND RESISTANCE ARE INVERSELY PROPORTIONAL.



“RULE OF THUMB”

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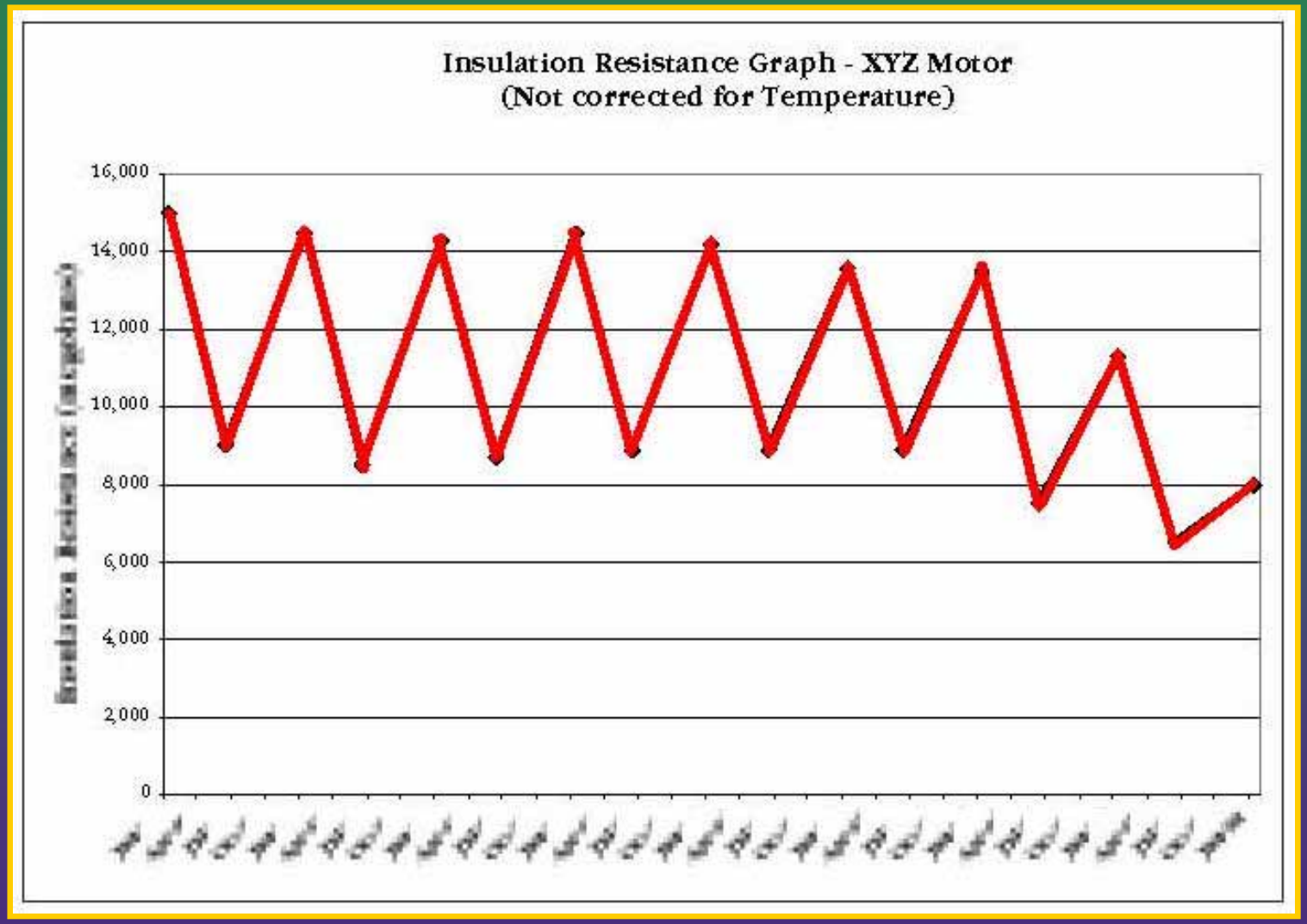
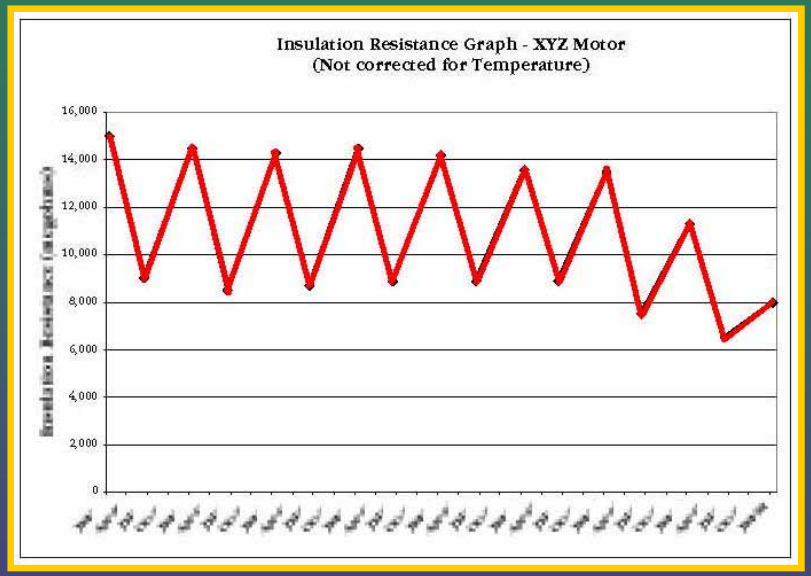
EFFECTS OF TEMPERATURE



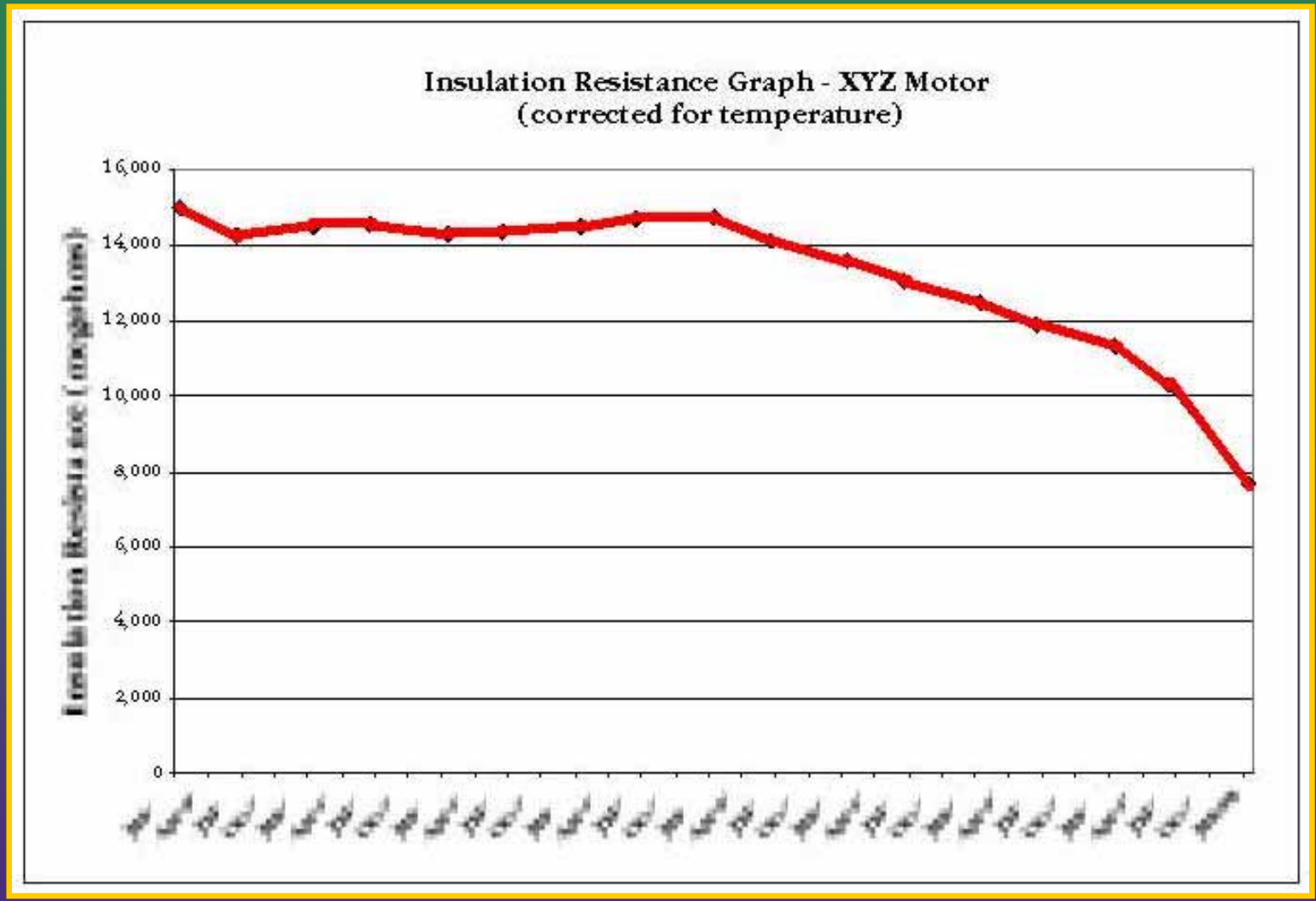
EFFECTS OF TEMPERATURE

Date	Insulation Resistance (MΩ)	Temperature °F	Temp. Adjusted Insulation Resistance (MΩ)
Jan-90	15,000	68	14,990
Jun-90	9,000	80	14,276
Jan-91	14,500	68	14,490
Jun-91	8,500	82	14,562
Jan-92	14,300	68	14,290
Jun-92	8,700	81	14,341
Jan-93	14,500	68	14,490
Jun-93	8,900	81	14,671
Jan-94	14,200	69	14,748
Jun-94	8,900	80	14,117
Jan-95	13,600	68	13,591
Jun-95	8,900	78	13,071
Jan-96	13,500	66	12,491
Jun-96	7,500	80	11,896
Jan-97	11,300	68	11,292
Jun-97	6,500	80	10,310
Jan-98	8,000	67	7,693



DO YOU SEE A TREND IN THE TEST RESULTS?

EFFECTS OF TEMPERATURE



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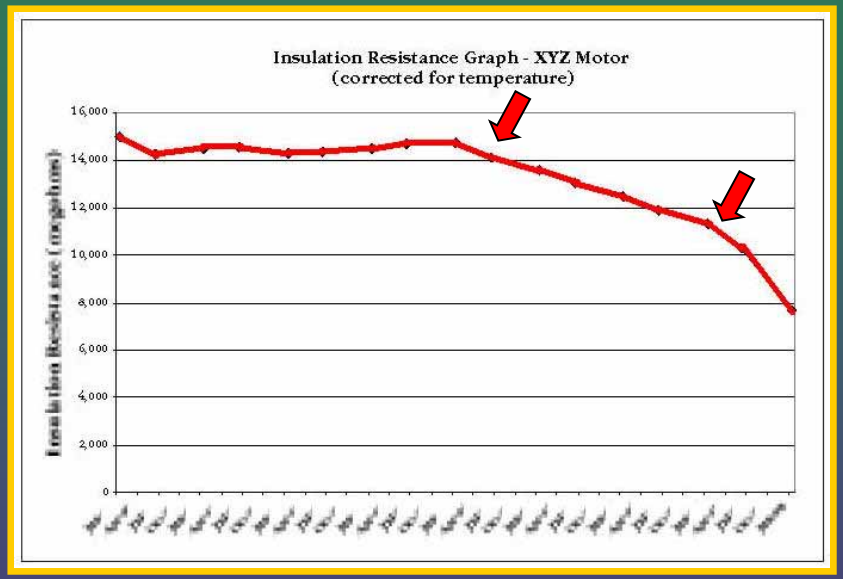

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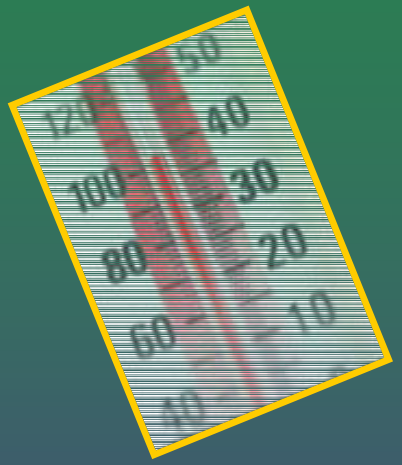
EFFECTS OF TEMPERATURE



BASE TEMPERATURE CORRECTION TO 60 DEGREES FAHRENHEIT.

TCF

Draka Cableteq Temperature Correction Factor Table For L-824B & L-824C Cables

Use Only This Column For All L-824B & L824C Cables Manufactured By Draka Cableteq.

Mean Number For All Calculations.

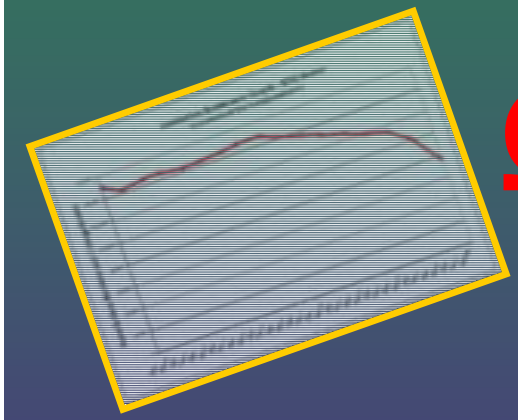
Table 2-2
TEMPERATURE CORRECTION FACTORS (TCF) FOR CONVERTING INSULATION RESISTANCE TO 15.6 °C

Temperature		1 °F Coefficient*									
°F	°C	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
40	4.4	0.55	0.46	0.38	0.31	0.26	0.22	0.18	0.15	0.12	0.10
41	5.0	0.57	0.48	0.40	0.33	0.28	0.23	0.19	0.16	0.14	0.12
42	5.6	0.59	0.49	0.42	0.35	0.30	0.25	0.21	0.18	0.15	0.13
43	6.1	0.60	0.51	0.44	0.37	0.32	0.27	0.23	0.20	0.17	0.15
44	6.7	0.62	0.53	0.46	0.39	0.34	0.29	0.25	0.22	0.19	0.16
45	7.2	0.64	0.56	0.48	0.42	0.36	0.32	0.28	0.24	0.21	0.18
46	7.8	0.66	0.58	0.50	0.44	0.39	0.34	0.30	0.26	0.23	0.20
47	8.3	0.68	0.60	0.53	0.47	0.42	0.37	0.33	0.29	0.26	0.23
48	8.9	0.70	0.62	0.56	0.50	0.44	0.40	0.36	0.32	0.29	0.26
49	9.4	0.72	0.65	0.59	0.53	0.48	0.42	0.39	0.35	0.32	0.29
50	10.0	0.74	0.68	0.61	0.56	0.51	0.46	0.42	0.39	0.35	0.32
51	10.6	0.77	0.70	0.64	0.59	0.54	0.50	0.46	0.42	0.39	0.36
52	11.1	0.79	0.73	0.68	0.63	0.58	0.54	0.50	0.47	0.43	0.40
53	11.7	0.81	0.76	0.71	0.67	0.62	0.58	0.55	0.51	0.48	0.45
54	12.2	0.84	0.79	0.75	0.70	0.67	0.63	0.60	0.56	0.54	0.51
55	12.8	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.59	0.57
56	13.3	0.89	0.86	0.82	0.79	0.76	0.74	0.71	0.68	0.66	0.64
57	13.9	0.92	0.89	0.86	0.84	0.82	0.79	0.77	0.75	0.73	0.71
58	14.4	0.94	0.93	0.91	0.89	0.87	0.86	0.84	0.83	0.81	0.80
59	15.0	0.97	0.96	0.94	0.95	0.94	0.93	0.92	0.91	0.90	0.89
60	15.6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
61	16.1	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
62	16.7	1.06	1.08	1.10	1.12	1.14	1.17	1.19	1.21	1.23	1.25
63	17.2	1.09	1.12	1.16	1.19	1.23	1.26	1.30	1.33	1.37	1.40
64	17.8	1.13	1.17	1.22	1.26	1.31	1.36	1.41	1.46	1.52	1.57
65	18.3	1.16	1.22	1.28	1.34	1.40	1.47	1.54	1.61	1.69	1.76
66	18.9	1.19	1.27	1.34	1.42	1.50	1.58	1.68	1.77	1.87	1.97
67	19.4	1.23	1.32	1.41	1.50	1.61	1.71	1.83	1.95	2.08	2.21
68	20.0	1.27	1.37	1.48	1.59	1.72	1.85	1.99	2.14	2.30	2.48
69	20.6	1.30	1.42	1.55	1.69	1.84	2.00	2.17	2.36	2.56	2.77
70	21.1	1.34	1.48	1.63	1.79	1.97	2.16	2.37	2.59	2.84	3.11
71	21.7	1.38	1.54	1.71	1.90	2.10	2.33	2.58	2.85	3.15	3.48
72	22.2	1.43	1.60	1.80	2.01	2.25	2.52	2.81	3.14	3.50	3.90
73	22.8	1.47	1.67	1.89	2.13	2.41	2.72	3.07	3.45	3.88	4.36
74	23.3	1.51	1.73	1.98	2.26	2.58	2.94	3.34	3.80	4.31	4.89
75	23.9	1.56	1.80	2.08	2.40	2.76	3.17	3.64	4.18	4.78	5.47
76	24.4	1.60	1.87	2.18	2.54	2.95	3.43	3.97	4.59	5.31	6.13
77	25.0	1.65	1.95	2.29	2.69	3.16	3.70	4.33	5.05	5.90	6.87
78	25.6	1.70	2.03	2.41	2.85	3.38	4.00	4.72	5.56	6.54	7.69
79	26.1	1.75	2.11	2.53	3.30	3.62	4.32	5.14	6.12	7.26	8.61
80	26.7	1.81	2.19	2.65	3.21	3.87	4.66	5.60	6.73	8.06	9.65
81	27.2	1.86	2.28	2.79	3.40	4.14	5.03	6.11	7.40	8.95	10.8
82	27.8	1.92	2.37	2.93	3.60	4.43	5.44	6.66	8.14	9.93	12.1
83	28.3	1.97	2.46	3.07	3.82	4.74	5.87	7.26	8.95	11.0	13.6
84	28.9	2.03	2.56	3.23	4.05	5.07	6.34	7.91	9.85	12.2	15.3
85	29.4	2.09	2.67	3.39	4.29	5.43	6.85	8.62	10.8	13.6	17.0

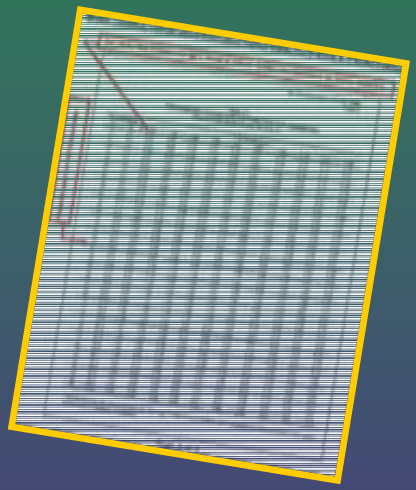
*Calculated from the following formula: $TCF=C_{tb}^{(t-60)}$ where C_{tb} is determined in accordance with 2.3.3 and t is the cable temperature in degrees Fahrenheit.

EFFECTS OF TEMPERATURE

THE INSULATION RESISTANCE READING IN OHMS ÷ TCF = TEMPERATURE CORRECTED INSULATION RESISTANCE.



Ω ÷ TCF = TCΩ



FOR EVERY 10^{0}C INCREASE IN TEMPERATURE HALF THE RESISTANCE.

FOR EVERY 10^{0}C DECREASE IN TEMPERATURE DOUBLE THE RESISTANCE.

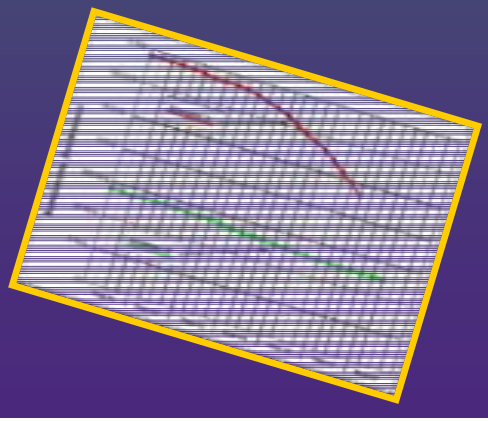
PRACTICAL APPLICATIONS

- THE “INFINITY” INDICATION IS A DELIGHT TO THE REPAIR TECHNICIAN, BUT REPRESENTS A VOID TO THE DIAGNOSTICIAN.
- INFINITY IS NOT A MEASUREMENT. IT IS AN INDICATION THAT THE INSULATION BEING TESTED HAS AN INSULATION RESISTANCE VALUE THAT EXCEEDS THE MEASURING CAPABILITIES OF THE TESTER.
- IT SHOULD BE RECORDED AS “GREATER THAN 1000 MΩ” OR HIGHEST AVAILABLE RANGE ON THE TESTER.

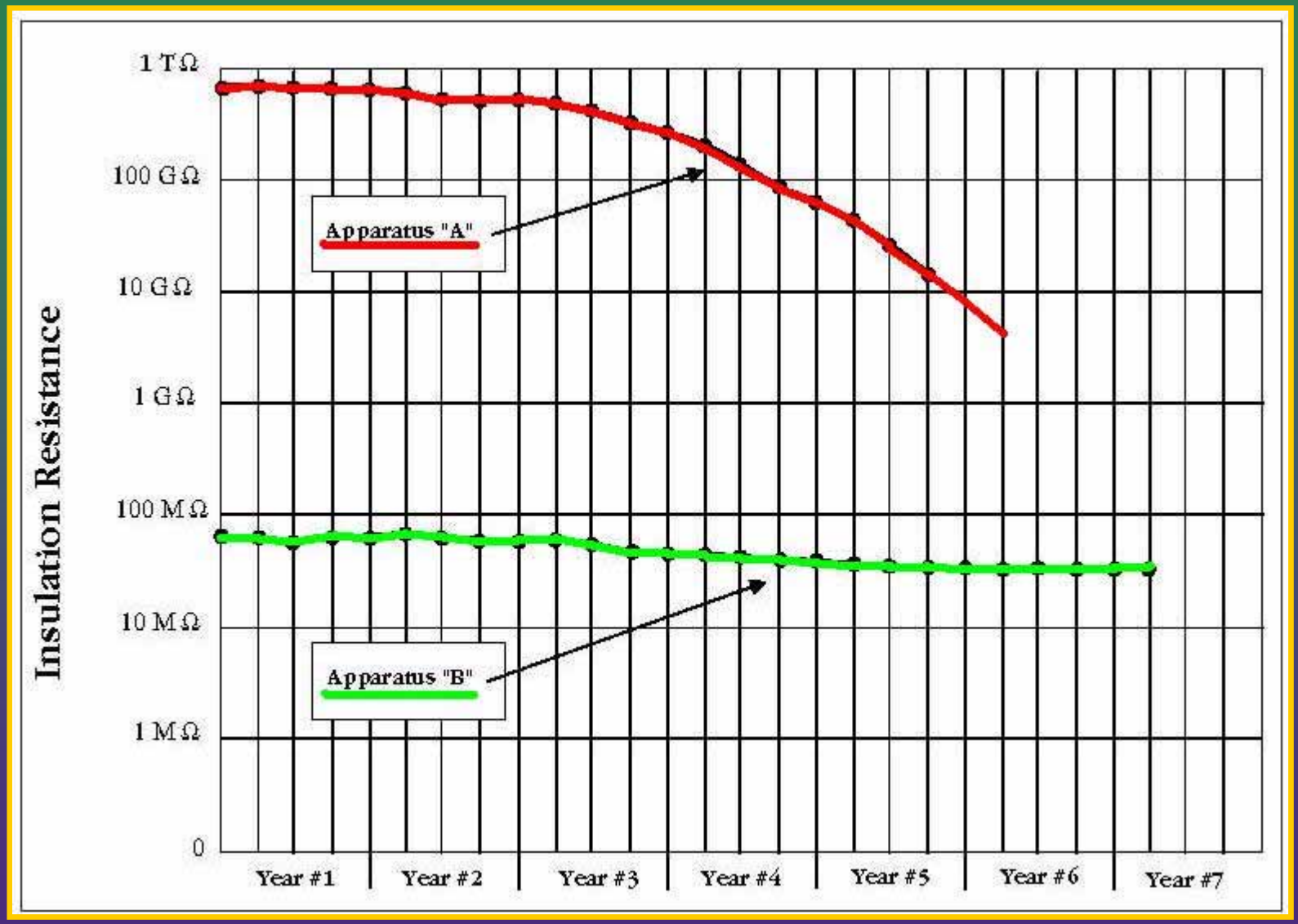
PRACTICAL APPLICATIONS

REMEMBERING THAT -

- **TREND MORE IMPORTANT THAN THE ABSOLUTE VALUE.**
- **INSULATION RESISTANCE VALUES SHOULD BE CONSIDERED RELATIVELY.**
- **EVALUATE THE TEST RESULTS BASED UPON EXPERIMENTATION AND EXPERIENCE WITH YOUR OWN FACILITY.**
  - **LENGTH OF CIRCUIT, AGE**
  - **INITIAL ACCEPTANCE IR VALUE**



PRACTICAL APPLICATIONS



PRACTICAL APPLICATIONS

- ELECTRICAL INSULATION WILL EXHIBIT DYNAMIC BEHAVIOR DURING THE COURSE OF TESTING.
- TO EVALUATE A NUMBER OF TEST RESULTS ON THE SAME PIECE OF EQUIPMENT OR CABLE, WE MUST CONDUCT THE TESTS THE SAME WAY AND UNDER THE RELATIVELY SAME ENVIRONMENTAL PARAMETERS, EACH AND EVERY TIME.

IDEAL INSULATION RESISTANCE VALUE

- AC 150/5345-26C STATES: ANY CIRCUIT READING LESS THAN 1 MEGOHM IS DESTINED FOR RAPID FAILURE.
- AAAE ACE MANUAL DISCUSSES A “ONE-MEGOHM RULE”. THE MANUAL IS IN AGREEMENT WITH 26C AND GOES ON TO REFER TO ONE MEGOHM PER 1,000 VOLTS OR 5 MEGOHM VALUE FOR 5KV CIRCUITS.

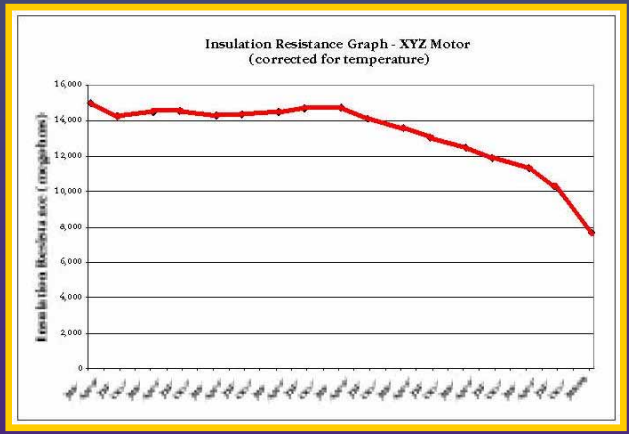
IDEAL INSULATION RESISTANCE VALUE

- SOUTHWIRE'S POWER CABLE INSTALLATION GUIDE INCLUDES A "2 TO 50 MEGOHM RULE".
- AC 150/5370-10F SETS THE MINIMUM ACCEPTABLE VALUE FOR NEW WORK AT 50 MEGOHMS USING A 1,000 VOLT TESTER.
- AAAE ACE MANUAL RECOMMENDS NEW WORK ACCEPTANCE MINIMUM AS 500 MEGOHMS.

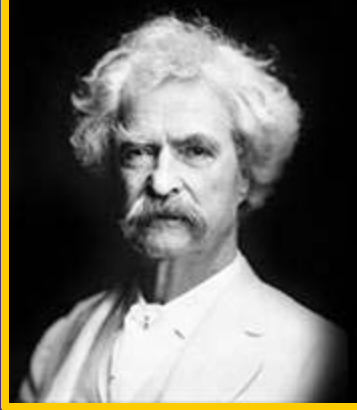
IDEAL INSULATION RESISTANCE VALUE

MY RECOMMENDATION IS:

- USE THE “2 TO 50 MEGOHM RULE” FOR MAINTENANCE.
- SET A MINIMUM ACCEPTANCE VALUE FOR NEW WORK IN EXCESS OF 500 MEGOHMS.



GET YOUR FACTS FIRST, THEN YOU CAN DISTORT THEM AS YOU PLEASE.



Mark Twain

American Author and Humorist

(1835-1910)

QuoteHD.com

PREREQUISITES TO TESTING

1. ONLY NFPA 70E DEFINED “QUALIFIED PERSONS” SHOULD PERFORM THE INSULATION RESISTANCE TESTS.
2. REVIEW CIRCUIT PLANS AND EQUIPMENT SPECIFICATIONS; DETERMINE THE SCOPE AND EXTENTS OF THE TEST.
3. PERFORM A HAZARD ANALYSIS OF THE TESTING TASK. CONDUCT A PRE-TASK BRIEFING TO ADDRESS ALL HAZARDS AND TO PLAN THE WORK.

PREREQUISITES TO TESTING

4. IDENTIFY AND BARRICADE FLASH PROTECTION BOUNDARY AND LIMITED & RESTRICTED APPROACH BOUNDARIES, PER NFPA 70E.
5. LIMIT ACCESS IN THE TESTING AREA TO QUALIFIED AND NECESSARY PERSONS ONLY.
6. DETERMINE AND WEAR THE NECESSARY PPE.

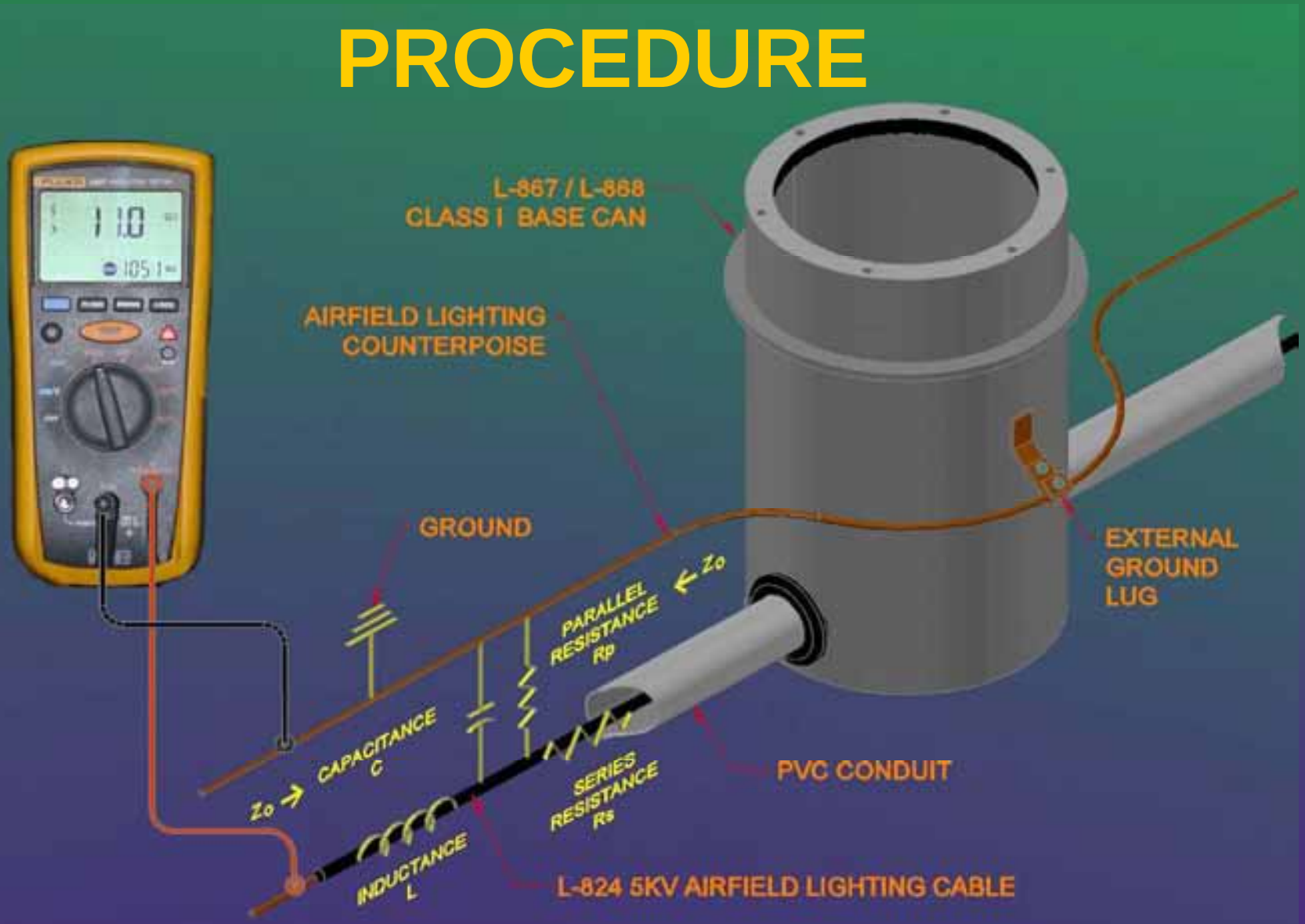
PREREQUISITES TO TESTING

7. COMPLY WITH EMPLOYER, UNION, GOVERNMENT, FAA, OSHA & NFPA 70E SAFETY AND LOTO REQUIREMENTS.
8. VERIFY THE CIRCUIT IS DE-ENERGIZED (3 POINT TEST) (CCR OUTPUT USE CLAMP-ON).
9. VERIFY THE CIRCUIT IS ISOLATED FROM ALL OTHER CIRCUITS.
10. VERIFY CIRCUITS WITHIN THE SAME RACEWAY/CONDUIT SYSTEM ARE DE-ENERGIZED AND ISOLATED. APPLY SAFETY GROUNDS AS REQUIRED.

PREREQUISITES TO TESTING

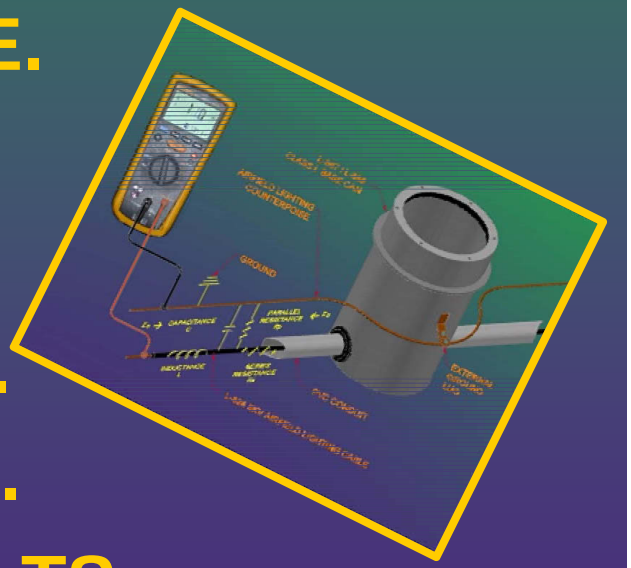
11. VERIFY ALL CABLE ENDS BEING TESTED ARE CLEAN AND DRY.
12. VERIFY ADEQUATE CLEARANCE EXISTS BETWEEN THE CABLE ENDS AND OTHER SURFACES.
13. BE PREPARED FOR EMERGENCIES.
14. CONNECT THE TESTER TO THE UNIT UNDER TEST (UUT).

RECOMMENDED TEST PROCEDURE

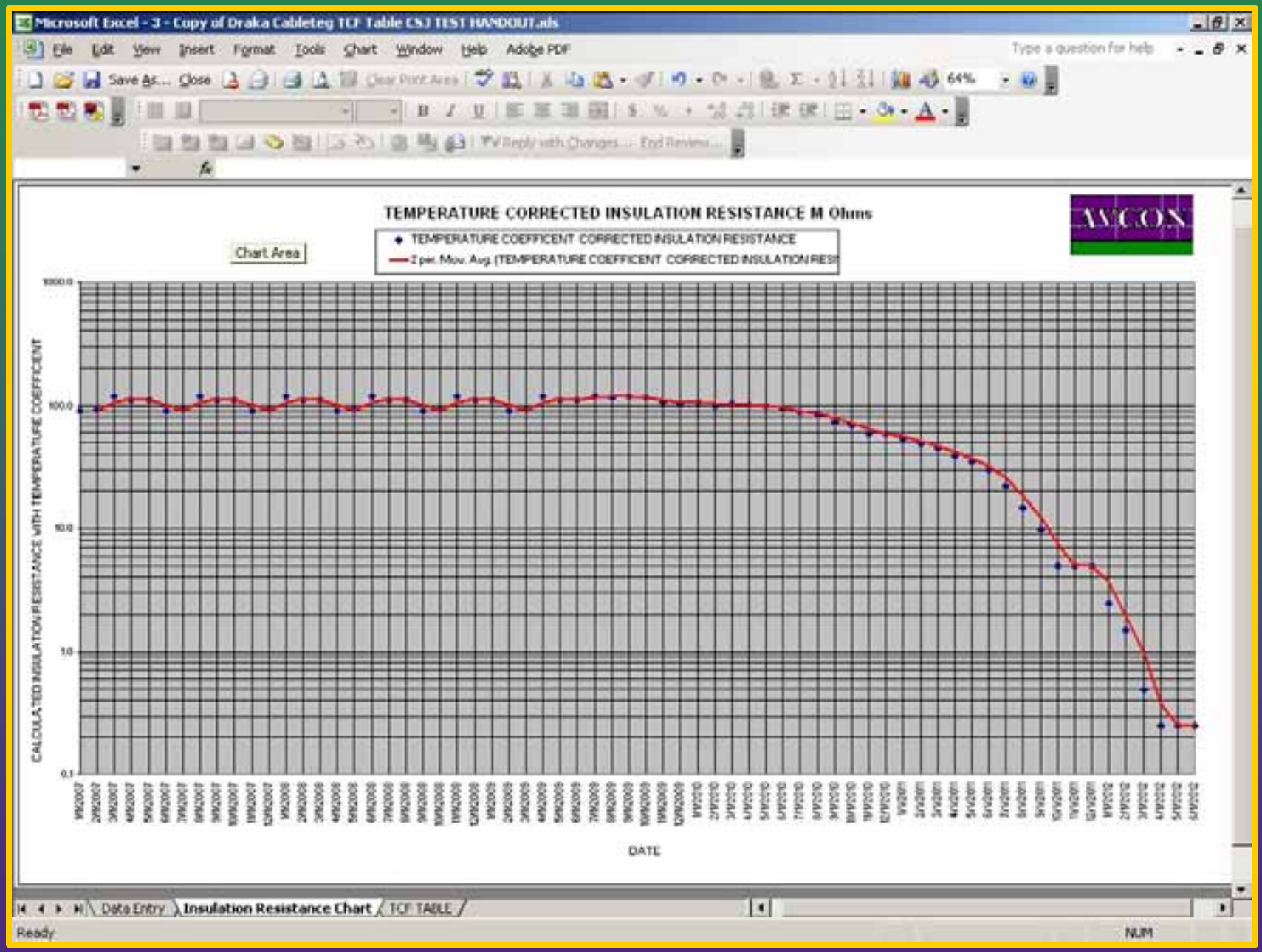


RECOMMENDED TEST PROCEDURE

1. PERFORM A SHORT TIME RESISTANCE TEST.
2. TEST SEVERAL HOURS AFTER OPERATION.
3. TEST PROCEDURE MUST BE REPEATABLE.
4. USE 1000 VOLT TEST VOLTAGE.
5. OBSERVE TESTER POLARITY.
6. TEST FOR ONE MINUTE.
7. APPLY TCF TO TEST RESULTS.
8. RECORD TC IR TEST RESULTS.
9. GRAPH THE TC IR TEST RESULTS.



RECORD THE TC TEST RESULTS



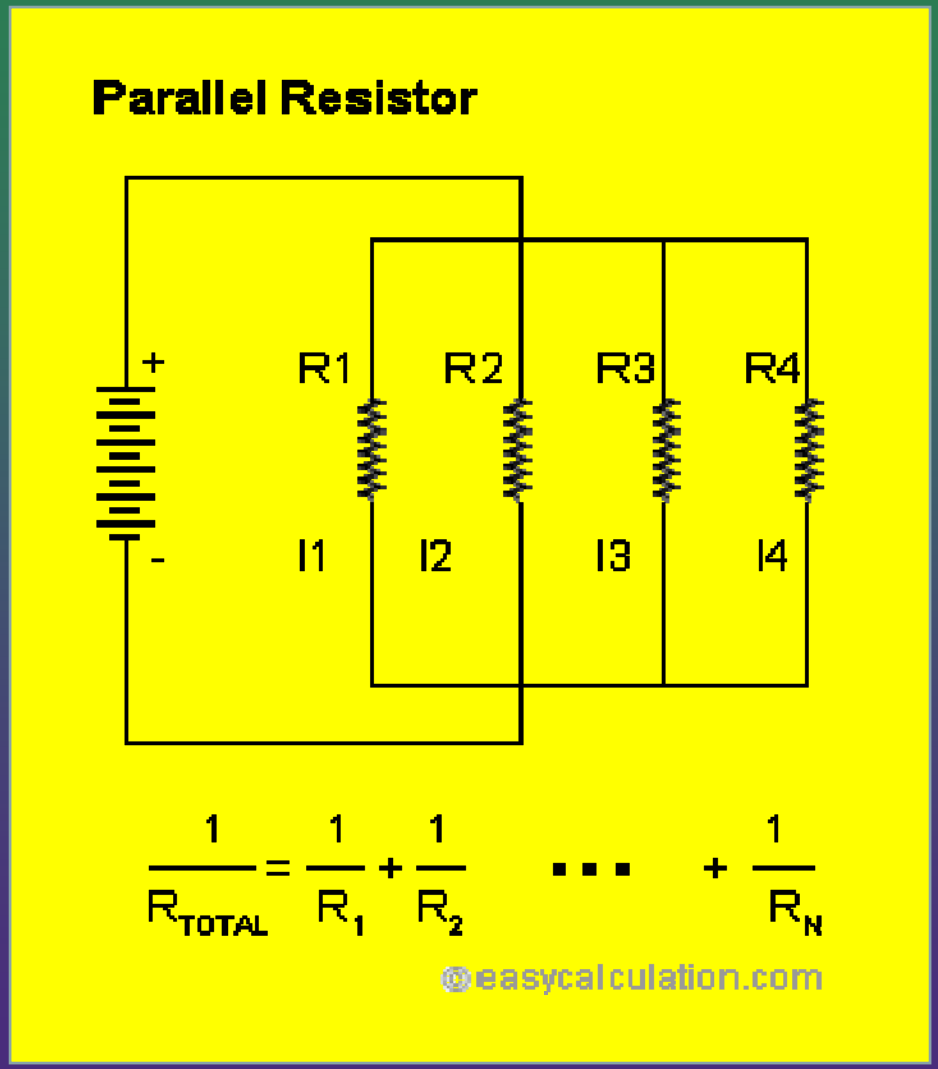
FIELD LIGHTNING ARRESTORS

FIELD LIGHTNING ARRESTORS

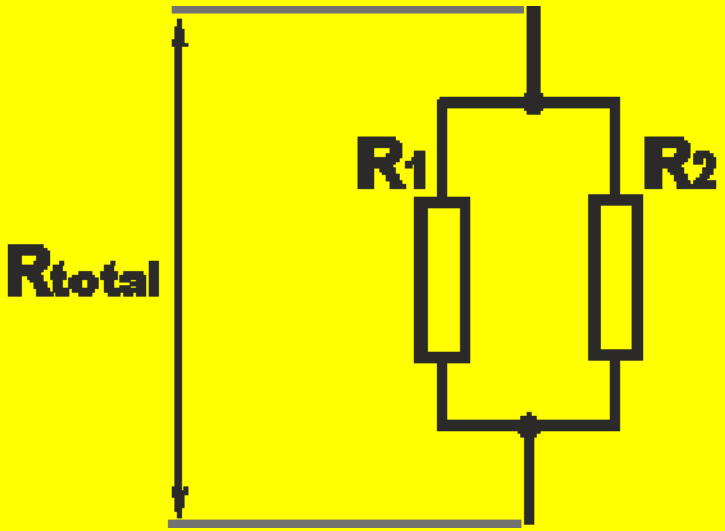
TO UNDERSTAND THE IMPACTS OF THE FIELD LIGHTING ARRESTORS ON OUR SERIES LIGHTING CIRCUITS WE NEED TO UNDERSTAND HOW TO CALCULATE PARALLEL RESISTANCES.

How I see math word problems: If you have 4 pencils and I have 7 apples, how many pancakes will fit on the roof? Purple, because aliens don't wear hats.

PARALLEL RESISTANCES

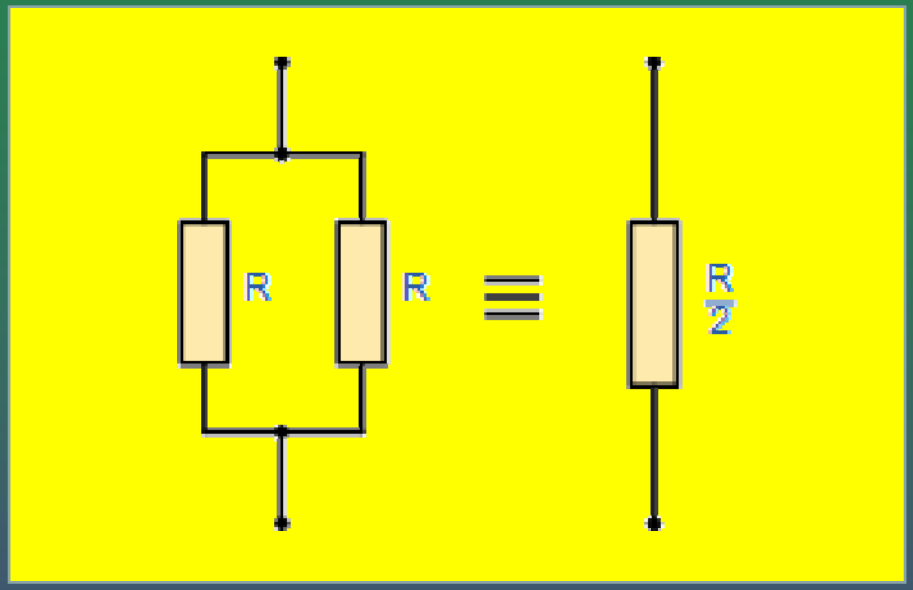


PARALLEL RESISTANCES



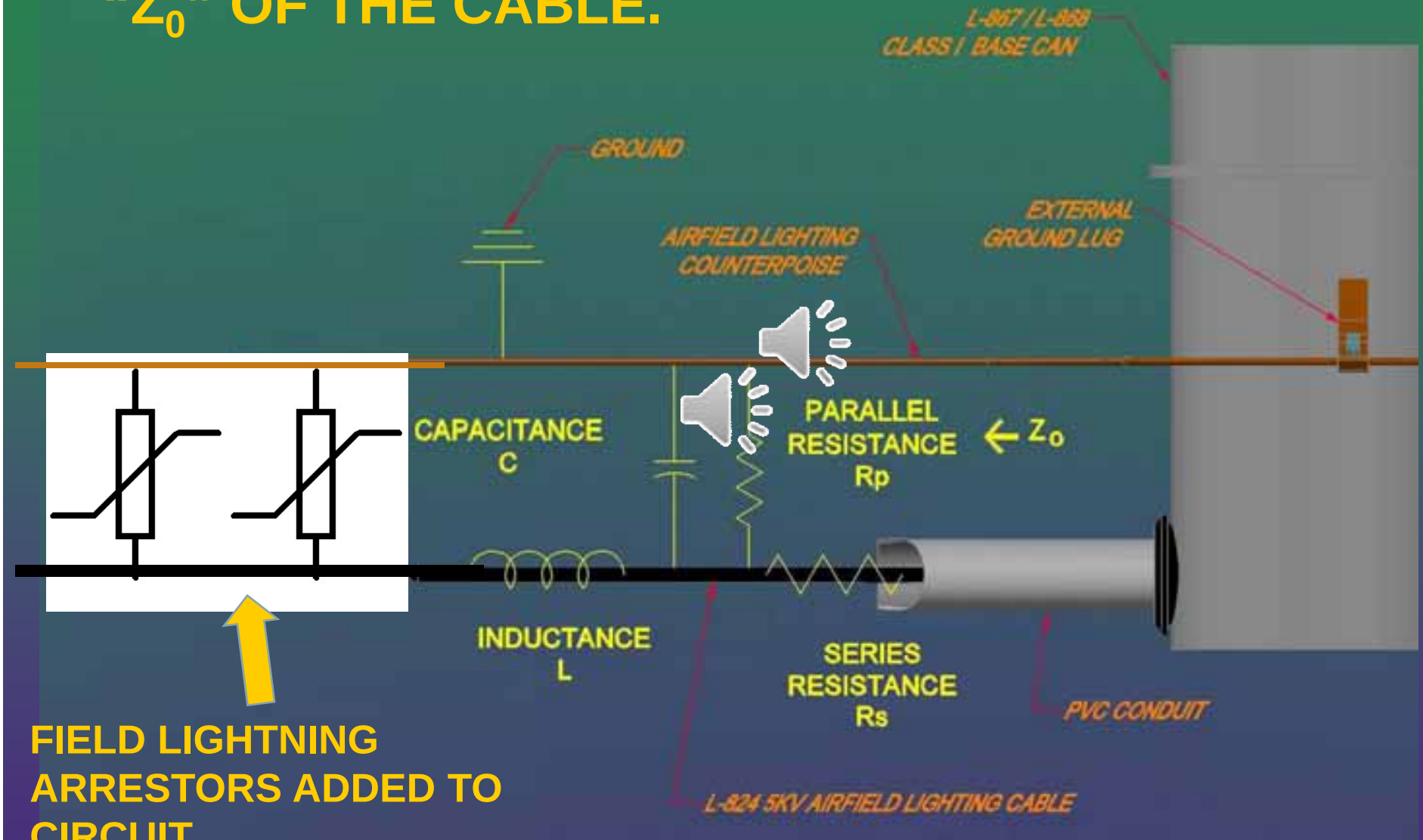
$$R_{total} = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

PARALLEL RESISTANCES



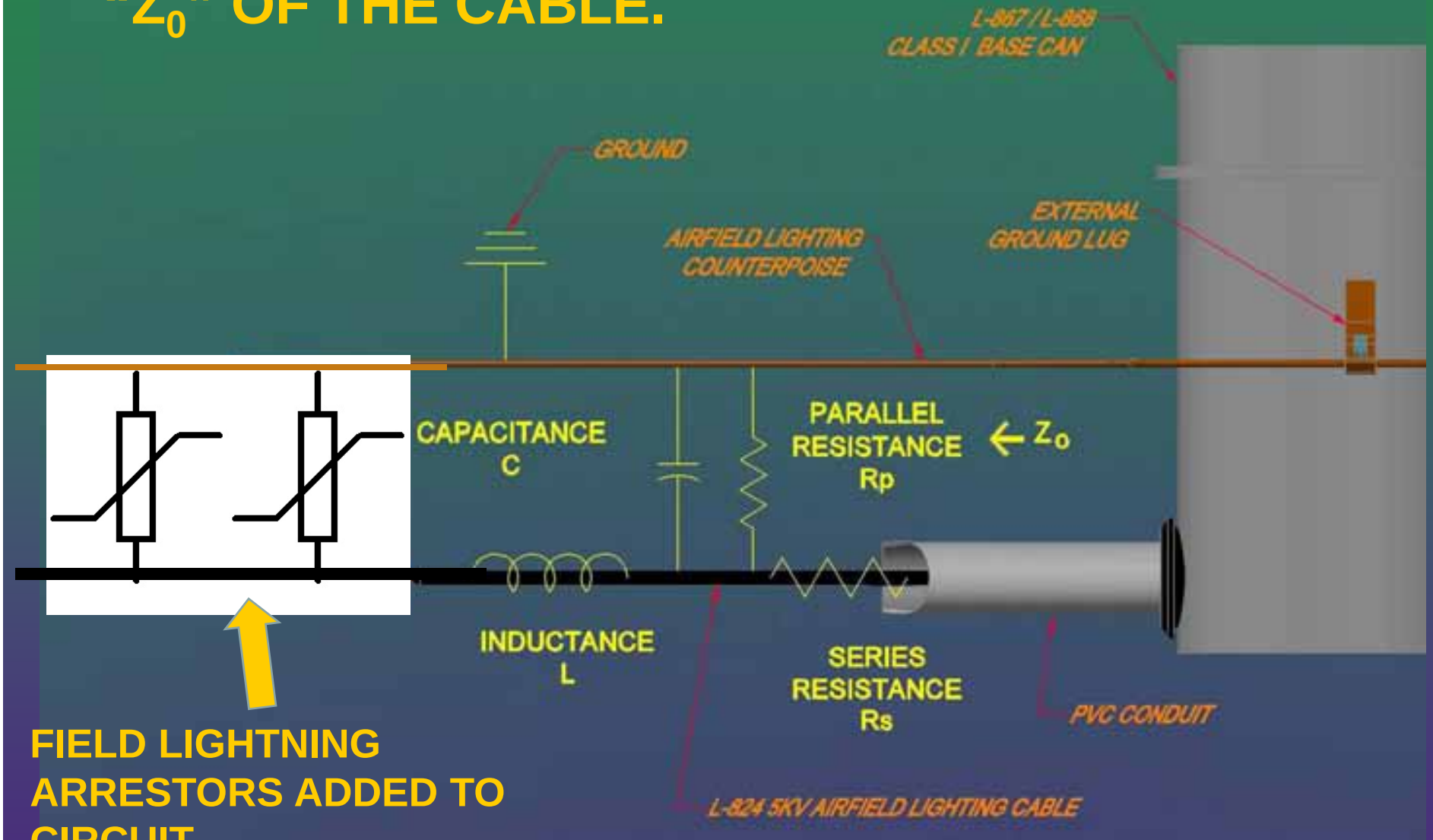
- IF TWO RESISTANCES IN PARALLEL ARE EQUAL, THEN THE TOTAL RESISTANCE, R_T IS EQUAL TO HALF THE VALUE OF ONE RESISTOR.
- TWO EQUAL RESISTORS IN PARALLEL = R/2
- THREE EQUAL RESISTORS IN PARALLEL = R/3, ETC.

THE CHARACTERISTIC IMPEDANCE "Z_0" OF THE CABLE.



FIELD LIGHTNING ARRESTORS ADDED TO CIRCUIT

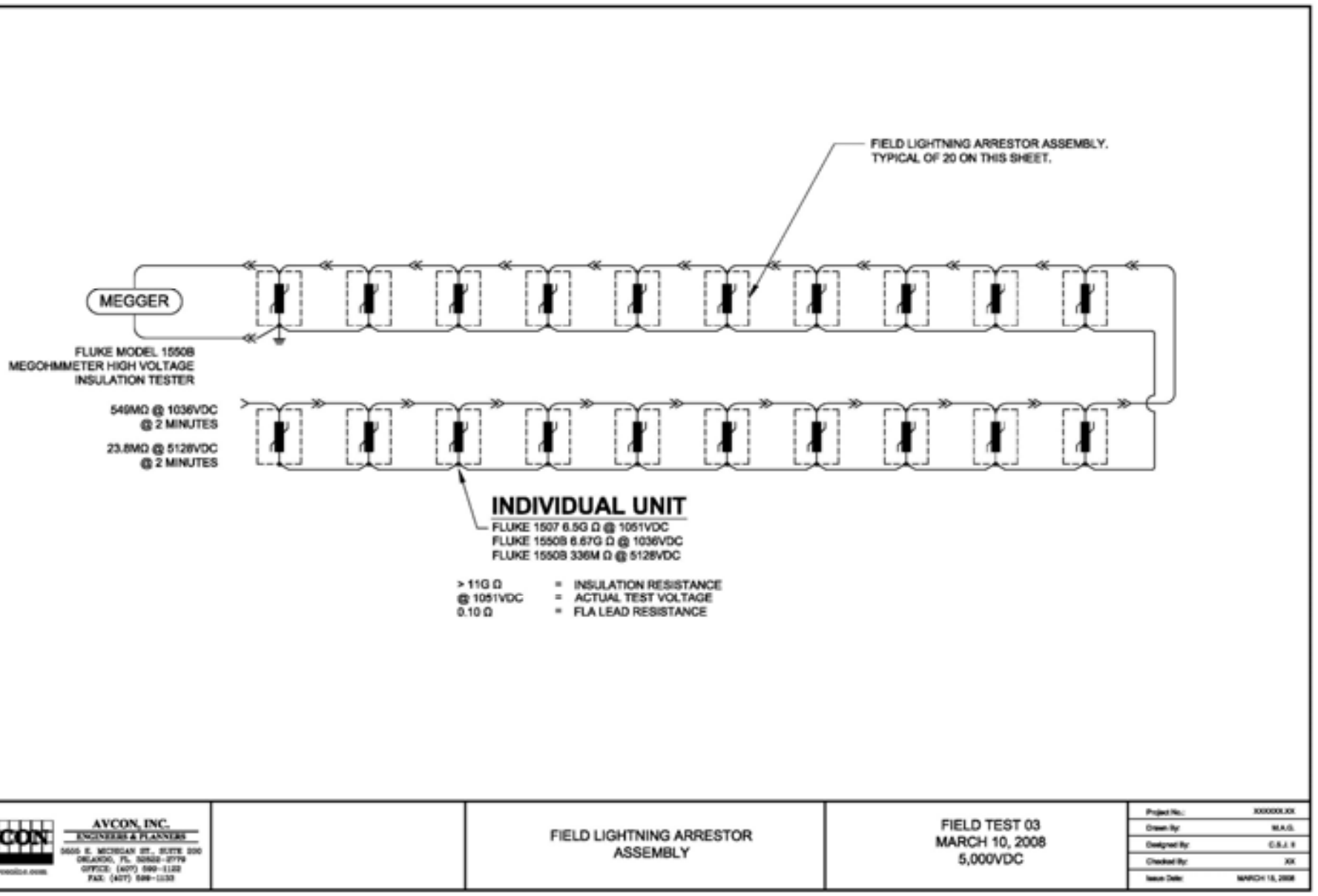
THE CHARACTERISTIC IMPEDANCE "Z_0" OF THE CABLE.



FIELD LIGHTNING ARRESTORS ADDED TO CIRCUIT


110
MAR 4 2008


CAUTION
MAR 4 2008



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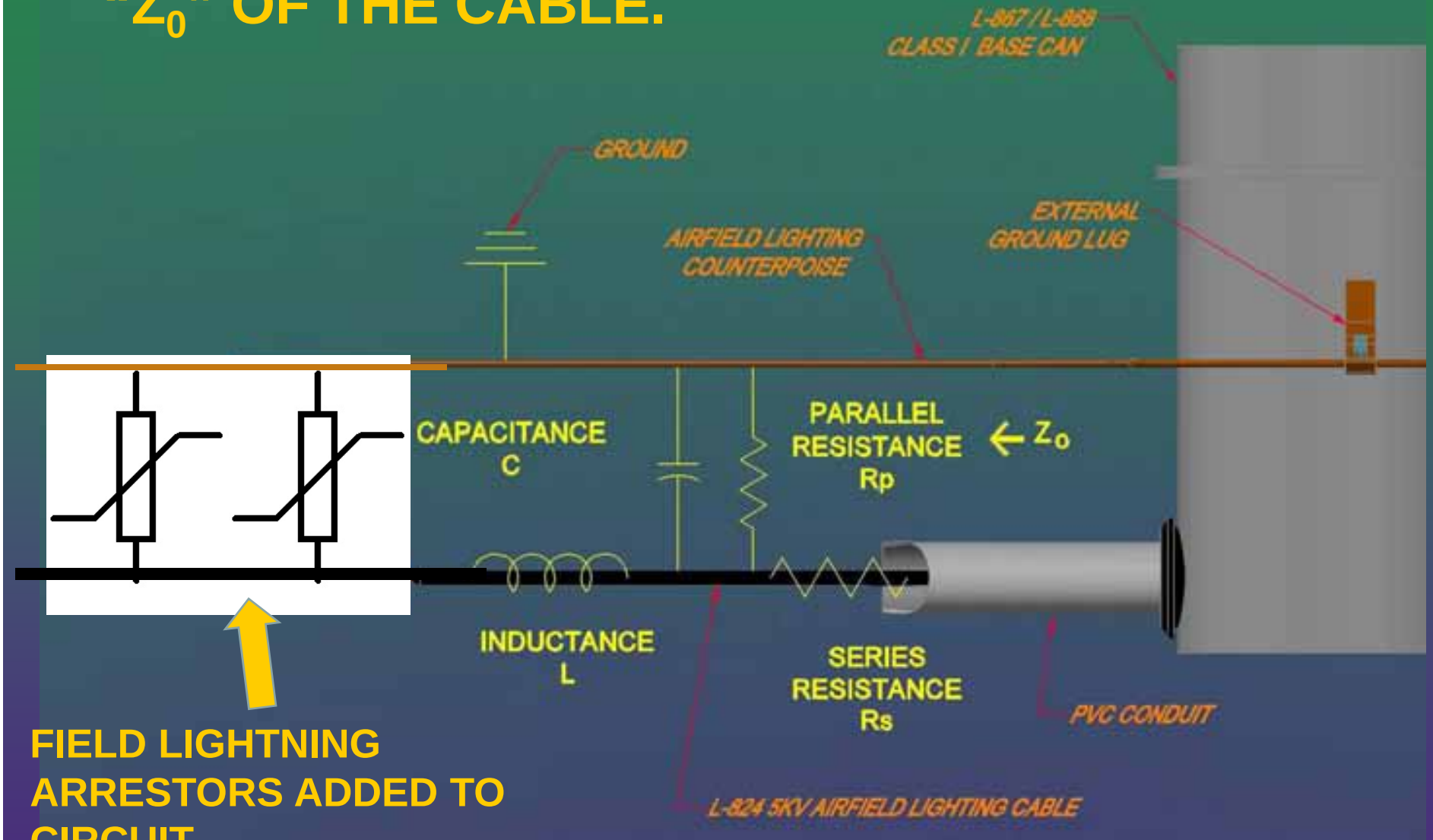
495
MAR 4 2008

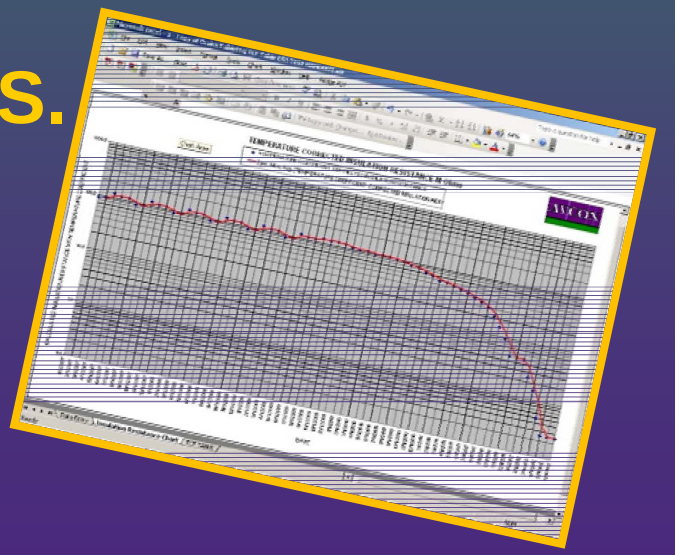
THE CHARACTERISTIC IMPEDANCE "Z_0" OF THE CABLE.

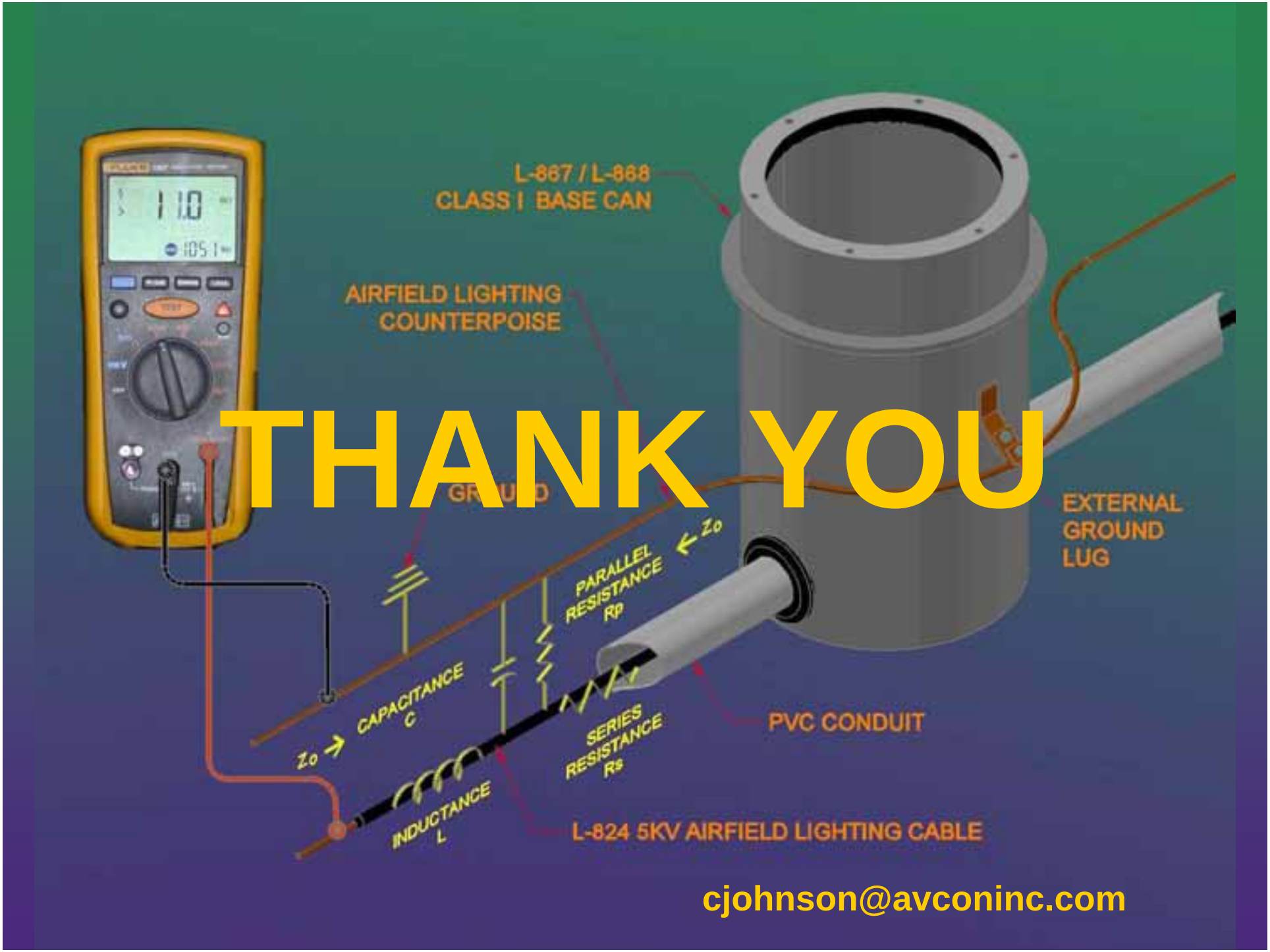


FIELD LIGHTNING ARRESTORS ADDED TO CIRCUIT

SUMMARY

- PERFORM INSULATION RESISTANCE TESTING ON A MONTHLY BASIS.
- CORRECT FOR TEMPERATURE.
- RECORD TC IR TEST RESULTS.
- TREND TC IR TEST RESULTS.
- KNOWLEDGE IS POWER!





THANK YOU

cjohnson@avconinc.com

INSULATION RESISTANCE TESTING

IES AVIATION LIGHTING COMMITTEE
85TH ANNUAL FALL CONFERENCE - 2014

PRESENTED BY: CARL JOHNSON ©
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ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE

AVCON

GIBBS HEAD SLAP

No explanation required