CALCULATION CHANGE NOTICE

CHANGE NOTICE NO. 001

Total Number of Pages Including Attachments 5

CALCULATION IDENTIFICATION NUMBER			
J.O. No.	DIV/GROUP	CALC. NO.	REV. NO.
16345	IC(B)	071	2

APPROVALS - SIGNATURE & DATE

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	Confirmation Required (✓)
W R POWER 1/22/90	J. DACANAY 1/23/90	William E. Mauke 1-23-90	[ ]Yes [✓]No

SUMMARY OF CHANGE

1. On Calculation Page 3:
   add to Loop Power Supply (40VDC):
   (Ref. 2, pg 1).

2. On Calculation Pages 6 and 6A:
   A. add to references 2, 7, 8, 9 & 12:
      the information as noted on pages 4 and 5 of this CCN.
   B. add reference 13, per Page 5 of this CCN.

3. On calculation Page 8, line 9:
   add to 327°F:
   (Ref. 1, Page 3).

4. On calculation Page 15 and 16:
   change remarks for
   1-AE-5506A and 5506B,
   1-AE-5506C and 5506D
   From: REF. CONCLUSIONS ON PAGE 6A
   TO: REF. CONCLUSIONS ON PAGE 6B.

REASON FOR CHANGE

FOR CALCULATION ENHANCEMENT, TO PROVIDE EASIER REFERENCE RETRIEVABILITY.

FOR CALCULATION ENHANCEMENT, TO PROVIDE EASIER REFERENCE RETRIEVABILITY.

REFERENCE SOURCE FOR INPUT WAS NOT PREVIOUSLY LISTED IN CALCULATION

FOR CALCULATION ENHANCEMENT, TO PROVIDE EASIER REFERENCE RETRIEVABILITY

Information was moved from page 6A to page 6B by Calculation Revision 2.

STONE & WEBSTER ENGINEERING CORPORATION

REVIEW STATEMENT FOR SAFETY RELATED CALCULATIONS

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 2
16345	IC(B)	071	NA	

Review of this calculation was based on the methods below:

Calc. Revision No. 2

Calc. Change Notice No. 001

1) Review of:

		Initial Upon Completion
a) Inputs to assure that they have been properly selected and correctly used in the calculation. (Check One)		
i) limited review (provide justification)	☐	
ii) line by line review	☒	jdd
b) Assumptions to assure their validity and need for later confirmation.	☐	
c) Methodology to assure the appropriateness of the overall approach, its implementation, and the correctness of the specific equations utilized. (Check One)		
i) limited review (provide justification)	☐	
ii) line by line review	☒	jdd
d) Results to assure reasonableness and accuracy	☒	jdd
e) If alternate calculation is performed to verify c) and d) check here and attach calculation as an appendix	☐	

2) Check of Calculation (Check One)

a) Complete numerical check	☒	jdd
b) Numerical check of critical items (state items and justification below)	☐	

3) Administrative check of format and content ☒ jdd

4) Comments/Justification

Review Methods Selected as Indicated Above

William E. Mottle — 1-23-90
Independent Reviewer — Date

Janardan G Amin — 1/23/90
Supervisor Concurrence — Date

Satisfactory Completion of Review (Calculation is Approved for Issue)

J. DACANAY — 1/23/90
Checker — Date

J. DACANAY — 1/23/90
Reviewer — Date

William E Mottle — 1-23-90
Independent Reviewer — Date

SUMMARY OF CHANGE	REASON FOR CHANGE
5. On Calculation Page 22: add to The Calculated IR for 23.8 The following reference: (PG. 23)	REFERENCE SOURCE FOR INPUT WAS NOT PREVIOUSLY LISTED IN CALCULATION.
6. On Calculation Page 23: A. add to (Ref. 12): (Book 1, section 802, subsection 3-1)	FOR CALCULATION ENHANCEMENT, TO PROVIDE EASIER REFERENCE RETRIEVABILITY.
B. add the following statement to bottom of page; CALCULATED IR = 0.98 x 100 Megohms FOR 10 FT SAMPLE (REF. 13). THIS IS EQUIVALENT TO 980 MOHMS PER FOOT. FOR CONSERVATISM WILL USE 23.8 MΩ/L (FOR HJTC CABLES ON PG 22)	BASIS FOR INPUT AND REFERENCE WAS NOT PREVIOUSLY LISTED IN CALCULATION.
7. On Calculation Page 1E: CHANGE DATE OF WPT-9784 LETTER FROM: (4/11/89) TO: (4/11/88)	THERE WAS A TRANSCRIPTION ERROR BETWEEN REV. 1 AND REV. 2 WHEN INFORMATION ON PAGE 1E WAS TRANSCRIBED FROM PAGE 1D IN REV. 1.

A 3010 66

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP IC(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	PAGE 6

THE ATTACHED TABULATION IDENTIFIES ALL INSTRUMENTS WITHIN THE CONTAINMENT WHICH MAY HAVE INACCURACIES DUE TO DECREASED INSULATION RESISTANCE DURING MSLB OR LOCA. THE TABULATION PROVIDES THE CABLE TYPE CABLE LENGTH AND %ERROR FOR HIGH AND LOW END OF TRANSMITTER SIGNAL.

UNLESS NOTED OTHERWISE:-
ALL % ERRORS WERE CALCULATED USING THE METHOD USED FOR THE EXAMPLE IN THIS CALCULATION.

ADD PER CCN-001

REFERENCES/INPUTS

REV 1

1. SWEC CALCULATION 16345/6-EE(B)-084, REV. 1
2. WESTINGHOUSE CORP. INSTRUCTIONS - 7300 SERIES ISOLATOR & LOOP POWER SUPPLY (NLP) CARD - STYLE NOS 2837A12G01 → G03 - SCHEMATIC DIAG. 2837A12-13, SHT. 14 (WESTINGHOUSE PROCESS INSTRUMENTATION AND CONTROL MANUAL CP-0001-089 REV. 1, SECTION 815)
3. SWEC INTEROFFICE CORRESPONDENCE OF 6-8-88 J.P. CARTER TO R. POLTRINO/J. BURNS (ATTACH. NO. 1)
4. SWEC INTEROFFICE CORRESPONDENCE OF 6-7-88 R.G. BRUNNER TO J.R. BURNS (ATTACH. NO. 2)
   NOTE: COMPARES FAVORABLY WITH 100 MEGOHM VALUE PUBLISHED IN ROSEMOUNT PDS-2498 FOR MODEL 353C NUCLEAR QUALIFIED CONDUIT SEAL
5. CONAX CORP. TEST REPORT IPS-585.2, APP. "A", TABLE 5.1
   NOTE: ON THE #16AWG & #16D-TP-T MULTICONDUCTOR FEEDTHROUGH MODELS, A FEW CONDUCTOR PAIRS EXPERIENCED LOW (< 1-MEGOHM) IR READINGS DURING DBE TESTING. AS TESTS PROGRESSED, THESE IR READINGS VARIED CONSIDERABLY, INDICATING POSSIBLE SPLICE PROBLEMS AS EXPERIENCED DURING SUPPLEMENTAL TESTING (SECT. 6.82.3). SINCE MOST CONDUCTOR PAIRS MAINTAINED HIGH IR VALUES DURING DBE TESTING, AN AVERAGE OF THE FINAL #16D-TP-T MODULE READINGS IS USED IN THIS CALCULATION - REFER TO SHEET #4 IN ABOVE TABLE 5.1
6. OKONITE CO., 1974 - ENGINEERING DATA FOR COPPER & ALUMINUM CONDUCTOR CABLES - TABLES 1-3 & 1-4.
7. FLUID COMPONENTS INC., 1982 - MODEL 8-66MA MULTIPOINT LEVEL SENSORS - OPERATION & INSTALLATION MANUAL. (CPF-01147-S-001, REV. 0)

ADD PER CCN-001

A 5019 88

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP IC(8)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	PAGE 6A

REFERENCES/ INPUTS (CONT'D)

8. CABLE PULL CARDS EO1352502, EO1352512, EO1352522, EG1352602, EG1352612, AND EG1352622 (11/15/82, 11/16/82, 11/16/82, 11/22/82, 11/22/82)

9. RGF CORP. INSTR. MANUAL T-10432, REV 2, 8-29-79 (CP-001-042, REV. 0)

10. WESTINGHOUSE LETTER WPT-9789, 4-11-88

11. CONAX CATALOG 3141, TEMPERATURE SENSORS

12. COMBUSTION ENGINEERING INSTRUCTION MANUAL ICE-145 (CPF-01233-S-001, Rev. 0)

13. BIW TEST REPORT TP-TU2, REPORT 921D, PAGE 15 FOR HJTC APPLICATIONS (DOCUMENTED IN EEQSP-TNES-28-01)

(2)

ADD PER CCN-001 INFORMATION AS CLOUDED

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

incldg. pgs 1A + 1B, 1C, 1D, 6
ds 8-24-88
REV 1

CLIENT & PROJECT	PAGE 1 OF ~~23~~ ~~25~~ 23
TU ELECTRIC/COMANCHE PEAK STEAM ELECTRIC STATION	TOTAL NO OF PAGES ~~23~~ ~~30~~ 38
CALCULATION TITLE (Indicative of the Objective): CALCULATION OF ERROR IN ACCURACY FOR INSTRUMENTS INSIDE CONTAINMENT DUE TO LOW CABLE INSULATION RESISTANCE DURING MSLB OR LOCA	DESIGN DOCUMENT CLASSIFICATION ☒ Class I ☐ Class II ☐ Non-Safety

CALCULATION IDENTIFICATION NUMBER				DESIGN VALIDATION PACK.
J.O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	WORK PACKAGE NO.
16345	IC(B)	071	N/A	15J 15A REV1

APPROVALS - SIGNATURE & DATE

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC. NO.	~~SUPPLEMENTS~~/ SUPERCEDES CALC./REV. NO.	CONFIRMATION REQUIRED YES	CONFIRMATION REQUIRED NO
G.S. Bellamacina G.S. BELLAMACINA 1/11/88	J.J. Wusteney J.J. WUSTENEY 6/8/88	J.J. Wusteney J.J. WUSTENEY 6/8/88	0	N/A		✓
J.J. Wusteney J.J. WUSTENEY 7/25/88 KHorelik KHorelik 11/8/88	FOR LIST OF CHANGES SEE PAGE 1C Y Gold Y GOLD 8.5.88 Y GOLD 11.23.88	Y Gold Y GOLD 8.5.88 Y GOLD 11.23.88	1	0		✓
R.E. THORN 10/16/89 R E Thorn	W.R. POWER 10/20/89 W R Power	G.M. PAYNE 10/20/89 G.M. Payne	2	1		✓

DISTRIBUTION

GROUP	NAME & LOCATION	GROUP	NAME & LOCATION
RECORDS MGT. FILES (OR FIRE FILE IF NONE)	Records Retention Coordinator-~~CAG~~ 8T/443	~~TGF~~ TURM	c/o ~~TGF Coordinator-~~ VIA SWEC RECORDS MGT 8T/443
~~EDG-CAG~~ CALC PROC GROUP	Job Book File 19-4-2 (Orig) Calc. Coordinator-~~CAG~~ PCE1	~~ELECTRICAL~~	PHolden ~~ds 8-24-88~~ ~~E. HENNEBERRY~~-245/7 ~~J.J. WUSTENEY-245/7~~
EDC-ESG	Job Book File 19-4-2 c/o Calc. Coordinator-ESG	I&C	~~J.R. BURNS-245/7~~
IMPELL CORP.	M. BAKER-F.W. TEXAS	~~WESTINGHOUSE~~	~~J.L. VOTA PITTSBURG, PA~~ R. POITRINO-245/7 12/7/88
I&C	R BURNHAM 1C/444		
PQEQ	C. WEARY IMI		
WESTINGHOUSE	J.L. VOTA PITTSBURG PA		

2

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

Rev 1

A 5010 85

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 1A
16345	IC(B)	071	N/A	

TABLE OF CONTENTS

STONE & WEBSTER ENGINEERING CORPORATION

REVIEW STATEMENT FOR SAFETY RELATED CALCULATIONS

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP IC(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	PAGE 1AA

Review of this calculation was based on the methods below:

Calc. Revision No. 2

Calc. Change Notice No. N/A

1) Review of:

		Initial Upon Completion
a) Inputs to assure that they have been properly selected and correctly used in the calculation. (Check One)		
i) limited review (provide justification)	☐	
ii) line by line review	☑	WRP
b) Assumptions to assure their validity and need for later confirmation.	☑	WRP
c) Methodology to assure the appropriateness of the overall approach, its implementation, and the correctness of the specific equations utilized. (Check One)		
i) limited review (provide justification)	☐	
ii) line by line review	☑	WRP
d) Results to assure reasonableness and accuracy	☑	WRP
e) If alternate calculation is performed to verify c) and d) check here and attach calculation as an appendix	☐	

2) Check of Calculation (Check One)

a) Complete numerical check	☑	WRP
b) Numerical check of critical items (state items and justification below)	☐	

3) Administrative check of format and content ☑ WRP

4) Comments/Justification

Review Methods Selected as Indicated Above

G.M. PAYNE	10/20/89	[signature]	10/20/89
Independent Reviewer	Date	Supervisor Concurrence	Date

Satisfactory Completion of Review (Calculation is Approved for Issue)

W.R. POWER	10/20/89	W.R. POWER	10/20/89
Checker	Date	Reviewer	Date
		G.M. PAYNE	10/20/89
		Independent Reviewer	Date

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

Rev 1

▲ 5010 55

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 1B
16345	IC(B)	071	N/A	

TABLE OF CONTENTS (continued)

NOTE: THIS CALCULATION CONTAINS PAGES 1, 1AA, 1A, 1B, 1C, 1D, 1E, 2, 3, 4, 5, 6, 6A, 6B, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 18A, 18B, 18C, 18D, 19, 20, 21, 22, 22a, 23 AND TWO ONE PAGE ATTACHMENTS (2)

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 5010 85

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE LC R 1
16345	IC(B)	071	N/A	

RECORD OF CHANGES

REV. 0 - INITIAL ISSUE

REV. 1 - PAGE 1A - ADDED TABLE OF CONTENTS

- PAGE 1C - ADDED RECORD OF CHANGES △2
- PAGE 1D - ADDED REASON FOR REVISION
- PAGE 19 - REVISED RX. CLNT. DSGN. TEMP. IN ACCORDANCE WITH W LETTER WPT-9789 OF 4/11/88
- REVISED RX. CLNT. RTD RESISTANCES TO AGREE WITH DESIGN TEMP. REVISIONS
- INCREASED IR MULTIPLICATION FACTOR OF 4-WIRE RTD, REF, SWEC LETTER SWW-0218 OF 8/16/88
- PAGE 16 - REVISE RTD ERROR TABULATIONS IN ACCORDANCE WITH PAGE 19 REVISIONS — REV 1
- PAGE 21 - INCREASED IR MULTIPLICATION FACTOR OF 3-WIRE RTD, REF. SWEC LETTER SWW-0218 OF 8/16/88
- ADDED COMPUTATION FOR RHR HT. EXCHGR. RTD & REF TO PAGE 14
- PAGE 14 - TE's 604 & 605 SIGNAL ERRORS REVISED TO AGREE WITH COMPUTATION ON PAGE 21. SIGNALS WERE ERRONIOUSLY SHOWN AS TRANSMITTER SIGNALS - NOT RTD's

PAGE 22 - REVISED RTD ERROR TABULATIONS IN ACCORDANCE WITH PAGE 21 REVISIONS

PAGE 23 - ADDED COMPUTATION TO CHANGE PERCENT ERROR SIGNAL TO MAX. TEMP. ERROR

PAGE 13, 16 - ADD H_2 ANALYZERS TO TABULATIONS

PAGES 14, 16, & 22 - CHANGED PERCENT ERROR SIGNALS TO MAX. TEMP. ERROR SIGNALS ON ALL RTD's & T/C's TO ACCOMODATE ASSOCIATED INSTRUMENT LOOP CALC's.

PAGE 6 Revised References to References/Inputs

PAGE 1 - REVISE PAGE NOS △2

Page 6A - added CONCLUSIONS

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 1D
J.O. OR W.O. NO. 16345	DIVISION & GROUP IC(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	

RECORD OF CHANGES (CONT'D)

REVISION 2

1. REVISION 1 PAGES 1, 1A, 1B, 1C, 2, 6, 11, 19, 20, 21 AND 23 REVISED - REVISION 1 PAGE 6A REPLACED WITH REVISION 2, PAGE 6A - ADDED PAGES 1AA 6B AND 22a (2)

2. REVISION 1, PAGES 1D, 17 AND 18 REPLACED WITH REVISION 2, PAGES 1D, 17 AND 18 - REVISION 1 PAGE 15 REVISED - ADDED PAGES 1E, 18A, 18B, 18C AND 18D

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

▲ 5010 85

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 1E of 2
16345	IC(B)	071	N/A	

REASON FOR REVISION

REVISION 1 REQUIRED TO INCORPORATE LATEST DATA RECEIVED FROM WESTINGHOUSE ON W LETTER WPT-9789 (4/11/89) AND UPDATE FORMAT TO ACCOMODATE REQUIREMENTS OF EAP 5.3

REVISION 2 REQUIRED TO:

1. INCORPORATE CCN-001 AND TO MAKE EDITORIAL CHANGES AS NOTED.

2. CLARIFY SECTION IV "CALCULATION OF MULTIPOINT LEVEL SENSOR SIGNAL ERROR" IN RESPONSE TO ATP-89-137, DEFICIENCY NO. 89-137-09, ITEM 7.

△2

A 5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP 1C(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	PAGE 2

OBJECTIVE OF CALCULATION

DURING A MAIN STEAM LINE BREAK (MSLB) OR LOSS OF COOLANT ACCIDENT (LOCA), THE ENVIRONMENTAL TEMPERATURE IS SIGNIFICANTLY HIGHER THAN THE NORMAL TEMPERATURE. CABLE INSULATION RESISTANCE DECREASES SIGNIFICANTLY WITH INCREASING TEMPERATURE. (REFERENCE NO.1) THE RESULTING LOW INSTRUMENT CABLE INSULATION RESISTANCE, DURING A MSLB OR LOCA, MAY AFFECT THE PERFORMANCE OR ACCURACY OF THE CONNECTED INSTRUMENT(S). THIS CALCULATION WILL DETERMINE THE PERCENT ERROR IN THE SIGNAL FOR THE LISTED INSTRUMENTS INSIDE CONTAINMENT AS WELL AS THE LISTED INSTRUMENTS OUTSIDE CONTAINMENT SUBJECT TO MSLB OR LOCA ENVIRONMENTAL TEMPERATURES GREATER THAN 200 °F. △2

I. CALCULATION METHOD

THE AFFECTS OF CHANGES IN INSULATION RESISTANCE TO INSTRUMENT SIGNAL ACCURACY HAVE BEEN CALCULATED USING THE CIRCUIT SHOWN BELOW. THE PERCENT ERROR HAS BEEN CALCULATED USING ROCKBESTOS CABLE* INSULATION RESISTANCE AS DETERMINED BY CALCULATION (REF. NO.1)

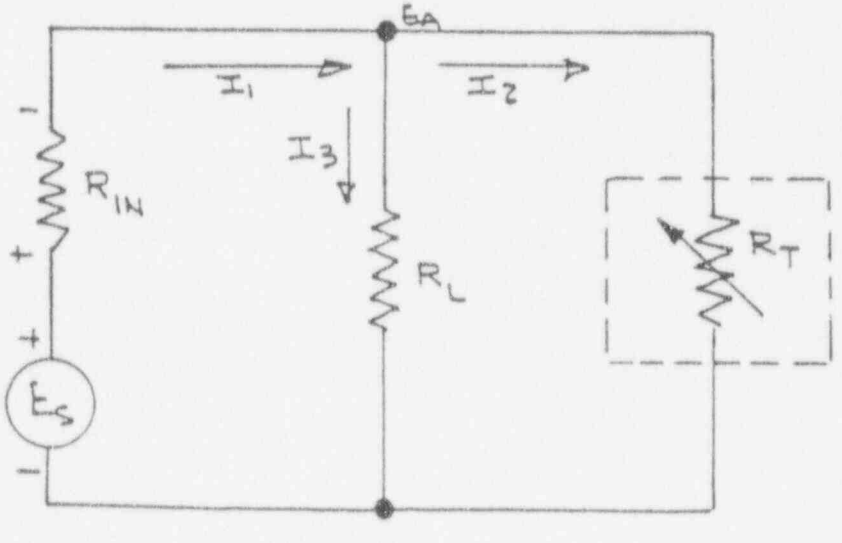


FIG. NO.1

*EXCEPT-WHEN THE CABLE MANUFACTURER HAS BEEN VERIFIED OTHERWISE, IT IS SO NOTED ON TABULATION SHEETS 9 → 16 & 22.

E_S — Loop Power Supply (40VDC)
R_{IN} — NLP Card Input Resistance (Ref. 2)
R_T — Transmitter Resistance (Variable)
R_L — Cable Insulation Resistance
I_2 — Transmitter Current
I_3 — Leakage Current
I_1 — Loop Power Supply Current

① $I_1 = I_2 + I_3$

② $I_1 = \frac{E_S - E_A}{R_{IN}}$, $I_2 = \frac{E_A}{R_T}$, $I_3 = \frac{E_A}{R_L}$

③ Substituting Values From ② into ①

$$\frac{E_S - E_A}{R_{IN}} = \frac{E_A}{R_T} + \frac{E_A}{R_L}$$

$$E_S - E_A = \frac{E_A R_{IN}}{R_T} + \frac{E_A R_{IN}}{R_L}$$

$$E_A = \frac{E_S}{\frac{R_{IN}}{R_T} + \frac{R_{IN}}{R_L} + 1}$$

For Ideal Conditions $R_L \longrightarrow \infty$

④ $$E_A = \frac{E_S}{\frac{R_{IN}}{R_T} + 1}$$

$I_1 = I_2$, $I_3 = 0$

⑤ $$I_1 = I_2 = \frac{E_S}{R_{IN} + R_T}$$

⑥ $$R_T = \frac{E_S - I_1 R_{IN}}{I_1}$$

ASSUMING $I_1 = 4.0$ ma

$$R_T = \frac{40 - (4\times10^{-3})(250)}{4\times10^{-3}} = 9.75\times10^{3} \text{ ohms}$$

ASSUMING $I_1 = 20$ ma

$$R_T = \frac{40 - (20\times10^{-3})(250)}{20\times10^{-3}} = 1.75\times10^{3} \text{ ohms}$$

FOR A NON-IDEAL CONDITION, $I_1 = I_2 + I_3$ & $E_A = \frac{E_S}{\frac{R_{IN}}{R_T} + \frac{R_{IN}}{R_L} + 1}$

USING INSULATION RESISTANCE FROM CALCULATION (REF. #1) FOR ROCKBESTOS CABLE AND A TYPICAL CABLE LENGTH OF 488 FT. (SEE LT-460, PAGE #9)

$$I_R = \frac{*1300 \text{ MEGOHMS}}{488 \text{ FT}} = 2.66 \text{ M}\Omega$$

*CALCULATED $I_R/_L$ (REF. #1) IS EXPRESSED ON A CONDUCTOR FOOT BASIS BETWEEN CONDUCTOR & SHEATH. THE IR BETWEEN TWO SIGNAL CONDUCTORS HAS TWO PATHS

- CONDUCTOR TO SHEATH TO CONDUCTOR (C-S-C)
- CONDUCTOR TO CONDUCTOR DIRECTLY (C-C)

TOTAL LEAKAGE ($I_{R(C)}$) BETWEEN CONDUCTORS IS EXPRESSED AS THE SUM OF THE RESISTANCES (C-S-C) & (C-C) CONNECTED IN PARALLEL $\frac{1}{I_{R(C)}} = \frac{1}{2IR} + \frac{1}{2IR}$ & $I_{R(C)} = \frac{2IR}{2} = IR$

FOR THE ABOVE EXAMPLE – $I_{R(C)} = 2.66$ MEGOHMS $= R_L$

ASSUMING TRANSMITTER CURRENT (I_2) TO BE 4.0 ma

$$E_A = \frac{40}{\frac{250}{9.75\times10^{3}} + \frac{250}{2660\times10^{3}} + 1} = \frac{40}{1.026} = 39 \text{ VOLTS}$$

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 3010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP IC(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	PAGE 5

$$I_3 = \frac{E_A}{R_L} = \frac{39}{2660 \times 10^3} = 0.0147 \times 10^{-3} = 0.0147 \text{ ma}$$

$$I_1 = I_2 + I_3 = 4.0 + .0147 \text{ ma}$$

$$\% \text{ ERROR} = \frac{I_1 - I_2}{I_2} \times 100 = \frac{0.0147}{4} \times 100 = 0.37\%$$

ASSUMING TRANSMITTER CURRENT (I_2) TO BE 20.0 ma

$$E_A = \frac{40}{\frac{250}{1.75 \times 10^3} + \frac{250}{2660 \times 10^3} + 1} = \frac{40}{1.1421} = 35 \text{ VOLTS}$$

$$I_3 = \frac{35}{2660 \times 10^3} = 0.0132 \times 10^{-3} = 0.0132 \text{ ma}$$

$$I_1 = 20.0 + .0132 = 20.0132 \text{ ma}$$

$$\% \text{ ERROR} = \frac{.0132}{20} \times 100 = 0.066\%$$

THE PERCENT ERROR IN SIGNAL DUE TO

FOR THE TYPICAL CASE IS:

CABLE LENGTH	488 FT - ROCKBESTOS
R_L	2.66 MEGOHMS
% ERROR @ 4.0 ma	0.37 %
% ERROR @ 20.0 ma	0.066 %

THE ATTACHED TABULATION IDENTIFIES ALL INSTRUMENTS IN OR OUT OF THE CONTAINMENT WHICH MAY HAVE INACCURACIES DUE TO DECREASED INSULATION RESISTANCE WHEN THE TEMP EXCEEDS 200°F (2) (2)
THE TABULATION PROVIDES THE CABLE TYPE CABLE LENGTH AND % ERROR FOR HIGH AND LOW END OF TRANSMITTER SIGNAL.

UNLESS NOTED OTHERWISE:-
ALL % ERRORS WERE CALCULATED USING THE METHOD USED FOR THE EXAMPLE IN THIS CALCULATION.

REFERENCES/INPUTS

RN 1

1. SWEC CALCULATION 16345/6-EE(B)-084, REV. 1

2. WESTINGHOUSE CORP. INSTRUCTIONS - 7300 SERIES ISOLATOR & LOOP POWER SUPPLY (NLP) CARD - STYLE NOS 2837A12G01 → G03 - SCHEMATIC DIAG. 2837A12-13, SHT. 14

3. SWEC INTEROFFICE CORRESPONDENCE OF 6-8-88 J.P. CARTER TO R. POLTRINO/J. BURNS (ATTACH. NO. 1)

4. SWEC INTEROFFICE CORRESPONDENCE OF 6-7-88 R.G. BRUNNER TO J.R. BURNS (ATTACH. NO. 2)
NOTE: COMPARES FAVORABLY WITH 100 MEGOHM VALUE PUBLISHED IN ROSEMOUNT PDS-2498 FOR MODEL 353C NUCLEAR QUALIFIED CONDUIT SEAL

5. CONAX CORP. TEST REPORT IPS-585.2, APP. "A", TABLE 5.1
NOTE: ON THE #16AWG & #16D-TP-T MULTICONDUCTOR FEEDTHROUGH MODELS, A FEW CONDUCTOR PAIRS EXPERIENCED LOW (< 1-MEGOHM) IR READINGS DURING DBE TESTING. AS TESTS PROGRESSED, THESE IR READINGS VARIED CONSIDERABLY, INDICATING POSSIBLE SPLICE PROBLEMS AS EXPERIENCED DURING SUPPLEMENTAL TESTING (SECT. 6.8.2.3) SINCE MOST CONDUCTOR PAIRS MAINTAINED HIGH IR VALUES DURING DBE TESTING, AN AVERAGE OF THE FINAL #16D-TP-T MODULE READINGS IS USED IN THIS CALCULATION - REFER TO SHEET #4 IN ABOVE TABLE 5.1

6. OKONITE CO., 1974 - ENGINEERING DATA FOR COPPER & ALUMINUM CONDUCTOR CABLES - TABLES 1-3 & 1-4.

7. FLUID COMPONENTS INC., 1982 - MODEL 8-66MA MULTIPOINT LEVEL SENSORS - OPERATION & INSTALLATION MANUAL.

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

▲ 5010 55

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 6A
16345	IC(B)	071	N/A	

REFERENCES/ INPUTS (CONT'D)

8. CABLE PULL CARDS EO1352502, EO1352512, EO1352522, EG1352602, EG1352612 AND EG1352622

9. RdF CORP. INSTR. MANUAL T-10432, REV 2, 8-29-79 △2

10. WESTINGHOUSE LETTER WPT-9789, 4-11-88

11. CONAX CATALOG 3141, TEMPERATURE SENSORS

12. COMBUSTION ENGINEERING INSTRUCTION MANUAL ICE-145

▲ 5010.55

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 6B (2)
16345	IC(B)	071	N/A	

NOTE: IT IS ASSUMED THAT CABLE LEAKAGE EFFECT ARE NEGLIGIBLE FOR 4-20 mA INSTRUMENTS (AND CABLE) LOCATED IN ENVIRONMENTS LESS THAN 200°F. BASIS: THIS CALCULATION CONCLUSIONS NOTE THAT FOR ALL REQUIRED INSTRUMENTS, CABLE LEAKAGE IS NEGLIGIBLE AT TEMPERATURES MUCH GREATER THAN 200°F (2)

CONCLUSIONS

THE HIGHEST PERCENT ERROR AT 4 mA (PAGE 10) IS 0.49 PERCENT AND AT 20 mA IS 0.084 PERCENT. FOR TRANSMITTERS WITH 4-20 mA OUTPUT, THESE ERRORS TRANSLATE AS FOLLOWS:

$$\frac{0.49}{100} \times 4 = 0.0196 \text{ mA}$$

$$\frac{0.084}{100} \times 20 = 0.0168 \text{ mA}$$

FOR THE 4-20 mA TRANSMITTERS, SPAN IS 16 mA AND 0.0196 mA ERROR IN TERMS OF PERCENT SPAN WILL BE

$$\frac{0.0196}{16} \times 100 = 0.12\% \text{ SPAN}$$

THE CABLE LEAKAGE ERROR EQUIVALENT OF 0.12 PERCENT SPAN OR LESS IS CONSIDERED VERY SMALL AND IT IMPACT ON CPSES SETPOINTS IS CONSIDERED NEGLIGIBLE.

PROVIDED ROCKBESTOS INSTRUMENT CABLE IS USED (REF NO. 1) SIGNAL LOSSES ASSOCIATED WITH INSTRUMENT LOCATED IN AN ACCIDENT ENVIRONMENT (MSLB OR LOCA) ARE INSIGNIFICANT AND MAY BE OMITTED FROM INSTRUMENT LOOP ERROR CALCULATIONS.

OTHER CONCLUSIONS AS TABULATED ON PAGES 9 TO 16, 22 AND 22a (2)

II. ADDITIONAL INSULATION RESISTANCE (IR) LOSSES

IN ADDITION TO THE IR(C) OF THE CABLE, THE FOLLOWING DEVICES CONTRIBUTE TO THE TOTAL IR OF THE INSTRUMENT LOOP.

1. CABLE SPLICES - IR(S) = 10 MEGOHMS (3-SPLICES IN SERIES) X 2 (FOR TWISTED PAIR CABLE) - SEE REF. NO. 3

2. ELECTRICAL PENETRATIONS - IR(EP) = 125 MEGOHMS - REF. NO. 5

3. ELECTRIC CONDUCTOR SEAL ASSEMBLY (ECSA's) - IR(ECS) = 100 MEGOHMS - SEE REF. NO. 4.

THE TOTAL LOOP - IR(T) = THE SUM OF THE ABOVE IR's CONNECTED IN PARALLEL

$$\frac{1}{IR(T)} = \frac{1}{R_L} + \frac{1}{IR(EP)} + \frac{1}{IR(S)} + \frac{1}{IR(ECS)}$$

CONTINUING WITH THE RockBESTOS CABLE DEFINED ON PAGE NO. 4 OF THIS CALCULATION, FURTHER INVESTIGATION REVEALS THAT THIS INSTRUMENT LOOP CONTAINS:

- ONE ELECTRICAL CONTAINMENT PENETRATION
- ONE ECSA
- THREE CABLE SPLICES

$$\therefore \frac{1}{IR(T)} = \frac{1}{2.66 \times 10^6} + \frac{1}{125 \times 10^6} + \frac{1}{20 \times 10^6} + \frac{1}{100 \times 10^6}$$

$$\frac{1}{IR(T)} = \frac{37.6 + 0.8 + 5 + 1}{100 \times 10^6} = \frac{44.4}{100 \times 10^6}$$

$$IR(T) = \frac{100 \times 10^6}{44.4} = 2.25 \text{ MEGOHMS}$$

THE CONTRIBUTIONS PROVIDED BY EP's, ECSA's, AND SPLICES TO THE OVERALL LOOP IR ARE INSIGNIFICANT AND MAY BE OMITTED FROM THE COMPUTATIONS.

III. EFFECT OF INCREASED CONDUCTOR RESISTANCE ON INSTRUMENT LOOP SIGNAL ACCURACY DUE TO MSLB OR LOCA TEMPERATURE ENVIRONMENT

FROM REFERENCE NO.6 - THE RESISTANCE (R_1) OF #16AWG COPPER WIRE AT 25°C = 4.44 OHMS/1000 FT.

AT 327°F (163.8°C) – $R_2 = R_1\left(\frac{234.5+T_2}{234.5+T_1}\right) = 4.44\left(\frac{398.3}{259.5}\right)$

$R_2 = 6.82$ OHMS/1000 ft @ 327°F

FOR THE TYPICAL CASE CABLE DEFINED ON PAGE NO.4:

- CONDUCTOR LENGTH = 2 × 488 FT. = 976 FT.
- AT 25°C – $R(T_1) = \frac{976 \times 4.44}{1000} = 4.33$ OHMS
- AT 163.8°C – $R(T_2) = \frac{976 \times 6.82}{1000} = 6.65$ OHMS
- MAX $IR(T_1)$ = 20ma × 4.33Ω = 0.087 VOLTS
- MAX $IR(T_2)$ = 20ma × 6.65Ω = 0.133 VOLTS

$$\text{ERROR INCREASE} = \frac{IR(T_2) - IR(T_1)}{\text{LOOP VOLTS}(T_1)} = \frac{0.133 - 0.087}{40 - 0.087}$$

$$\%\text{ ERROR INCREASE} = \frac{0.046}{39.913} \times 100 = 0.11\%$$

THE INCREASED SIGNAL ERROR, DUE TO THE INCREASE OF CONDUCTOR RESISTANCE, IS INSIGNIFICANT AND MAY BE OMITTED FROM THE COMPUTATIONS.

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

INSTR. NO.	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED IR (MΩ/L)	CALCULATED RL (MΩ)	% ERROR @ 4ma	% ERROR @ 20ma	REMARKS
LT-459	RockBestos #16 TW PR	173	1300	7.51	0.13	0.022	
-460		488		2.67	0.37	0.066	
-461		172		7.56	0.13	0.022	
LPI-JE-410A	BIW #16 TRIAX	119	529×10^3	4.44×10^3	INSIGNIFICANT		
-410B		119		4.44×10^3			
420A		168		3.15×10^3			
420B		168		3.15×10^3			
430A		262		2.02×10^3			
430B		262		2.02×10^3			
440A		200		2.65×10^3			
440B		200		2.65×10^3			
LPI-LT-517	RockBestos #16 TW PR	499	1300	2.60	0.38	0.066	
-518		247		5.25	0.19	0.032	
-519		576		2.25	0.44	0.072	
-551		264		4.9	0.20	0.032	

J.O. OR W.O. NO: 16345
DIVISION & GROUP: HC(B)
CALCULATION NO.: 071
OPTIONAL TASK CODE: N/A
CALCULATION IDENTIFICATION NUMBER:
PAGE 9

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

J.O. OR W.O. NO. 16345 | CALCULATION IDENTIFICATION NUMBER

DIVISION & GROUP IC (B) | CALCULATION NO. 071 | OPTIONAL TASK CODE N/A | PAGE 10

INSTR. NO.	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED IR (MΩ/L)	CALCULATED RL (MΩ)	% ERROR @ 4ma	% ERROR @ 20ma	REMARKS
LP2-LT-527	Rockbestos 3/16 TW PR	296	1300	4.39	0.22	0.038	
-528		211		6.16	0.16	0.027	
-529		167		7.8	0.13	0.022	
-552		223		5.8	0.17	0.028	
LP3-LT-537		293		4.44	0.22	0.036	
-538		250		5.16	0.19	0.030	
-539		289		4.5	0.22	0.036	
-553		232		5.6	0.17	0.030	
LP4-LT-547		562		2.3	0.42	0.072	
-548		195		6.67	0.15	0.025	
-549		653		2.0	0.49	0.084	
-554		193		6.72	0.14	0.024	
PT-455		194		6.71	0.15	0.025	
-456		529		2.46	0.40	0.07	
-457		194		6.71	0.15	0.025	
-458		425		3.06	0.32	0.06	

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

J.O. OR W.O. NO. 16345 | DIVISION & GROUP IC(B) | CALCULATION NO. 071 | OPTIONAL TASK CODE N/A | CALCULATION IDENTIFICATION NUMBER | PAGE 11

INSTR. NO.	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED IR (MΩ/L)	CALCULATED RL (MΩ)	% ERROR @ 4ma	% ERROR @ 20ma	REMARKS
LPI-LT-501	Rockbestos #16 TW PR	45	1300	29.0	0.034	0.005	
-502		249		5.22	0.19	0.032	
-503		204		6.43	0.15	0.025	
-504		136		9.61	0.10	0.017	
PT-403		123		10.62	0.093	0.016	
PT-405		137		9.56	0.10	0.017	
PT-960		68		18.90	0.051	0.008	
-961		64		20.40	0.048	0.008	
-962		84		15.57	0.063	0.010	
-963		119		10.85	0.090	0.015	
-964		219		5.90	0.16	0.027	
-965		246		5.28	0.18	0.032	
-966		236		5.55	0.17	0.03	
-967		228		5.72	0.18	0.029	
FT-4678		154		8.44	0.12	0.02	
-4682		160		8.13	0.12	0.02	
-4686		290		4.48	0.22	0.039	(2)
-4670		178		7.3	0.13	0.024	

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

J.O. OR W.O. NO. 16345 | DIVISION & GROUP IC(B) | CALCULATION NO. 071 | OPTIONAL TASK CODE N/A | CALCULATION IDENTIFICATION NUMBER | PAGE 12

INSTR. NO.	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED IR (MΩ/L)	CALCULATED RL (MΩ)	% ERROR @ 4ma	% ERROR @ 20ma	REMARKS
PT-934	Rockbestos #16 TW PR	264	1300	4.92	0.20	0.034	
-935		298		4.32	0.22	0.04	
-936		283		4.56	0.21	0.04	
-937		251		5.16	0.19	0.032	
-938		239		5.43	0.18	0.03	
-939		276		4.78	0.20	0.04	
LP1-PT-514		329		3.95	0.24	0.04	
-515		419		3.1	0.32	0.054	
-516		300		4.38	0.22	0.036	
LP2-PT-524		282		4.56	0.21	0.04	
-525		421		3.24	0.32	0.052	
-526		312		4.17	0.24	0.04	
LP3-PT-534		315		4.12	0.24	0.04	
-535		387		3.36	0.30	0.05	
-536		290		4.44	0.22	0.04	

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

INSTR. NO.	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED IR (MΩ/L)	CALCULATED RL (MΩ)	% ERROR @4ma	% ERROR @20ma	REMARKS
LP4-PT-544	ROCKBESTOS #16 TW PR	315	1300	4.13	0.24	0.04	
-545		387		3.36	0.30	0.05	
-546		290		4.48	0.22	0.36	
LT-930		569		2.28	0.44	0.072	
-931		577		2.25	0.44	0.074	
-932		586		2.22	0.44	0.074	
-933		637		2.04	0.48	0.08	
1-PV-2325		123		10.57	0.094	0.014	
-2326		169		7.70	0.13	0.022	
-2327		102		12.74	0.076	0.012	
-2328		151		8.60	0.11	0.018	
1-FT-414		153		8.50	0.11	0.02	
-415		167		7.78	0.13	0.022	
-416		67		19.5	0.05	0.008	
-424		202		6.43	0.15	0.025	
-425		283		4.59	0.22	0.04	
-426		205		6.34	0.15	0.027	

J.O. OR W.O. NO. 16345

DIVISION & GROUP IC(B)

CALCULATION NO. 071

OPTIONAL TASK CODE N/A

CALCULATION IDENTIFICATION NUMBER

PAGE 13

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

J.O. OR W.O. NO. 16345 | CALCULATION IDENTIFICATION NUMBER | PAGE 14

DIVISION & GROUP HC(B) | CALCULATION NO. 071 | OPTIONAL TASK CODE N/A

INSTR. NO.	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED IR (MΩ/L)	CALCULATED RL (MΩ)	% ERROR @ 4 ma	% ERROR @ 20 ma	REMARKS
1-FT-434	ROCKBESTOS #16 TW PR	225	1300	5.78	0.17	0.029	
-435		328		3.96	0.25	0.040	
-436		235		5.53	0.17	0.030	
-444		209		6.27	0.16	0.027	
-445		454		2.86	0.34	0.06	
-446		203		6.4	0.15	0.026	
FT-917	ROCKBESTOS #16 TW PR	333					NOT REQUIRED - INSTRUMENT NOT LOCATED IN HARSH (ACCIDENT) ENVIRONMENT
-918	ANACONDA #16 TW PR	400					
-922	ROCKBESTOS #16 TW PR	404					
-618	ANACONDA #16 TW PR	420					
-619	ROCKBESTOS #16 TW PR	426					
					TEMP. @	ERROR 327°F	REF. RTD CALC
TE-604		349	1300	3.72		0.097°	VI PAGE 21
TE-605		288		4.51		0.08°	
					% ERROR @ 4 ma	% ERROR @ 20 ma	
X-LT-102		130		10.0	0.095	0.017	
-104		188		6.91	0.14	0.024	
-105		106		12.26	0.08	0.014	
-106		180		7.22	0.14	0.023	

REV 1

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

INSTR. NO.	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED IR (MΩ/L)	CALCULATED RL (MΩ)	% ERROR @ 4ma	% ERROR @ 20ma	REMARKS
1-PT-2325	ROCKBESTOS #16 TW PR	427	1300	3.04	0.32	0.054	
-2326		604		2.15	0.46	0.076	
-2327		401		3.24	0.30	0.05	
-2328		574		2.26	0.44	0.074	
1-FT-2463A	ROCKBESTOS #16 AWG 2-TW PR	353		3.68	0.26	0.046	
-2464A				3.68	0.26	0.046	
-2465A	ROCKBESTOS #16 AWG 2-TW PR	596		2.18	0.44	0.08	
-2466A				2.18	0.44	0.08	
-2463B	ROCKBESTOS #16 AWG 2-TW PR	596		2.18	0.44	0.08	
-2464B				2.18	0.44	0.08	
-2465B	ROCKBESTOS #16 AWG 2-TW PR	353		3.68	0.26	0.046	
-2466B				3.68	0.26	0.046	
					% ERROR @ HI LEV	% ERROR @ LO LEV	
1-LT-4781	ROCKBESTOS #16-12C	360		3.62 (MAX)	0.00	0.00	REF. CALC IV, Pg #17
1-LT-4779	↓	130		↓	0.00	0.00	↓
1-AE-5506A	ROCKBESTOS #16 4PR TW	590		2.20	NO CALC. NECESSARY		
↓	ROCKBESTOS #16-TW TRI	550		2.36	ROCKBESTOS CABLE		REV 1
1-AE-5506B	ROCKBESTOS #16-TW PR	780		1.67	REF. CONCLUSION		
	ROCKBESTOS	740	↓	1.75	ON PAGE 6A		

(2)

CALCULATION IDENTIFICATION NUMBER

W.O. OR W.O. NO. 16345

DIVISION & GROUP HC (B)

CALCULATION NO. 071

OPTIONAL TASK CODE N/A

PAGE 15

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

CALCULATION IDENTIFICATION NUMBER

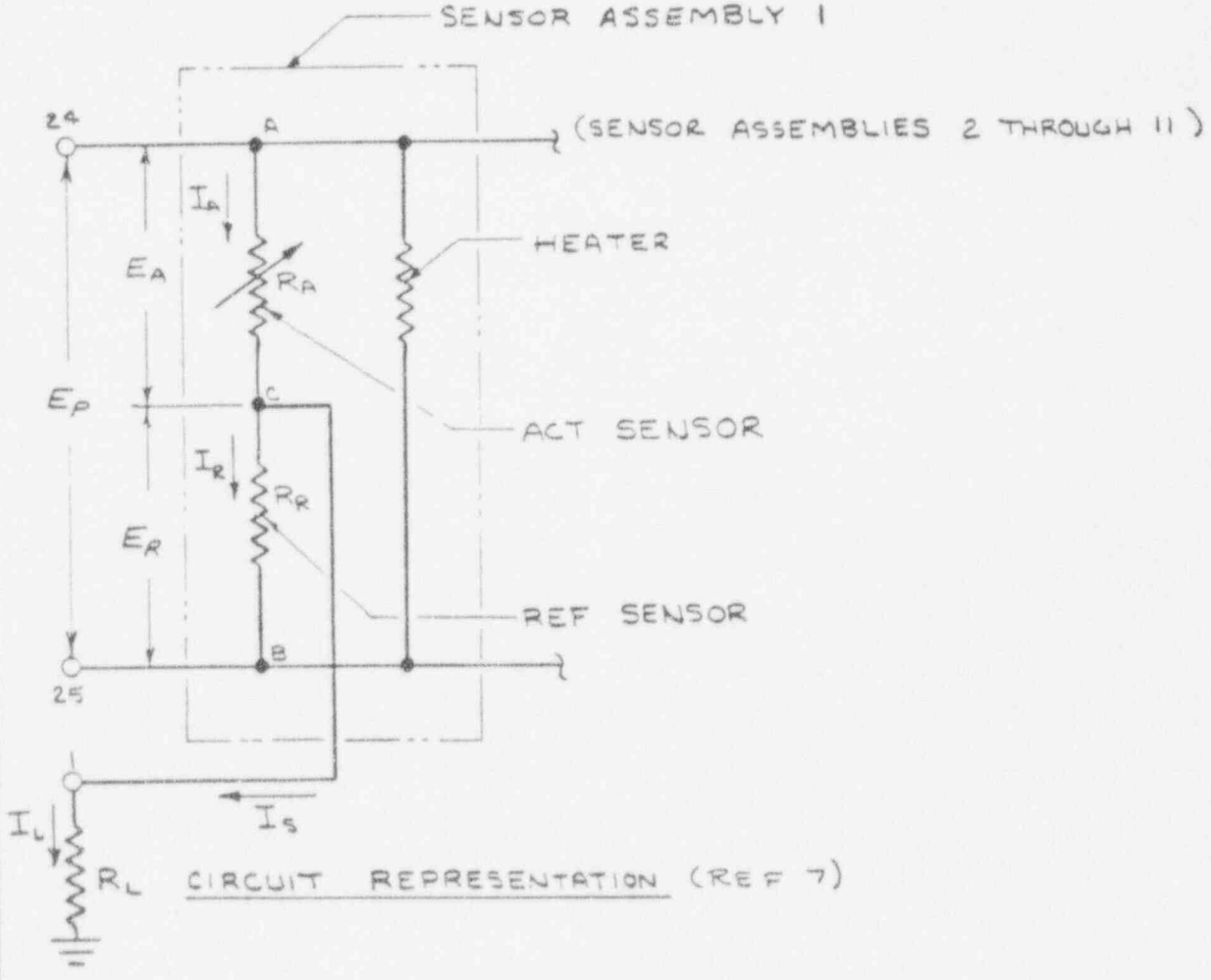
J.O. OR W.O. NO. 16345 | DIVISION & GROUP IC(B) | CALCULATION NO. 071 | OPTIONAL TASK CODE N/A | PAGE 16

INSTR. NO.	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED IR (MΩ/L)	CALCULATED RL (MΩ)	TEMP. ERROR @ 700°F	REMARKS	REV 1
LP1-TE-413A	Rockbestos #16 TW QUAD	125	1300	10.40	0.20°	"RTD" LEAKAGE - REF CALC. V, PAGE "19	
↓ -413B		147		8.84	0.24°		
LP2-TE-423A		271		4.80	0.44°		
↓ -423B		328		3.96	0.53°		
LP3-TE-433A		392		3.32	0.64°		
↓ -433B		268		4.85	0.44°		
LP4-TE-443A		490		2.65	0.80°		
↓ -443B		175		7.43	0.28°		
					TEMP. ERROR @ 650°F		REV 1
LP1-TE-410B		125		10.4	0.19°		
↓ -411B		126		10.3	0.19°		
LP2-TE-420B		341		3.8	0.51°		
↓ -421B		342		3.8	0.51°		
LP3-TE-430B		357		3.65	0.53°		
↓ -431B		356		3.65	0.53°		
LP4-TE-440B		565		2.3	0.84°		
↓ -441B	↓	568	↓	2.29	0.85°	↓	
1-AE-5506C	Rockbestos 16-4 PR TW	628	1300	2.07	No CALC NECESSARY		
↓	Rockbestos #16-TW TRI	602		2.16	ROCKBESTOS CABLE		REV 1
1-AE-5506D	Rockbestos #16-TW PR	669		1.94	REF. CONCLUSION		
↓	Rockbestos #16-TW TRI	643	↓	2.02	ON PAGE	6A	

▲ 5010.55

CALCULATION IDENTIFICATION NUMBER				PAGE 17
J.O. OR W.O. NO. 16345	DIVISION & GROUP 1C(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	

IV CALCULATION OF MULTIPOINT LEVEL SENSOR SIGNAL ERROR



CIRCUIT REPRESENTATION (REF 7)

2

E_P = SENSOR ARRAY POWER SUPPLY VOLTAGE
E_A = VOLTAGE ACROSS ACT SENSOR
E_R = VOLTAGE ACROSS REF SENSOR
I_A = CURRENT THROUGH ACT SENSOR
I_R = CURRENT THROUGH REF SENSOR
I_S = SIGNAL CURRENT
I_L = LEAKAGE CURRENT
R_A = ACT SENSOR RESISTANCE
R_R = REF SENSOR RESISTANCE
R_L = CABLE INSULATION RESISTANCE

▲ 5010 55

CALCULATION IDENTIFICATION NUMBER				PAGE 18
J.O. OR W.O. NO. 16345	DIVISION & GROUP 1C(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	

PAGE 5 OF REFERENCE 7 GIVES THE VOLTAGE BETWEEN TERMINALS 24 AND 25 AS BEING FROM 24 VDC TO 32 VDC. TO BE CONCERVATIVE THE HIGHEST VOLTAGE WILL BE USED.

$$\therefore E_p = 32 \text{ VDC}$$

PAGE 3 OF REFERENCE 7 STATES THAT THE HEATER IN EACH OF THE ELEVEN SENSOR ASSEMBLIES IS THERMALLY CONNECTED TO ONE OF THE RTD'S (ACT SENSOR). WHEN THE SENSOR ASSEMBLIES ARE DRY THE HEATER WARMS THE ACT SENSOR AND INCREASES ITS RESISTANCE.

$$R_A > R_F \quad \text{(DRY)}$$

WHEN THE SENSOR ASSEMBLIES ARE WET THE HEATER'S ENERGY IS DISPERSED BY THE WATER, LOWERING THE TEMPERATURE OF THE ACT SENSOR AND LOWERING ITS RESISTANCE. △2

IN THE EXTREME CASE THE WATER WOULD DISPERSE ALL THE HEATER'S ENERGY AND THE TEMPERATURES OF ACT AND REF SENSORS WOULD BE EQUAL ALONG WITH THEIR RESISTANCES

$$R_A = R_F \quad \text{(WET)}$$

PER REFERENCE 7 PAGE 3, THE RTD'S (SENSORS) FORM TWO LEGS OF A HALF BRIDGE WHICH CONVERTS THE RESISTANCE CHANGE INTO A VOLTAGE CHANGE. SINCE THE AMPLIFIER/FILTER IS LOOKING AT THE VOLTAGE BETWEEN THE TWO SENSORS IT WILL BE ASSUMED THAT THE RESISTANCE OF THE AMPLIFIER/FILTER IS HIGH ENOUGH TO MAKE SIGNAL CURRENT IN THE SIGNAL WIRE NEGLIGIBLE.

$$I_s = 0$$

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP IC(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	PAGE 18A

THIS ASSUMPTION IS JUSTIFIED BECAUSE HIGH CURRENTS IN THE SENSOR LINES WOULD RESULT IN VOLTAGE DROPS IN THESE LINES WHICH WOULD DISTORT THE VOLTAGE SIGNAL THE AMPLIFIER/FILTER IS TRYING TO READ. FURTHER THE ASSUMPTION OF HIGH AMPLIFIER/FILTER RESISTANCE MAXIMIZES THE VOLTAGE AT POINT C AND THIS VOLTAGE WILL BE DRIVING THE CABLE INSULATION LEAKAGE CURRENT SO AN ASSUMPTION THAT MAXIMIZES THE VOLTAGE AT POINT C IS CONSERVATIVE BECAUSE IT WILL MAXIMIZE THE LEAKAGE ERROR

$$I_S = 0$$

WHEN $I_S = 0$

$$I_P = I_R$$

$$E_A = I_A R_A \quad \text{AND} \quad E_R = I_R R_R$$ (2)

WHEN SENSORS ARE WET $R_A = R_R$

IF $R_A = R_R$ AND $I_A = I_R$

THEN $E_A = E_R$

$$E_P = E_R + E_A = E_R + E_R$$

$$E_R = \frac{E_P}{2} = \frac{32 \text{ VDC}}{2} = 16 \text{ VDC}$$

$$E_R = 16 \text{ VDC}$$

LET E_G = VOLTAGE BETWEEN POINT C AND GROUND

PER PAGE 5 OF REFERENCE 7 THE HIGHEST VOLTAGE BETWEEN TERMINAL 25 AND GROUND IS 5 VDC

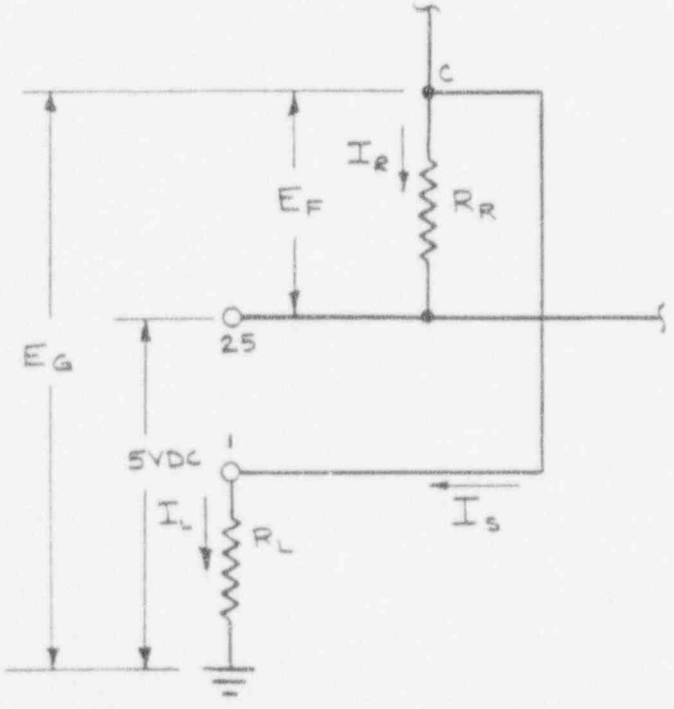
$\therefore E_G = E_F + 5\text{VDC}$

$= 16\text{VDC} + 5\text{VDC}$

$= 21\text{ VDC}$

AS PREVIOUSLY STATED THE VOLTAGE STATED THE VOLTAGE BETWEEN POINT C AND GROUND (E_G) IS THE VOLTAGE DRIVING SENSOR CABLE INSULATION LEAKAGE.

2



SOLVING FOR THE LEAKAGE CURRENT

$$E_G = I_L R_L$$

WHERE $R_L = \frac{1304 \times 10^6 \Omega}{\text{CABLE LENGTH}}$

THE LONGEST CUT LENTH OF CABLE FOR 1-LT-4779 OR 1-LT-4781 INSIDE THE CONTAINMENT IS 360 FT (REF 8)

$$R_L = \frac{1304 \times 10^6 \Omega}{360}$$

$$= 3.622 \times 10^6 \Omega$$

$$I_L = \frac{E_G}{R_L}$$

$$= \frac{21}{3.622 \times 10^6}$$

$$= 5.798 \times 10^{-6} \text{ AMP}$$

PER REFERENCE 7, PAGE 10, NOTE 16 THE MAXIMUM SENSOR LINE RESISTANCE IS 10 OHMS.

IF WE ASSUME I_L EXISTS AND IS CONSTANT EVERYWHERE ALONG THE SENSOR LINE (CONSERVATIVE BECAUSE THE LEAKAGE CURRENT WILL DECREASE THE FARTHER ONE GETS FROM THE SENSOR)

NOW VOLTAGE LOSS IN THE SENSOR LINE DUE TO LEAKAGE BECOMES:

$$E_{LOSS} = I_L (10 \Omega)$$

$$= 5.798 \times 10^{-5} \text{ VOLTS}$$

△2

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

▲ 5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 18D
16345	IC(B)	071	N/A	

ERRORS ON THE ORDER OF 10^{-5} (5798×10^{-5} VDC) ARE INSIGNIFICANT FOR SIGNALS ON THE ORDER OF 10^{1} (16 VDC)

THEREFORE CABLE INSULATION LEAKAGE ERROR FOR MULTIPOINT LEVEL SENSORS WILL BE ZERO.

△2

▲ 5010 65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP IC(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	PAGE 19

V. EFFECT OF DECREASED "IR" ON RX COOL'NT 4-WIRE "RTD" SIGNALS

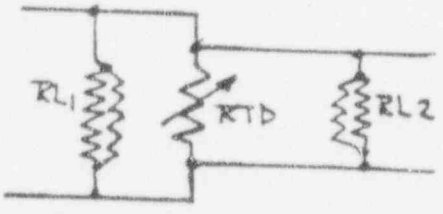
(REFER - 9) | 2

FROM SAMPLE CALCULATION

- RTD RESISTANCE @ 32°F ≈ 201 OHMS
  @ 212°F ≈ 280
  @ 525°F ≈ 411
  @ 625°F ≈ 451

FROM REF 10 | 2
Rx COOL'NT. DESIGN TEMP - NARROW RANGE - 650°F, WIDE RANGE - 700°F
(REFER RdF 200 OHM RTD CURVE - PAGE 20)

- RTD RESISTANCE @ 650°F ≈ 460 OHMS, @ 700°F ≈ 480 OHMS
- ΔT/OHM ≈ 2.3°F



(WITH IR LEAKAGE @ 327°F)

$$\frac{1}{R_T} = \frac{1}{R_{RTD}} + \frac{2}{R_{L1}} + \frac{2}{R_{L2}}$$

(REF. TE-443A, PAGE 16)

$$\frac{1}{R_T} = \frac{1}{480} + \frac{4}{2.65 \times 10^6}$$

$$R_T = \frac{480 \times 2.65 \times 10^6}{1920 + 2.65 \times 10^6}$$

$$R_T = \frac{1272 \times 10^6}{2.65192 \times 10^6} = 479.65^+$$

$\Delta R = 480 - 479.65^+ = 0.35\,\Omega$

TEMP. ERROR = ΔR @ 700°F × 2.3°F/Ω = 0.80°F

% ERROR @ 700°F = $\frac{0.8}{700} \times 100 = 0.11$ %

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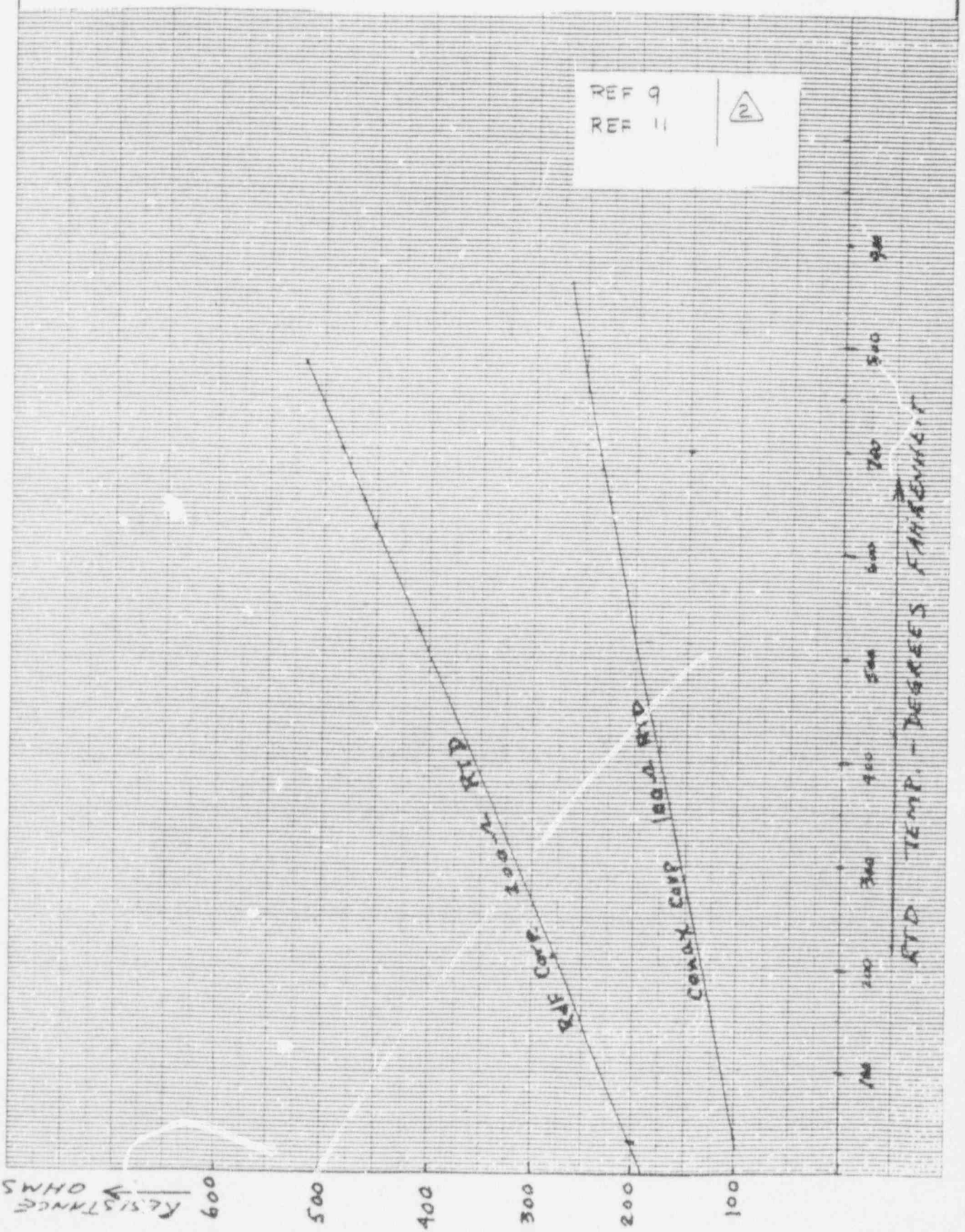
CALCULATION SHEET

▲ 5010 55

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 20
16345	IC(B)	071	N/A	



46 1516

K&E 10 X 10 TO THE CENTIMETER

VI. EFFECT OF DECREASED "IR" ON CNTMT. & RHR. HT. EXCGR. TEMP. 3-WIRE "RTD" SIGNALS - (REFERENCE 11)

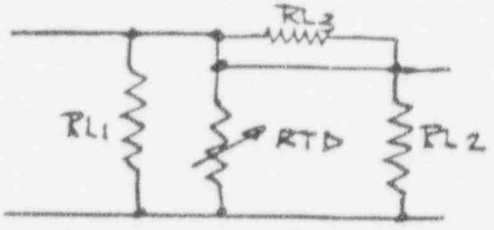
2

FROM TEMP/RESISTANCE CHART – PLAT. RTD's 43, 44 & 45

- RTD RESISTANCE @ 32°F ≅ 100 OHMS
- @ 212°F ≅ 139
- @ 500°F ≅ 198
- @ 680°F ≅ 234

REFER CONAX 100 OHM RTD CURVE – PAGE 20

- RTD RESISTANCE @ 327°F ≅ 160 OHMS
- ΔT/OHM ≅ 4.7°F



(WITH IR LEAKAGE @ 327°F)

$$\frac{1}{R_T} = \frac{1}{R_{RDT}} + \frac{1}{R_{L1}} + \frac{1}{R_{L2}} + \frac{1}{R_{L3}}$$

(REF. TE-5400, PAGE 22)

$$\frac{1}{R_T} = \frac{1}{160} + \frac{3}{1.08 \times 10^6}$$

(REF. TE-604, PAGE 14)

$$\frac{1}{R_T} = \frac{1}{160} + \frac{3}{3.72 \times 10^6}$$

(TE-5400)

$$R_T = \frac{160 \times 1.08 \times 10^6}{480 + 1.08 \times 10^6}$$

$$R_T = \frac{172.8 \times 10^6}{1.08048 \times 10^6} = 159.93$$

$\Delta R = 160 - 159.93 = 0.07\ \Omega$

TEMP ERROR = ΔR @ 327°F × 4.7°F/Ω = 0.33 °F

% ERROR @ 327°F = $\frac{0.33}{327} \times 100 = 0.10\ \%$

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

J.O. OR W.O. NO. 16345 | DIVISION & GROUP HC(B) | CALCULATION NO. 071 | OPTIONAL TASK CODE N/A | PAGE 22

CALCULATION IDENTIFICATION NUMBER

INSTR. NO.	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED IR (MΩ/L)	CALCULATED RL (MΩ)	TEMP. ERROR @ 327°F	REMARKS	REV 1
1-TE-5400	ROCKBESTOS #16 TW TRIAX	1200	1300	1.08	0.33°	REF. CALC VI, Pg 21	
-5401		790		1.65	0.22°		
-5402		735		1.77	0.20°		REV -
-5403		890		1.46	0.27°		
-5404		580		2.24	0.16°		
1-TE-3613A-1	BIW TW TRIAX T/C-X	841	23.8	0.0283	0.85°	REF. CALC VII, Pg 23	
-2							
-3							
-4							
-5							
-6							
-7		774		0.0307	0.82°		
-8		774		0.0307	0.82°		REV -
1-TE-3613B-1		884		0.0269	0.88°		
-2							
-3							
-4							
-5							
-6							
-7		853		0.0279			
-8		858		0.0277			

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

INSTR No	CABLE TYPE (MFR)	CABLE LENGTH (FT)	CALCULATED ER (MR/L)	CALCULATED RL (MR)	TEMP ERROR @	TEMP ERROR 327°F	REMARKS	REV
TE-4691	ROCKBESTOS #16 TW TRIPLE	90	1300	11.4		0.047	REF. CALC VI Pg 21	2
-4692		219		6.13		0.061		2
-4693		254		5.12		0.094		2
-4694		160		8.13		0.055		2

CALCULATION IDENTIFICATION NUMBER

J.O. OR W.O. NO. 16345

DIVISION & GROUP IC (B)

CALCULATION NO. 071

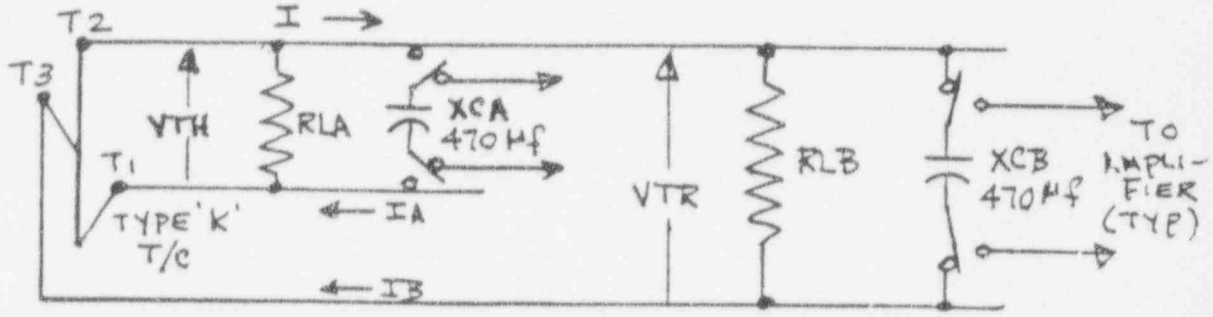
OPTIONAL TASK CODE N/A

PAGE 229

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 16345	DIVISION & GROUP IC(B)	CALCULATION NO. 071	OPTIONAL TASK CODE N/A	PAGE 23

VII. EFFECT OF DECREASED "IR" ON HJTC SIGNALS

(REF. 12) 2



XCA & XCB ARE ALTERNATELY CHARGED FROM T/C & DISCHARGED TO THE AMPLIFIER AT APPROX. 30 CYCLES PER SECOND

$$XCA = XCB = \frac{1}{fc} = \frac{1}{30 \times 470 \times 10^{-6}} = 70.92 \text{ OHMS}$$

RLA = RLB = 0.0283 MEGOHM (REF. TE-3613A-1, PAGE #22)

AT 327°F VTH = VTR = 6.695 mV (REF. OMEGA TEMP. HNDBK. - 1986 SECT. T, TABLE IX)

WITHOUT IR LEAKAGE @ 327°F

$$IA = IB = \frac{VTH}{XCA} = \frac{6.7 \times 10^{-3}}{70.92} = 0.09447 \text{ ma}, \quad I = IA + IB = \underline{0.1889 \text{ ma}}$$

WITH IR LEAKAGE @ 327°F

$$\frac{1}{RTA} = \frac{1}{RLA} + \frac{1}{XCA}$$

$$RTA = \frac{(28.3 \times 10^3)(70.92)}{28.3 \times 10^3 + 70.92} = \frac{2007 \times 10^3}{28.371 \times 10^3} = 70.74 \text{ OHMS}$$

$$IA' = IB' = \frac{6.7 \times 10^{-3}}{70.74} = 0.0947 \text{ ma}, \quad I' = 0.1894 \text{ ma}$$

$$\%\text{ ERROR} = \frac{I' - I}{I} \times 100 = \frac{0.1894 - 0.1889}{0.1889} \times 100 = 0.26\%$$

TEMP ERROR @ 327°F = 0.26% × 327°F = 0.85°F

REV 1

Interoffice Correspondence

Date: June 8, 1988

To: R. Poltrino/J. Burns

From: J. P. Carter

J.O. 18051.03

Subject: Insulation Resistance of Splices

2CN 1

In containment connections are typically insulated with nuclear grade heat shrinkable materials by Raychem Corp., WCSF-N. A review of Wylie Laboratories Test Report No. 58442-1, "Environmental Qualification Test Report of Raychem WCSF-N Nuclear In-Line Cable Splice Assemblies for Raychem Corporation Menlo Park, California", shows that this material has good insulation resistance during heightened temperatures and LOCA conditions. The test samples consisted of three splices in series on 1/c #12 Rockbestos Firewall III insulated wire (0.030 in. wall).

Six samples were tested during the test. Two samples were not tested at high temperature because of failures in the test device which were not associated with the splices. Two others at 314F had Insulation Resistance values of 1.8E+07 ohms (these samples were aged to 1000 hrs. at 150C. and irradiated to 2.0E+08 Rads). The remaining two samples exhibited insulation resistance values of 3.6E+07 and 3.4E+07 at 314F. These cables were unaged. It is estimated that these values will be in the vicinity of 1.0E+07 at 327F, the highest temperature seen by the cables. The samples were tested with their cables attached. The effects of the cable on the insulation resistance value was not separated from the splices. It is expected that the value of the Raychem heat shrink material would be higher then that for the combination.

SWEC calculation 084 gives the following per foot values for the Insulation Resistance of the cables at the CPSES job site: a.) Rockbestos--1304/L M-ohms per conductor foot, b.) Anaconda--31.56/L M-ohms per conductor foot, c.) BIW--50.21/L M-ohms per conductor foot. Additionally, the BIW RG 11/U cable has an insulation value of 52.9E+04/L M-Ohms per conductor foot.

INTEROFFICE CORRESPONDENCE
CALC. NO. 16345-IC(B)-071 ATTACHMENT NO. 2

TO: J. R. Burns	LOCATION 7	SUBJECT / REFERENCE / J.O. NO. 18051.02 Insulation Resistance - Electrical Conductor Seal Assemblies (ECSA)
FROM: R. G. Brunner	LOCATION 14	

MESSAGE: —

ECSA INSULATION RESISTANCE AT 327 °F (163.9 °C)

An aged, irradiated, conditioned ECSA sample measured $> 1 \times 10^{10}$ ohms at 72°F (22.2°C) Ref Conax IPS-1079, 1139 - E.I. DuPont publication E-72087 dtd. 1-87 "Kapton Polyimide Film, Summary of Properties," Plot Volume Resistivity vs Temperature (page 16)

at 22.2°C 1×10^{16} ohm-meter

at 163.9 °C 1.0×10^{14} ohm-meter

DATE _____ SIGNATURE _____ TELEPHONE _____

REPLY:

Calculation

At 327 °F (163.9 °C) insulation resistance would be greater than:

$$R > 1 \times 10^{10}\ \Omega \times \frac{1.0 \times 10^{14}\ \Omega\text{-M}}{1.0 \times 10^{16}\ \Omega\text{-M}} = 1.0 \times 10^{8}\ \text{ohms per conductor}$$

RG Brunner

6-7-88 x-2258

DATE _____ SIGNATURE _____ TELEPHONE _____

▲ 040 138