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One of the most widespread myths of electrical maintenance is that the hot electrical connection highlighted by an infrared camera can always be fixed by tightening the connection. That may only make it worse.

Despite the 30-year history and worldwide use of infrared electrical inspections, there is much misconceived, mistaken, and false information circulating within the industry on how to accurately perform these inspections. One of the most widespread ideas is that infrared inspections are not necessary when all the connections are tightened regularly as part of a preventive maintenance program.

Similarly, it is assumed that the thermal anomalies at electrical connections highlighted by an infrared camera are loose connections that can be corrected by tightening the fasteners. Both are false.

During conventional preventive maintenance, a number of procedures can be carried out, including visual inspection, equipment cleaning, tightening connections, over-current device testing, resistance testing, and insulation testing. All of these procedures have their place except one: the systematic tightening of electrical connections.

The case of reappearing anomalies

The "loose connection" myth first presented itself to the author in 1979. An infrared electrical inspection was carried out at a pulp and paper mill prior to shutdown. Afterwards another inspection was requested to evaluate the repairs as well as inspect newly installed equipment. The results were disconcerting to both thermographer and electrical supervisor--40 percent of the anomalies discovered in the first inspection were still there. Of the 40 percent, some anomalies had worsened, while in others the temperature had fallen.

Over the years, this percentage of anomalies remaining after maintenance has turned out to be quite consistent worldwide, regardless of the type of electrical area inspected. The reasons are usually two-fold: the chosen method of repair was incorrect for the type of problem, or the problem was not identified or diagnosed properly and maintenance was performed on the wrong component.

Thermographers know the greatest percentage of faults found during electrical inspections are connections of one type or another. So it was not surprising for the mill to find 60 percent of the

anomalies still in existence were connection problems.

Notice I did not say loose connections. Typically, when a connection is identified as a thermal anomaly, it is assumed the connection is loose and hence the chosen repair is to tighten the bolt or screw. This seems like a proper repair procedure since, if something is loose, it must be tightened. The mill electrical supervisor wanted answers to the high percentage of repeat connection problems on what he thought was simple corrective procedure.

Looking into the repair records it was discovered that connections which were disassembled, cleaned, and reassembled had a 92 percent success rate. The ones which were just tightened had approximately a 20 percent success rate. It was concluded that the surface of the faulty connection had time to become dirty and oxidize.

When a loose connection was tightened, good contact was not restored and the fault remained. This made good sense but did not fully answer all the questions. One repair person put forth a possibility: The connections were not loose at all, so when they were tightened they actually became too tight which aggravated the problem.

The mill felt enough time had been spent on this problem and did no further investigation. It did, however, initiate a new repair procedure for electrical connections which increased their efficiency greatly.

What makes a good connection?
To have a good connection, two elements must be taken into account--clean contact surfaces and proper exertion of force and pressure.

It is important to understand that just because a connection is identified as a thermal anomaly does not mean it is loose. It could have oxidized, corroded, or dirty contact surfaces. There may be a problem with cross threading, the wrong bolt or screw may be in place, the connection may be wrongly sized, or conductor stands may be broken away from the fitting.

In these situations, applying a specified torque will not result in a proper connection. As we have

seen in the preceding case, the solution can be worse than the problem.

Purpose of a thermographic electrical inspection
Thermographic electrical inspections monitor the operating condition of electrical components and equipment. The inspection will identify thermal anomalies associated with increased resistance to the flow of electrical energy.

The purpose of the inspection is to accurately identify, locate, measure, classify, and document the anomalies so the maintenance department can proactively maintain the electrical system. When thermographers begin to diagnose problems and suggest corrective actions, we are going beyond the scope of the inspection and looking into crystal balls.

If the thermographer has been hired not only to identify anomalies, but to establish cause and corrective actions, then it will be necessary to secure the services of a qualified electrician and make arrangements to de-energize the components for disassembly and investigation.

Thermographers often are guilty of diagnosing problems without a full investigation. Very often a standard phrase in the comments section of the report page is "loose connection, remove, clean, tighten and replace." First, how does the thermographer know it is a loose connection? Unless the threads are exposed, he doesn't. Overall, as thermographers we do not know what is causing the anomaly. We know where the anomaly is, but not what problem is causing it. The only way to know for sure is to de-energize the component, disassemble it, and look at it. Then and only then can a proper diagnosis and repair procedure be established. We do not have x-ray vision, but thermal vision of a surface phenomena.

The case of overlooked anomalies
During a follow-up infrared electrical inspection at a process plant, the scenario of the paper mill case was duplicated with 36 percent of the same anomalies showing up again, some worse, some a little better. This time, however, the request was not only to re-inspect the previous faults, but to re-inspect the entire facility.

The most unbelievable finding was that more anomalies were found in the second inspection than in the first inspection which took place two months before. The immediate question was, "Why were they not found during the first inspection?" The thermographer was contacted and

an investigation was launched.

Four possible explanations were presented:

- The thermographer missed them.
- Some components were operational during the follow-up that were not during the first inspection.
- New anomalies developed since the previous inspection.
- During routine maintenance new anomalies were created.

Thermographer error is always a possibility but a very low probability for this case because the inspector was a trained, experienced technician on a routine inspection of a familiar facility and electrical system. If it was a first-time inspection at the facility, more weight would have been given to this point.

The fact that some equipment was not operational during the first inspection did play a role in the new faults found. Some of the electrical apparatus operational during the follow-up inspection was not operating during the first inspection. Since the thermographer was not documenting the nonoperating components, it was difficult to assess the exact percentage of new anomalies attributed to this.

It is highly recommended that thermographers document all the components not operating during an inspection, or carry additional liability insurance. If a component failed and shut down a portion of the plant or caused injury soon after an inspection, it would be good to have documented that the particular component was not operating and therefore unable to be inspected.

New anomalies are developing on a continuous basis so the third point has some validity. The operating environment will dictate the frequency of new problems developing. This is why some industries require more frequent inspections than others. A clean, relatively vibration free, climate controlled building environment requires only a yearly inspection, while a dirty, high vibration environment should have bi-yearly inspections.

Prior to suggesting that routine maintenance was introducing more anomalies, the ongoing investigation identified the types of new anomalies which had appeared--5 percent were on connections. The thermographer, who was involved in the first case several years earlier, asked the question, "As part of routine maintenance, are all connections re-torqued?" The answer was: Yes. Looking into this aspect a little further, it was concluded that routine tightening of connections was the culprit.

With over 20 years of performing inspections on electrical systems as well as receiving similar feedback from more than 2000 electrical thermography students worldwide, my experience has verified the conclusion. Under these circumstances, the main culprit contributing to new connection problems is the routine tightening of connections.

The basic purpose of a bolt in an electrical system is to bring two metal surfaces together and hold them in position with the least resistance to current flow. Joint performance is a function of the clamping force applied by the fastener. Clamping force is developed by stretching the bolt an appropriate amount by tightening the nut. Because the bolt continually tries to return to its original condition, it pulls and holds the joint together.

It is important when assembling bolted connections that a torque wrench be used and appropriate torque values as received from manufacturers, codes, or standards be applied. It has been noted that bolts tightened with a torque wrench can vary 30 percent on the same assembly. Consider what the variance would be if a torque wrench is not used.

Joints can be undertightened but typically they become overtightened after years of routine tightening (typically without a torque wrench). The joint can become over compressed to the point of deforming the metal faces and creating a poor connection as shown in the accompanying diagram. As well, a bolt can become over-stretched and the joint will not attain the proper compression and will create a thermal anomaly just like a loose connection.

It has been suggested by several experts that the routine tightening of electrical connections be stopped and maintenance be performed only on the anomalies identified with infrared thermography. Thus more time can be given to proper maintenance on real problems and new ones will not be created. **MT**

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