675/TW, Type 11, 3M Brand Composite Conductor Compression Connector Qualification - Tensile, Sustained Load, and High-temperature Sustained Load

3M Company
Purchase Order 0001094629

NEETRAC Project Number: 03-202

January, 2004

NEETRAC – National Electric Energy Testing, Research & Applications Center

A Research Center of
The Georgia Institute of Technology

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Summary:

3M contracted with NEETRAC for a series of qualification tests in accordance with the ANSI C119.4 connector performance requirements. Splice connectors and dead-end terminal connectors provided by Alcoa Fujikura Limited (AFL) pass the tensile loading requirements. Dead-end connectors were subject to sustained load testing at both room temperature and at 240^{o} C. Both sustained load samples passed the sustained load test, and exceeded the nominal rated breaking strength (RBS) on the residual strength test.

Samples:

1) Five (5) samples 675/TW, Type 11, 3M Brand Composite Conductor, 25-ft long with AFL compression dead-end (catalogue # B9085-C) on one end. Compression dead-end fittings were installed by AFL at their Spartanburg, SC facility. NEETRAC installed a lab termination on the end opposite the AFL dead-end. The conductor may also be referred to as 675 ACCR/TW.
2) Three (3) samples 675/TW, Type 11, 3M Composite Conductor, 25-ft long with AFL compression splice (catalogue # B9095-D) in the center. Compression splices were installed by AFL at their Spartanburg, SC facility. NEETRAC installed lab terminations on both ends of each sample.

References:

1) "Proprietary Information Agreement …." Dated 3/27/01, and renewed 3/03.
2) ANSI C119.4 – 2003, (Connector performance requirements).
3) 3M Purchase Order 0001094629.
4) PRJ 03-202, NEETRAC Project Plan.

Equipment Used:

1) MTS Servo-hydraulic tensile machine, Control # CQ 0195.
2) Fowler 42-inch caliper micrometer, Control # CN3020.
3) Load frame 25K load cells Control #s CN 3056 and CN 3057
4) Load frame extensometers, Control #s CN 3041 and CN 3042
5) Temperature measurement system (sustained load samples), Control # CN 3040.

Procedure:

1.0 Tensile Tests on compression splices and dead-end terminals:

Fittings were installed on the conductor by AFL at their factory in South Carolina. NEETRAC installed special cast resin terminations on the free ends of the samples. Two lab terminations are needed for the free ends of the splice sample. Dead end samples need only one lab fitting. All samples were approximately 22 feet long overall, with approximately 20 ft of exposed conductor in the test section. Samples were pulled to destruction at a loading rate of 10,000 lb/min. ANSI C119.4 requires that a connector hold a minimum of 95% of the conductor rated breaking strength. According to the 3M conductor specifications, the rated breaking strength (RBS) for the 675/TW conductor is 22,487 lbs. Two additional dead end samples were tested to determine residual strength following the sustained load test. See the section on the sustained load test for a description of those tests. The tensile results from the sustained load test are included here for completeness. Tensile test results are as follows:

Sample	Max. load (lbs)	%RBS	Failure description
Splice 1	21,730	97	Core strands slipped in resin, tensile break, aluminum strands 5” inside splice
Splice 2	22,560	100	Tensile break, all strands, 5” inside splice
Splice 3	21,840	97	Tensile break, all strands, 5” inside splice
Dead end 1	24,130	107	Tensile break, all strands, 5” inside dead-end
Dead end 2	23,140	103	Tensile break, core 7” inside dead end, aluminum 5” inside dead-end
Dead end 3	22,500	100	Tensile break, all strands, 5” inside dead-end
RT Sust Load	25,410	113	Gage section break – all strands
HT Sust Load	22,210	109	Gage section break – all strands

Figures 1 and 2 show the tension versus actuator displacement for the splice and dead end tests, respectively.

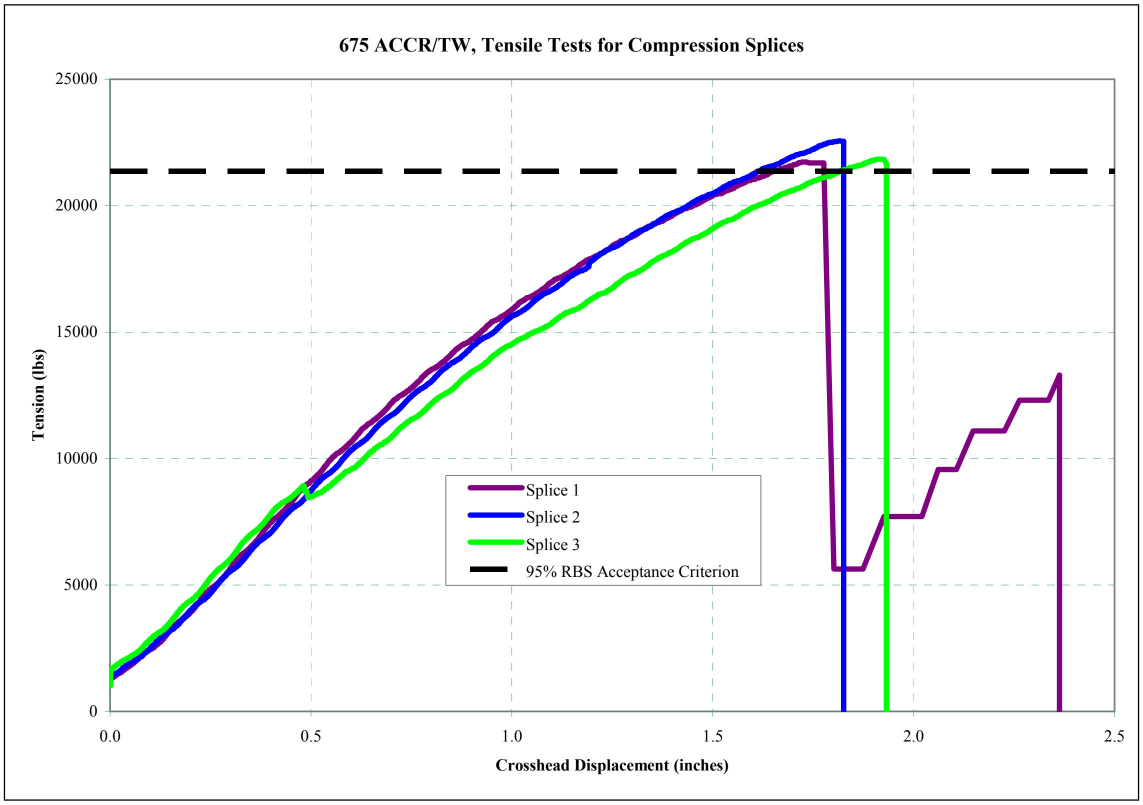

Figure 1, Tensile Test Data for AFL Compression Splices

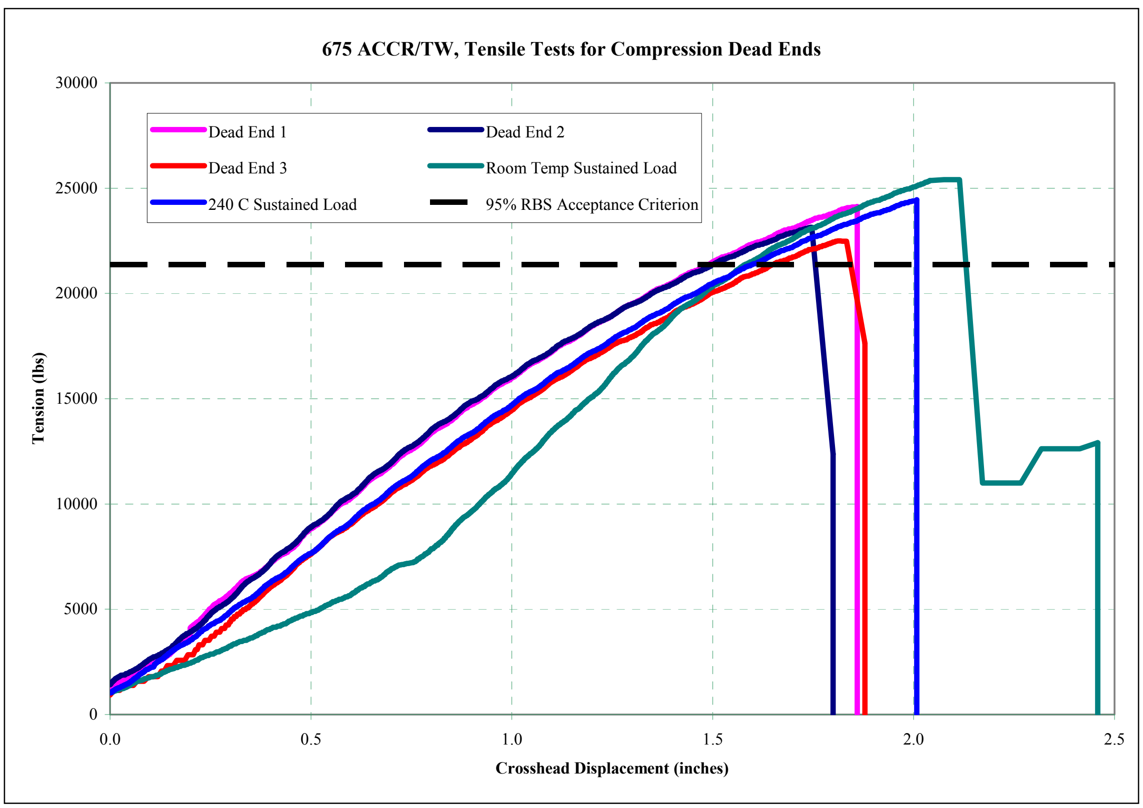

Figure 2, Tensile Test Data for AFL Compression Dead Ends

2.0 Sustained Load Test Per ANSI C119.4:

Samples identical to the tensile test samples were used for the sustained load test. To qualify under the ANSI standard, a connector must hold 77% of the conductor's rated breaking strength (RBS) for seven days (168 hours). At the end of the sustained load period, the residual strength must exceed 95% of the conductor RBS.

There is no ANSI requirement for high temperature sustained load testing. The second sustained load sample was subjected to a test designed to demonstrate sustained load performance of the connector system at extreme high temperature. AC current was used to raise the conductor temperature to 240^{o} C for the duration of the 168 hour test. Tension for the high temperature sample was 15% RBS. Lower tension was used for the high-temperature test to simulate the expected field tensions, where 15% RBS is considered an upper limit for tension at extreme conductor temperatures.

Both samples were installed in a load frame. Both samples were fitted with extensometers to monitor conductor creep. Both samples are maintained at the tension target by computer control. An electric-drive lead screw operates to correct tension whenever the load falls outside of a +/- 0.5% dead band. The high temperature sample was instrumented for temperature in the center surface, center core, and at both ends. A data acquisition system logs tension, elongation, and temperature data. Figure 3 shows the ambient temperature, tension, and elongation for the conductor and connector barrel for the room-temperature sample. Figure 4 shows temperature, tension, and elongation data for the high-temperature sample. Both samples appeared to be in good condition at the end of the sustained load phase. Both samples exceeded RBS in the residual strength test.

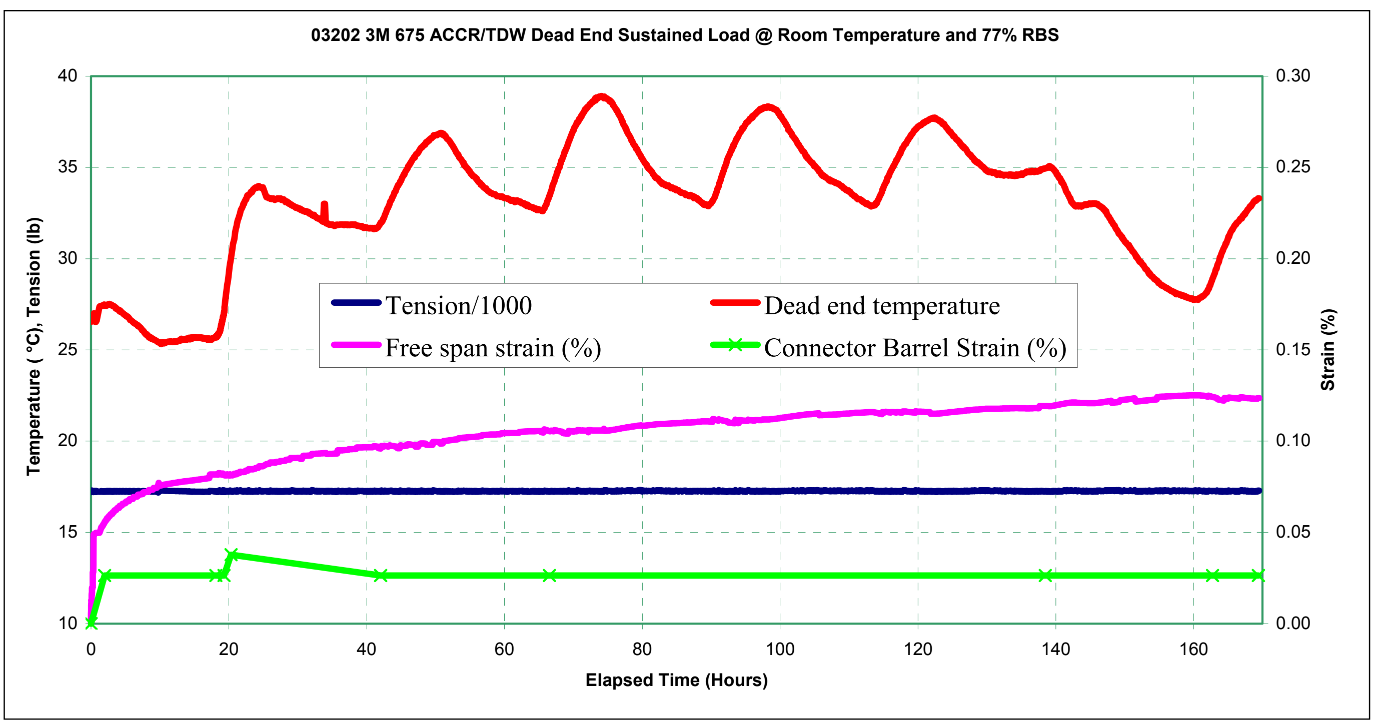

Figure 3, Data Recorded during the Room Temperature Sustained Load Test

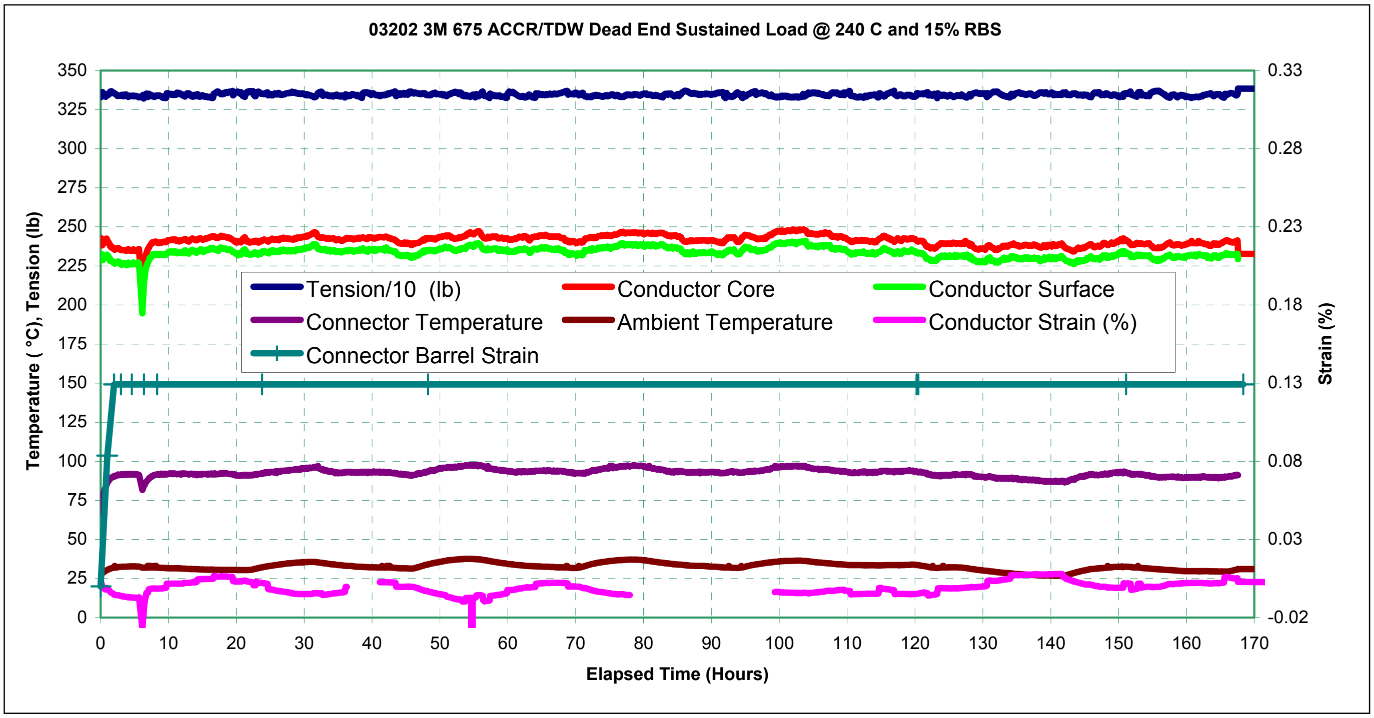

Figure 4, Data Recorded during the High-temperature Sustained Load Test

Notes:

1) Temperature drop approximately 5 hours into the test was caused by a brief power failure.
2) Conductor strain (bottom line in Figure 4), is too small to measure reliably. Any variation in the creep curve is due to load and temperature effects. Gaps in the record were caused by a loose connector.
3) Connector barrel strain is essentially zero after the first 2 to 3 hours of both the room-temperature and high-temperature tests.

3.0 Residual Strength Test:

Following the sustained load period, the samples were loaded to destruction at a rate of 10,000 lb/min. The room temperature sample held 25,410 lb, or 113% RBS. The high temperature sample failed at 24,450 lb, or 109% RBS. Both samples failed in the middle of the gage section. Figure 2 shows the load versus actuator motion data for the sustained load samples, along with the data from the initial tensile tests. The curve from the high-temperature sustained load sample is similar to curves from the initial tensile tests. This confirms the creep results, which show that the high-temperature sample did not exhibit significant creep at 15% RBS. The curve from the room-temperature sustained load sample has a knee-point that is not present during the initial tensile tests. This observation shows that the creep measured during the sustained load phase is likely due to creep in the aluminum layers.

The reason for higher ultimate load for the sustained load samples is not known, but is likely due to sample or connector conditioning during the sustained load phase.

Conclusions:

The tests were designed to qualify the AFL full-tension connectors for the 675/TW 3M Composite Conductor with an RBS value of 22,487 lb. All samples exceeded the 95% RBS strength criterion specified in ANSI C119.4-2003. The high temperature sustained load test is not required by ANSI C119.4, but was performed to demonstrate connector performance during extreme high temperature operation. Sustained load samples exhibit residual strength significantly higher than RBS, which shows that the conditioning during extreme load and extreme temperature does not degrade the strength of the conductor or the connectors.

Acknowledgement:

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