Guide to Operation of Conventional Conductor Systems above 100°C

CIGRE Working Group B2-42
Stockholm, Sweden
21 May 2010

Len Custer, Convener
Bente Brahe, Secretary

AGENDA

Terms of reference of WG 42
Topics
Links with other WGs
Websites and information
Membership
Assignments

Needs of Target Groups: TAG Survey Oct 2009:

□□ **Increased power flow with existing lines**

Needs of Target Groups: SC B2 Srategic Plan, July 2009:

□□ **Safely operate lines at their thermal limit**

□□ **Provide more reliable lines**

Terms of reference

Quantify the various detrimental effects (conductor creep elongation, annealing of aluminium, connector degradation) of high temperature operation on existing transmission line conductor systems. Conventional conductors, connectors and hardware will be included. Emphasis will be upon extended operation at temperatures above 100^{o}C. Incorporate references to previously published Electra papers on annealing, creep elongation, and sag-tension as well as the recent IEEE Guide 1283.

Expected Contributions from other Committees:

Various members of TAG B2.04 have extensive knowledge regarding high temperature operation of conventional conductor systems. They will be asked to contribute even though not formal members of the group.

TAG B2.06 members will also be asked to contribute. These experts have extensive knowledge

concerning high temperature effects in connectors and conductor hardware.

Deliverables and Time Schedule:

Technical brochure + ELECTRA summary: Guide to the calculation of line for Application of

Direct Real Time Capability Monitoring Systems for Overhead Transmission Lines.

Time schedule:- to be published by end 2012.

High Temperature: 100 to 200 °C

- Continuous Rating
- Emergency Ratings
- Mitigation Measures
- Monitoring
- Safety and Reliability

Conventional Conductors

- ACSR and AACSR: Aluminum (Alloy) Conductor Steel Reinforced
- AAC and AAAC: All Aluminum (Alloy) Conductor
- ACAR: Aluminum Conductor Alloy Reinforced
- No ACSS: Aluminum Conductor Steel Supported
- Copper

Annealing of aluminum

- Loss of strength
- Changes in Modulus of Elasticity
- References:
  - Loss of Strength of Overhead Electrical Conductors Caused by Elevated Temperature Operation, Working Group 12 of Study Committee 22, Electra, Oct. 1995
  - Effect of Elevated Temperature Operation on the Tensile Strength of Overhead Conductors, V. Morgan
  - The Effect of Temperature on the Loss of Tensile Strength of Overhead Conductors, V.T. Morgan
  - Overhead Electrical Conductors – Calculation Methods for Stranded Bare Conductors, CEI/IEC 1597: 1995

Sag/Tension Calculations at High-Temperature

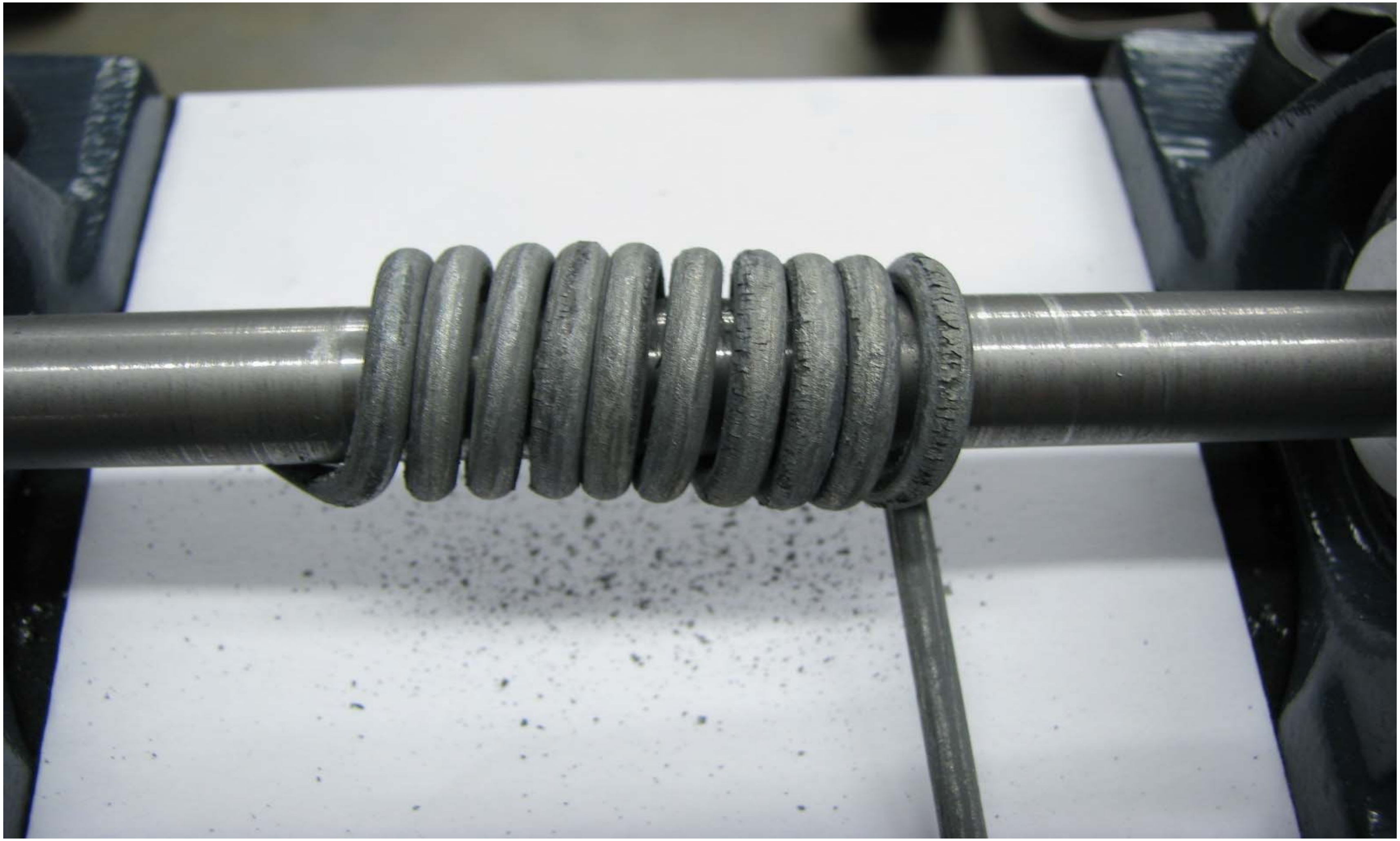
- CIGRE TB 324: Sag/Tension Calculations
- CIGRE TB 244
- CIGRE TB 345: AC Resistance Calculations
- IEEE 738: Standard for Calculating the Current-Temperature of Bare Overhead Conductors - 2006
- CIGRE TB 207:
- CIGRE TB 299: Guide for Selection of Weather Parameters for Bare Overhead Conductor Ratings - 2006

Galvanizing of Steel Core Wire

- Zinc may crack, flake, or peel at higher temperatures
- Wrap test to determine acceptable conductor temperatures (ASTM B498)
- Zinc integrity crucial to long term corrosion resistance of the steel conductor core
- Conductor Grease Performance
- CIGRE 216:

Drake core wire after 1100 cycles for two-hour hold periods at 150 °C

Drake core wire after 1500 cycles for two-hour hold to 233 °C



Drake core wire after 1500 cycles for two-hours to 246 °C

Increased Sag

- Higher Temperature Sag/Tension Conductor Models
- Accelerated creep of Aluminum
- Thermal Expansion of Conductor Strand materials
- Thermal Gradient between Aluminum Layers and Conductor Core
- AC/DC Resistance at high-temperatures
- Ruling Span Models

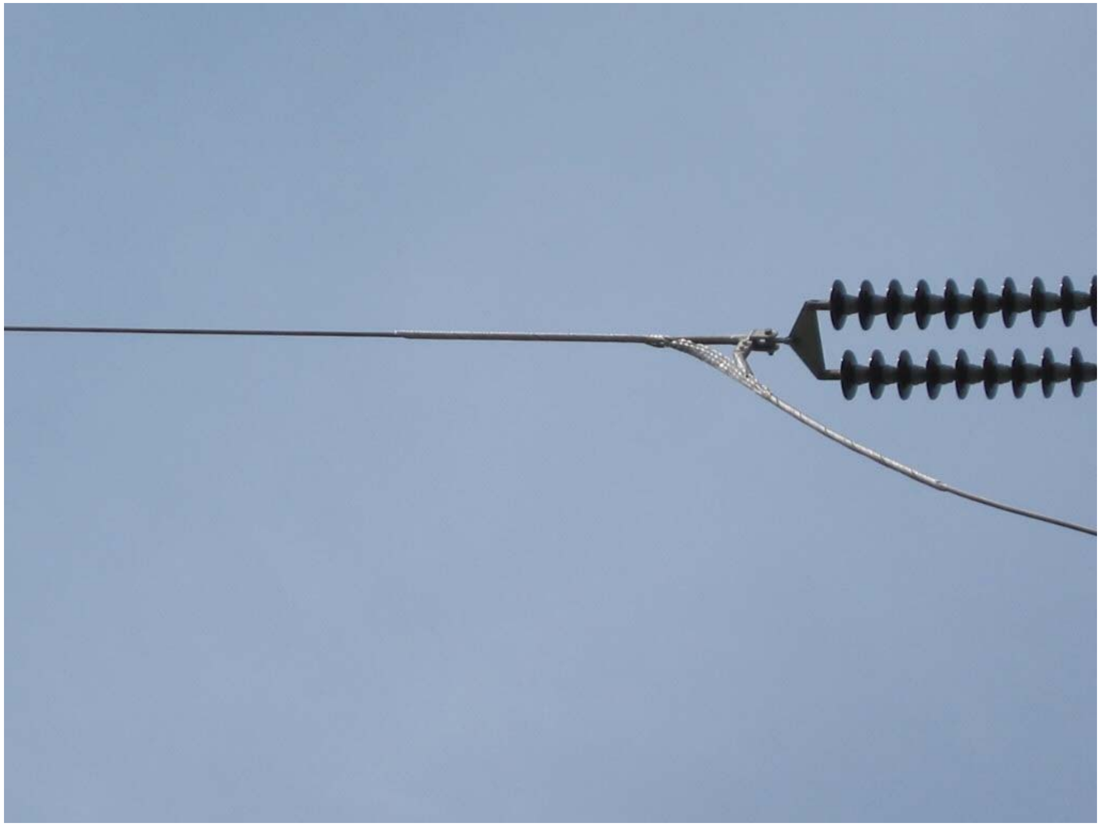
Connectors

- Limited and Full Tension Connectors
- Electrical, Thermal, and Mechanical Breakdown
- Failure Criteria
- Replacement or Mitigation Measures

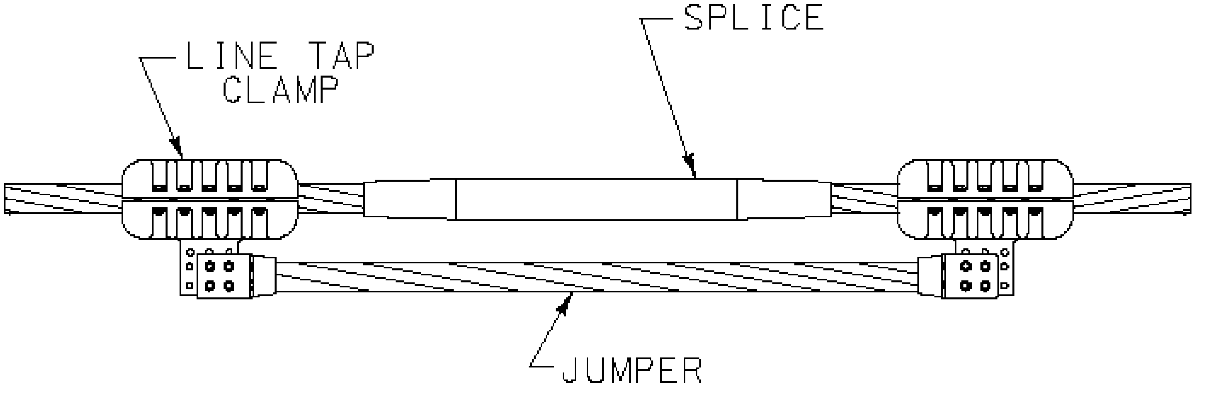
Shunts in the box

Splice Shunt

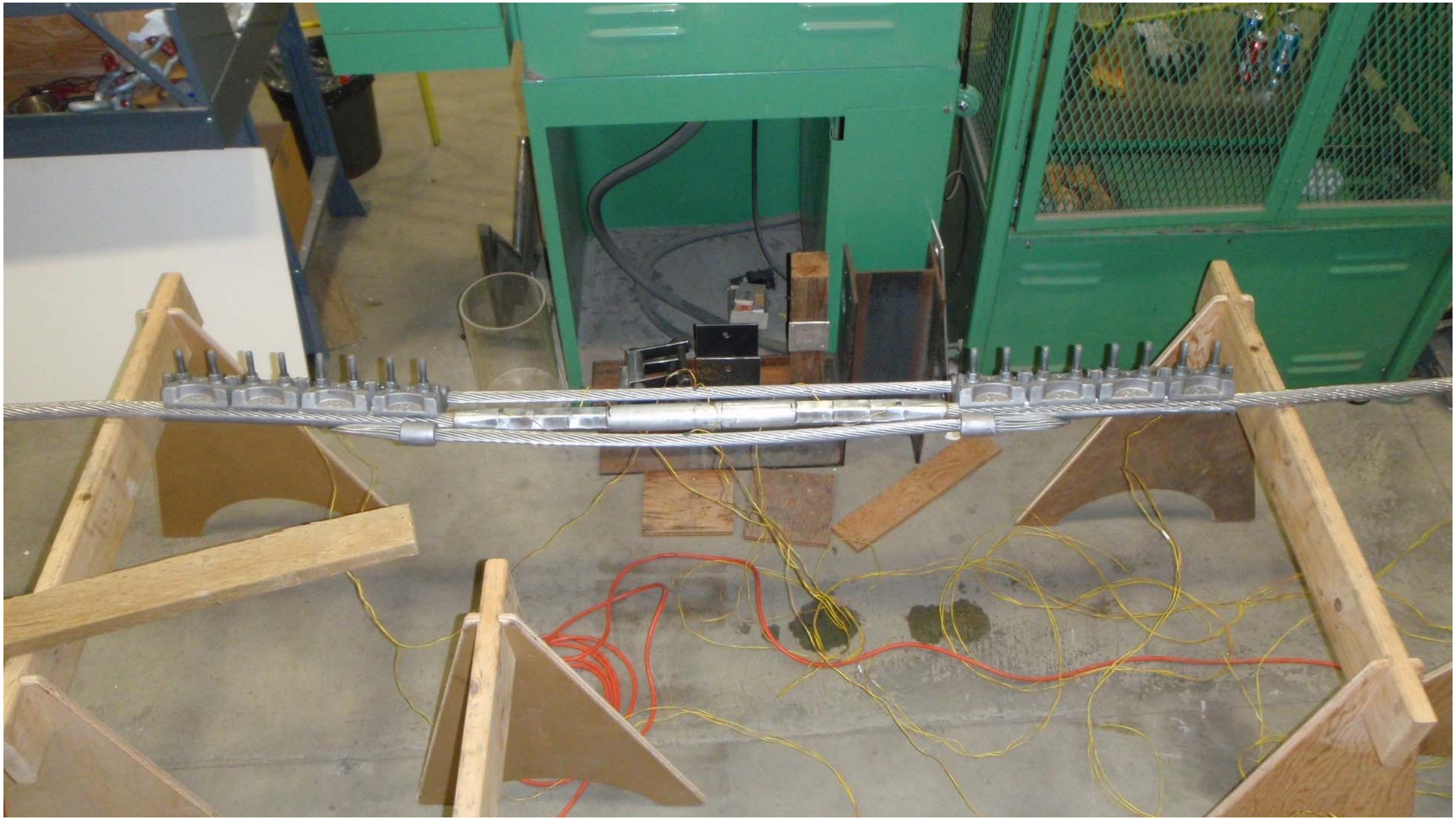
Deadend Shunt



Alternate Shunt



ClampStar Bolted Shunt



BPA Drake Lab Test (20 °C ambient, no wind)

- 1070 A Continuous <u>Summer Rating</u>

		Rise
Conductor:		90°C
Splice:	<u>now</u>	60°C
Splice (Shunt):		20°C
Shunt:		25°C
Shunt (Splice):		20°C

- 1500 A Emergency <u>Summer Rating</u>

		Rise
Conductor:		180°C
Splice:		110°C
Splice(Shunt):	<u>now</u>	40°C
Shunt:		45°C
Shunt (Splice):		40°C

EPRI Connector Test

TEST RESULTS

The temperature responses of the various connectors which were shunted and some which were left un-shunted.

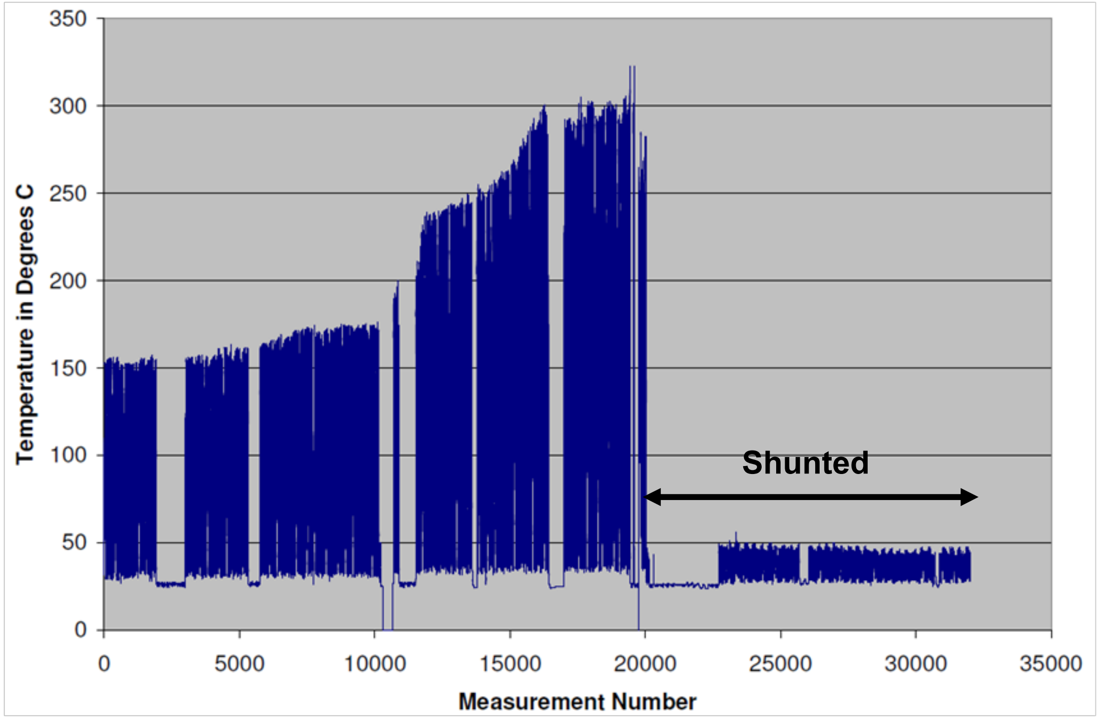
Connector Temperatures

From the table, the effectiveness of the shunting devices in reducing the connector temperature is clear. Single stage connectors that were shunted, some of which installed after the connectors had been operating at high temperatures, experienced significant temperature reductions. After being shunted, the average maximum temperature of these connectors was comparable to the average maximum temperature of those single stage connectors which were shunted at installation.

Connector Type	**Average Maximum Temperature in °C**
Single Stage - unshunted	**312.3**
Single Stage – shunted at installation	**64.0**
Single Stage – shunted after installation	**68.8 (304.2 before shunting)**
Two Stage – unshunted	**151.6**
Two Stage – shunted at installation	**57 (only a single connector)**

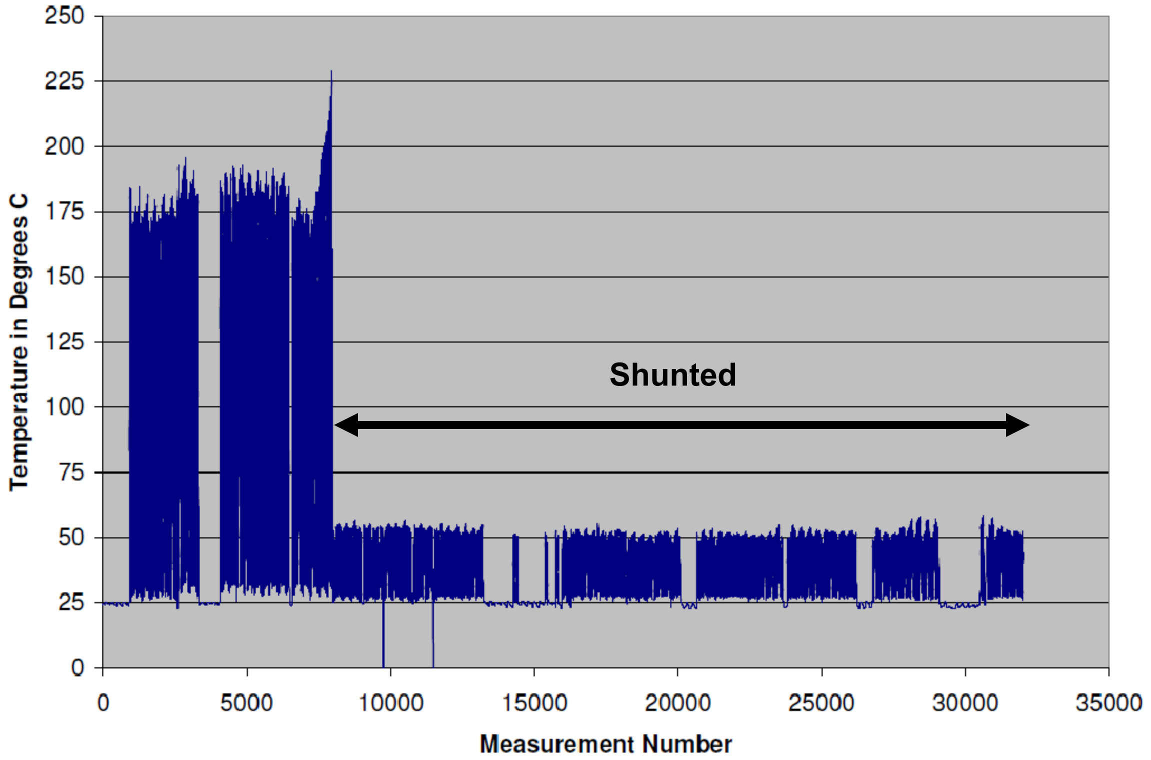
Single Stage Dead-end

Shunt installed due to dead-end slipping, and dead-end maintained test tension.



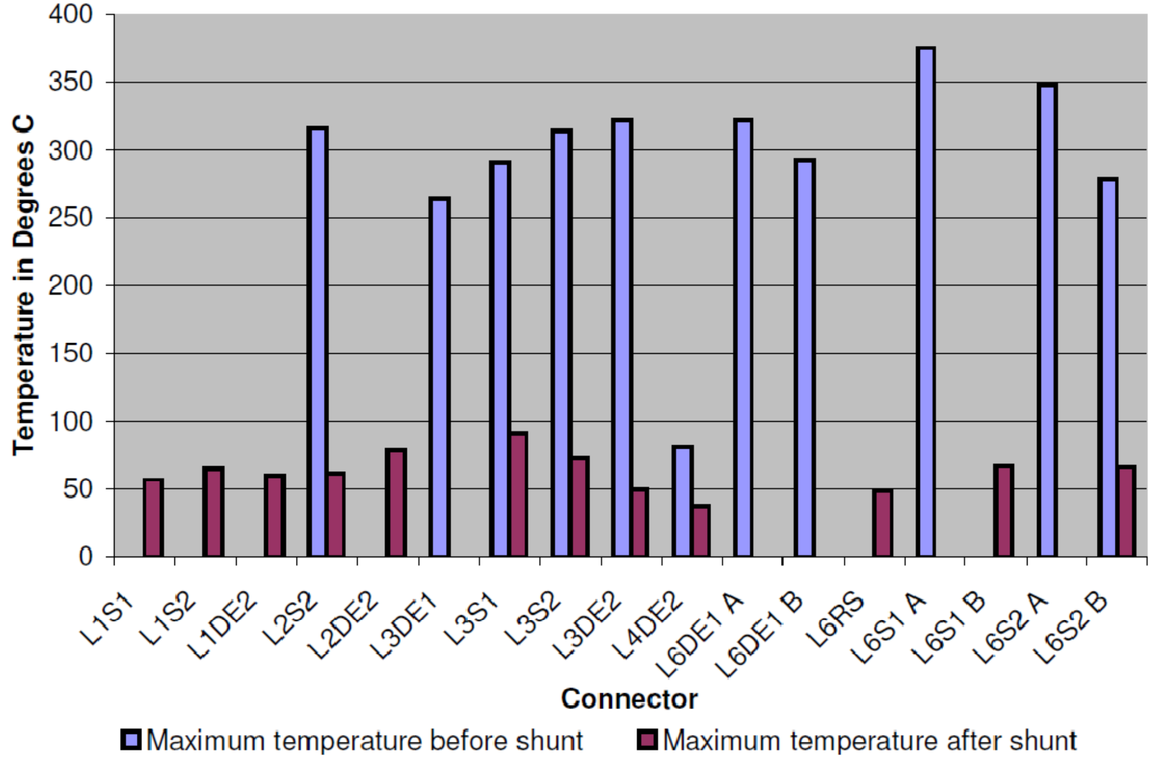
Single Stage Splice

Shunt installed due to splice slipping, within 150 cycles.



Comparison of Temperatures with and without Shunts

It is clear that the shunts decrease the temperatures dramatically.



Comparison of Temperatures with and without Shunts

Suspension Clamp without Armor Rod

- **Heat Profile (Bare 795 Suspension Clamp)**

Pin: 103° C

Ear: 147° C

Keeper: 152° C

Conductor: 240° C

Suspension Clamp with Armor Rod

Heat Profile (795 Suspension Clamp w/ ARMOR Rods)

Conductor Hardware

- Ferrous Conductor Hardware
- Non-Ferrous Conductor Hardware
- Non-Metallic Conductor Hardware

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