Tel.800-269-1462 Fax.800-311-9857
P.O. Box 100279, Birmingham, AL 35210

www.ClassicConnectors.com

Classic Connectors, Inc.

DO YOU KNOW THE CONDITION OF YOUR SPLICES?

Joe Renowden, Consulting Engineer
(Article provided by SensorLink)

Why would that question be important when industry wide there have been relatively few failures? The answer is: The risk of failure can't be managed until the splice's condition is assessed and characterized. Managing the risk means planned replacement, as opposed to "Uh Oh! Get a crew out there and put it back up!"

At a splice reliability workshop in September of 1999 an EPRI survey reported a trend toward increasing transmission line splice failures. Transmission line reliability has an Achilles heel! These aging fittings are deteriorating at a time when load currents and fault currents are increasing!

Note: time is not an "aging factor" for fittings. Deterioration is due to increases in resistance of the connection. The increased resistance is produced in part by peaks of load and fault current that can heat the interface even if only temporarily or for a few cycles. (Also in part by oxidation of the interfaces during thermal expansion and cooling, and by corrosion accelerated by moisture and chemicals in very small quantities that get in between the strands.) Every splice has at least one "uphill" side for water, etc. to run to. The reason we tend to hear that fewer "deadends" fail; may be that most of them are pointed "downhill".

All these influences accelerate the deterioration of fittings that are not installed properly. Cleaning and roughening the conductor always was important in making a "good fitting", and with today's shorter, harder alloy tube fittings, we have found it critically important, even with the new conductor. Proper dispersion of inhibitor will help keep the interfaces from oxidizing. All major manufacturers have frequently found missing or inadequately dispersed inhibitor when examining failed fittings. Proper die closure is very important, especially with the newer (last 20 years or so) alloy tube "single die" type compression fittings. There is generally less conductor inserted in the fitting than in the older "hex die" type of fitting, so it is less forgiving of installation error. These consequences of installation lead to incremental increases in resistance during the service life of the fitting. Resistance measurements of newly made alloy tube fittings indicate they are more likely to start service at the higher end of the normal range than the lower end.

All that has been learned about fitting reliability lately indicates that there will be more problems with unexpected failures than we have in the past. This comes at a time when we need just the opposite. We need to repair or replace on a planned basis before failure occurs.

There are two practical methods of doing condition assessment of splices and other connectors while they are energized and carrying load current. They have very different thresholds of detection and consequently different impacts on reliability.

The first method provides definitive actionable early warning of a deteriorating fitting. It is to directly measure the resistance of the connection with an Ohmstik™. The resistance is the electrical condition of the splice! If it is outside the normal range, the connection is deteriorating!

A connection with resistance above the normal range is in a failure process where the time to failure depends on how high the resistance is. The appropriate planned actions for ranges of resistance above normal are shown in the following Table. The resistance ratio is calculated by comparing the resistance of the fitting over the resistance of the conductor.

The Ohmstik™ is a microhmeter mounted on a hot stick. It measures the resistance of the conductor and the connection, at any level of line loading above 5 amps, on energized lines up to 500 kV.

Actions required based on resistance ratios ($R_{fitting} / R_{conductor}$)

Category	Resistance ratio	Condition of fitting	Action
1	**0.3 to 1.0**	**Normal connection** New Connections are expected to be in the 0.3 to 0.8 range	**None**
2	**1.01 to 1.2**	**Serviceable, shows deterioration** Overloads & faults may deteriorate the connection.	**Re-inspect in one year, or after next fault**
3	**1.21 to 1.5**	**Serviceable, poor** Overloads & faults may deteriorate the connection.	**Re-inspect in 6 months, or after next fault**
4	**1.51 to 2.0**	**Serviceable, very poor** High loads, over loads, or faults may deteriorate the connection.	**Schedule repair or replacement in less than 3 months**
5	**2.01 to 3.0**	**Bad, deterioration rate is increasing** High loads, overloads, or faults may fail the connection. High tensions from cold weather or wind may initiate failure under normal loading.	**Schedule repair or replacement very soon**
6	**> 3.0**	**Failing** Normal loads, overloads, or faults may fail the connection. High tensions from cold weather or wind are likely to initiate failure under normal loading.	**Repair or replace As Soon As Possible**

Note: This information was developed from field measurements, manufacturer data, lab tests, failure analysis, and understanding of deterioration mechanisms. This guideline may be modified as field & test data accumulates.

The second method is the somewhat familiar Infrared inspection technique (IR for short), used extensively to find thermally "hot" connections, switchblades, and other overheated power equipment.

IR can find "hot" splices <u>in the last stages of failure</u>, IF:

A. The line has enough electrical load during the inspection to overcome the cooling effects of the wind on the splices. (They are larger in crossection than the conductor and cool more effectively.) Even light winds of 3 to 5 mph have a major cooling effect (read masking effect) on splices. Daytime winds at conductor elevations are rarely less than this.

B. The splices are not shinier than the adjacent conductor. If their emissivity is low (i.e., shinier) they will emit less heat than the conductor and can appear to the IR to be cooler than the conductor, even though the actual temperature is higher (1.) {Improving the Results of Thermographic Inspections of Electrical Transmission & Distribution Lines, John Snell, Joe Renowden. ESMO 2000 paper 28C-TPC-17}

C. The Sun heating of the fitting or conductor doesn't mask the internal heat from the connection.

D. The distance of the IR camera from the fitting doesn't reduce the "object size" so much that the heat source is "dimmed". This effect always reduces the indicated temperature, thereby "masking" the actual temperature.

These effects can, individually or in combination, keep many splices in the earlier stages of failure from being detected. The early stages of failure are in the form of internal resistance increases, detectable by resistance measurement. The IR masking effects can and do conceal badly deteriorated fittings. This is known to have resulted in a failure, after several IR inspection cycles, where a new (shiny) fitting was improperly installed on a weathered conductor.

First, IR does indeed find "hot" fittings! What has not been fully understood is that these fittings are in the last stages of failure and could have failed from a combination of loading and weather conditions before they were IR inspected!

Second, there have been failures of fittings after IR inspections did not detect the deteriorated fittings!

It is only the later stages of failure that produce fittings hot enough to be detected by IR. (See the following table.) Experience bears this out with several well-known facts:

The following table indicates the likelihood of an Infrared survey finding fittings in the various categories where the resistance ratios indicate action for deteriorated fittings.

Action Category	Resistance Ratio	Action Needed (based on resistance ratio)	Likelihood of Infrared detection (Notes 1. & 2.)
1	0.3 – 1.0	None	None - splice will be cooler than conductor
2	1.01 – 1.2	Re-inspect in 12 months, or after next fault	None - splice will appear to be cooler than conductor
3	1.21 – 1.5	Re-inspect in 6 months, or after next fault	Unlikely - Splice may appear to be cooler than conductor
4	1.51 – 2.0	Schedule replacement in less than 3 months	Unlikely - Splice may appear to be cooler than conductor
5	2.0 – 3.0	Schedule replacement very soon	Possible - Splice may be close to or the same as conductor temperature
6	> 3.0	Replace ASAP	Somewhat likely – Splice may still be masked at this load level

Notes:

1) Estimates of likelihood of detection are based on IEEE ESMO 2000 paper 28C-TPC 17 by J. Snell & J. Renowden
2) Conductor is 795 ACSR 26/7 and has 25% of rated load current. Wind is 3 mph (day time air is rarely this slow!) cooling the splice more than the conductor due to its larger surface area, and thereby further masking the splice. Emissivity on conductor & splice is set at 0.7. The splice emissivity can be lower than the conductor, further masking it.

SensorLink Corporation
1360 Stonegate Way
Ferndale, WA 98248 USA
Phone: 360-595-1000
Fax: 360-595-1001
www.sensorlink.com

Contact Information:
Joe Renowden
E-Mail: joe_renowden@att.net
Phone: (561)747-2180