



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
WASHINGTON, D.C. 20555-0001

November 16, 1994

APPLICANT: Tennessee Valley Authority (TVA)  
FACILITY: Watts Bar Nuclear Plant, Unit 1  
SUBJECT: MEETING SUMMARY - NOVEMBER 3, 1994, MEETING WITH THE  
TENNESSEE VALLEY AUTHORITY (TVA) REGARDING SPLICES ON  
ELECTRICAL CABLES (TAC M89109)  
REFERENCE: Meeting notice by Peter Tam, October 31, 1994

On November 3, 1994, NRC and TVA representatives met in Rockville, Maryland to discuss issues regarding splices on cables used in Watts Bar Nuclear Plant Unit 1. Enclosure 1 is the list of meeting participants. Enclosure 2 is the handout material provided by TVA.

TVA's presentation focused on the results and implications of their cable splice inspections, primarily regarding connectors that were improperly rated, and connectors that were not crimped according to the manufacturers' specifications. TVA provided the bases for their determination that these safety-related splices are adequate. TVA stated that the concerns about splices and connectors are on ampacity and mechanical integrity (pull test). According to tests performed so far by TVA and contractors, TVA found no ampacity and mechanical integrity problem. TVA further stated that voltage concerns are addressed by insulation and shielding materials; since proper materials have been used, there is no voltage concern.

The staff expressed these concerns: (1) the root cause that led to the utilization of improper splices, (2) the formal docketing of detailed information to justify the adequacy of any improperly installed splice, (3) post-modification tests that need to be performed, per Criterion 11 of 10 CFR 50, Appendix B, on any corrective action and (4) the large number of splices in the diesel generator cables. The staff requested TVA's response in writing. Finally, the staff stated that they would need to review the information to be provided in TVA's response regarding the quantities and quality of splices and the ensuing long-term solutions associated with these items before the staff could render a determination on the acceptability of the situation and TVA's proposed fixes.

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The staff stated that they saw no fatal flaw that would prevent TVA's performance of the Integrated Safeguards Test (IST). However, TVA should be aware of risks on IST validity as a result of future corrective action of cable splice problems, if required.



Laura A. Dudes, Project Engineer  
Project Directorate II-4  
Division of Reactor Projects - I/II  
Office of Nuclear Reactor Regulation

Enclosures: 1. Participants List  
2. Handout Material

cc w/enclosure 1: See next page

WATTS BAR NUCLEAR PLANT

cc:

Mr. Craven Crowell, Chairman  
Tennessee Valley Authority  
ET 12A  
400 West Summit Hill Drive  
Knoxville, TN 37902

Mr. W. H. Kennoy, Director  
Tennessee Valley Authority  
ET 12A  
400 West Summit Hill Drive  
Knoxville, TN 37902

Mr. Johnny H. Hayes, Director  
Tennessee Valley Authority  
ET 12A  
400 West Summit Hill Drive  
Knoxville, TN 37902

Mr. Oliver D. Kingsley, Jr.  
President, TVA Nuclear and  
Chief Nuclear Officer  
Tennessee Valley Authority  
6A Lookout Place  
1101 Market Street  
Chattanooga, Tennessee 37402-2801

Dr. Mark O. Medford, Vice President  
Engineering & Technical Services  
Tennessee Valley Authority  
3B Lookout Place  
1101 Market Street  
Chattanooga, TN 37402-2801

Mr. D. E. Nunn, Vice President  
New Plant Completion  
Tennessee Valley Authority  
3B Lookout Place  
1101 Market Street  
Chattanooga, TN 37402-2801

Mr. J. A. Scalice, Site Vice President  
Watts Bar Nuclear Plant  
Tennessee Valley Authority  
P.O. Box 2000  
Spring City, TN 37381

General Counsel  
Tennessee Valley Authority  
ET 11H  
400 West Summit Hill Drive  
Knoxville, TN 37902

Mr. Roger W. Huston, Manager  
Nuclear Licensing and Regulatory Affairs  
Tennessee Valley Authority  
4G Blue Ridge  
1101 Market Street  
Chattanooga, TN 37402-2801

Mr. B. S. Schofield  
Site Licensing Manager  
Watts Bar Nuclear Plant  
Tennessee Valley Authority  
P.O. Box 2000  
Spring City, TN 37381

TVA Representative  
Tennessee Valley Authority  
11921 Rockville Pike  
Suite 402  
Rockville, MD 20852

Regional Administrator  
U.S. Nuclear Regulatory Commission  
Region II  
101 Marietta Street, NW., Suite 2900  
Atlanta, GA 30323

Senior Resident Inspector  
Watts Bar Nuclear Plant  
U.S. Nuclear Regulatory Commission  
Route 2, Box 700  
Spring City, TN 37381

The Honorable Robert Aikman  
County Executive  
Rhea County Courthouse  
Dayton, TN 37321

The Honorable Garland Lanksford  
County Executive  
Meigs County Courthouse  
Decatur, TN 37322

Mr. Michael H. Mobley, Director  
Division of Radiological Health  
3rd Floor, L and C Annex  
401 Church Street  
Nashville, TN 37243-1532

Ms. Danielle Droitsch  
Energy Project  
The Foundation for  
Global Sustainability  
P.O. Box 1101  
Knoxville, TN 37901

Mr. Bill Harris  
Route 1, Box 26  
Ten Mile, TN 37880

Distribution w/enclosure 1

W. Russell/F. Miraglia	0-12G18
R. Zimmerman	0-12G18
A. Thadani	0-12G18
S. Varga	0-14E4
J. Zwolinski	0-14E1
OGC	0-15G18
E. Jordan, D/AEOD	T-4D18
F. Ashe	0-7E4
V. Beaston	0-7E4
E. Brown	0-7E4
F. Burrows	0-7E4
H. Garg	0-8H3
C. Gatton	0-8D3
G. Hubbard	0-8D3
J. Knox	0-7E4
G. Lainas	0-7D23
J. Lazevnick	0-7E4
D. Nguyen	0-7E4
P. Pal	0-7E4
E. Weiss	0-7E4
R. Jenkins	RII
B. Boger	RII
G. Walton	RII
J. Lara	RII
C. Julian	RII
J. Jaudon	RII
ACRS (4)	
G. Tracy, EDO	0-17G21
<u>w/enclosures 1 and 2</u>	
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P. Fredrickson	RII

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LIST OF PARTICIPANTS AND OBSERVERS

ROCKVILLE, MARYLAND

NOVEMBER 3, 1994

<u>Name</u>	<u>Affiliation</u>
Don Arp	TVA
Frank Ashe	NRC/NRR/DE/Electrical Engineering Branch
Virgil Beaston	NRC/NRR/DE/Electrical Engineering Branch
Carl Berlinger	NRC/NRR/DE/Electrical Engineering Branch
Mike Brickey	TVA/Lead Electrical Engineer
Eva Brown	NRC/NRR/DE/Electrical Engineering Branch
Fred Burrows	NRC/NRR/DE/Electrical Engineering Branch
Laura Dudes	NRC/NRR/Project Directorate II-4
Walt Elliot	TVA/Engineering
Paul Fredrickson	NRC/RII/DRP
Hukam Garg	NRC/NRR/Instrumentation and Controls Branch
Chris Gratton	NRC/DSSA/Plant Systems Branch
Frederick Hebdon	NRC/NRR/Project Directorate II-4
George Hubbard	NRC/NRC/Plant Systems Branch
Johns P. Jaudon	NRC/RII/DRP
Ronaldo Jenkins	NRC/NRR/DE/Electrical Engineering Branch
John Knox	NRC/NRR/DE/Electrical Engineering Branch
Jim Krieg	TVA
Gus Lainas	NRC/NRR/Division of Engineering
Julio F. Lara	NRC/RII/Resident Inspector
Jim Lazevnick	NRC/NRR/DE/Electrical Engineering Branch
Duc Nguyen	NRC/NRR/DE/Electrical Engineering Branch
Amar N. Pal	NRC/DE/Electrical Engineering Branch
Jose Piriz	TVA/Thomas & Betts
Bruce Schofield	TVA/Watts Bar Site Licensing
John Simmons	TVA/ESI/CAP and Sp Manager
Peter Tam	NRC/NRR/Project Directorate II-4
Glenn Tracy	NRC/Office of Executive Director
Glenn Walton	NRC/RII/Senior Resident Inspector
Eric Weiss	NRC/DE/Electrical Engineering Branch
Harry Yaworski	TVA/RAYCHEM

ENCLOSURE 1

The staff stated that they saw no fatal flaw that would prevent TVA's performance of the Integrated Safeguards Test (IST). However, TVA should be aware of risks on IST validity as a result of future corrective action of cable splice problems, if required.

Original signed by  
Laura A. Dudes, Project Engineer  
Project Directorate II-4  
Division of Reactor Projects - I/II  
Office of Nuclear Reactor Regulation

Enclosures: 1. Participants List  
2. Handout Material

cc w/enclosure 1: See next page

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NAME	BC [signature]		LDudes [signature]		PTam [signature]		CBerlinger		FHebdon [signature]	
DATE	11/16/94		11/16/94		11/16/94		11/16/94		11/16/94	

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## **SPLICE ISSUES**

- **PURPOSE OF MEETING**
  - **DESCRIBE ADEQUACY OF WBN-1 SAFETY-RELATED SPLICES**
    - **LONG-TERM OPERATIONS**
      - **600V BURNDY IN 6.9 KV APPLICATIONS**
      - **600V T&B IN 6.9 KV APPLICATIONS**
    - **INTEGRATED TESTING SEQUENCE (ITS)**
      - **600V PENN UNION IN 6.9 KV APPLICATIONS**
      - **15 KV T&B IN 6.9 KV APPLICATIONS**
  - **STATUS OF RELATED ITEMS**
    - **MANHOLE ISSUES (INCLUDING TREEING)**
    - **UNDOCUMENTED SPLICES**
    - **DOCUMENTATION ISSUES**
    - **CONFORMAL COATING FOR KAPTON PIGTAILS**
    - **NUMBER OF INSTALLED 6.9 KV SPLICES**
  - **POST MODIFICATION TEST REQUIREMENTS, IF CONNECTORS ARE REPLACED AFTER ITS**
  - **OUTLINE PRESENT PLAN FOR ENSURING LONG-TERM CAPABILITY OF SAFETY-RELATED SPLICES FOR OPERATION OF WBN-1**
- **DISCUSSION/BACKGROUND**
  - **RECENTLY WBN HAS HAD SEVERAL SPLICE RELATED ISSUES**
    - **IMPROPER CRIMPING OF 15 KV CONNECTORS IN 6.9 KV APPLICATION**
    - **USE OF 600V CONNECTOR IN 6.9 KV APPLICATION WITHOUT PRIOR APPROVAL**

- **TVA HAS DETERMINED THAT THE SAFETY-RELATED SPLICES IN LOW AND MEDIUM VOLTAGE ARE ADEQUATE**
  - **LOW VOLTAGE (600VAC, 120VAC, 125VDC)**
    - **ADEQUATE FOR LONG-TERM OPERATION (TAB 1)**
  - **MEDIUM VOLTAGE**
    - **TOTAL POPULATION - ~ 828 LOCATIONS**
    - **ADEQUATE FOR LONG-TERM OPERATION**
      - **50 - 600V BURNDY IN 6.9 KV**
      - **490 - 600V T&B IN 6.9 KV**
    - **ADEQUATE FOR ITS**
      - **29 - 600V PENN UNION IN 6.9 KV**
      - **146 - 15 KV T&B IN 6.9 KV**
    - **113 - CONNECTOR TYPES NOT YET IDENTIFIED**
      - **5 CAST (T&B OR PENN UNION)  
(FURTHER EVALUATION REQUIRED)**
      - **53 IN DIESEL TERMINAL BOXES (POSTULATED AS PENN UNION)  
(SAMPLE 4/53)**
      - **4 POSTULATED AS T&B 600V  
(BASED ON 2 OF 2 PRESSURIZER HEATER TRANSFORMER INSPECTION)**
      - **3 SYSTEM 212 TRANSFORMER (T&B OR PENN UNION)  
(FURTHER EVALUATION REQUIRED)**
      - **48 MOTOR LEADS (POSTULATED AS T&B)  
(REVIEW OF UNIT 2 EQUIPMENT AND U1 RECORDS)**
- **719/828 = 87% REVIEWED**



- **ADEQUACY OF 4 GROUPINGS**

- **ADEQUATE FOR LONG-TERM OPERATION (TAB 2)**
  - **600V BURNDY IN 6.9 KV APPLICATIONS**
  - **600V T&B IN 6.9 KV APPLICATIONS**
- **ADEQUATE FOR ITS AS A MINIMUM (TAB 2)**
  - **600V PENN UNION IN 6.9 KV APPLICATIONS**
  - **15 KV T&B IN 6.9 KV APPLICATIONS**

- **OTHER RELATED ITEMS**

- **UNDOCUMENTED SPLICES**
- **DOCUMENTATION ISSUES**
  - **WORKPLAN DATA SHEETS (WRONG TOOL DOCUMENTED)**
  - **MARK NUMBER DIFFERENCE (COMPUTERIZED CABLE ROUTING SYSTEM VERSUS INSTALLATION)**
  - **PROCUREMENT ENGINEERING GROUP EVALUATION PACKAGE ISSUE**
  - **TVA REQUISITION FORM 575 DIFFERENT FROM TVA ITEMS IDENTIFICATION CODE (TIIC)**
- **MANHOLE ISSUES**
  - **LACK OF AN OVERSLEEVE**
  - **TAPE**
  - **RING CUT**
  - **QUALIFICATION OF KITS**
  - **TREEING ISSUES**
- **NUMBER OF SPLICES**
- **CONFORMAL COATING OF KAPTON PIGTAILS**

- **CURRENT PLAN FOR LONG-TERM ACCEPTABILITY OF CLASS 1E SPLICES**
  - **EVALUATE MEDIUM VOLTAGE SAFETY RELATED SPLICES THAT DO NOT MEET CURRENT VENDOR CRITERIA**
    - **DEVELOP AND CONDUCT INSPECTION/TEST METHODS TO DETERMINE THE ADEQUACY OF SPLICES ACCEPTED FOR ITS.**
    - **QUALIFY OR REPLACE SPLICES WHERE INADEQUACIES ARE FOUND**
  - **POST MODIFICATION TESTING, IF CONNECTORS REPLACED AFTER ITS (TAB 3)**
  - **CONFIDENCE IN SPLICE REPLACEMENT PROGRAM**

## **TAB 1**

- **ADEQUACY OF LOW VOLTAGE SPLICES FOR LONG-TERM OPERATION**

- **BACKGROUND**

- **WBSCA940063 EXTENT OF CONDITION IDENTIFIED IMPROPERLY INSTALLED T&B 15KV BUTT SPLICE CONNECTORS.**

- **CONNECTORS TO BE INSTALLED WITH T&B "R-SUFFIX" DIES REQUIRE OVERLAP OF CRIMPS AND 90° ROTATION OF DIES TO PRODUCE A SMOOTH AND ROUND CONNECTOR.**

- **DEFICIENCIES HAVE BEEN IDENTIFIED WITH BOTH THE OVERLAPPING AND ROTATION REQUIREMENTS.**

- **THE T&B 15KV CONNECTOR INSTALLATION PROCESS IS COMPLEX WHEN COMPARED TO OTHER CRIMPING OPERATIONS USED FOR LOW VOLTAGE APPLICATIONS (I.E., T&B, BURNDY, AND AMP 600V AND LESS INSULATED AND UNINSULATED CONNECTORS AND TERMINAL LUGS).**

- **CONNECTOR/LUGS UTILIZED IN LOW VOLTAGE APPLICATIONS**

- **THE ESTIMATED NUMBER OF LOW VOLTAGE TERMINATIONS OF 49,000 IS DIVIDED INTO THE FOLLOWING CATEGORIES:**

- **480V POWER**
- **120 VAC & 125 VDC CONTROL**
- **INSTRUMENTATION**

- **480V POWER UNINSULATED LUGS ARE CONSIDERED THE NEXT MOST COMPLEX CRIMPING OPERATION (ONE OR MULTIPLE FULL COMPRESSION CRIMPS AT PROPER LOCATION AND USING PROPER DIE WITH HYDRAULIC COMPRESSION TOOLS AND REMOVAL OF RESULTANT FLASHING).**

- **A WALKDOWN HAS BEEN PERFORMED ON APPROXIMATELY 200 600V UNINSULATED TERMINAL LUGS INSTALLED ON 480V SHUTDOWN BOARDS. ALL WERE PROPERLY INSTALLED.**

- **ROOT CAUSE DETERMINATION FOR WBSCA940063 HAS IDENTIFIED CONFUSING INSTRUCTIONS IN THE INSTALLATION PROCEDURES AS A CONTRIBUTION TO THE IMPROPERLY INSTALLED 15KV T&B CONNECTORS IN MEDIUM VOLTAGE APPLICATION. THE INSTRUCTIONS ARE CLEAR FOR OTHER TERMINATIONS EXCEPT FOR BURNDY 600V UNINSULATED CONNECTORS UTILIZED IN 6.9 KV APPLICATIONS (MEDIUM VOLTAGE).**
- **TWO PREVIOUSLY INSTALLED BURNDY CONNECTORS HAVE HAD INSULATION REMOVED AND PROPER INSTALLATION VERIFIED. CRIMPING OPERATION IS SIMILAR TO T&B 600V CONNECTORS.**
- **BASED UPON THE RESULTS OF VERIFICATION OF 600V CONNECTORS INSTALLED IN 480V APPLICATIONS AND BURNDY CONNECTORS APPLIED IN 6.9KV CIRCUITS, IT IS CONCLUDED THAT INSTALLATION PROBLEMS ARE LIMITED TO THE T&B 15KV CONNECTORS. LOW VOLTAGE CONNECTORS HAVE BEEN INSTALLED PROPERLY AND ARE SATISFACTORY FOR THE LONG-TERM OPERATION OF THE PLANT.**

## **TAB 2**

- **ADEQUACY OF MEDIUM VOLTAGE SPLICES FOR ITS AND LONG-TERM OPERATION**

- **1. THOMAS & BETTS 600V CONNECTORS/LUGS**

- **SERIES 54100 AND 54200 (1 & 2 SHORT BARREL HOLE LUG)**
- **SERIES 53100 AND 53200 (1 & 2 HOLE CAST LUG - HEAVY DUTY)**
- **SERIES 53500 (CAST 2-WAY CONNECTOR - HEAVY DUTY)**
- **SERIES 54500 (2-WAY SHORT BARREL CONNECTOR)**

- **LONG-TERM TECHNICAL ACCEPTABILITY**

- **FIELD INSPECTIONS NOTED CRIMP REQUIREMENTS PERFORMED CORRECTLY AND FLASHING PROPERLY REMOVED BY CRAFT (APPROXIMATELY 200 INSPECTED).**
- **PROPER CRIMP TOOL/DIE UTILIZED (ONE OR TWO CRIMP(S) WITH HEX DIE AS REQUIRED).**
- **VENDOR CERTIFICATION THAT ABOVE CONNECTORS/LUGS ARE SUITABLE FOR 6.9KV APPLICATION (VENDOR RATED TO 35KV FOR LUGS AND 15KV FOR 2-WAY CONNECTORS).**
- **CORONA AND STRESS CONTROL ADEQUATE DUE TO CORRECT INSTALLATION OF RAYCHEM KITS.**
- **RAYCHEM HAS SUCCESSFULLY TESTED KITS UTILIZING LOW VOLTAGE (600 V) NON-TAPERED CONNECTORS, TYPICAL OF T&B AND BURNDY CONNECTORS.**
- **STARTUP AND TEST (SUT) HAS COMPLETED 2 HOUR 110 PERCENT LOAD TESTS AND 22 HOUR 100 PERCENT LOAD TESTS FOR ALL 4 DIESEL GENERATORS (DG).**

- **CONCLUSION**

**THE ABOVE LUGS/CONNECTORS HAVE BEEN CERTIFIED BY THE VENDOR TO MEET ALL TECHNICAL AND UL486A REQUIREMENTS FOR ITS AND LONG TERM OPERATION.**

- **2. BURNDY YS SERIES HYLINK CONNECTORS**

- **SERIES YS 28 AND YS 34 (LONG BARREL CONNECTORS)**

- **LONG-TERM TECHNICAL ACCEPTABILITY**

- **FIELD INSPECTIONS NOTED CRIMP REQUIREMENTS PERFORMED CORRECTLY (2 INSPECTED).**
- **PROPER CRIMP TOOL/DIE UTILIZED (TWO CRIMPS ON EACH END FOR 4/0 CABLE AND FOUR CRIMPS ON EACH END FOR 500 MCM CABLE).**
- **VENDOR CERTIFICATION THAT ABOVE CONNECTORS ARE SUITABLE FOR 6.9KV APPLICATION (VENDOR RATED TO 35KV).**
- **CORONA AND STRESS CONTROL ADEQUATE DUE TO CORRECT INSTALLATION OF RAYCHEM KITS.**
- **RAYCHEM HAS SUCCESSFULLY TESTED KITS UTILIZING LOW VOLTAGE NON-TAPERED CONNECTORS, TYPICAL OF T&B AND BURNDY CONNECTORS.**
- **SUT HAS COMPLETED 2 HOUR 110 PERCENT LOAD TEST AND 22 HOUR 100 PERCENT LOAD TEST FOR ALL 4 DGS.**

- **CONCLUSION**

**THE ABOVE LUGS/CONNECTORS HAVE BEEN CERTIFIED BY THE VENDOR TO MEET ALL TECHNICAL AND UL486A REQUIREMENTS FOR LONG-TERM OPERATION.**

- 3. THOMAS & BETTS 15KV CONNECTORS/LUGS
  - SERIES 54400 (1 & 2 HOLE LUG)
  - SERIES 54000 (2-WAY CONNECTORS)
- ITS ACCEPTABILITY
  - FIELD INSPECTIONS NOTED CORRECT TOOL/DIE UTILIZED
    - PROBLEM IDENTIFIED CONCERNING NUMBER OF CRIMPS PERFORMED BY CRAFT AND TOOL ROTATION REQUIREMENTS NOT CONSISTENTLY FOLLOWED.
  - T&B HAS PERFORMED SUCCESSFUL UL 486A TEST ON 2-WAY CONNECTORS (54000 SERIES) WITH ONLY ONE CRIMP ON EACH END WITH NO TOOL ROTATION.

#### TEST SUMMARY OF SIX TESTS

CABLE CONNECTOR	SECURENESS TEST	HEATING TEST (C°) ALLOWABLE/ACTUAL		PULL TEST VALUE	PULLOUT ACTUAL VALUE	% ABOVE ALLOWABLE
2/0 (54010)	PASS	69	60/60	300 LBS.	1110 LB.	370
4/0 (54012)	PASS	70	63/65	450 LBS.	1331 LB.	296
500 (54018)	PASS	70	58/59	800 LBS.	2483 LB.	310

- T&B DOCUMENTED THAT TEST PERFORMED ON 2-WAY CONNECTORS (54000 SERIES) BOUNDS THE 1 & 2 HOLE LUGS (54400 SERIES).
- RAYCHEM FIELD INSPECTIONS OF IMPROPERLY CRIMPED 2-WAY CONNECTOR NOTED THAT INSTALLED RAYCHEM KITS WILL PERFORM AS RATED ON SUBJECT CONNECTORS.
- SUT HAS COMPLETED 2 HOUR 110 PERCENT LOAD TEST AND 22 HOUR 100 PERCENT LOAD TEST FOR ALL 4 DGS.
- CONCLUSION
 

THE ABOVE LUGS/CONNECTORS HAVE BEEN TESTED/CERTIFIED BY THE VENDOR TO MEET ALL TECHNICAL AND UL486A REQUIREMENTS FOR ITS OPERATION.

- **4. PENN UNION TLU LUGS**

- **SERIES TLU (1 & 2 HOLE CAST LUGS)**

- **ITS ACCEPTABILITY**

- **PENN UNION HAS SUCCESSFULLY TESTED A 500 MCM TLU LUG TO REQUIREMENTS OF UL 486A.**
- **VENDOR HAS SUPPLIED LUGS OF THIS TYPE FOR SUBSTATION APPLICATIONS WHICH IS THEIR PRIMARY CUSTOMER**
- **FIELD INSPECTION NOTED THAT CORRECT DIE UTILIZED AND PROPER CRIMP PERFORMED**
- **NO SIGN OF DEGRADATION ON LUGS THAT HAVE CARRIED CURRENT**
- **PENN UNION TLU LUGS ARE DIMENSIONALLY SIMILAR TO OTHER MANUFACTURED LUGS, E.G., T&B. T&B CRIMP TOOL/DIE SPECIFIED BY PENN UNION.**
- **LUGS DESIGNED FOR CURRENT CARRYING APPLICATIONS**
- **SUT HAS COMPLETED 2 HOUR 110 PERCENT LOAD TEST AND 22 HOUR 100 PERCENT LOAD TEST FOR ALL 4 DGS.**

- **CONCLUSION**

**BASED UPON SUCCESSFUL PREOP/STARTUP TESTING, THE HEAVY DUTY "TLU" DESIGN AND DIMENSIONAL SIMILARITY TO OTHER MANUFACTURERS PRODUCTS (T&B), PERFORMANCE OF THE TLU LUGS FOR 4/0 AND 400 MCM CABLES ARE CONSIDERED TO BE GOOD AND SIMILAR TO THE UL486A TESTED 500 MCM LUG AND THUS ACCEPTABLE FOR ITS OPERATION.**



### **TAB 3**

- **GUIDELINES FOR POST-MODIFICATION TESTING OF SPLICE REPLACEMENTS**

**THE SPLICE INSPECTIONS AND REPLACEMENTS CURRENTLY UNDERWAY ON 6.9KV CABLES WILL INVALIDATE SOME COMPONENT TESTING ON THE CABLES AND END DEVICES. THE PROCESS INVOLVES, AS A MINIMUM, THE REMOVAL OF THE INSULATING SLEEVE, BOOT, OR TAPE AROUND THE LUG OR SPLICE AND REQUIRES A RE-VERIFICATION OF THE INSULATION INTEGRITY. WHERE THE CONNECTIONS ARE BROKEN AT THE SPLICE OR CONNECTION POINT, PHASE CONFIGURATION MUST BE RE-VERIFIED. THE FOLLOWING GUIDELINE SHALL BE UTILIZED IN ASSIGNING RETESTS FOR SYSTEMS STILL IN THE CUSTODY OF STARTUP.**

- 1. HI-POT TESTING SHALL BE RE-PERFORMED ON ALL AFFECTED CABLES TO VERIFY THE INTEGRITY OF THE NEW INSULATION AND VERIFY NO OTHER INSULATION DAMAGE HAS OCCURRED DURING THE WORK PROCESS.**
- 2. FOR CASES WHERE ONLY ONE PHASE OF THE CIRCUIT HAS BEEN DISCONNECTED, NO FURTHER TESTING WILL BE REQUIRED AS PHASE ROTATION COULD NOT BE AFFECTED.**
- 3. FOR CASES WHERE MORE THAN ONE PHASE IS AFFECTED, PROPER PHASE ROTATION SHALL BE VERIFIED BY A MOTOR BUMP OR OTHER APPROPRIATE TEST.**
- 4. MOTOR BUMPS OR OTHER PHASE ROTATION VERIFICATIONS MAY BE WAIVED PROVIDED THE FOLLOWING CRITERIA IS MET: PRIOR TO ANY DISASSEMBLY OF THE CONNECTIONS, THE STARTUP ENGINEER OR STARTUP SUPPORT TECHNICIAN SHALL HAVE THE CABLE PHASES COLOR CODED AND DOCUMENT IN THE ACTUAL WORK PERFORMED SECTION OF THE WORK ORDER. FOR SPLICES WHICH ARE BEING RE-WORKED, THE COLOR CODING SHALL BE DONE ON BOTH SIDES OF THE SPLICE. AFTER COMPLETION OF THE RE-WORK, THE CABLE PHASES WILL BE VERIFIED TO BE RETURNED TO THE ORIGINAL CONFIGURATION AND DOCUMENTED IN THE ACTUAL WORK PERFORMED SECTION OF THE WORK ORDER. THIS VERIFICATION SHALL BE PERFORMED BY STARTUP OR STARTUP SUPPORT PERSONNEL - IT IS NOT ACCEPTABLE FOR THE MODIFICATIONS ELECTRICIANS TO PERFORM THE VERIFICATION.**