DOE Cooperative Agreement on Composite Conductors

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Team

The Valley Group

BPA

South California Edison

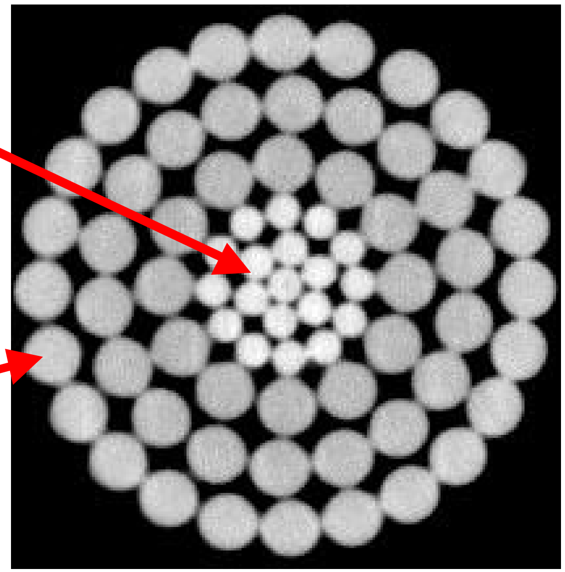
Exelon Co

Hydro One

3 Composite Conductor (ACCR)

A Materials Innovation

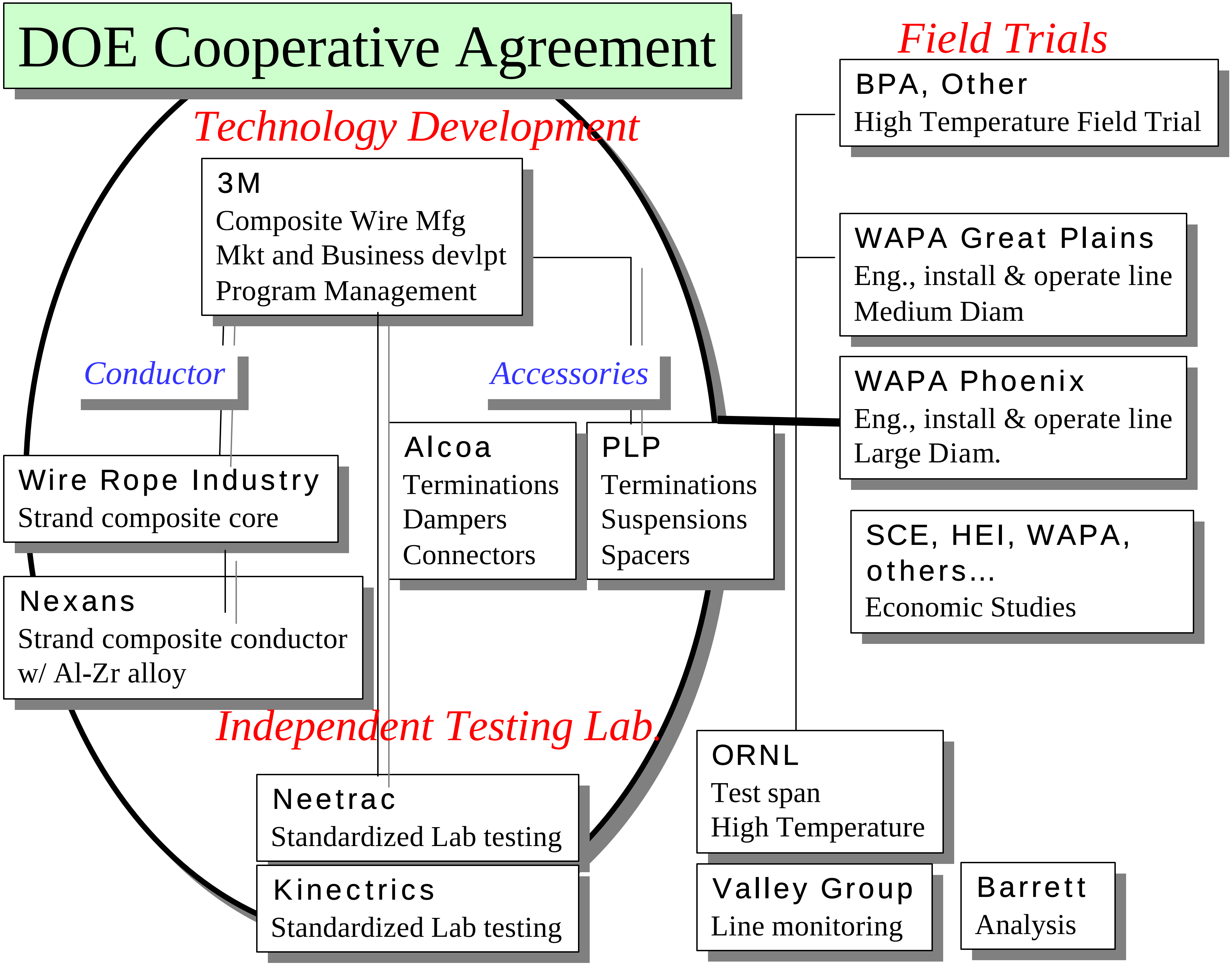
New Composite Material *(replaces steel)*



High Temperature Aluminum

High Performance

- Lightweight – High Strength
- Low Sag at High Temperature


DOE Cooperative Agreement
Technology Development
3M
Composite Wire Mfg
Mkt and Business devlpt
Program Management
Conductor
Accessories
Wire Rope Industry
Strand composite core
Nexans
Strand composite conductor
w/ Al-Zr alloy
Alcoa
Terminations
Dampers
Connectors
PLP
Terminations
Suspensions
Spacers
Independent Testing Lab.
Neetrac
Standardized Lab testing
Kinectrics
Standardized Lab testing
Field Trials
BPA, Other
High Temperature Field Trial
WAPA Great Plains
Eng., install & operate line
Medium Diam
WAPA Phoenix
Eng., install & operate line
Large Diam.
SCE, HEI, WAPA, others...
Economic Studies
ORNL
Test span
High Temperature
Valley Group
Line monitoring
Barrett
Analysis

Accessory Package

Demonstrated Accessory Performance

Installation Procedure

3 YEAR ROADMAP

		Small Diameter	Medium Diameter	Large Diameter
Conductor Devel		WRI & NEXANS	WRI & NEXANS	WRI & NEXANS
Lab Testing		NEETRAC, Kinectrics	NEETRAC	NEETRAC
Accessory Devel		Alcoa & PLP	PLP & Alcoa	PLP & Alcoa
Test Span		EDF (sag-tension)	ORNL (sag-tension)	ORNL (sag-tension)
Thermal Aging		ORNL (500 cycles)	ORNL (500 cycles)	ORNL (500 cycles)
Installation		Xcel Energy (single span) Hawaii Electric (multi-span)	WAPA (multi-span)	WAPA-Phoenix (multi-span)
Field Evaluation	*High Temp Operation*	BPA	SRP	WAPA
	Heavy Ice Loads		WAPA	
	Corrosion	HECO		

Field Tests

Reliability Data

Validated Constitutive Response

High Temp Data

Demo Multiple Sizes

3M Solution Addresses Critical Transmission Issues

Thermal Constraints

Physical Limitations of Conductor ö
Clearance Violations ö

Voltage Constraints

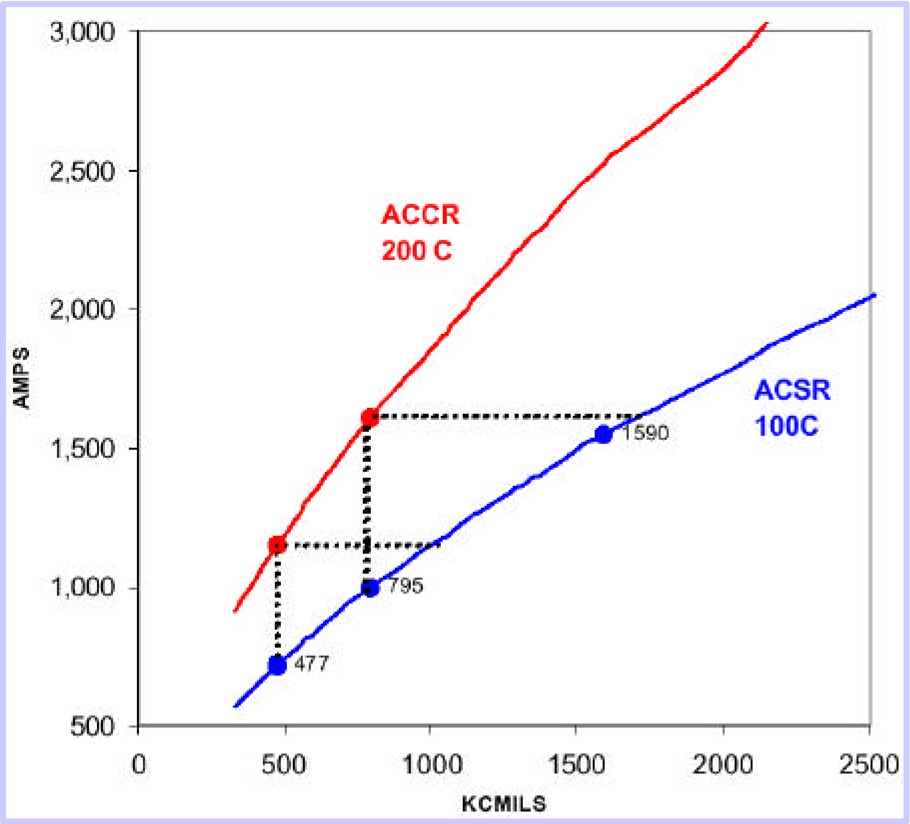
Voltage Drop On Lines > 100 miles

System Operating Constraints

Overloads in Contingency Situations ö
Transient Stability Issues
Voltage Collapse

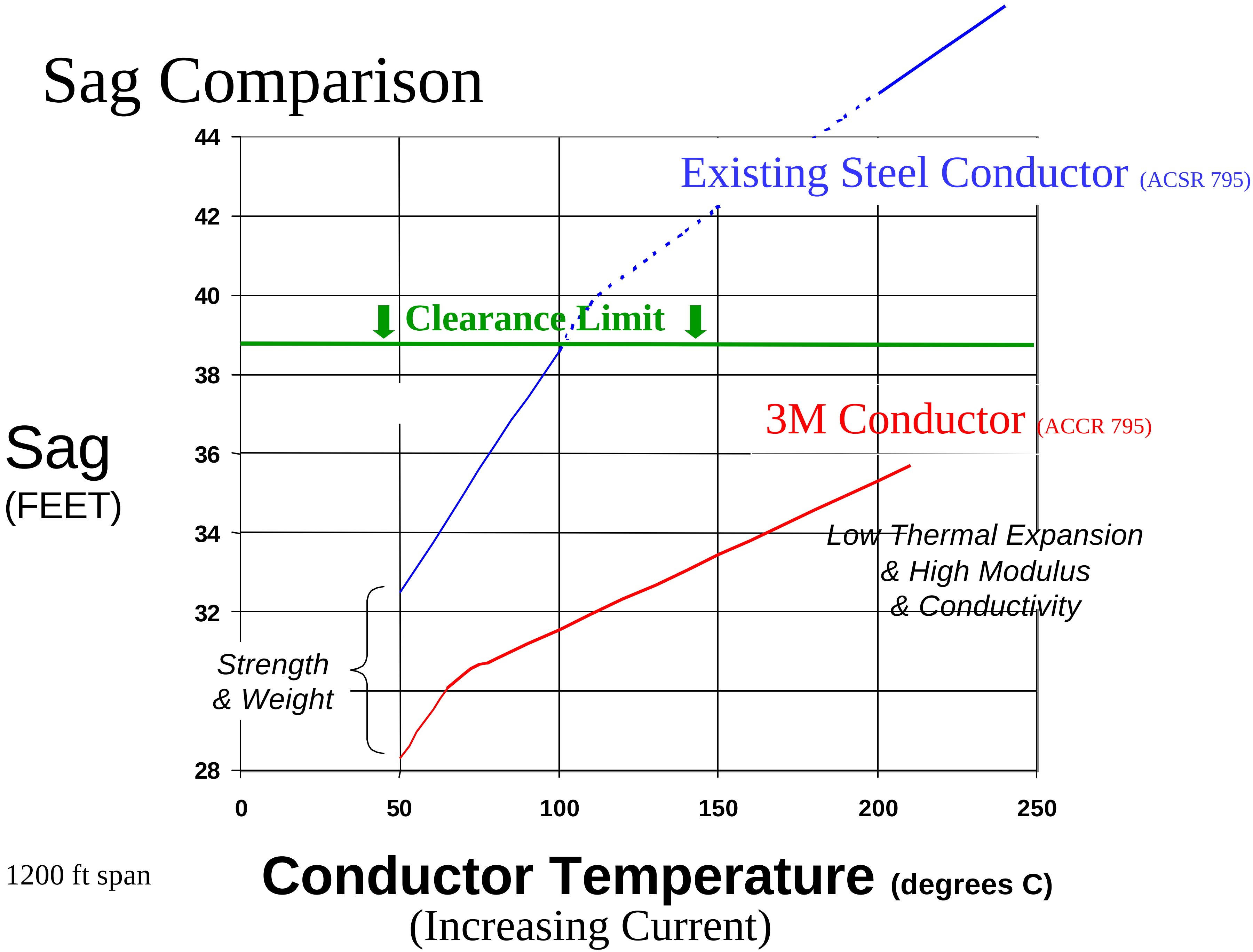
** Applicability needs to be determined on project by project basis*

Advantages of ACCR



- Twice the ampacity
- Less weight/length
- Higher Stringing Tensions
- No visual change to line
- Simpler solution

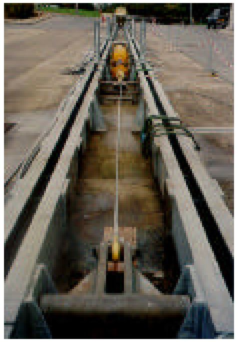
Sag Comparison



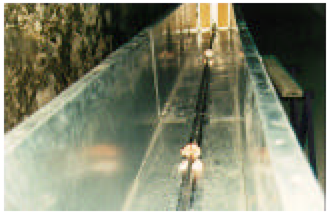
1200 ft span

ACCR Technology Development

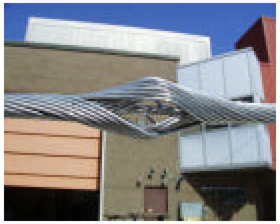
Focus on Reliability: Conductor and Accessories Undergoing Wide Range of Laboratory Tests



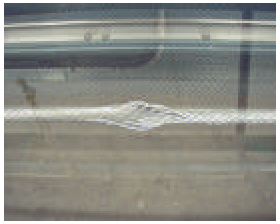
Strength Stress-strain



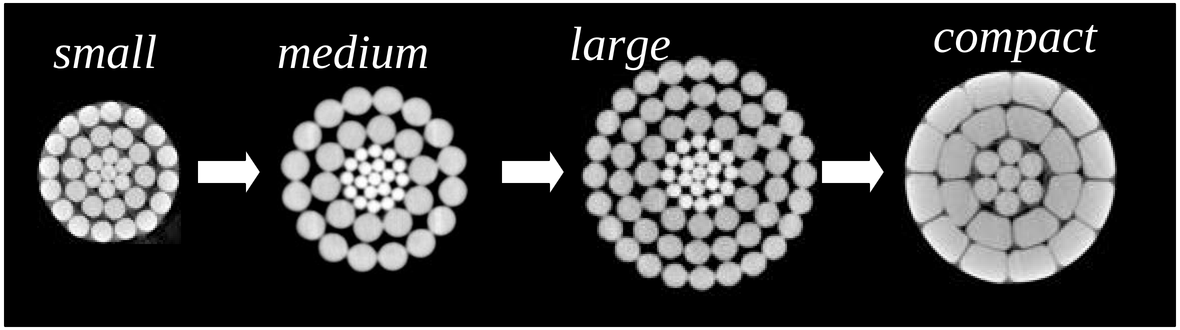
Thermal Expansion



Short Circuit

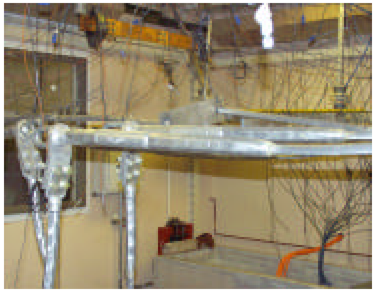


Torsional Ductility



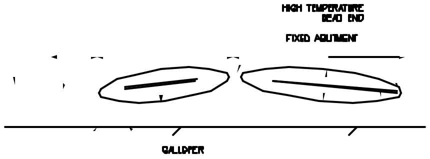
Drop Test

Axial Impact



High Temperature testing

Shotgun



Galloping

Conductor Testing

	477	795	1272	TW	
Tensile Strength	ö	ö	ö	ö	
Stress-Strain Curves	ö	ö	ö	ö	
RT Creep	ö	ö	ö	-	-
ET Creep	ö	-	-	-	-
Impact	ö	ö	-	-	-
Crush	ö	ö	-	-	-
Torsion	ö	ö	-	-	-
CTE	ö	ö	-	-	-
Core strain f(T,S)	ö	-	-	-	-
DC Resistance	ö	ö	ö	ö	
Fault Current	ö	ö	-	ö	
Lightning Strike	ö	ö	-	-	
Aeolian Vibration	ö	ö	active	ö	
Galloping	ö	ö	ö	ö	
Sag-Tension	ö	active		-	

Accessory Testing

AFL	477	795	1272	TW
DE Strength	ö	ö	ö	ö
Joint Strength	ö	ö	ö	ö
RT Sustained Load DE	ö	ö	ö	ö
ET Sustained Load DE	ö	ö	ö	ö
Current Cycle	ö	ö	active	ö
Repair Sleeve	ö	active	active	
Dampers	ö	ö	ö	ö
PLP				
DE Strength	ö	ö	ö	
Joint Strength	ö	ö	active	
RT Sustained Load DE	ö	ö	ö	
ET Sustained Load DE	ö	ö		
Current Cycle	active	active		
Suspension - turn angle	ö	ö		
Suspension - unbalanced load	ö	ö	ö	ö
Suspension - ET profile	ö	ö	ö	
Galloping	ö	ö	ö	ö
Aeolian Vibration	ö	ö	ö	ö
Corona RIV	ö	ö		

Splice installed in field test in Fargo

-- Installation Similar to ACSR

-- Designed to run cool

Current Cycle Connector Test

477, 795 ACCR

Component Temperatures

CONNECTOR	477 ACCR Average Temperature (C)	795 ACCR Average Temperature (C)
Conductor	242	240
Joint	90	85
PG Clamp	100	90
Dead-end	90	80
Terminal	105	80
Repair Sleeve	120	90
Jumper Connector	135	100

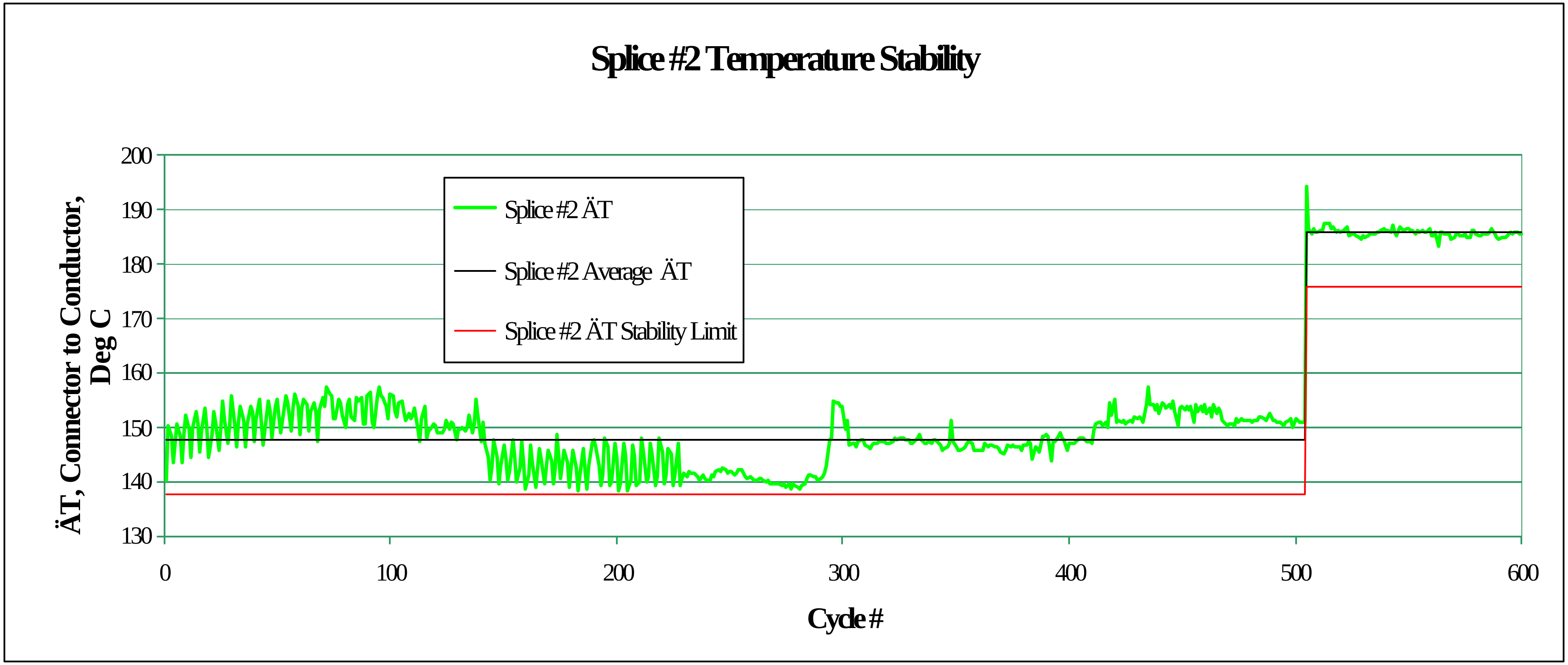
CONNECTOR	477 ACCR Average Temperature (C)	795 ACCR Average Temperature (C)
Conductor	300	300
Joint	105	110
PG Clamp	110	115
Dead-end	105	100
Terminal	120	95
Repair Sleeve	140	100
Jumper Connector	160	120

All Components run much cooler than conductor

Current Cycle Connector Test

477, 795 ACCR

Temperature Stability



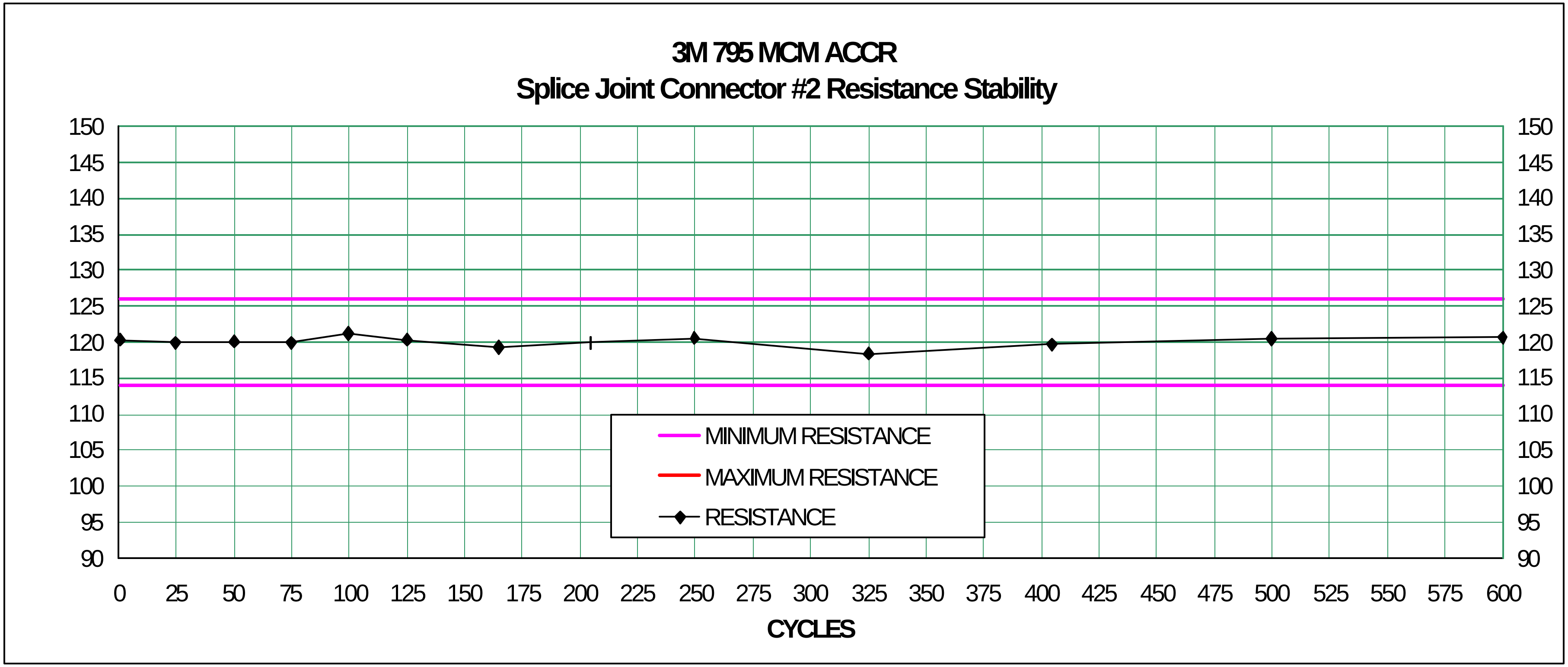
795 ACCR Joint #2

For all Components -
All temperature difference stabilities within 10°C of component average
- satisfies standard

Current Cycle Connector Test

477, 795 ACCR

Resistance Stability



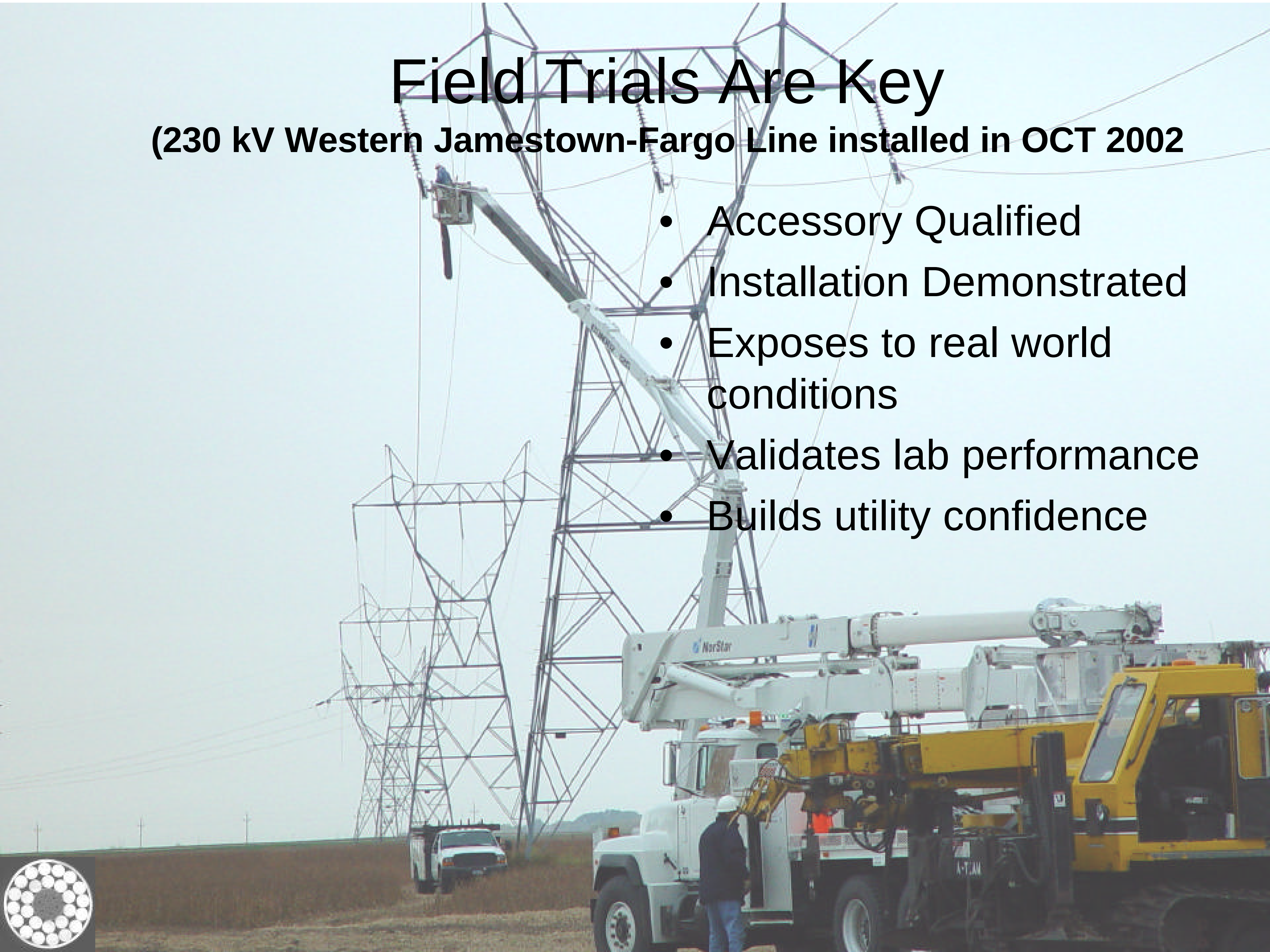
795 ACCR Joint #2

For all components -
All resistances < ±5%
of component average
- satisfies standard

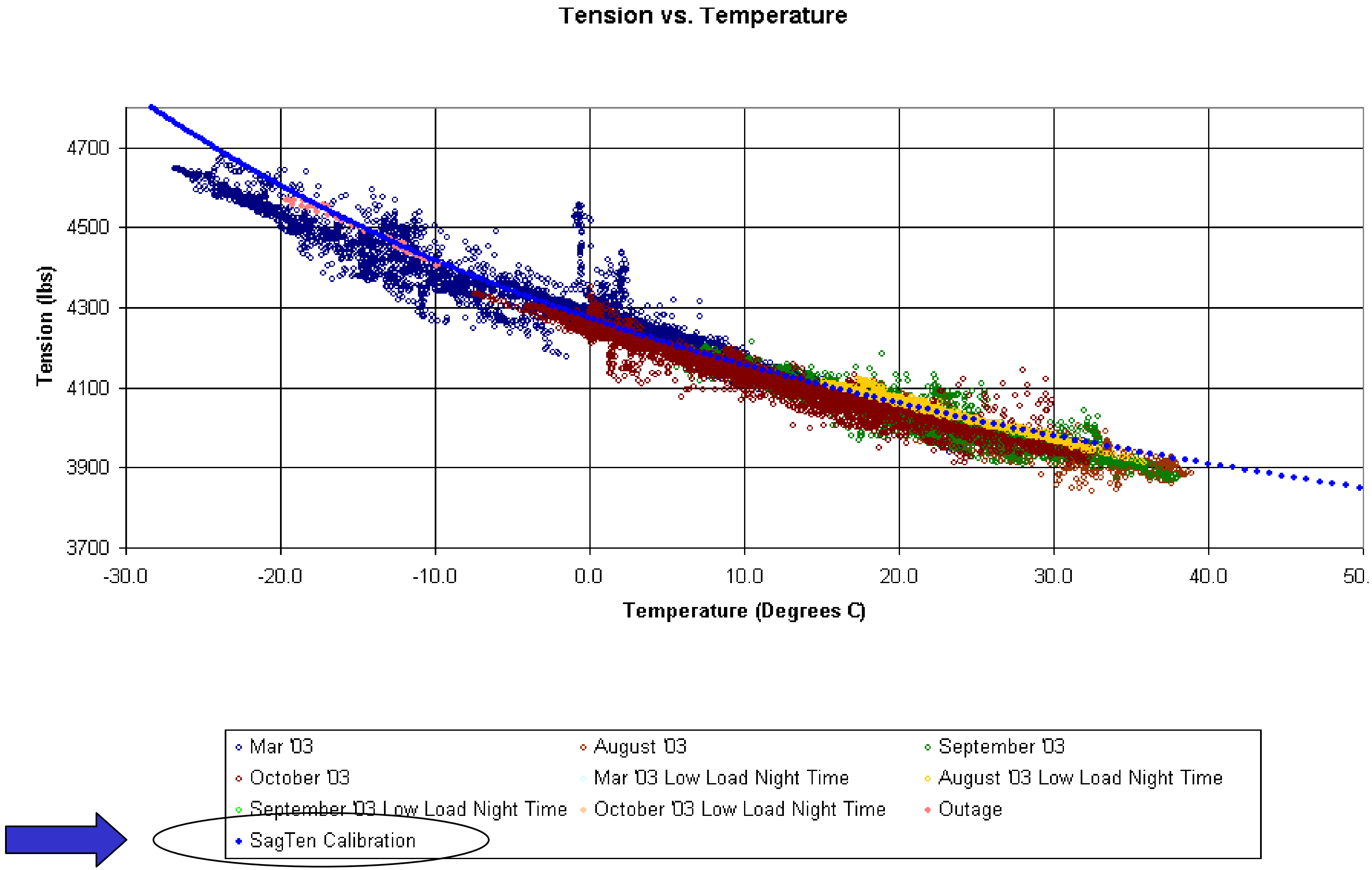
Field Trials Are Key

(230 kV Western Jamestown-Fargo Line installed in OCT 2002

- Accessory Qualified
- Installation Demonstrated
- Exposes to real world conditions
- Validates lab performance
- Builds utility confidence



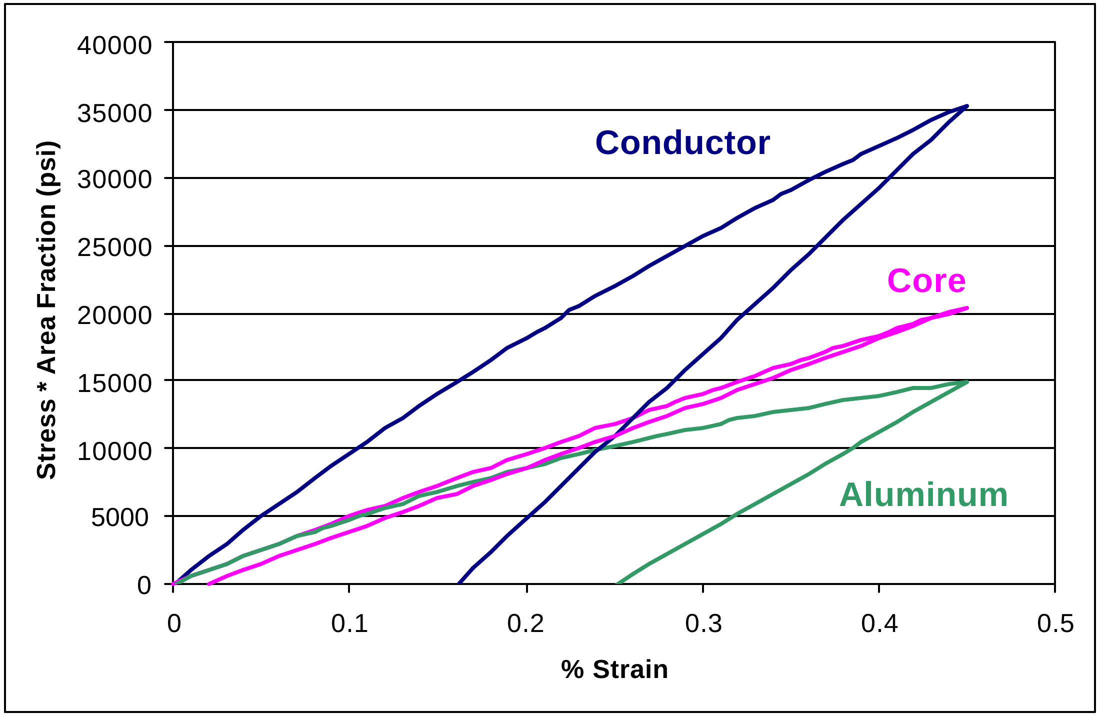
FARGO: Sag-tension monitoring – SAG 10 calibration fits data



795 kcmil ACCR

RT Strength and Stress-strain

Standard: 1999 Aluminum Association Test Guideline



ACCR 795 kcmil (RBS = 31,134 lbs)

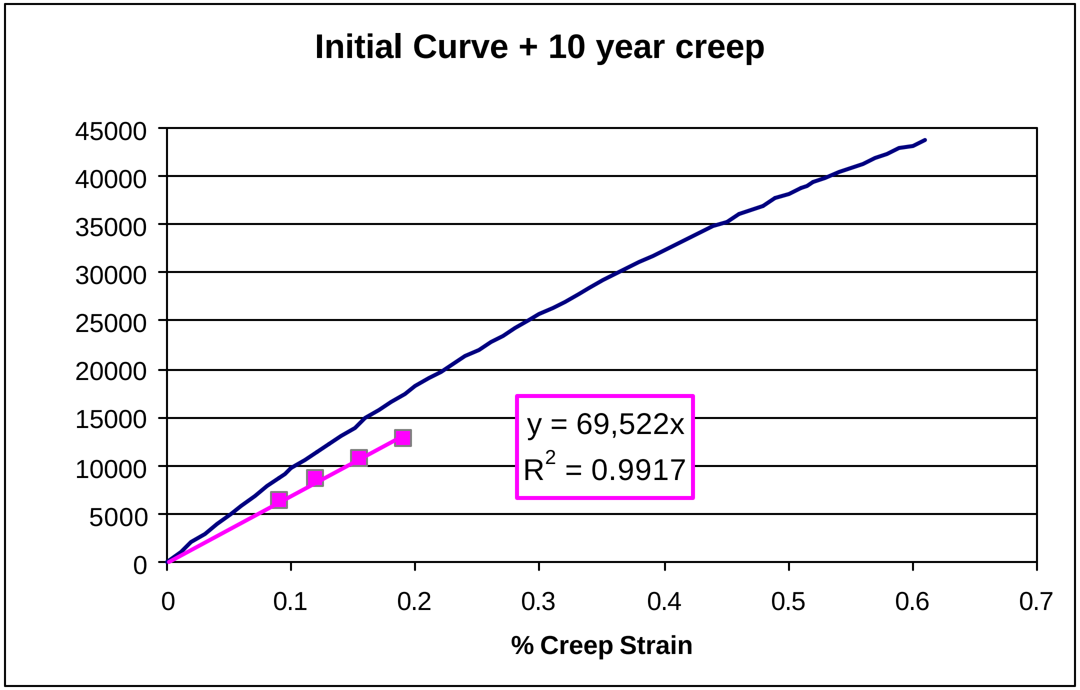
Load/lbs	%RBS	Test Type
31,870	102	Tensile
31040	100	Tensile
30720	99	Tensile

Sag10 Design Coefficients

A0	A1	A2	A3	A4	AF	TREF	Aluminum
-73	53260	-56747	35117	-17439	74602	71	
B0	B1	B2	B3	B4	α (Al)		10 yr creep
0	19446	12378	-8047	6929	0.00128		
C0	C1	C2	C3	C4	CF		Core
-0.03	49769	-9492.5	-14.95	14.79	48119		
D0	D1	D2	D3	D4	α (core)		10 yr creep
-0.03	49769	-9492.5	-14.95	14.79	0.000353		

795 ACCR

Room Temperature Creep



19 ft Cable Length
4 tests, 1000 hr each
Tension = 15, 20, 25, 30% RBS
Temperature of 20°C (± 5 °C)
Extrapolations to 10 yrs

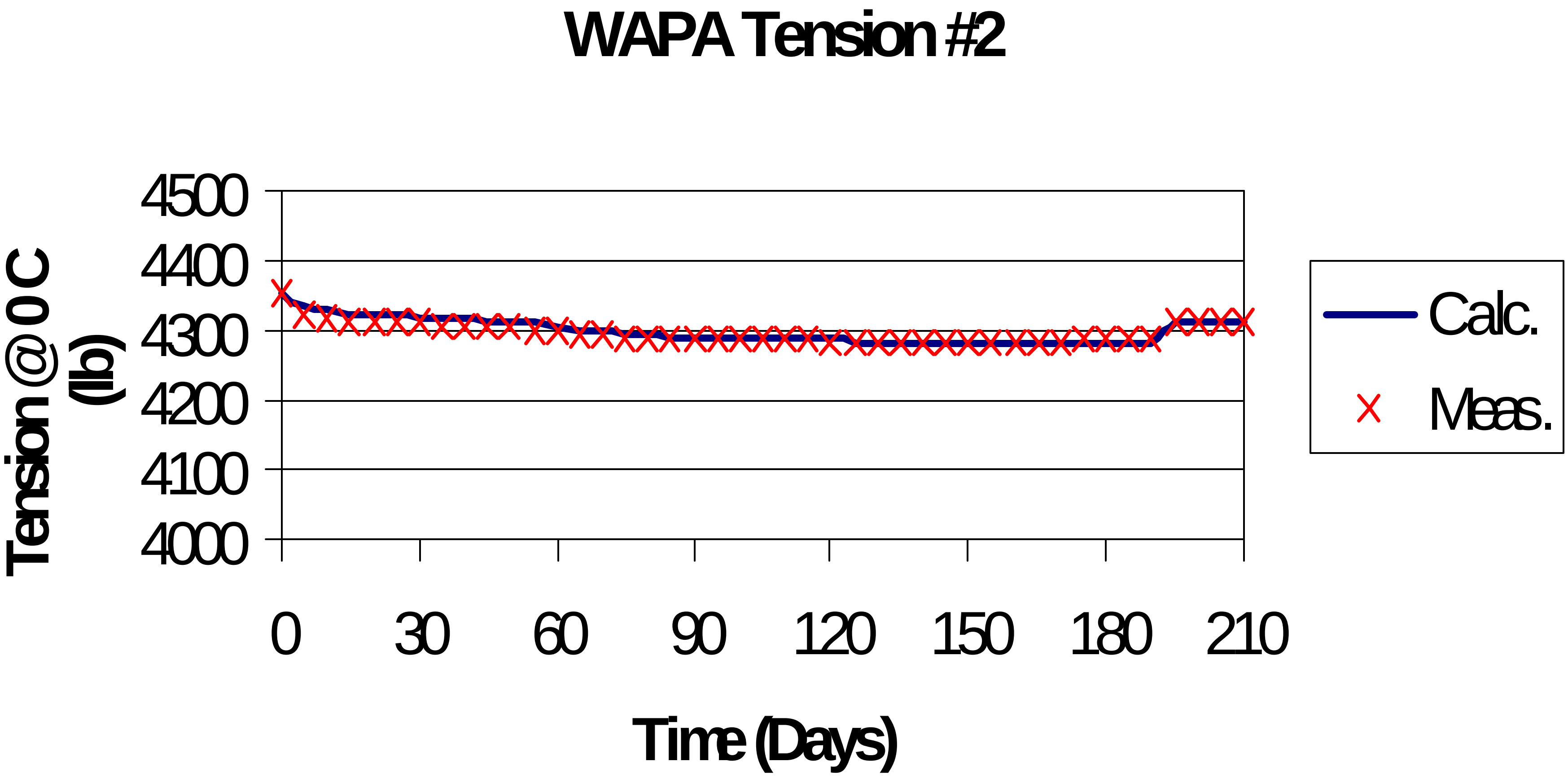
Very low creep strain
10yr creep at 30%RBS ~ 0.05%

Conductor Initial:Stress (psi) = -17,424*(%Strain)^4 + 35,102*(%Strain)^3 – 66,240*(%Strain)^2 + 103,029*(%Strain) - 73

Initial + 10 yr. Creep   Stress (psi) = 69,522*(%Strain)

Standard: 1999 Aluminum Association Test Guideline

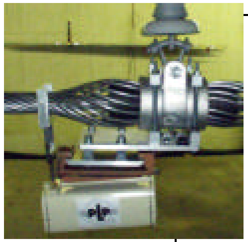
Fargo: Detailed analysis of data sag response within inches

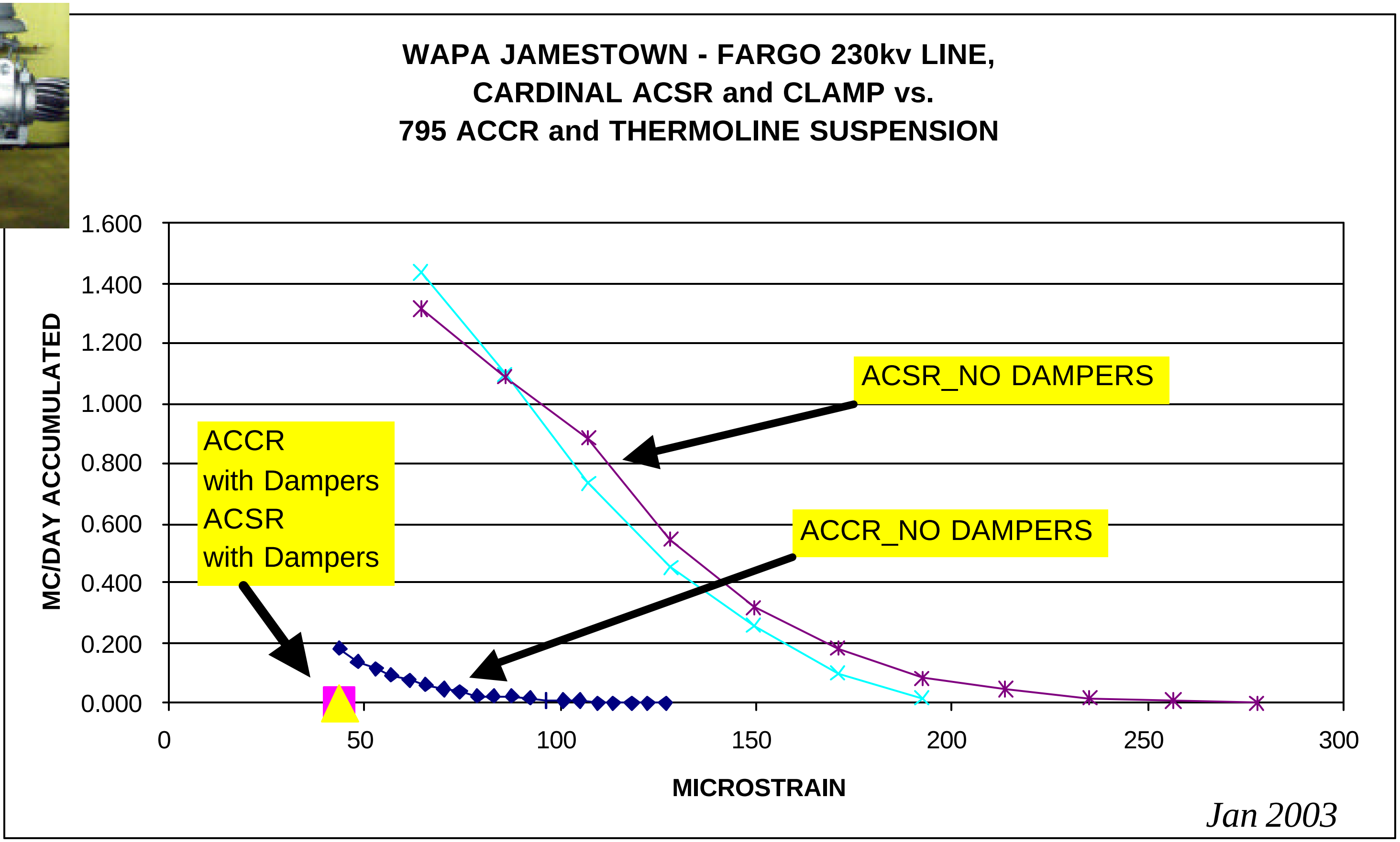


Dr. Steve Barrett

Field Vibration Study

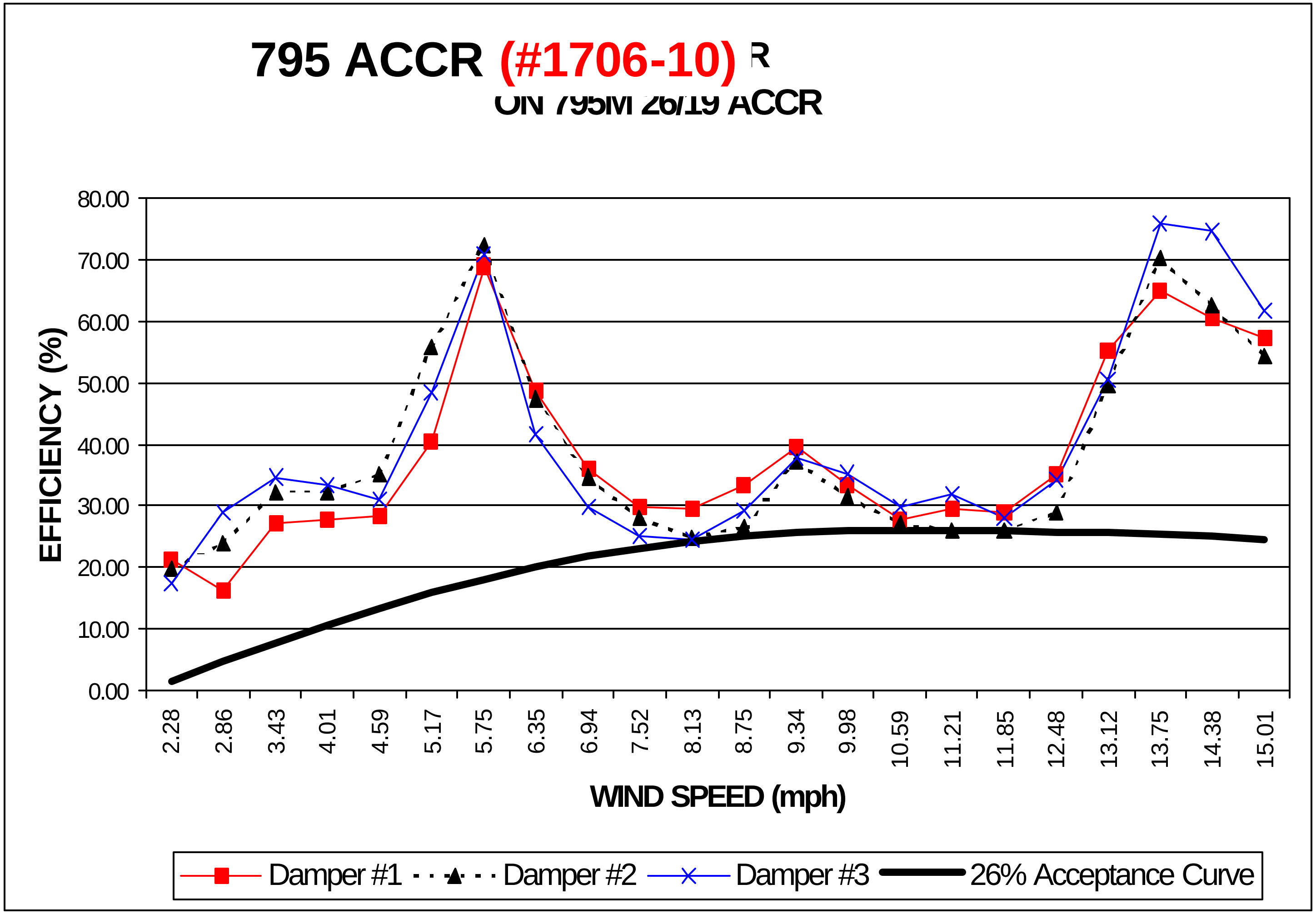
Jan-Feb 2003





Damper Efficiency Test

ACCR (IEEE 664 – SWRM))



Dampers Selected with Suitable Damping Performance

Phoenix: 1272 Field Trial

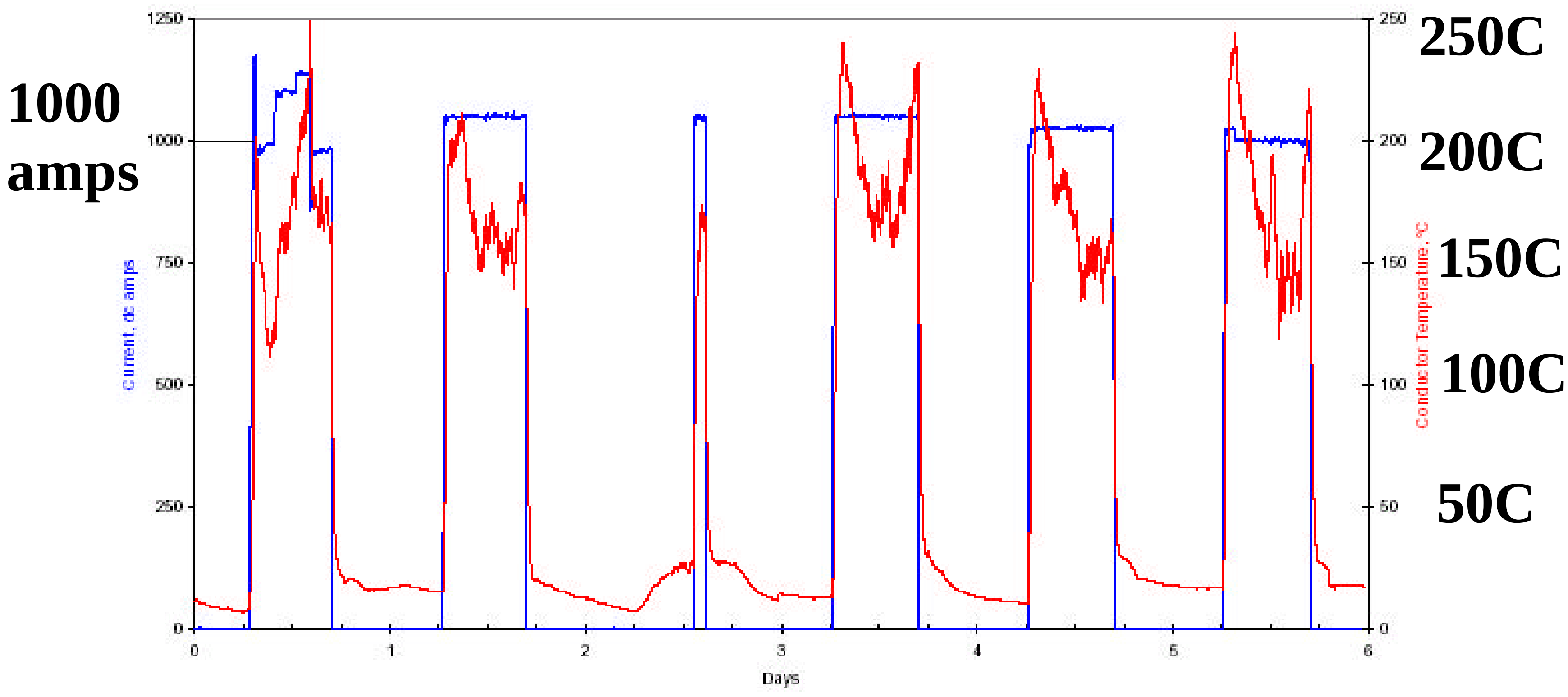
- 230 KV
- Liberty Substation- West Phoenix
- Demonstrate 1272 ACCR
- CAT-1 Monitoring of ACCR and ACSR
- Length 1,800 feet
- Installed in Jan 2004

Reliability at High Temperature PCAT Test Line - ORNL

- Validate Laboratory Performance (sag-tension) at high temperature
- Demonstrate reliability at high temperature
- Measure stability of conductor and accessory after repeated thermal cycles

Over 100 CYCLES to 240C (464 F) (477 ACCR)

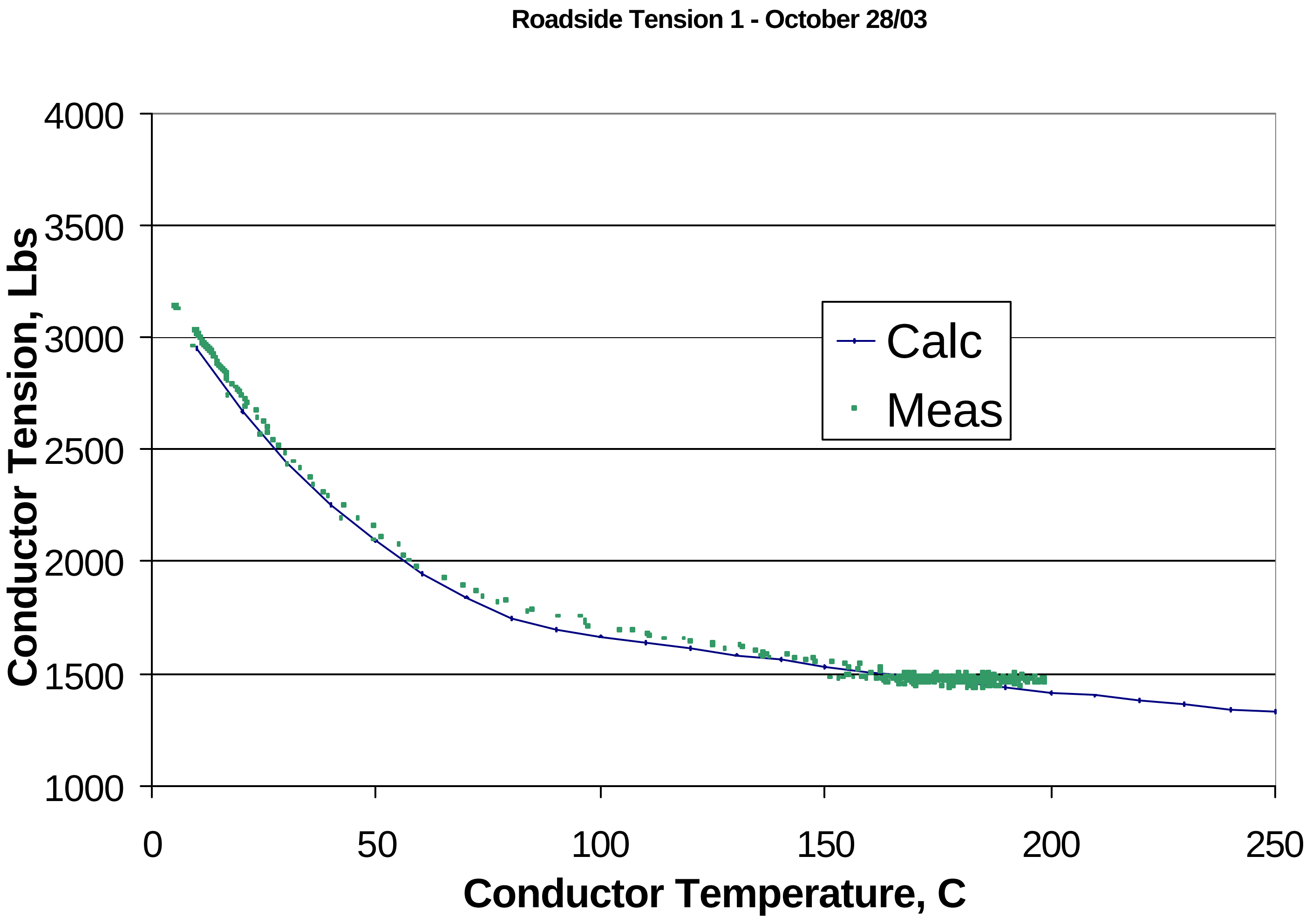
Fig. 1. Current and temperature profile for the 6 days of testing.



DAYS

Over 100 Cycles

Overall shows consistent sag-temperature response



2002-2003 Accomplishments

High Temperature Operation (ORNL)

- Over 100 hours and 100 cycles of high temp. operation on 477 ACCR at ORNL
- Conductor and dead end tested to full strength after high temperature exposure
- Multiple cycles confirms that ACCR sag-tension response up to 240 C follows prediction based on creep, stress-strain and CTE models.
- medium size TW installed on PCAT line and operated at high temperature
- Cycling completed– Results follow prediction.

Field Testing

- 477 installed in Hawaii in 2002 and performing well in corrosive environment
- 795 installed in Fargo in 2002 and performing as expected under severe weather
- 1272 installed in Phoenix in 2004, data is now being collected.

Conductor and Accessory Testing and Qualification

- 477 and 795 conductor testing complete in 2003
- 1272 conductor and accessory laboratory tests: 90% complete in 2003
- TW conductor and accessory lab tests: 90% complete in 2003

2004 Objectives

High Temperature Cycling (ORNL)

- Accumulate 100 hrs of high temp operation on TW at ORNL
- Post testing of 477 after 2003 thermal cycles
- Post testing of TW construction after thermal cycles
- Install 795 and complete 100 hrs, 100 cycles test
- Post testing of 795 after thermal cycles
- Install 1272 for testing in 2005

Field Testing

- Monitor and report on existing field tests (Hawaii, Fargo)
- Install 1272 in Phoenix – Monitor and report
- Install ACCR for high temp operation – Goal is 2 year high temperature operation of small and med diam. ACCR –

Conductor and Accessory Testing and Qualification

- Finish Laboratory sag-tension tests
- Finish creep and ANSI tests on 1272
- Test matrix on river crossing conductor
- Generate quantitative corrosion data to complement the HEI field test
- Draft ASTM standards for ACCR

Summary

- Provide technology solution for Nation's transmission bottlenecks with thermal constraints.
- ACCR provides a time saving option with little impact on the environment, the public and utilities
- DOE, industry and utility partnerships allowing technology development, demonstrating reliability and reducing risk to utilities.

Recognition & Awareness

R&D Magazine Award on 100 Best Technology *(2003)*

Response to National Energy Policy Task Force *2002*

Composite Conductor listed by DOE as one of the key technologies to address transmission bottlenecks. Composite conductor "could go along way to helping solve some of the transmission constraints"

IEEE Showcase of Innovation Award *July 2001*

"breakthrough technology which will have profound impact in 21st century"

Environmental Energy Study Institute *June 2001*

Technologies which will have dramatic impact on transmission line congestion.

National Energy Daily *June 2001*

"..including a revolutionary aluminum transmission wire"

Sierra Club: 12 Key Benchmarks for a Sound Energy Plan *July 2001*

Composite conductor sited as the example for "improve transmission lines"