Composite Conductor Field Trial Summary Report: ORNL ACCR 1277 Kcmil

Installation date	August 9, 2004
Field trial location	Oak Ridge, Tennessee, USA

Line Characteristics

Organization	Oak Ridge National Laboratory
Point of Contact	John Stovall, ORNL
Installation date	August 9, 2004
Conductor Installed	ACCR 1272
Length of line	1,200 feet (356.7 meters)
Conductor diameter	0.858 inch, (21.8 mm)
Voltage	400 VDC
Ruling span length	600 feet, (183 meters)
Structure Type	Steel Poles
Instrumentation:	(1) Load cell (2) Current, voltage (3) Weather station (4) Sag (5) Thermocouples in conductor and accessories

Hardware

Suspension Hardware	Preformed Line Product, THERMOLIGN™ SUSPENSION-TLS-0116-SE
Termination Hardware	AFL compression dead end, part# 1272M-54/19-ACCR, Drawing#B9085 AFL splice, part#1272M-54/19-ACCR, Drawing#B9095
Insulator type	Polymer
Dampers	Alcoa Dampers part# 1707-13
Terminals	AFL terminal connector, part#1272M-54/19-ACCR, Drawing# B9102 PLP THERMOLIGN™ DEAD END, part# TLDE-1272-N

Results and Measurements

Full range of temperature tests from 30°F – 412°F (0°C – 240°C) with currents ranging from 0 to 1,800 amps

Sag-Temperature data from 0°C – 240°C
Line tension data from 0 to > 200C
Measured thermal rating

Table of Contents

Abstract: ... 3

1- Background ... 3

2- Installation and Conductor Stringing ... 5

2-1 Overview ... 5
2-2 Installation details: ... 5
2-3- PCAT-1 Instrumentation: ... 7
2- 4 Conductor and Accessories Temperature Measurements: ... 9
2-5 Controls ... 9
2-6 Accessories: ... 10

3- Thermal Cycles and High Temperature Exposure: ... 11

3-1 Thermal cycles details: ... 11
3-2 Conductor Core VS Surface temperature: ... 15

4- Measured and Predicted Line Tension and Sag: ... 17

5- Accessories Response at High Temperature: ... 19

5-1 PLP Accessories: ... 20
5-2 Alcoa Accessories: ... 23

6- Ampaciy and Thermal Rating of Conductor ... 24

6-1 Ampacity Prediction using IEEE Model: ... 24
6-2 IEEE VS CIGRE' Ampacity Model: ... 27

7- Summary ... 28

8- Appendix ... 30

8-1 Conductor Specs ... 30

Abstract:

Under DOE funding Agreement No. DE-FC02-02CH11111 Oak Ridge National Laboratory, ORNL, jointly with The Tennessee Valley Authority, TVA, successfully installed ACCR 1272 conductor on ORNL high temperature test line. The line is 1200 feet (365 meters) long, and the ruling span is 600 feet (130 meters).

ORNL subjected the line to severe thermal cycling and extended high temperature load using 400 V DC and current as high as 2700 amps. The conductor was thermally cycled between ambient and 200^0+ C for over 300 hours and over 100 hours operation continuously above 200^0 C under changing wind conditions.

The conductor tension and sag measured during the high temperature test trial agree with predictive models.

Predicted conductor current, using IEEE thermal rating ampacity method, agree well with measured values.

The accessories performed well during the high temperature cycling and ran at much cooler temperature than the conductor.

1- Background

ORNL has built a fully instrumented low-voltage test line to evaluate the high-temperature operation of ACCR conductors by simulating dozens of emergency cycles where the conductor temperature reaches operating temperature 210^0 C (400^oF) and higher under a range of ambient conditions.

The ORNL test line instrumentation includes conductor tension measuring device, full weather station with anemometer, voltage, current, laser sensor device to measure sag, and temperature thermocouples in multiple locations in the conductor and in all accessories.

This report summarizes the 1272 ACCR conductor installation, testing and analysis at ORNL.

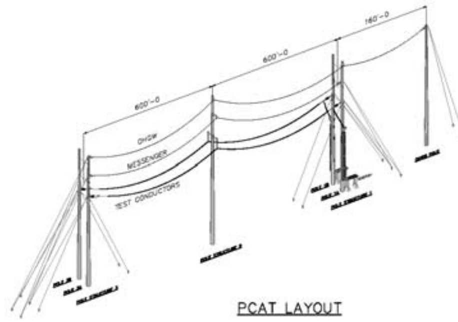
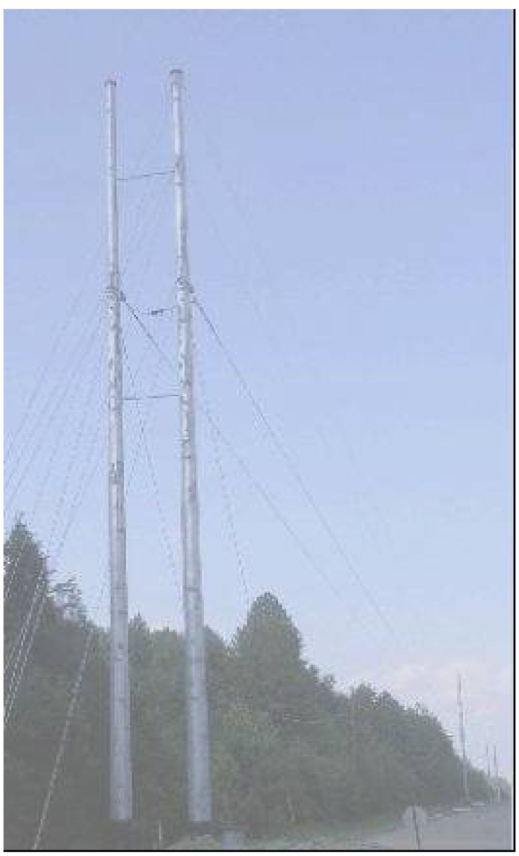
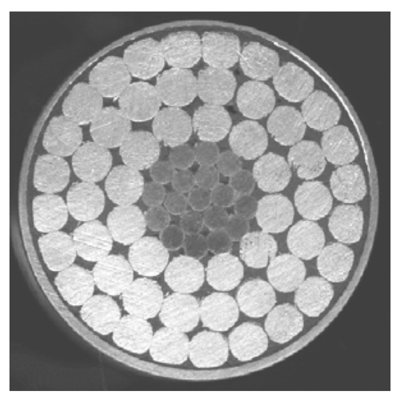
 Arial view of the line	 Layout
 High temperature Line at ORNL	 ACCR 1272

Figure 1- Conductor details and ORNL test line view

2- Installation and Conductor Stringing

2-1 Overview

A two span test line (from dead end to dead end) was constructed on the grounds of the Oak Ridge national Laboratory in Oak Ridge, TN, as a part of a Department of Energy program. Several sizes of ACCR composite conductors were installed and tested since then. ACCR 1272 is the latest of such installations. The installation procedures used is typical of that used when installing ACSR. Tables 2 and 3 show the typical hardware and procedures used during installations and the comparisons of each type of conductor.

2-2 Installation details:

The test line (Figure 1) consists of four 600 feet (183 meters) segments between a steel suspension pole and two guyed dual steel dead end poles. The test conductor forms a loop of two spans connected to a DC power supply located at one end of the line. Thermocouples were installed along the test conductor and on dead end, suspension and splice hardware to measure the temperature of these components during and after periods of high temperature operation.

Conductor was shipped to the installation site wound around wooden reels 84 " X36" X44 ". The installation of 1272 followed the IEEE 524 installation guideline for overhead transmission conductors. Grounded stringing blocks were used at all the dead end structures.

Particular care was given to the stringing operation. The combination of bending and tension if exceeds the core allowable strength could damage the conductor. Therefore stringing blocks and bull wheels were selected to keep the stringing loads way below conductor core strength. Table 2 specifies stringing blocks 28" diameter and bull wheels of 36" diameter to meet such criteria. Lined blocks were used with ACCR.

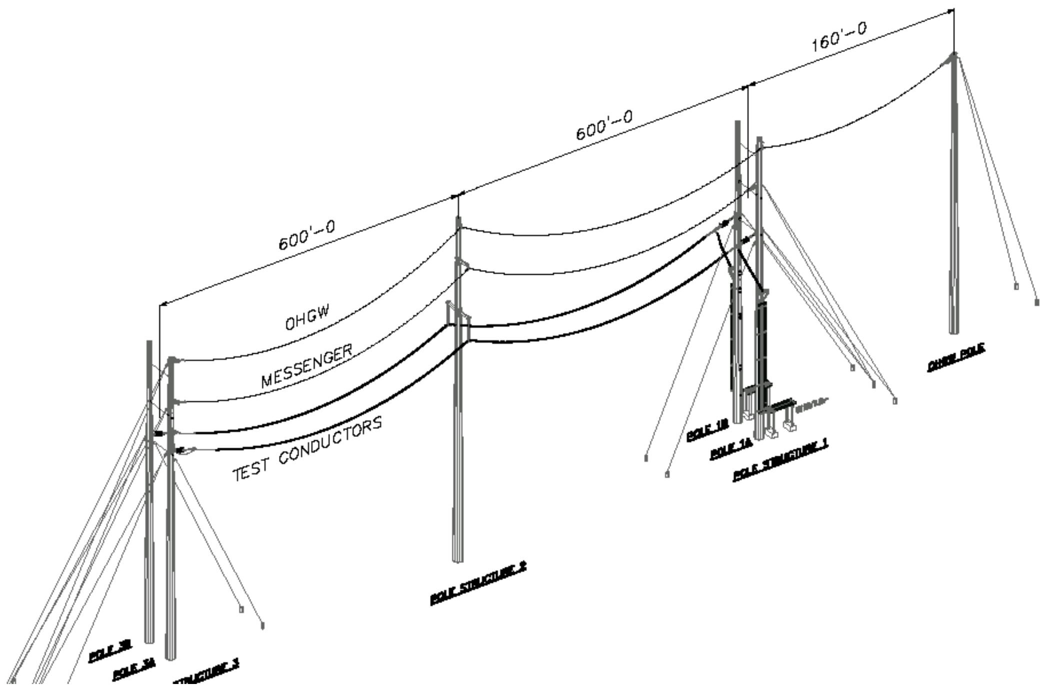


Figure 1 line Layout and PCAT –1 system

Figure 2- Sheave used in the installation

The sagging procedure of ACCR conductor is similar to that used to install ACSR; a dynometer was used to verify the final tension of the conductor.

Table 1- Installation Equipment and Procedure

Installation Equipment	ACSR	ACCR
Stringing Blocks	Yes	Yes (28")
Bull Wheel	Yes	Yes (36")
Drum Puller	Yes	Yes
Sock Splice	Yes	Yes
Conductor Grips	Any	DG-Grips
Cable Spools	Yes	Yes (40" Drum)
Cable Cutter	Yes	Yes
Reel Stands	Yes	Yes
Grounding Clamps	Yes	Yes
Running Ground	Yes	Yes

Installation Procedure	ACSR	ACCR
Cable Stringing	Tension / Slack	Tension
Sag Tensioning	Any	Line of sight, Dynometer
Dead Ending	Any	Use DG-Grip with chain hoists
Clipping	Any	Any

2-3- PCAT-1 Instrumentation:

A CAT-1 system from The Valley group was installed on one of the dead end structures to monitor the conductor tension and weather conditions (temperature, wind speed, and direction) at intervals of 10 minutes; see Figure 3. Two 10,000 pounds load cells were used for line tension. The CAT-1 system was equipped with anemometer to measure wind speed and direction. Data acquisition was done at 1minute interval for all channels

The CAT-1 main unit is in a NEMA-enclosed, solar powered, data acquisition and processing unit. Net Radiation Temperature, (NRT), was measured by the net radiation sensor, (NRS).

A- Load cell used to measure tension

B- CAT-1 System

3- C Net Radiation Sensor Measures
No Load Conductor Temperature

Figure 3- CAT system hardware

Net Radiation Temperature (NRT) was measured by the Net Radiation Sensor, Figure 3-C, which provides a simple method of combining ambient temperature with wind and solar effects (emissivity and conductor time constant).

2- 4 Conductor and Accessories Temperature Measurements:

A separate data acquisition system was used to collect the information from the thermocouples. Thermocouples were mounted at various locations along the span. The thermocouples were located on the conductor surface and several at the core. Additional thermocouples were installed on ALCOA compression dead ends, compression splice, Alcoa jumpers, PLP suspension, PLP splices and PLP dead ends.

2-5 Controls

The line was operated under either constant current and / or constant conductor temperature with thermal cycles lasting from one hour to several days.
Temperature data was acquired by thermocouples affixed directly to the outer surface and couple to the core. Multiple points along the length of the conductor were monitored this way. To accommodate the multiplicity of points along the conductor and withstand the accumulated voltage drop, many fiber-connected, isolated measurement nodes were used. A thermocouple measurement node was fabricated using a multiplexer (ICPCON I-7018) and a RS-485-to-fiber modem (B&B FOSTCDR). Up to eight thermocouples were monitored per node. The node required 120 VAC power and was connected through a duplex fiber optic network. The multiplexer, fiber modem, and a power supply were housed in an enclosure. The following images and those under accessories section show typical examples of the installation details

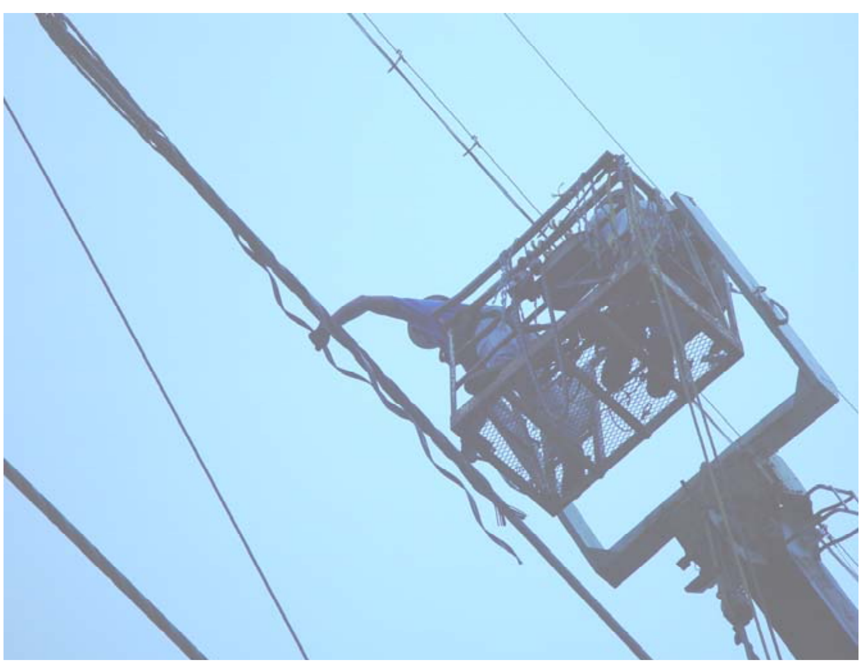


Figure 4- Installation of PLP THERMOLIGNTM DEAD ENDS next to stringing chain

The power supply used has a dual rating of 400 Vdc and 5000 amps or 600 Vdc and 3750 amps. The input voltage to the power supply is 4160 V, 3-phase. A dry-type ABB transformer was used to step down the voltage from a 13.8 KV distribution line.

2-6 Accessories:

Two types of accessories were installed; a compression type made by Alcoa (now named American Fujikura Limited, AFL) and formed wire type made by Preformed Line Products. The following specific parts were used:

- Four ALCOA compression dead ends; part # 1272-54/19-ACCR, Drawing # B9119, Dead ends consist of both direct core gripping parts and conductor gripping sleeve,
- One ALCOA full tension splice part# 1272M-54/19-ACCR, Drawing# B9095-D, it has the same design as the dead end for both direct core gripping and conductor.
- Six Alcoa terminal connectors; part# 1272M-54/19-ACCR, Drawing# B9102; those are all Aluminum sleeve parts
- Four Alcoa Stockbridge dampers; part# 1707-13
- Two PLP THERMOLIGN™, DEAD ENDS, part#TLDE-1272-N (includes extension link and Thimble- Clevis),
- PLP THERMOLIGN™ SPLICE part # TLSP-1272
- Two THERMOLIGN™ PLP SUSPENSIONS with Socket eye, part # TLS- 0116-SE

Figure 5- Installed Alcoa compression dead end next to insulator and dead end tower

Figure 6- Compression of jumper connector

3- Thermal Cycles and High Temperature Exposure:

3-1 Thermal cycles details:

The 1272 Conductor was thermally cycled starting in October 2004, between ambient temperature and 200^0+ C under wide range of weather and load conditions. A single cycle was carried out between ambient and 300^0 C and both conductor surface and core temperatures were recorded. Table 2 lists a summary of thermal cycles completed as of 4/6/2005

Table 2- Summary of Thermal cycling of conductor up to April 6, 2005

Date	#Cycles Per day	Total # Cycles	Hours Per day	Total Run Hours	Nature of cycle	Maximum Temperature, C	Maximum Current, amps
8/13/2004	1	1	9	9	Hi-Temp Run	220	2243
8/14/2004	0	1	21	30	Hi-Temp Run	221	2488
8/16/2004	1	2	8.5	38.5	Hi-Temp Run	222	2399
8/17/2004	0	2	24	62.5	Hi-Temp Run	228	2204
8/18/2004	0	2	24	86.5	Hi-Temp Run	224	2284
8/19/2004	0	2	24	110.5	Hi-Temp Run	223	2276
8/20/2004	1	3	5.5	116	Hi-Temp Run, Knee-point curve	217	2398
8/27/2004	7	10	7	123	Thermal/Mechanical Cycling	221	2500
8/28/2004	3	13	3	126	Thermal/Mechanical Cycling	217	2399
8/30/2004	1	14	1	127	Thermal/Mechanical Cycling	206	2400
8/31/2004	5	19	6	133	Thermal/Mechanical Cycling	213	2500
9/1/2004	8	27	8	141	Thermal/Mechanical Cycling	217	2500
9/2/2004	6	33	6	147	Thermal/Mechanical Cycling, rain	211	2499
9/3/2004	2	35	2	149	Thermal/Mechanical Cycling	205	2400
9/9/2004	6	41	6	155	Thermal/Mechanical Cycling	215	2400
9/10/2004	8	49	8	163	Thermal/Mechanical Cycling	222	2501
9/11/2004	8	57	8	171	Thermal/Mechanical Cycling	221	2500
9/12/2004	8	65	8	179	Thermal/Mechanical Cycling	218	2500
9/20/2004	5	70	5	184	Thermal/Mechanical Cycling	218	2501
9/21/2004	8	78	8	192	Thermal/Mechanical Cycling	221	2600
9/22/2004	8	86	8	200	Thermal/Mechanical Cycling	223	2600
9/23/2004	8	94	8	208	Thermal/Mechanical Cycling	221	2598
9/24/2004	6	100	6	214	Thermal/Mechanical Cycling	218	2599
11/9/2004	1	101	0	214	Checkout run, 1800 amps	143	2102
2/24/2005	1	102	7	221	7.5 hours @ 2000 amps	185	2003
3/18/2005	5	107	5	226	Thermal/Mechanical Cycling	222	2501
3/19/2005	8	115	8	234	Thermal/Mechanical Cycling	237	2721
3/20/2005	8	123	8	242	Thermal/Mechanical Cycling	233	2601
3/21/2005	8	131	8	250	Thermal/Mechanical Cycling	231	2600
3/22/2005	6	137	6	256	Thermal/Mechanical Cycling	198	2700
3/23/2005	5	142	5	261	Thermal/Mechanical Cycling	207	2703
3/24/2005	8	150	8	269	Thermal/Mechanical Cycling	200	2599
3/25/2005	8	158	8	277	Thermal/Mechanical Cycling	208	2500
3/26/2005	8	166	8	285	Thermal/Mechanical Cycling	211	2500
3/27/2005	4	170	4	289	Thermal/Mechanical Cycling	205	2601
3/29/2005	5	175	5	294	Thermal/Mechanical Cycling	201	2599
3/30/2005	8	183	8	302	Thermal/Mechanical Cycling	209	2699
4/4/2005	5	188	5	307	Thermal/Mechanical Cycling	203	2600
4/5/2005	8	196	8	315	Thermal/Mechanical Cycling	211	2602
4/6/2005	6	202	6	321	Thermal/Mechanical Cycling	206	2728
5/17/2005	1	203	13	334	Constant current	264	2002
5/18/2005		203	24	358	Constant current	216	1852
5/19/2005		203	11	369	Constant current	96	1231
5/26/2005	1	204	13	382	Constant current	165	1663
5/27/2005		204	17	399	Constant current	177	1777
6/7/2005	1	205	11	410	300C for 1 hour - 6:30 to 7:30 am	347	2275
6/8/2005	1	206	12	422	Constant temperature tests	143	1566

Figures 7 shows location of thermocouples for temperature recording along the entire conductor spans. Figures 8 to 10 show examples of the thermal cycling carried out on the conductor in the field; some cycles were of a constant temperature long duration, others were of a constant current and some cycles were very short. It should be noted that the used current sometimes exceeded the conductor rated ampacity, no evidence of conductor or accessory degradation.

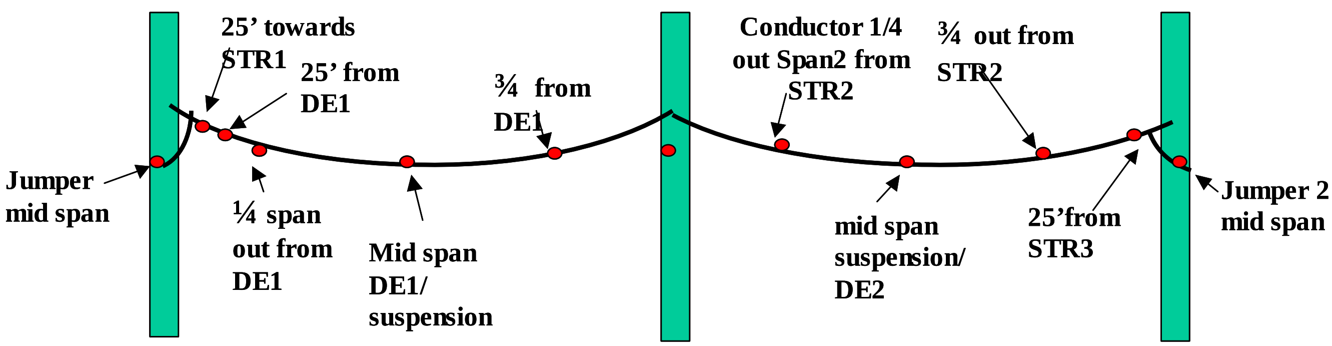


Figure 7- Schematics of thermocouples location along the test line spans; conductor surface temperature was measured at all locations while core temperature at only few.

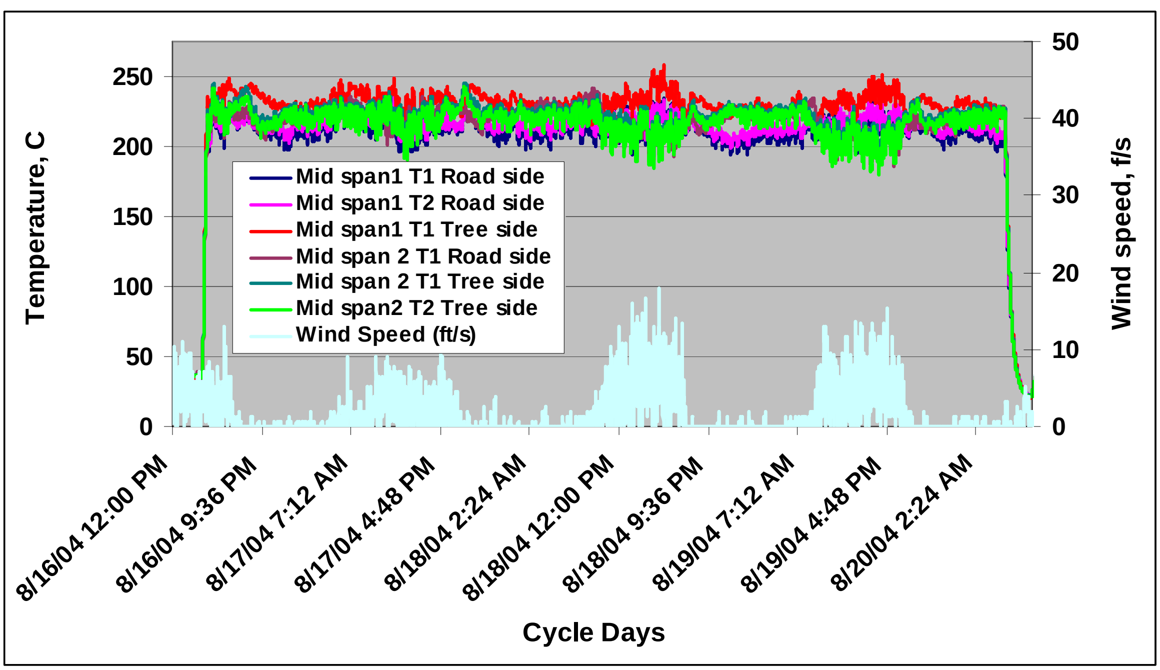


Figure 8 shows an example of about 85 hours single cycle above 200^0 C using DC current between 1900 to 2200 amps. Temperature was measured at two locations for each span for both the road and tree sides.

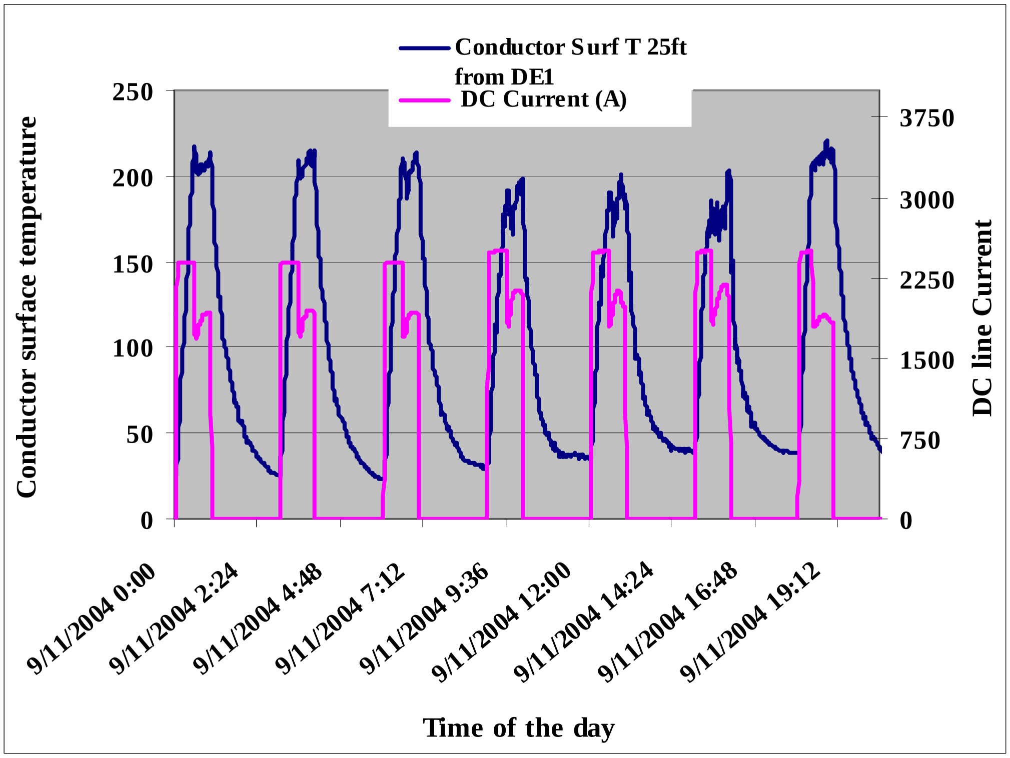


Figure 9 shows an example of short time multiple cycling of conductor in one day.

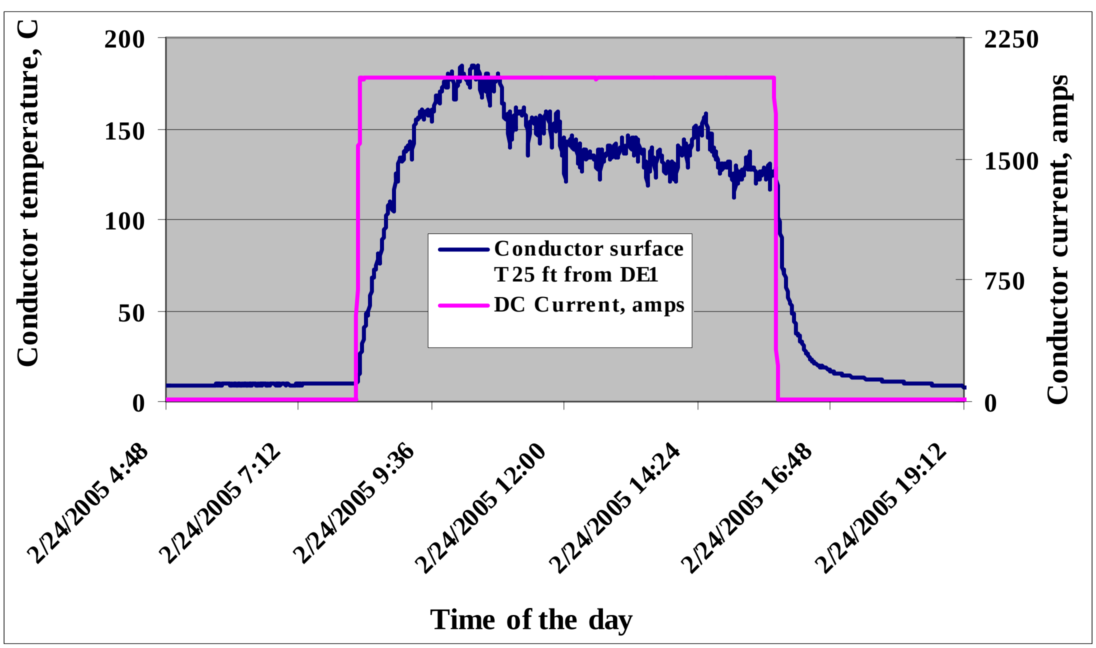


Figure 10 shows an example of a constant current cycle; conductor temperature is changing because of changing wind conditions.

3-2 Conductor Core VS Surface temperature:

Limited number of thermal cycles both at constant current and / or high temperature long time exposure was applied to ACCR 1272 while both core and surface temperatures were measured. Result shows that the core was only several degrees hotter than the conductor surface; see examples in figures 11 and 12. It also shows that the conductor was exposed to temperatures in excess of 230^0 C

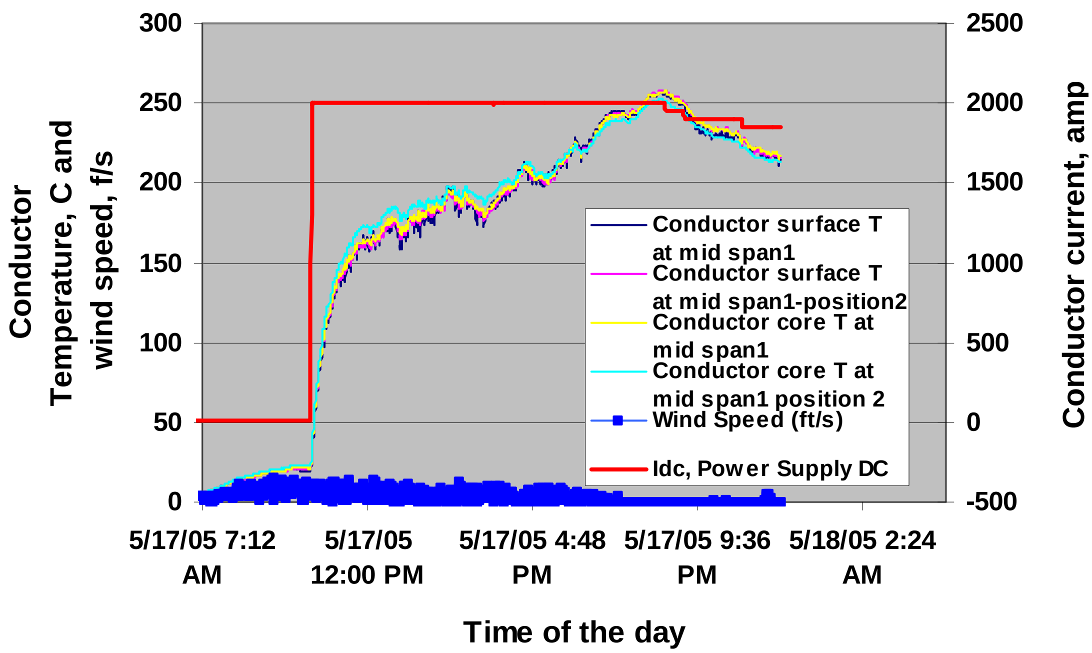


Figure 11. An example of a constant current thermal cycle of ACCR 1272 at ORNL on May 17, 2005

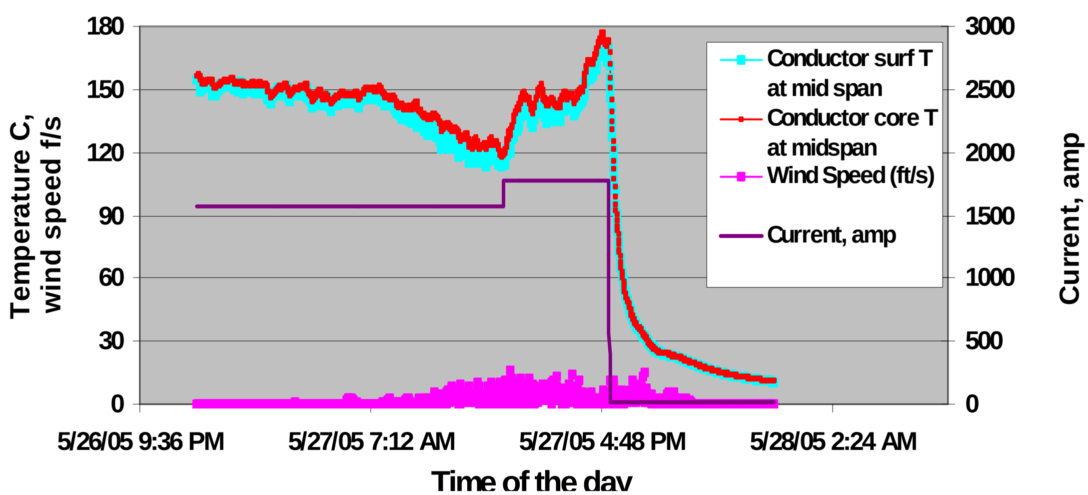


Figure 12. An example of a longer time thermal exposure with cycling around mid night of ACCR 1272 at ORNL on May 17, 2005

Wind speed appears to reduce both the Al strands surface temperature and core significantly as shown in the following figures 13 and 14.

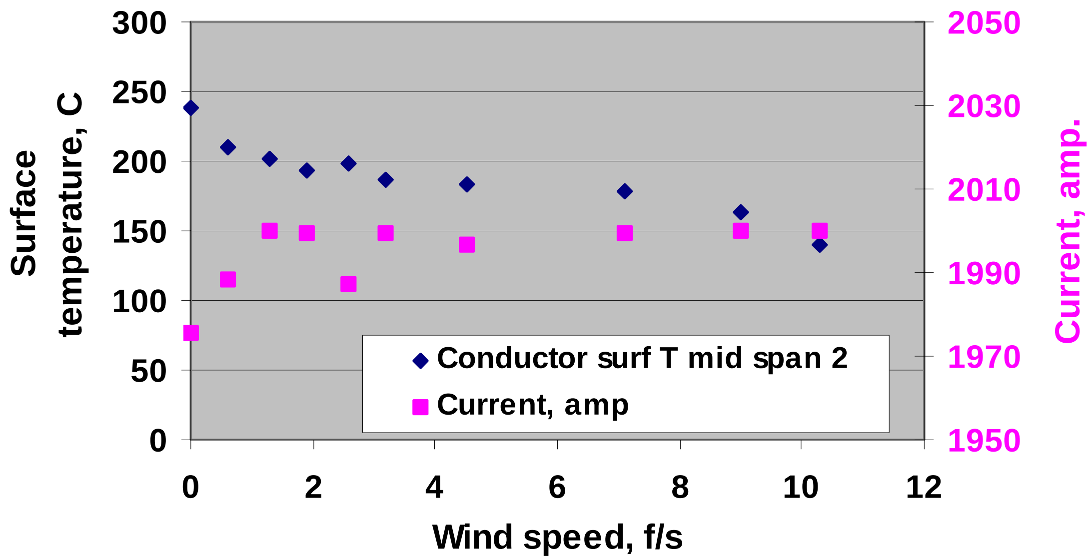


Figure 13. Effect of wind speed on conductor surface temperature at mid span when line is energized to about a current of 2000

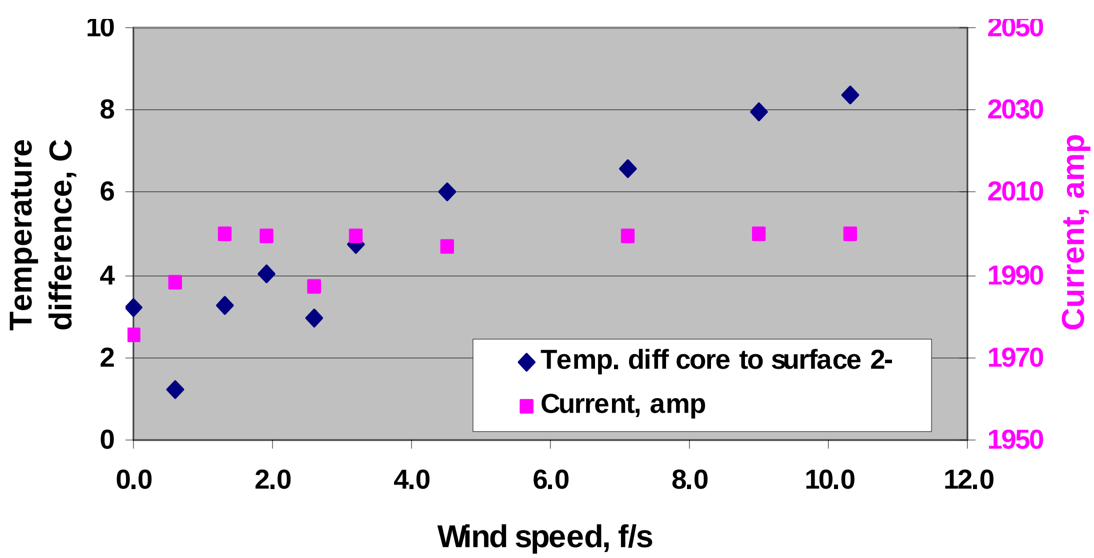


Figure 14. Temperature difference between core and surface at mid span VS wind speed at a constant current of 2000 amps at ORNL test line-

Conductor was exposed to a 300^0 C cycle for a short time and graph 15 shows the cycle details.

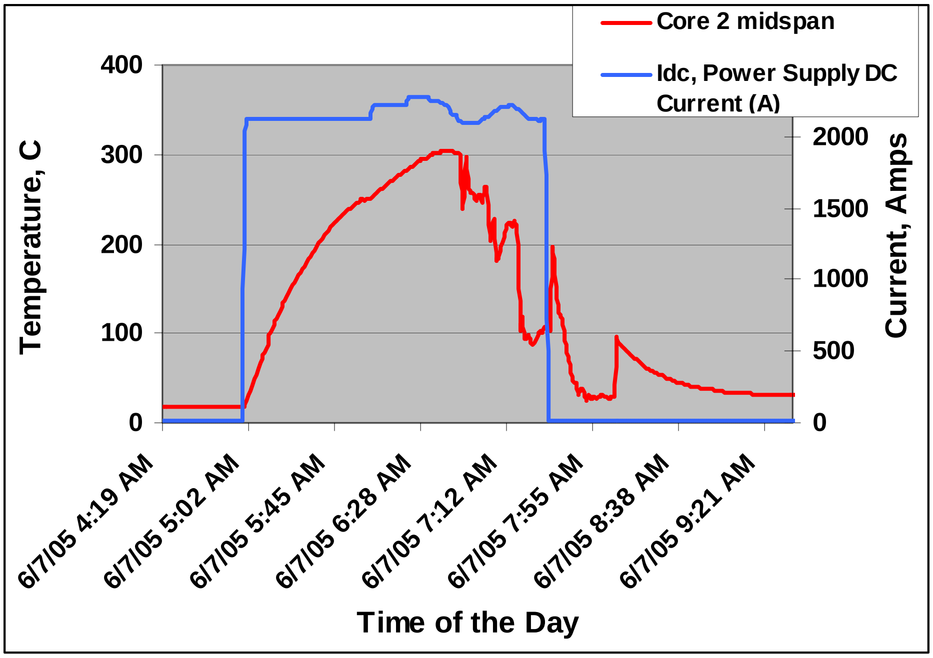


Figure 15 – Conductor core temperature and line DC current data measured during a 300^0 C cycle at the middle of span 1. The other thermocouples mounted on the conductor failed above 300^0 C.

Notice that the temperature gradient from surface to core was about several degrees, much lower than temperature gradients measured on smaller conductors (ACCR 477). Conductor was taken down in June 2005 and examined visually; it showed no damage and is being evaluated at NEETRAC Laboratories for effect of field testing.

4- Measured and Predicted Line Tension and Sag:

Sag was computed using, the Strain Summation Method (which accounts for the full loading history). The Strain Summation Method of Sag-Tension calculation takes into account creep as a function of time. The spans considered are two, tree side and roadside. Measured tension – temperature data is plotted in figure 16 for all tree side locations. The difference in tension is believed to be caused by differences in wind- speed, net radiation temperature, NRC (e.g. temperatures measured 25 ft from structure 3 in Span 2 were lower than temperatures at 3/4 Span 1) and line hysteresis. Figure 16 shows model predicted values using –1.45 Ksi compressive stress compared to measurement at ¾ span 1 and 25 feet away from STR3 on span 2; fit is good at high temperature. At lower temperatures the residual tension from line hysteresis raised the measured values above the computed ones. Calculated Curve is the same as that computed for the first heat cycle conducted on August 13- 14.

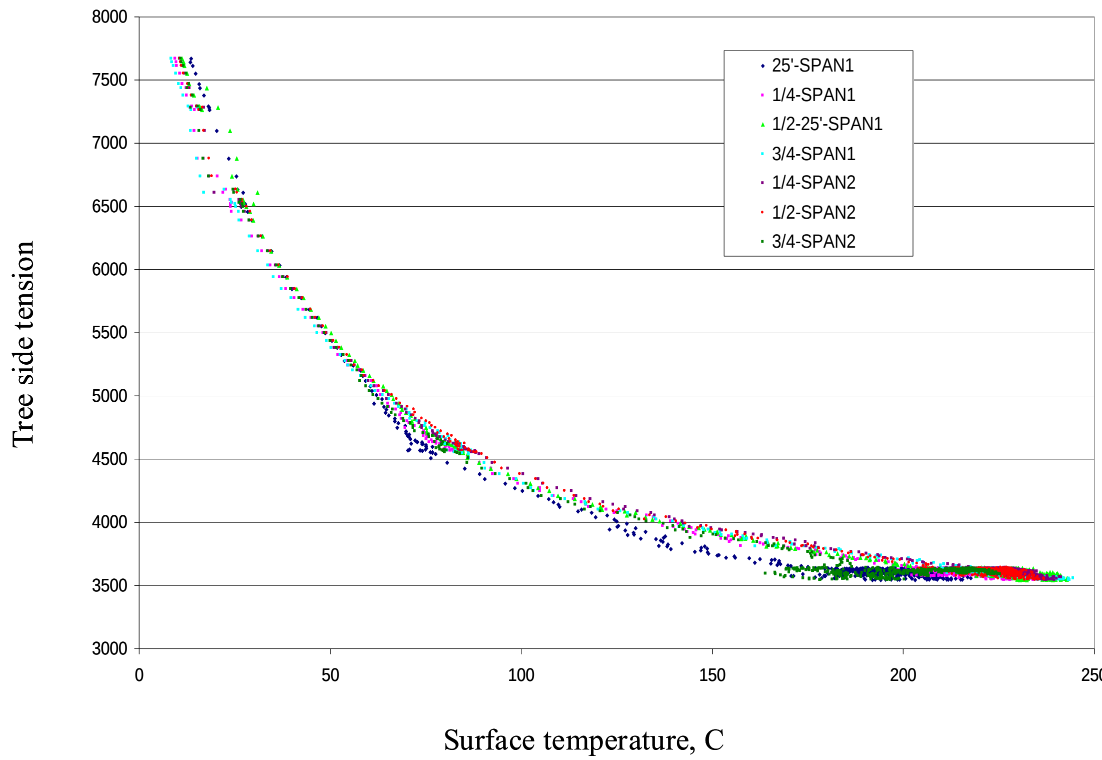


Figure 16- Measured line tension at various locations of spas 1 and 2 along the tree side VS conductor surface temperature.

Tensions (and sag) remained stable throughout 195 hours of heat cycling (81 cycles) up to nominally 220°C and sometimes up to 250°C.

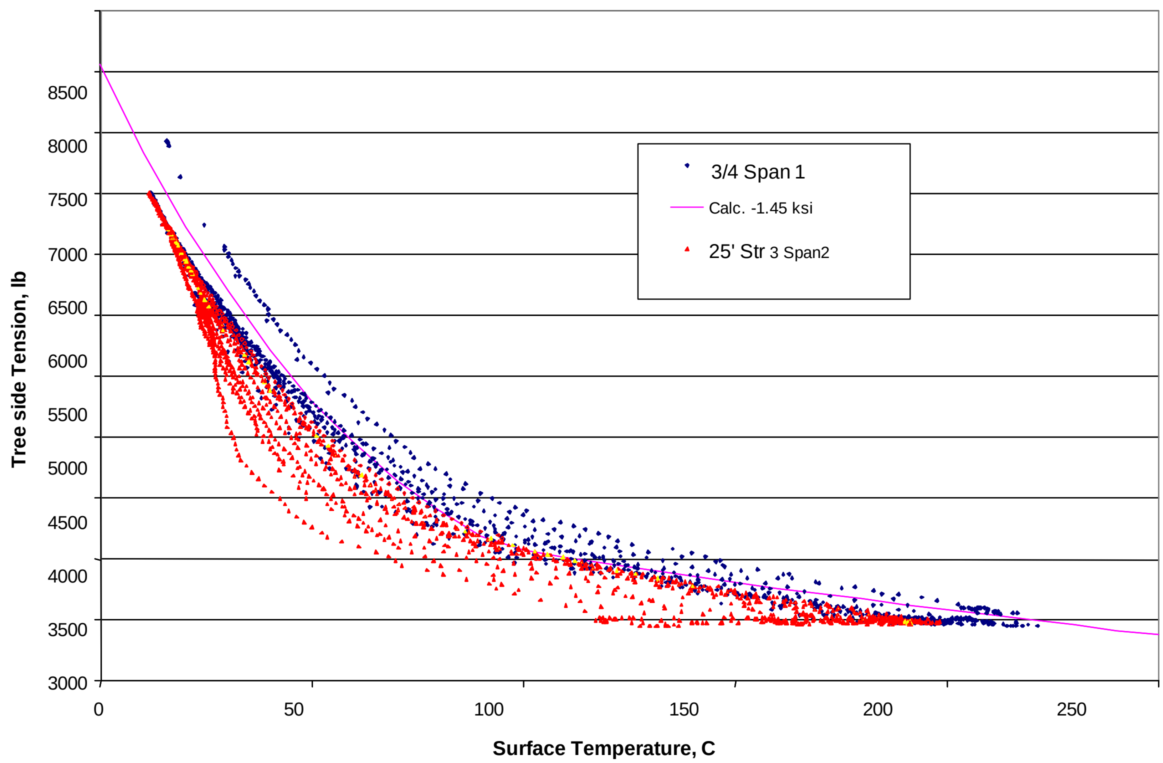


Figure 17- Field measured data acquired on September 21, 2004 for both spans 1,2 show good agreement with model using –1.45 Ksi compressive stress.

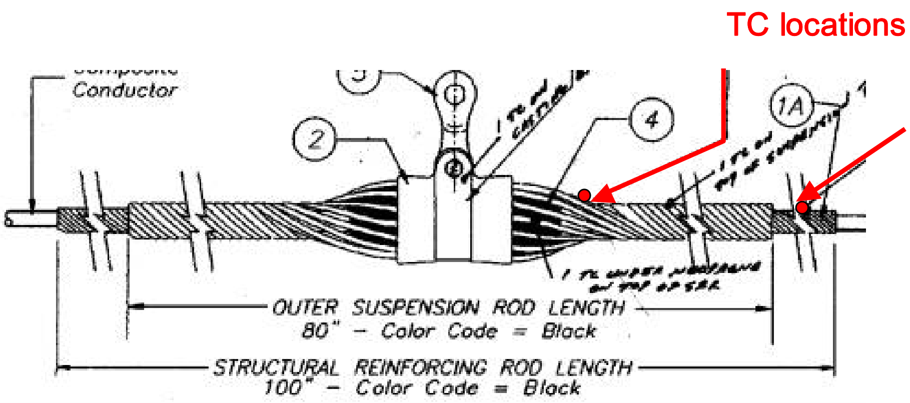
In conclusion the PCAT test line remained stable during the thermal cycle period analyzed here from August to September 2004. Model agrees well with measured values. Additional thermal cycling was carried out from October 2004 to June 2005.

5- Accessories Response at High Temperature:

Both Preformed Line Product and American Fujikura Ltd (Previously known as Alcoa Fujikura) accessories were used for installation of the line. They performed well, as expected, and ran much cooler than the conductor at temperatures above 200^0 C. Same was observed when they were tested in the laboratory at NEETRAC. The following Graphs 17 to 21 show examples of accessories temperature profile and location of thermocouples.

5-1 PLP Accessories:

Temperature profiles of suspension, dead end and splice were measured, figures 19.



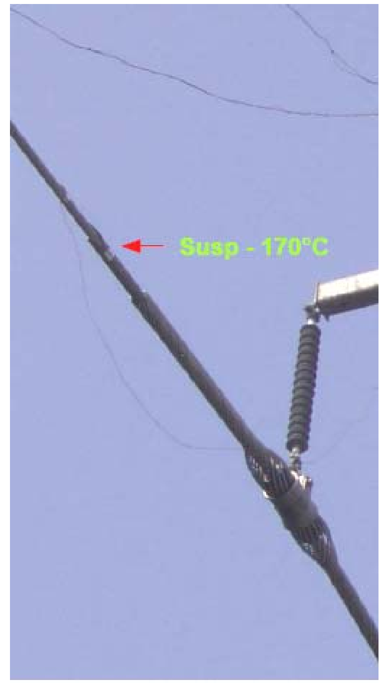


Figure 18 - Suspension System schematics showing thermocouples (TC) locations) , the inner rod TC location is shown in the image it is very close to conductor- the 170^0C is its temperature during a 300^0 C cycle

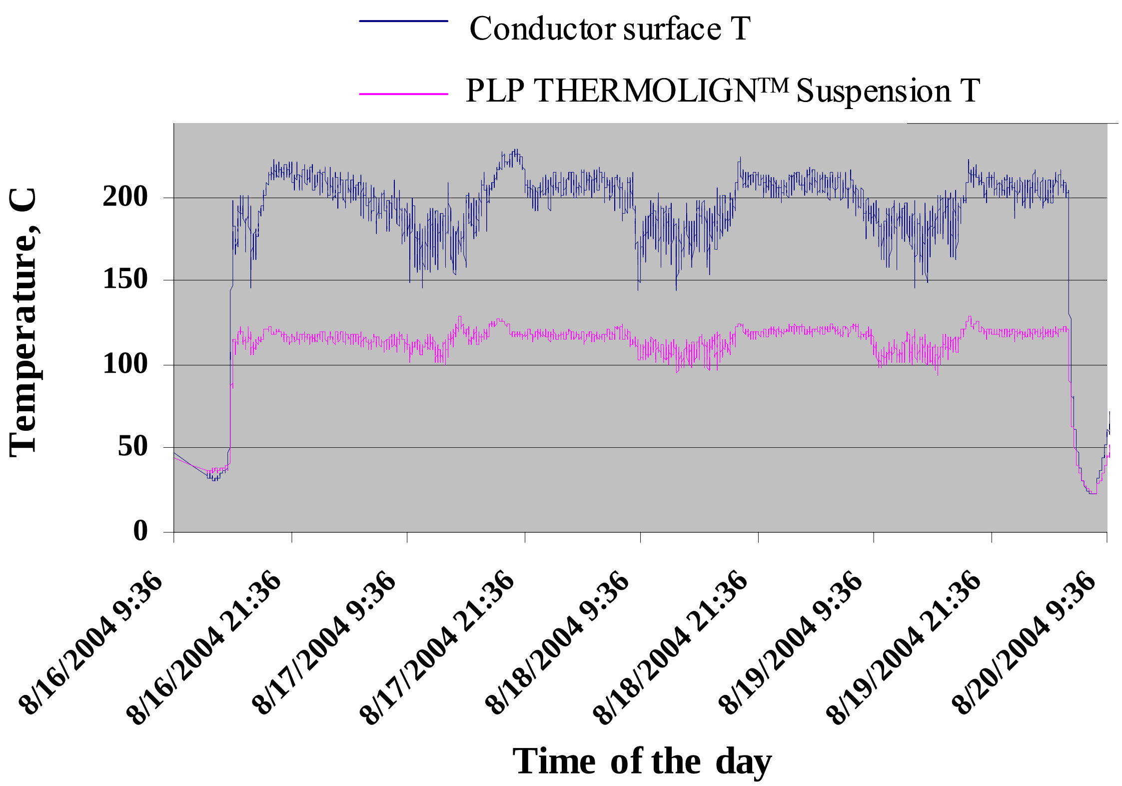
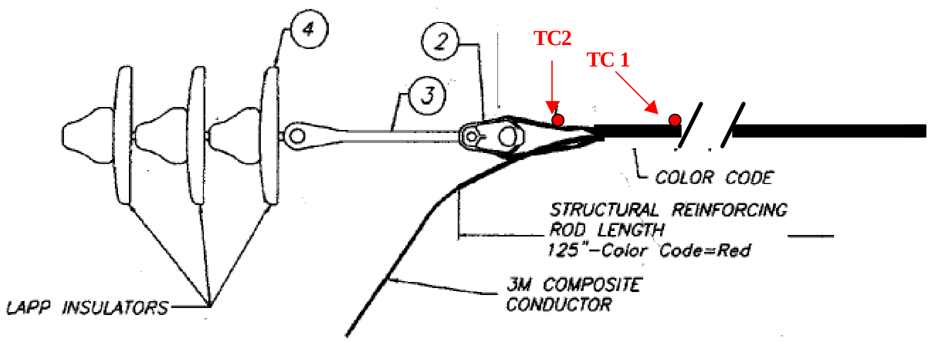
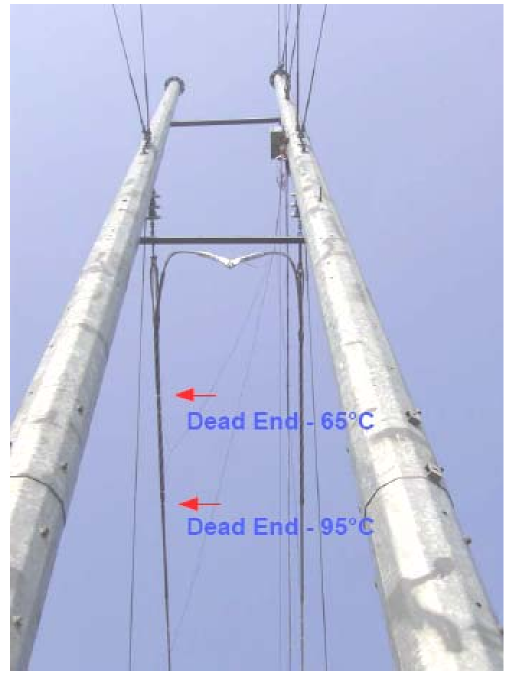


Figure 19 shows PLP THERMOLIGN™ SUSPENSION System temperature measured on the surface of the inner rod during a long time high temperature cycle- other location TC was not active.





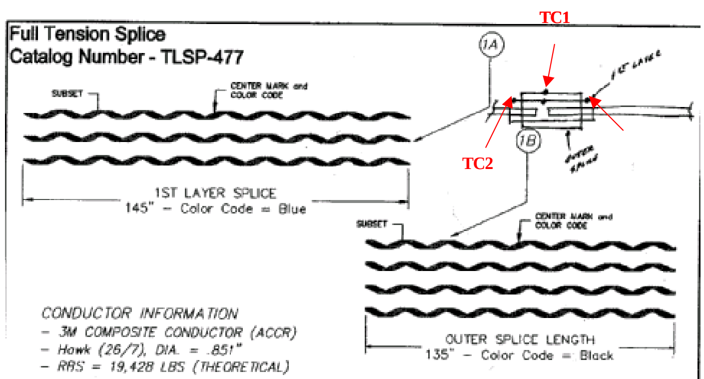


Figure 20- Schematics of thermocouples location on PLP THERMOLIGN^{TM} DEAD END and SPLICE. Image to the right shows location of the two thermocouples- temperatures of 190 and 105^{0} C were the highest when conductor was cycled to 300^{0} C.

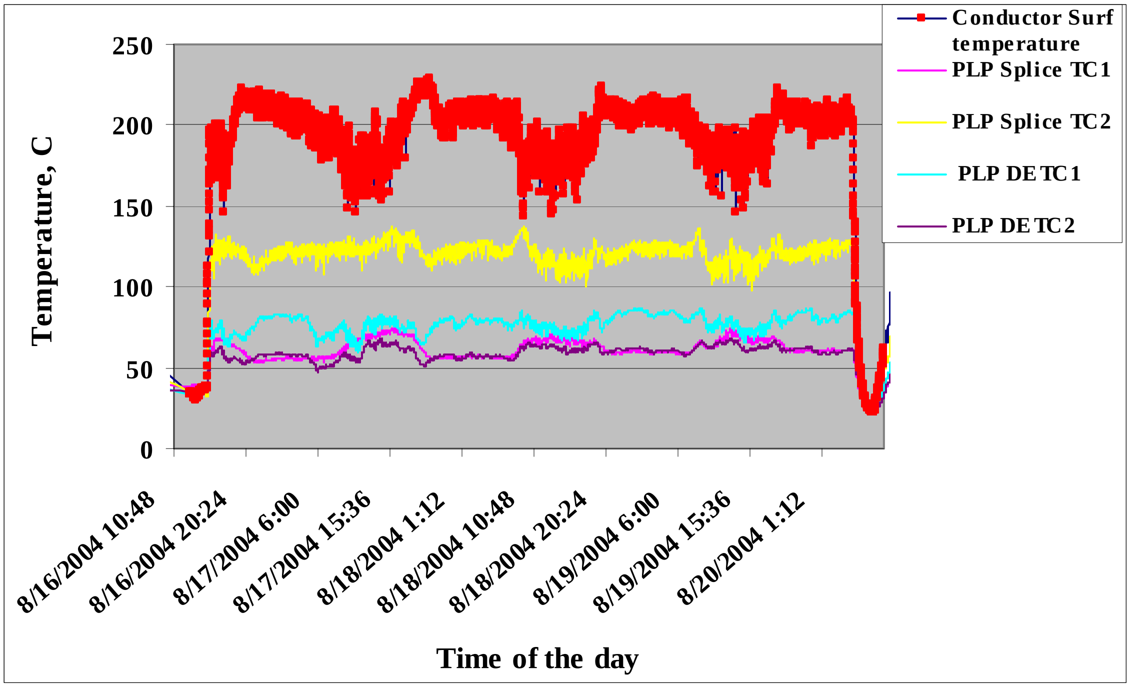


Figure 21- PLP THERMOLIGN™ SPLICE and DEAD END ran cool, maximum temperature was below 130^0 C when conductor was cycled to 210^0 C

High temperature cycle:

The PLP accessories temperature profile was measured during a 300^0 C single cycle.- see figure 22:

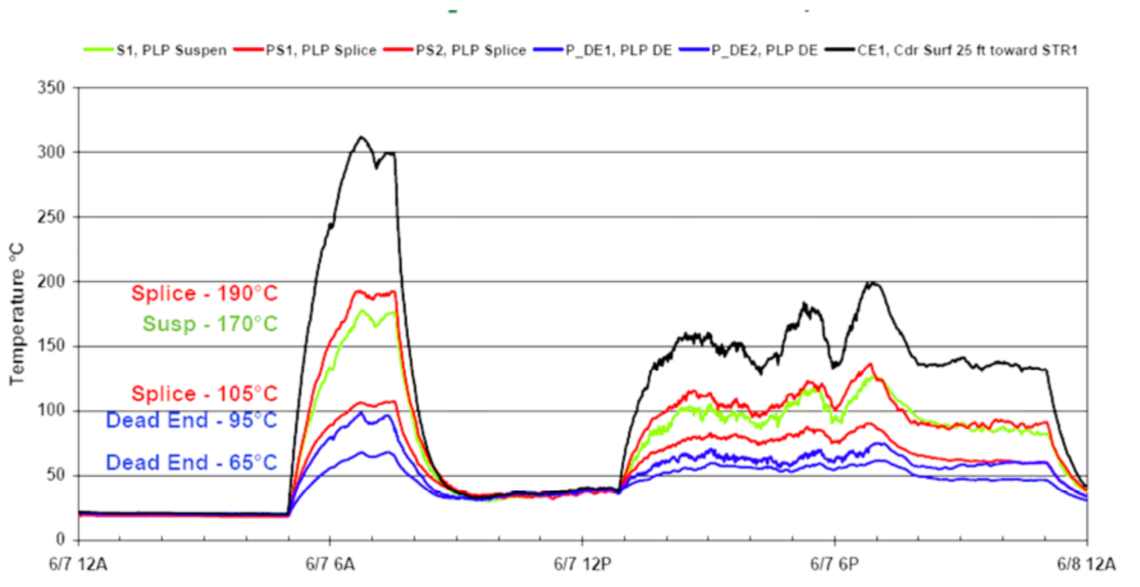


Figure 22- Temperature profile of PLP dead end, splice and suspension during 3000 C cycle of ACCR 1272 conductor. Some of the accessories temperature values was higher than 150^0 C because of the location of the thermocouples very close to the conductor- explained below

The splice temperature was 190^0 C and the suspension temperature was 170^0 C because thermocouples were placed on the inner rod first layer close to conductor. When the thermocouple was placed on the second rod layer mid way along the axial length of second layer of rods splice temperature dropped to 105^0 C. Dead end temperature was lower, 95^0 C (thermocouple placed on first layer of rod adjacent to second layer and 65^0 C (thermocouple placed on second layer of rods mid way along the axial length of the second layer of rods. The following images show location of thermocouples.

5-2 Alcoa Accessories:

Both compression splice and dead ends temperatures were below 105^0 C during conductor exposure to temperatures above 200^0 C- see Figure 22. They show no problem during continued thermal cycling since October 2004.

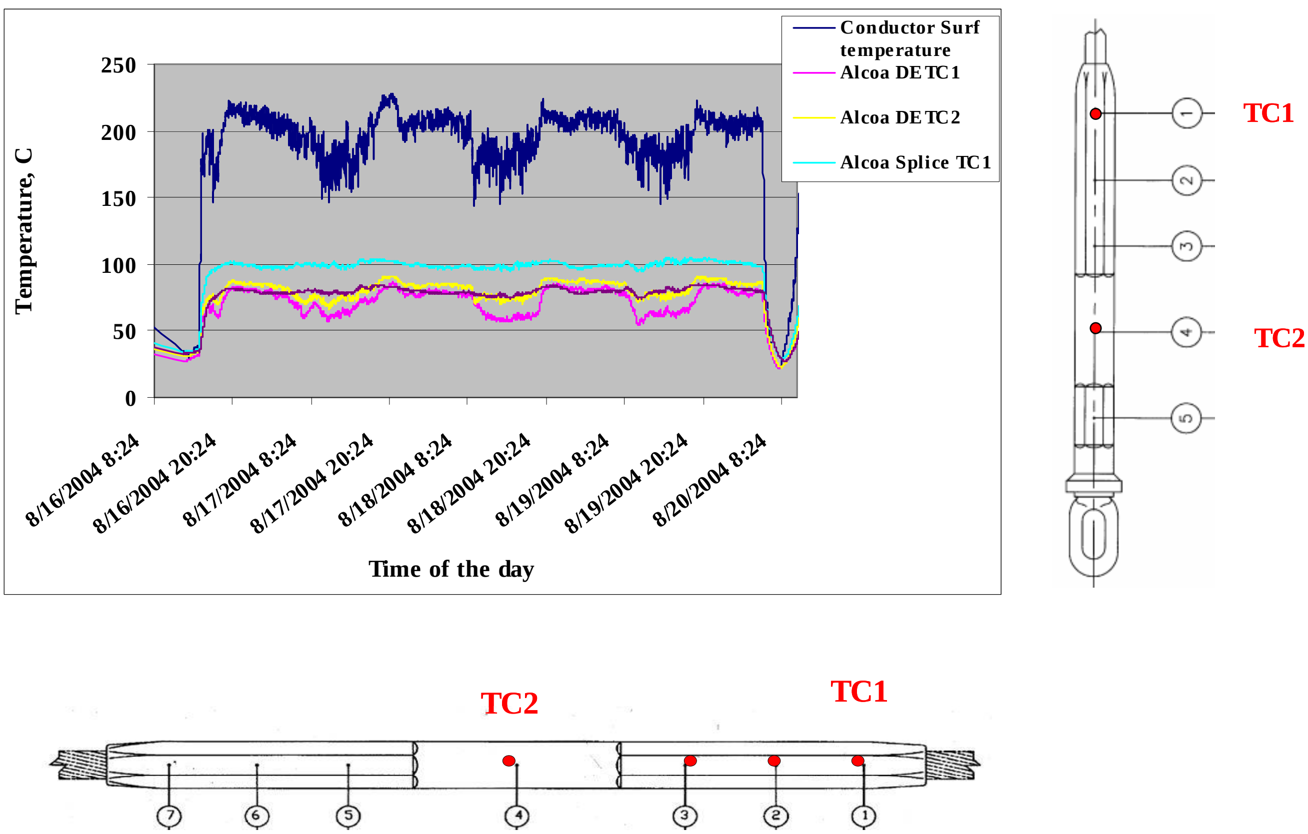


Figure 22- Alcoa compression splice and dead end temperature during one cycle; both ran very cool when conductor was at or above 200^0 C

High temperature cycle:

The Alcoa dead end and splice remained cool, below 1200 C when conductor was cycled to 300^0 C.

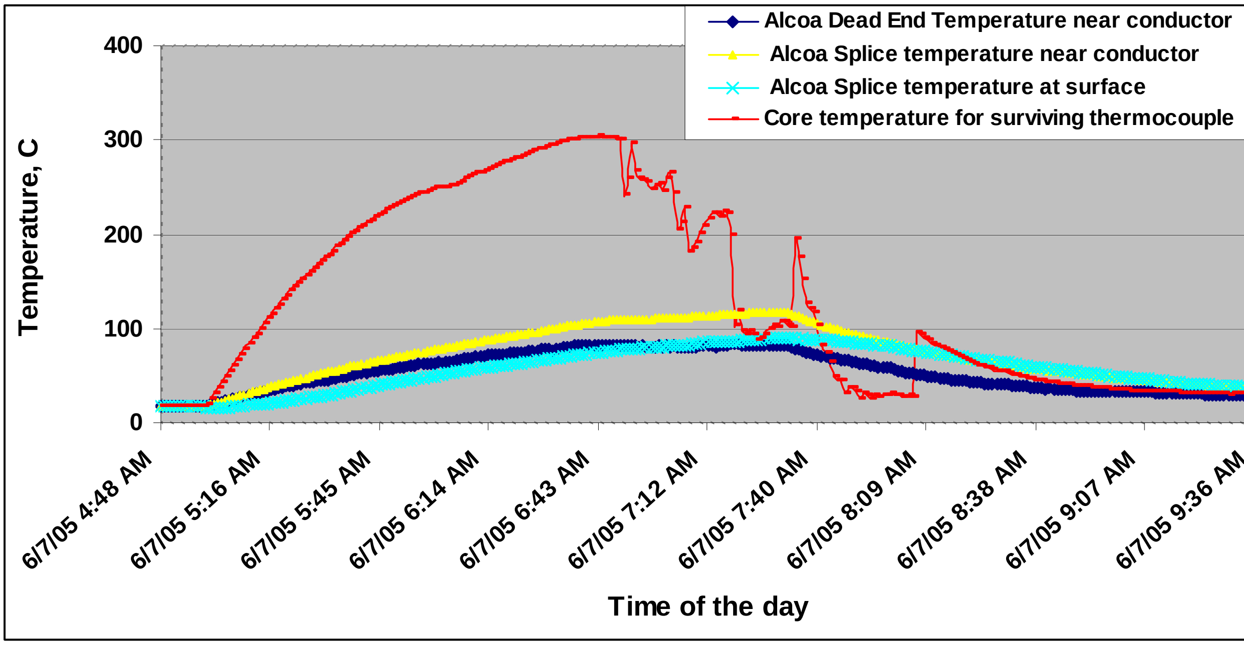


Figure 23- temperature profile of Alcoa dead end and splice during thermal cycling of the conductor to 300^0 C

All 1272 installed accessories behaved normally during thermal cycling of the conductor to above 200^0 C. Post thermal cycle conductor and accessories are being evaluated at NEETRAC.

6- Ampaciy and Thermal Rating of Conductor

6-1 Ampacity Prediction using IEEE Model:

The IEEE Standard 738-1993-was used to predict conductor temperature during cycling. The thermal cycle details are in Table 2. Weather conditions for constant current and wind were used in the model; Figure 24 shows an example of steady state, high temperature cycle data used in the model. Table 3 gives selective steady state data at each wind speed while Figure 25 plots measured current VS predicted one at conductor temperatures around 200^0 C; agreement is very good. Conductor emissivity, ε was measured at ORNL in 2003 and reported to be around 0.347 and used in the model.

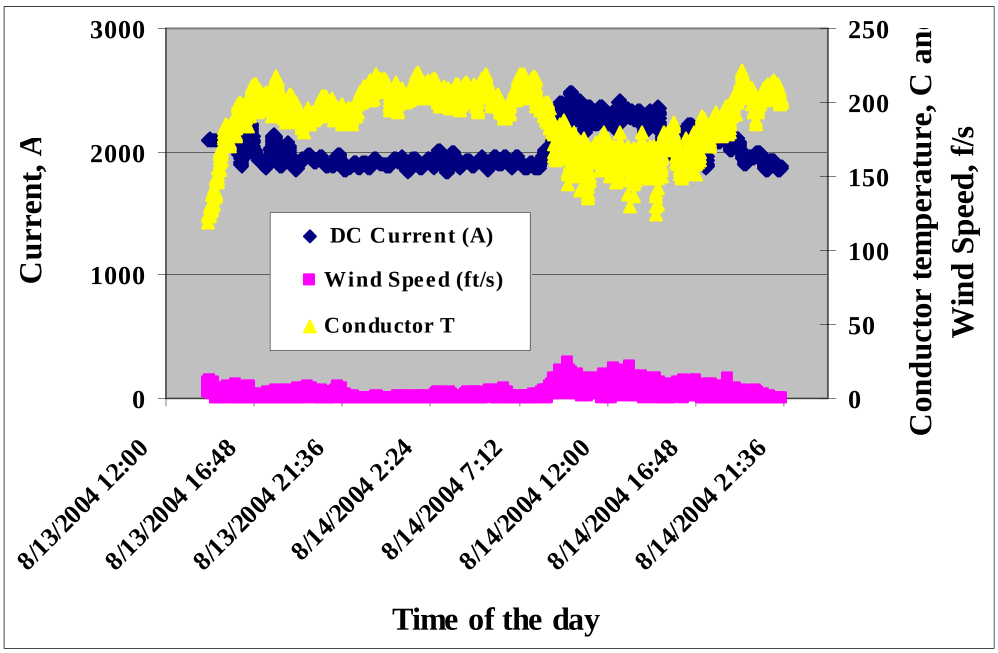


Figure 24- An example of high temperature steady state cycle conducted on ACCR 1272. Data from those cycles in August 2004 was used to predict current

Table 3 shows data for predicted VS measured current- IEEE Std. 738-1993 was used

Measured Current A	Ambient Temp. C	Wind Speed (ft/s)	Wind Angle degrees	Conductor Temp. C	Wind dirction degrees	Predicetd Current A		Measured Current A	Ambient Temp. C	Wind Speed (ft/s)	Wind Angle degrees	Conductor Temp. C	Wind dirction degrees	Predicetd Current A
0	23	0	10	23	0	0		1333	25	6	10	64	210	1141
545	20	1	13	23	53	213		1344	24	7	31	61	189	1376
698	20	0	30	26	10	309		1354	25	2	9	65	229	908
699	21	0	21	28	331	342		1364	25	6	29	68	249	1384
699	21	0	39	29	79	382		1376	25	3	4	68	224	938
699	21	0	57	31	97	405		1387	25	3	11	68	151	992
699	21	0	40	31	80	419		1396	25	5	15	69	235	1177
699	22	0	71	34	111	463		1408	25	2	5	71	215	965
700	20	0	18	27	328	327		1420	25	3	0	73	220	988
700	21	0	53	29	103	362		1429	25	9	13	70	207	1390
700	21	0	15	29	55	372		1439	25	11	14	70	206	1485
700	21	1	68	30	108	439		1448	25	6	9	72	211	1254
700	21	1	53	30	93	437		1459	25	7	14	67	206	1290
700	21	0	18	33	58	448		1471	25	5	27	71	193	1319
700	21	0	64	33	104	454		1480	25	6	36	66	176	1406
701	21	1	60	30	100	520		1489	25	8	12	70	208	1360
701	21	1	85	33	125	593		1499	25	5	12	73	208	1227
701	21	0	78	33	142	446		1510	25	10	0	74	220	1283
702	20	0	23	25	63	262		1520	25	13	2	72	218	1380
702	21	0	30	28	10	348		1530	25	8	14	72	206	1383
702	21	0	25	32	65	441		1540	25	5	38	75	182	1491
706	22	0	28	35	68	485		1550	25	15	13	73	207	1646
711	22	0	67	35	153	493		1561	25	13	7	75	213	1500
719	22	1	38	35	182	592		1572	25	14	7	73	213	1503
721	20	0	44	24	84	242		1581	25	8	1	75	221	1220
727	22	1	51	35	169	621		1591	25	6	19	74	201	1361
737	22	0	5	36	215	507		1601	25	8	0	77	220	1231
746	22	0	41	36	269	515		1610	25	6	29	79	191	1556
747	20	0	53	24	93	219		1621	25	12	0	77	220	1360
756	22	0	33	37	187	522		1630	25	3	57	80	163	1370
766	22	0	8	37	48	521		1639	25	8	10	77	210	1413
774	22	0	74	37	114	522		1648	25	6	17	83	203	1477
783	22	0	45	37	355	535		1657	25	5	56	88	276	1709
791	22	1	37	37	183	636		1666	26	2	2	82	204	1085
801	22	1	51	38	169	576		1674	26	6	6	87	180	1316
810	22	0	45	38	175	557		1683	26	5	5	87	227	1228
819	22	0	59	39	251	566		1692	26	11	11	89	227	1665
827	22	0	68	39	152	564		1699	26	6	6	92	207	1405
837	22	0	15	40	55	578		1709	26	7	7	94	235	1476
844	22	0	47	40	267	574		1717	26	8	8	95	237	1518
853	22	0	44	40	84	577		1728	26	8	8	96	238	1575
862	22	0	47	40	173	585		1737	26	6	6	94	197	1419
870	22	0	79	41	141	596		1746	26	5	5	91	269	1303
877	22	1	19	41	201	640		1758	26	5	5	93	193	1314
887	22	1	19	42	201	643		1772	26	3	3	96	197	1208
895	22	1	24	43	196	632		1785	26	1	1	103	200	1264
904	22	1	10	43	210	639		1798	26	5	5	99	215	1366
914	22	1	54	44	166	671		1809	26	10	10	97	206	1659
924	22	1	14	44	206	649		1825	26	8	8	103	237	1587
936	22	1	5	44	215	643		1837	29	2	54	182	94	1951
946	22	1	30	45	200	656		1837	26	12	12	105	224	1857
956	22	1	40	45	180	766		1849	26	8	8	105	215	1657
966	22	2	17	46	203	741		1859	26	5	5	107	234	1380
975	22	3	16	45	204	810		1869	26	5	5	110	222	1450
985	22	1	33	46	187	769		1879	26	4	4	110	218	1349
998	22	1	27	46	193	745		1886	26	8	8	110	251	1651
1010	22	3	54	46	166	945		1889	21	0	88	197	132	1884
1020	22	0	36	47	184	693		1893	26	3	3	115	246	1363
1032	23	2	17	48	203	774		1899	30	1	25	208	245	1892
1045	23	1	12	47	232	697		1899	29	1	1	214	221	1923
1055	23	4	3	48	217	788		1900	26	9	9	116	217	1782
1066	23	3	29	49	191	913		1908	26	1	1	117	291	1376
1076	23	2	2	50	222	737		1910	21	1	45	203	355	1925
1089	23	2	16	51	214	805		1914	26	4	4	120	232	1413
1097	23	1	12	51	232	754		1922	26	4	4	121	238	1417
1107	23	2	13	52	207	803		1929	26	5	5	121	231	1472
1119	23	2	1	51	221	754		1936	26	5	5	126	208	1558
1127	23	1	26	55	246	844		1946	26	6	6	126	239	1662
1139	23	1	2	56	222	812		1953	26	3	3	127	193	1449
1150	23	0	2	56	152	816		1962	26		11	127	224	1446

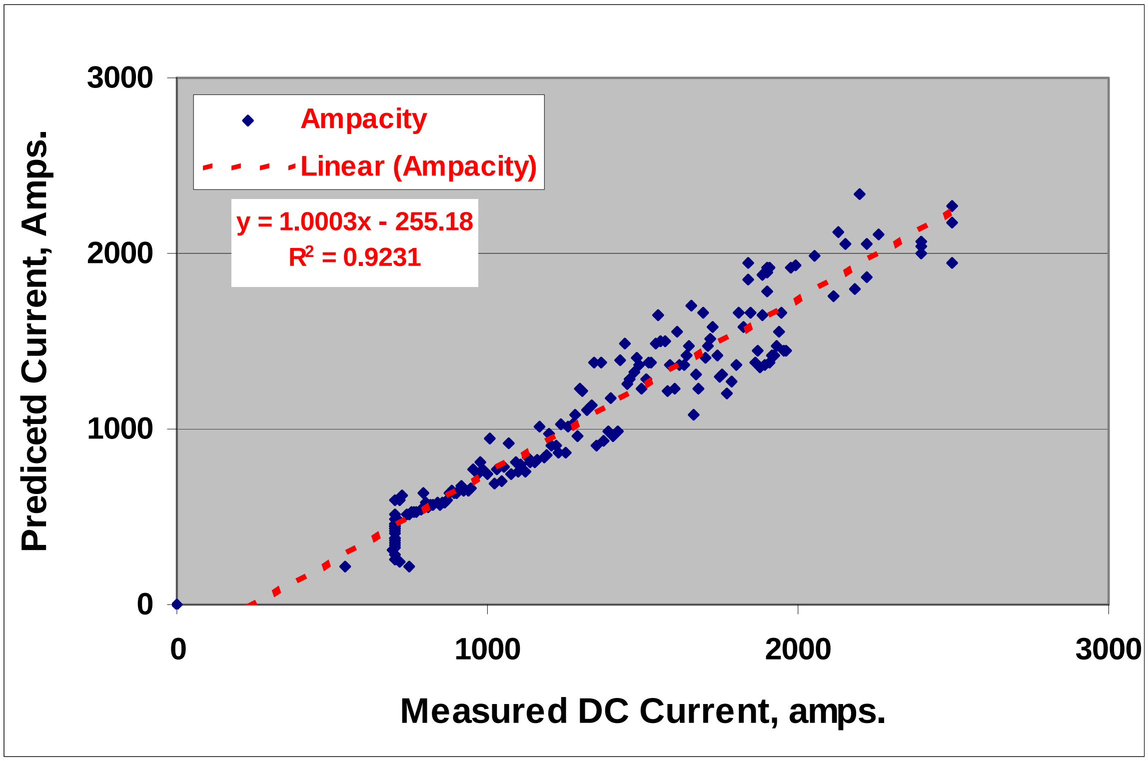


Figure 25- All Predicted VS measured current; IEEE Std 738 shows better agreement at temperatures above 1000^0 C.

ACCR 1272 Conductor was rated at 2229 amps continuous at 210^0 C and at 2402 amps emergency at 240^0 C. The data shows the conductor was sometimes exposed to temperature higher than 240C and current above 2400 amps

6-2 IEEE VS CIGRE' Ampacity Model:

The CIGRE' 1997 model was used to compute current and to compare with the IEEE Std 736 used above- both programs were provided by the Valley Group Rate kit software. There are small differences in the method of calculations and literature indicates that the difference is small. Our calculations show that the difference in predicted current was < 0.8% and the two approaches agree very well:

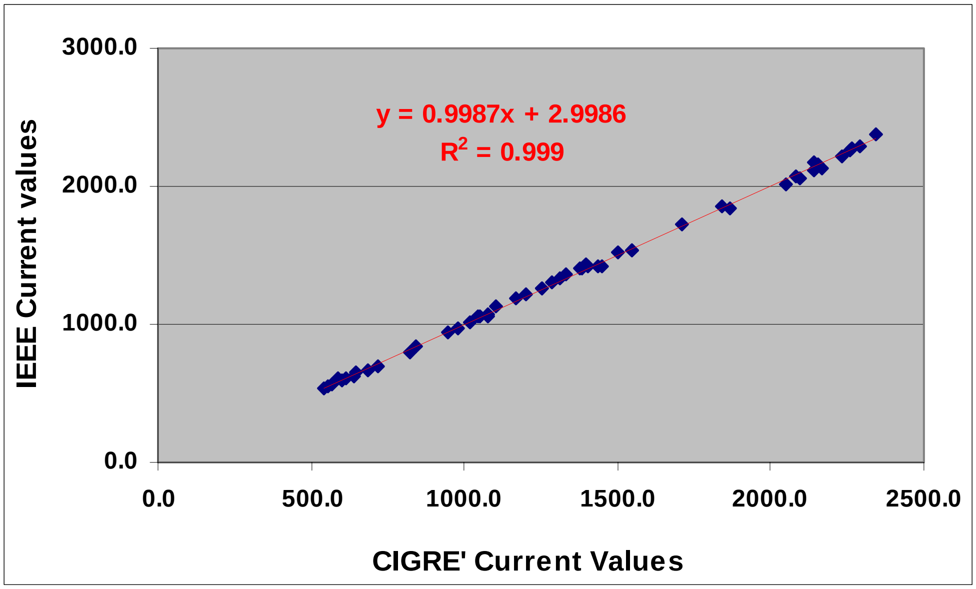


Figure 26- Comparison of Predicted Current values computed using both IEEE and CIGRE Ampacity models. Average difference between the two methods is about 0.89%.

7- Summary

ACCR 1272 conductor was successfully installed and tested at ORNL. It was thermally cycled from ambient to > 200^0 C for several hundred hours, using DC power supply. Measured temperature difference between conductor core and its surface was only several degrees at cycling temperatures in excess of 200^0 C. The wind speed appears to have a strong effect on cooling of the conductor

Data analysis shows that the measured conductor current agrees well with the IEEE thermal rating model predicted values. The conductor is rated at 2229 amps for continuous operation at 210^0 C and 2402 amps emergency at 240^0C. The CIGRE' model agrees well with the IEEE 736 model within 0.8%.

The conductor sag was stable during and after thermal cycling. Measured line tension agrees well with values computed using the strain summation method.

Both PLP and AFL accessories ran cool, < 120^0 C and show no visual damage.

Conductor was de- installed in June 2005, and sent to NEETRAC for testing and evaluation.

8- Appendix

8-1 Conductor Specs

Conductor Specs

Conductor Physical Properties		
Designation		1272-T13
Stranding		54/19
kcmils	kcmil	1272
	mm^2	644.5
Diameter		
Individual Core	in	0.092
Individual Aluminum	in	0.153
Core	In	0.46
Core diameter tolerance	in	+/- 0.005
Total Diameter		
Total diameter tolerance	in	+/- 0.014
Area		
Al	in^2	0.999
Total Area	in^2	1.126
Weight	lbs/ linear ft	1.392
Breaking Strength		
Core	Lbs	23, 622
Aluminum	Lbs	20,055
Complete Cable	000's lbs	43,677
Modulus		
Core	Msi	31.4
Aluminum	Msi	8.0
Complete Cable	Msi	10.6
Thermal Elongation		
Core		6
Aluminum		23
Complete Cable		17
Heat Capacity		
Core	W-sec/ft-C	28
Aluminum	W-sec/ft-C	520

Conductor Electrical Properties

Resistance		
DC @ 20C	Ohms/mile	0.0700
AC @ 25C	Ohms/mile	0.0717
AC @ 50C	Ohms/mile	0.0787
AC @ 75C	Ohms/mile	0.0858
		0.0466
Geometric Mean Radius		
Inductive Ax		0.372
		0.0847
Capacitance Ax's		