

TVA EMPLOYEE CONCERNS  
SPECIAL PROGRAM

REPORT NUMBER: 241.2(B)

REPORT TYPE: SEQUOYAH ELEMENT

REVISION NUMBER: 1

TITLE: CABLE TERMINATION AND SPLICES  
Crimp Connections

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REASON FOR REVISION:

Incorporate TVA's comments.

PREPARATION

PREPARED BY:

George S. W.  
SIGNATURE

MD ch-m

12/5/86  
DATE

REVIEWS

PEER:

REVIEW COMMITTEE

W. J. Lankford Karl Spidner  
SIGNATURE

12/5/86  
DATE

TAS:

SIGNATURE

DATE

CONCURRENCES

Paul B. Nesbitt 12/6/86

CEG-H: George R. Muntz 12-6-86

SRP:

SIGNATURE

DATE

SIGNATURE

DATE

APPROVED BY:

ECSP MANAGER

DATE

MANAGER OF NUCLEAR POWER

DATE

CONCURRENCE (FINAL REPORT ONLY)

8701090474 861222  
PDR ADOCK 05000327  
P PDR

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1. CHARACTERIZATION OF ISSUE(S):

Concerns:

JLH-85-004

"PIDG lugs have apparently been used for making crimps on solid conductors resulting in reduced current capacity for CSSC fire dampers."

Issues:

The use of pre-insulated diamond grip (PIDG) lugs to make crimps on solid conductors may result in reduced current capacity. The practice of crimping on solid conductors requires reevaluation.

PH-85-003-003

"The practice of terminating diodes and rectifiers without soldering the wiring but only splicing by crimping to the lead-ins needs to be reevaluated for quality construction.  
Control room 757' elev."

2. HAVE ISSUES BEEN IDENTIFIED IN ANOTHER SYSTEMATIC ANALYSIS? YES X NO

o Identified by TVA WBN OC

Date May 13, 1985

Nonconformance Report NCR No. WBN 6076 R0, AMP diamond grip insulation terminal lugs, (05/13/85)

o Identified by TVA WBN EEB/WBEP

Date August 14, 1985

SCR WBNEEB8537 R0, Misapplication of AMP PIDG Terminal Lugs (08/14/85)

o Identified by TVA WBN NSRS

Date September 23, 1985

TVA WBN (SQN) Nuclear Safety Review Staff Investigation Report I-85-101-WBN (SQN)-1, Improper Termination Techniques, (09/23/85)

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o Identified by TVA SQN GSTF

Date May 6, 1986

TVA SNP Generic Concern Task Force "Crimp on Connectors on  
Diodes and Rectifiers" (05/06/86)

3. DOCUMENT NOS., TAG NOS., LOCATIONS, OR OTHER SPECIFIC DESCRIPTIVE  
IDENTIFICATIONS STATED IN ELEMENT:

No further information available. Employee concern addresses the  
use of crimp versus soldered connections on diodes and rectifiers,  
and solid conductors on critical systems' fire dampers.

4. INTERVIEW FILES REVIEWED:

Files JLH-85-004 and PH-85-003 were reviewed and no additional  
unreviewed information for Sequoyah was identified.

5. DOCUMENTS REVIEWED RELATED TO THE ELEMENT:

See Appendix A.

6. WHAT REGULATIONS, LICENSING COMMITMENTS, DESIGN REQUIREMENTS, OR OTHER  
APPLY OR CONTROL IN THIS AREA?

See Appendix A.

7. LIST REQUESTS FOR INFORMATION, MEETINGS, TELEPHONE CALLS, AND OTHER  
DISCUSSIONS RELATED TO ELEMENT.

See Appendix A.

8. EVALUATION PROCESS:

- a. Reviewed available transcripts of NRC investigative  
interviews for additional information on the concerns.
- b. Reviewed existing TVA reports to determine the extent to  
which these reports and corrective actions satisfy the  
concerns.



- c. Reviewed existing TVA Construction, QA/QC, Operations, and Material Control reports for the Employee Concerns Evaluation Program for applicability to the concerns discussed in this report.
- d. Investigated the adequacy of using PIDG crimps on solid conductors and the consequences of their use on solid conductors in safety-related systems.

9. DISCUSSION, FINDINGS, AND CONCLUSIONS:

Discussion:

On April 3, 1985, AMP Products Corporation, manufacturer of pre-insulated diamond grip (PIDG) terminal lugs, sent a letter to F. W. Chandler (App. A, 5. ff) stating that use of PIDG terminal lugs with solid copper conductors proved unsatisfactory in tests under any voltage or current condition. An April 23, 1985 memo from J. C. Standifer to G. Wadewitz instructed WBN to replace the PIDG terminal lugs that were installed on solid wires.

NCR 6076 RO (App. A, 5. b) was issued on May 13, 1985, identifying this condition. The NCR revealed that AMP PIDG terminal lugs have been employed with solid copper conductors on safety systems for the installation of small electronic components. Westinghouse responded to NCR 6076 in their letter of May 24, 1985 to J. A. Raulston (App. A, 5. gg). They stated that, based on discussions with the author of the AMP April 3, 1985 letter, they determined that the AMP tests on the PIDG terminals used relatively high voltages and currents which resulted in basic material breakdown of the terminal lugs. They concluded that since the Foxboro H-line process equipment was low voltage and low current, the PIDG lugs would maintain structural and electrical integrity for the life of the plant if terminal lugs were installed properly. They went on to state that problems with the lugs would be detected during periodic tests and that no history of problems was known to exist at WBN or SQN. On this basis, the use of PIDG terminals is acceptable to Westinghouse.

A June 17, 1985 memo from Standifer to Wadewitz (App. A, 5. x) stated that on the basis of Westinghouse's evaluation (App. A, 5. gg) and the fact that TVA's use of the PIDG terminals is for similar control loop applications, the PIDG terminal is satisfactory in this application. This memo dispositioned the NCR to "use as is".



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An NSRS investigation of employee concerns from June 17, 1985 to July 26, 1985 was reported on September 23, 1985 in I-85-101-WBN (SQN)-1 (App. A, 5.hh). The NSRS report included the following findings related to the use of PIDG terminal lugs at SQN:

- a. "AMP Corporation attempted to obtain UL approval for the use of the PIDG Terminal Lugs on solid copper conductor wire but was unable to because of test failures (UL 486)."
- b. "Foxboro drawing specified Burndy terminal lugs. However, Foxboro racks contain AMP terminal lugs (PIDGs)."
- c. "As a result of interviews with SQN personnel, it was learned that Foxboro had soldered over some terminal lugs (PIDGs) in the Foxboro racks."
- d. "Although Westinghouse had accepted the usage of PIDG terminal lugs on solid wire in the Foxboro racks, the justification for their approval of the termination process in view of the problems (broken wires, loose connections, etc.) and failures experienced at both plants was considered by NSRS to be questionable. Westinghouse had apparently not had knowledge of these failures during their evaluations and had erroneously assumed '... no history of any terminal lug problem has ever existed at either plant.'"
- e. "Although Nonconformance Report (NCR) WBNNCR6076 was generated for WBN, OE as well as OC management personnel were aware of existence of the same nonconforming condition at SQN. Nonetheless, an NCR was not generated for SQN."
- f. "The PIDG terminal lugs have been installed in safety-related systems and failures have been identified at both plants. Therefore the potential exists for the degradation of those safety-related systems."
- g. "SQN has experienced failures in test point resistors in the Foxboro racks. Crimp failures resulted in additional resistance in the test point resistors, which are 10 to 100 ohm resistors with 1 percent tolerances. Problem test point resistors have been replaced with test point resistors where the terminal lugs have been crimped on and then soldered.

"Interviews with responsible personnel at SQN revealed that all PIDG terminal lugs utilized in the security system and crimped on solid wire were replaced with terminal lugs appropriate for the application."

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- h. "G-38 requires selection of terminal lugs to be made based on manufacturer's recommendations. The manufacturer's recommendation was ignored in this case."
  - i. "SQN NUC PR procedure M&AI-12, 'Modification and Additions Instruction - Interconnecting Cable Termination and Insulation Inspection,' R7, very clearly and appropriately states, 'Solid conductors shall be lugged or spliced with AMP Solistrand lugs. . .'"

In response to a draft of the NSRS Report No. I-85-101-WBN, WBN Project Management Organization (PMO) conducted telephone interviews with operations and construction personnel (R.C. McKay memo to PMO Files, App. A, 5.s; 08/07/85) to determine if the failure history of the discrete electronic components was due to the misapplication of PIDG terminal lugs. The results of these interviews at the Sequoyah Plant are:

- o No failure could be directly or indirectly attributed to the misapplication of the PIDG terminal lugs.
- o A program for soldering terminal lugs was started in 1976-1977 and continued after transfer from OC to NUC PR.
- o Test point resistor failure of the Foxboro instrument racks was not attributed to the PIDG terminals lugs because the failures continued after they were soldered.

On August 6, 1985, Regulatory Engineering Section (RES) issued Operating Experience Review OER SQNB850024001 (App. A, 5.a) which documented random inspections and interviews performed at Sequoyah. The inspections and interviews revealed the application of PIDG terminal lugs in several areas:

1. Fire damper fuse links
2. Solenoid valves suppression networks
3. D/G control panel and logic relay panel
4. 6.9 kV breaker control logic
5. Conax Connectors
6. 125 V dc vital battery board
7. 480 V shutdown board
8. Vital inverters

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The OER also indicated that Specification Revision Notice SRN-G-38-6 was issued to initiate the revision to General Construction Specification G-38. The revision specifies the AMP approved SOLIDSTRAND terminal lug for solid conductors.

H. G. Parris memo to K. W. Whitt dated September 13, 1985 (App. A, 5.cc) responded to the draft NSRS report and initiated corrective action to solder or replace all safety-related PIDG terminals except those used on surge suppression networks. These networks are used on solenoid valves and 6.9kV and 480 V shutdown board status monitoring relays. The memo stated that solenoid valve surge suppression networks will be addressed on a second priority as the surge suppression networks do not provide a safety function and serve only to enhance the life of the contacts in the circuits that power the solenoids. (Note: Although this does not specifically address the 6.9kV and 480 V shutdown board status monitoring relays, the response would be applicable).

A pull test and resistance measurements of PIDG terminal lug crimped to one end of a diode were performed by TVA Central Laboratories (App. A, 5.j). Ten terminal lugs on solid conductors were tested on 10/04/85 in accordance with Sequoyah Nuclear Plant Special Test Instruction STI-3 R0 (App. A, 5.h; 10/02/85).

The test results showed that the average contact resistance between the terminal lug and solid conductor was less than 0.00125 ohm. All 10 terminal lugs withstood a gradual application of 8 pounds of force without evidence of slippage between the conductor and terminal lug. The minimum force causing separation was 28.5 pounds. Even though the test results appeared favorable the decision was made to proceed with the modifications.

Subsequently, SQN completed inspections of more than 1,300 terminal connections in various areas (TVA memo from Abercrombie to Parris, App. A, 5.g; 11/15/85). These inspections evaluated the rework as follows:

<u>Area Inspected</u>	<u>Rework</u>
Fire damper fuse links	All rework complete
MSIV solenoid valve suppression network	Rework not required (safety-related but not required for safe shutdown)
6.9 kV shutdown board (suppression network on status monitoring relay)	Rework not required (nonsafety-related)
MSIV control circuit (diodes)	Rework required



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Area Inspected	Rework
125 V vital battery board filter network	Rework required
480 V shutdown board (suppression network on status monitoring relay)	Rework not required (nonsafety-related)
125 V vital inverters	No PIDG connections found
Diesel generator control panel and relay panel	No PIDG connections found
Units 1 and 2 auxiliary control rooms	Rework required
Units 1 and 2 auxiliary instrument rooms	Rework required
Units 1 and 2 main control rooms	Rework required
Units 1 and 2 fire detection panels (resistor across second horn)	Rework required

To formalize and implement the method of soldering or replacing PIDG terminal lugs, Special Maintenance Instruction SMI-2-317-25 RO, (App. A, 5.i), was issued for SQN Unit 2 on 01/24/86. Its purpose was to require soldering of all AMP (PIDG) terminal lugs or replacement with AMP (SOLIDSTRAND) terminal lugs for all solid conductors in the critical systems and components found in the previous inspections.

TVA SQN Generic Concern Task Force report on EC #PH-85-003-003 (App. A, 5.k; 05/06/86) stated that Unit 2 rework has been completed for the areas identified above. Similar rework will be completed for Unit 1 before it is restarted. The report recommended that EEB review the results of the test conducted by TVA Central Laboratories because rework "seems" to be unnecessary in view of the test results. EEB's response was to take a more conservative approach (i.e., soldering or replacing PIDG terminal lugs).

A September 15, 1986 memo from P. R. Wallace to D. W. Wilson (App. A, 5.ee) requested DNE's position on the need of surge suppression network in the solenoid valve circuit. A draft memo from D. W. Wilson to P. R. Wallace (App. A, 5.p; 10/24/86) expressed EEB's position on surge suppression network. This memo stated that the purpose of surge suppression networks is to protect circuit contacts against pitting and burning caused by arcing associated with breaking the inductive load current of the solenoid valve. Therefore, the reliability of PIDG connectors used on surge suppression networks should be assured. The memo also stated that PIDG connectors on surge suppression networks associated with solenoid valves required to perform a safety function must be replaced or soldered prior to restart. For the remaining class 1E surge suppression networks, inoperability would not create an immediate safety problem, but over a period of time excessive contact wear would increase the potential for a contact failure. Therefore, field testing prior to restart must assure that the surge suppression networks have not developed an open circuit. This test should be repeated periodically until the surge suppression networks are permanently fixed by replacing or soldering the PIDG terminal lugs. This memo has not been formally issued, and no followup program has been identified for closing out the recommended actions.

Findings:

AMP Products Corporation (manufacturer of PIDG terminal lugs) stated that, on the basis of its engineering department's evaluation and tests previously performed, using PIDG terminal lugs on solid conductors is unsatisfactory (App. A, 5.ff; 04/03/85). Reduced current capacity could occur if terminal lugs are improperly installed.

A rework program (soldering or replacing the existing terminal lugs) was performed and completed for SQN Unit 2 in all safety-related applications with the exception of the surge suppression networks for solenoid valves. TVA must perform similar rework for SQN Unit 1.

Conclusion:

The concern regarding improper use of PIDG terminal on solid conductors is valid. The adequacy of this application was found to be deficient and corrective action has been taken. Rework on these terminations was completed for Unit 2 except for the rework on the surge suppression networks. TVA must implement the similar rework for SQN Unit 1.

DNE is recommending that all PIDG terminal lugs in surge suppression networks for safety-related circuits be replaced or soldered but no plan for this work presently exists.



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APPENDIX A

5. DOCUMENTS REVIEWED RELATED TO THE ELEMENT:

- a. Operating Experience Review, OER SQN850024001 (WBNP NCR6076, R0), (08/06/85)
- b. NCR 6076 R0, (C24 850513 103), (05/13/85)
- c. AMP Inc., catalog No. 4507-1, Engineering and Purchasing Guide, Fifth Edition, "PIDG Terminal" and "SOLIDSTRAND Terminal," Copyright 1984
- d. TVA General Construction Specification G-38 R6, (09/15/85) and R7 (01/15/86), "Installing Insulated Cables Rated Up to 15,000 Volts"
- e. Potential Reportable Occurrence (PRO) 1-85-258, Originator: M. Garman, "Possible misuse of PIDG lugs," (08/05/85)
- f. Significant Condition Report SCR WBNEEB8537 R0, (B43850819 928), (08/14/85)
- g. TVA memo from Abercrombie to Parris, "Sequoyah Nuclear Plant (SQN)-Nuclear Safety Review Staff Report No. I-85-101-WBN(SQN) - Use of PIDG Lugs for Electrical Terminations," (S53 851113 825), (11/15/85)
- h. TVA, SNP, Special Test Instruction STI-3 R0, "Pull Test of Solid Conductor Crimped Connections," (10/02/85)
- i. TVA, SNP, Special Maintenance Instruction SMI-2-317-25 R0 (01/24/86), and R1 (03/17/86), "Solder or Replacement of AMP (PIDG) Lugs Terminated on Solid Wire in CSSC Equipment, Unit 2"
- j. TVA Central Laboratories Report 86-6365, (E13 851004 201), (10/04/85)
- k. TVA, SQN Generic Concern Task Force, "Crimp On Connectors On Diodes and Rectifiers," R1, (05/06/86)
- l. QIR SQN86082, "EQ Binder No. SQNEQ-JBOX-001; Open Item," (S03 860321 875), (03/21/86)
- m. ECN L5773, (B25 851107 514), (11/07/85)

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APPENDIX A (Cont'd)

- n. SCR SQNEQP8618 RO, "Reanalyzed the Failure Effects of Solenoid Valve Arc Suppression Networks," (B70 860624 001), (06/20/86)
- o. Engineering Report CAQ SQNEQP8618 RO, (B45 860827 000), (08/22/86)
- p. TVA memo Wilson to Wallace, "Sequoyah Nuclear Plant (SQN) - PIDG Connector - Surge Suppression Networks," (10/24/86)
- q. SNP Modification and Addition Instructions M&AI-7 R6, "Cable Termination Splicing and Repairing of Damaged Cables," (08/07/85)
- r. SNP Inspection Instruction No. 10, "Interconnecting Cable Termination and Insulation Inspection," R16, (04/04/83)
- s. TVA memo McKay to PMO Files, "Review of NSRS Investigation of Alleged Improper Electrical Termination Technique At WBNF - Nuclear Safety Staff Report No. I-85-101-WBN," (08/07/85)
- t. Underwriters Laboratories Inc., Standard No. UL 486 A-80, Seventh Edition, Fourth Impression, "Wire Connectors and Soldering Lugs for Use with Copper Conductors," (06/02/84)
- u. TVA memo from Vineyard to Rankin, "Sequoyah Nuclear Plant Units 1 and 2 - Potential Generic Condition Evaluation," (B24851008 014), (10/08/85)
- v. F. W. Chandler, TVA, letter to Joseph J. Naples, AMP Products Corporation, "Sequoyah and Watts Bar Nuclear Plants PIDG Terminal Lugs," (B433 851120 903), (11/15/85)
- w. TVA memo Chandler to Vineyard, "Potential Generic Condition Evaluation" (B43850923 916), (09/23/85)
- x. TVA memo Standifer to Wadewitz, "Watts Bar Nuclear Plant-Non-ASME Significant Nonconformance Report 6076 RO," (B26 850617 004), (06/17/85)
- y. Letter from B. J. Youngblood, NRC, to S. A. White, TVA, (06/25/86) with the attached transcript of the investigative interview conducted by the NRC on 2/21/86 at the First Tennessee Bank Building in Knoxville, TN.

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APPENDIX A (Cont'd)

- z. TVA Electrical Design Guide DG-E20.3.5, R0, "Transient Suppression Networks for Inductive Loads," (06/25/84)
- aa. TVA memo from T. G. Robinson to Electrical Engineering Files, "Sequoyah Nuclear Plant Arc Suppression Network for Safety-Related Equipment," (B43 851028 916), (10/25/85)
- bb. TVA memo from Chandler to Raulston (EEB 840313 905), (03/12/84)
- cc. TVA Response to NSRS Report I-85-101-WBN (A02 850904 010), (09/13/85)
- dd. TVA Engineering Report CAQ SCR WBNEEB8537 (B45 850909 260), (09/03/85)
- ee. TVA memo from Wallace to Wilson "Sequoyah Nuclear Plant (SQN) - Surge Suppression Networks - PIDG Connectors (S53 860911 938) (09/15/86)
- ff. Letter from J. J. Naples, AMP Products Corporation to F. W. Chandler, TVA, "Use of AMP Diamond Grip Insulated Terminal Lugs with Copper Wire" (B43 50408021), (04/03/85)
- gg. Letter from E. A. Nootnak, Westinghouse, to J. A. Raulston, TVA, "Response to TVA NCR #6076 Concerning AMP Products Corporation Letter on Diamond Grip Insulated Terminal Lugs," (B45 850524 614), (05/24/85)
- hh. TVA Nuclear Safety Review Staff (NSRS) Investigation Report I-85-101-WBN (09/23/85)

6. WHAT REGULATIONS, LICENSING COMMITMENTS, DESIGN REQUIREMENTS, OR OTHER APPLY OR CONTROL IN THIS AREA?

- a. General Construction Specification G-38, "Installing Insulated Cables Rated up to 15,000 Volts"
- b. Office of Engineering - Procedure - OEP-09, "Procurement"
- c. SNP Modification and Additions Instructions M&AI-7, "Cable Termination Splicing and Repairing of Damaged Cables"
- d. TVA division of construction SNP, Inspection Instruction No. 10



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- e. EVA, SNP Special Maintenance Instruction SMI-2-317-25 R0  
(01-24-86); R1 (03-17-86) Construction process/procedure

7. LIST REQUESTS FOR INFORMATION, MEETINGS, TELEPHONE CALLS, AND OTHER  
DISCUSSIONS RELATED TO ELEMENT:

Knoxville Meeting, Wheeler, Don-Doncow, Bechtel, and  
C. Sudduth, TVA, (04/22/86)

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CATD LIST

The following CATD forms are included as part of this report:

241.02(B) SQN 01 (revised 12/05/86)  
241.02(B) SQN 02 (revised 12/05/86)

1. Immediate Corrective Action Required: ☐ Yes ☒ No  
2. Stop Work Recommended: ☐ Yes ☒ No  
3. CAID No. 241.02-SQN-01 4. INITIATION DATE \_\_\_\_\_  
5. RESPONSIBLE ORGANIZATION: DNE  
6. PROBLEM DESCRIPTION: ☒ QR ☐ NQR

		<input type="checkbox"/> ATTACHMENTS
7.	PREPARED BY: NAME <u>George J. W...</u>	DATE: <u>12/5/86</u>
8.	CONCURRENCE: <u>ECTG-H</u> <u>Duke R. Mc...</u>	DATE: <u>12-6-86</u>
9.	APPROVAL: ECTG PROGRAM MGR.	DATE:

[illegible]

13. Approved corrective actions have been verified as satisfactorily implemented.

DATE \_\_\_\_\_



1. Immediate Corrective Action Required: ☒ Yes ☐ No  
2. Stop Work Recommended: ☐ Yes ☒ No  
3. CATD No. 241.02-SAN-02 4. INITIATION DATE \_\_\_\_\_  
5. RESPONSIBLE ORGANIZATION: DNE  
6. PROBLEM DESCRIPTION: ☒ QR ☐ NOR

		<input type="checkbox"/> ATTACHMENTS
7.	PREPARED BY: NAME <u>George S. Wm</u>	DATE: <u>12/5/86</u>
8.	CONCURRENCE <u>FOR</u> CEG-H <u>George R. M. Nutt</u>	DATE: <u>12-6-86</u>
9.	APPROVAL: ECTG PROGRAM MGR.	DATE:

[illegible]

13. Approved corrective actions have been verified as satisfactorily implemented.

DATE \_\_\_\_\_

Enclosure 4