Avoiding Common Mistakes that Can Compromise an Infrared Inspection Program

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Abstract

Infrared technology is now a well established tool for the condition monitoring of both mechanical and electrical systems. Its use is considered a "best practice" throughout the facilities-services industry. Although facility managers often believe they have a solid program in place, there are often defects in their approach. While implemented with good intentions, these oversights and shortcuts can create unintended consequences and lead to far bigger problems. Left as they are, these programs can be a significant liability to the plant and its parent company. A well-designed infrared program takes into consideration the greater regulator environment in which the plant operates, as well as providing management with the metrics with which to gauge the effectiveness of the program. The benefits are reduced liability along with a program which demonstrates its own cost effectiveness. This paper will address these issues and how to avoid the common mistakes which can undermine program effectiveness, thereby compromising any benefits which might otherwise have been achieved.

Introduction

The price of thermal imagers has dropped considerably in the last decade. This has allowed for an expansion of thermal-imaging service providers as the barriers to entry have decreased. There is also an expansion in the marketplace as demand for services increases. Companies can now find local service providers when, in the past, they were unable to afford thermography services, or had no idea of their existence. However, when discussing thermographic services with facility managers and plant engineers I am fairly consistently picking up on what to them is an unknown problem. Sometimes when I inquire about the predictive maintenance program for their switchgear and the possibility of providing thermographic services the response I get is that they already have a program in place. That's fine; it is always great to find pro-active managers who

are tired of reactively dealing with problems. In some of these cases they inform me that the facility has purchased a small IR imager and they use it to find “hot spots.” Once again, there is nothing wrong with that.

But, the next bit of information is where things take a wrong turn. I am usually then told that they employ a two-person team to walk around the facility looking at the switchgear. While both of the employees were trained electricians, neither was a certified thermographer.

Thermography of electrical switchgear involves imaging the electrical components while they are in an energized or “live” state. Any time they found a “hot spot” they immediately fixed it by tightening any loose connections. They also immediately verified their repairs by using the imager and watching the temperature of the connection drop to a “normal” operating range. They were quite happy with this system, stating it was efficient and no time was wasted by needless reports or sending another worker to fix the problem at a later date. The problem was found and solved on the spot. Even better, the “camera” they purchased was inexpensive and they didn’t need to hire a thermographer to take the “pictures.”

What could be the problem with that? The most serious problem is that such a method is in violation of OSHA standards and NFPA 70E: Electrical Safety in the Workplace and NFPA 70B: Recommended Practice for Electrical Equipment Maintenance. If anything, such as an arc-flash, were to happen during the survey, the company would be immediately subject to substantial fines. Not to mention damage to equipment, loss of production, and the serious injuries or loss of life of facility workers. This facility’s procedures were cobbled together in the belief that these time-saving shortcuts would also save them money. The reality is that the costs associated with a single accident would most likely wipe out all the savings associated with previous shortcuts.

That isn’t the only problem with this short-cut of a thermography program. There were no pre-planned routes for them to follow. No images of the anomalies found were saved for future reference. No reports were generated documenting the anomalies found during the survey. There was no method of tracking problem areas or their repairs and the costs associated with same. Also, of course, because they were making repairs “on the fly,” there were no energized work permits. At least there was one positive note; the employees on the “IR team” performed their tasks in the appropriate PPE.

Safety First

Safety is always our top priority. While we all hear a constant stream of criticism against bureaucracy in general, and OSHA in particular, we need to remember one thing; every rule they impose is because someone has been injured or killed by the event the rule is trying to prevent. When dealing with electrical hazards and worker safety, OSHA references NFPA 70E and 70B. Informative Annex J of NFPA 70E describes the process of determining if an energized work permit is required. No energized work permit is required for systems of less than 50 volts.

The next step is determining if there will be live components exposed. The answer is “yes” because a thermographic survey requires that components be energized and exposed for viewing. And next is the crucial part. What type of work will be performed?

Any planned physical contact, such as making or tightening connections or removing or replacing components while the system is energized, requires an energized work permit. Inspections of equipment do not require work permits. A thermographic survey is a form of inspection and does not require any physical contact with the exposed energized parts and therefore does not require an energized work permit. Problems found during the survey are recorded for later documentation in the thermographers report.

No repairs or adjustments to the equipment are made during the survey. Any problems found during the thermographic survey will need an energized work permit if the repairs are to be made while the system is live.

While an energized work permit is not needed for a thermographic survey, I will discuss the issue so as to further clarify why repairs should not be performed while the thermographic survey is taking place. An energized work permit is issued for each individual item that needs repairs or other work. In other words, it is not a "blanket" permit (for example, “All distribution panels in Maintenance Corridor A” is not a proper listing). The request gives a description and location of the circuit or equipment along with what work is being done and a justification as to why the work is being conducted while the system is energized.

If the system can be shut down so the repairs can be completed then no energized work permit is necessary. It is always preferable to work on de-energized equipment and systems. When working on an energized system, the individuals doing the actual work must describe the procedures they will use and the safe work practices they will employ. The very process of completing the permit leads the personnel through shock-hazard and arc-flash analysis. The process is designed in a way that forces them to determine the various safety boundaries, and plan methods of restricting the access of unqualified personnel from the work area.

There must also be documented evidence of a job briefing which includes a discussion of any job-related hazards and how they will be mitigated. The final approval for the work permit comes from the facility's general manager, and is also signed by the safety manager as well as the maintenance manager and the person doing the actual work. While this may seem tedious to some, it helps ensure not only worker safety, but management awareness and support of the work being performed. It also forces management to take responsibility for electrical safety in the workplace. No one can claim after an accident to have "not known" hazardous work was being performed if their signature of approval is on the work permit. Having this kind of management buy-in can also address a morale issue.

In most cases, the maintenance department and its workers are invisible to management and facility operations until something important breaks. While many of the maintenance personnel may prefer this situation, it is not beneficial to the maintenance program overall. If nothing seems to break, the tendency of management is not to credit proper and continuous maintenance but rather to believe "that's how things are supposed to be". The requests for work permits and other maintenance documents allow management to see and understand that well-planned and safely-executed ongoing maintenance is responsible for the efficient operation of the facility. In this case, visibility is the key to a well-run and properly funded predictive maintenance program.

The Importance of a Certified Thermographer

One of the signifiers of a profession is the use of specialized terms or a language which is unique to one working within that profession. It isn't simply a matter of using "big words" to impress your client or employer. It gives your client or employer confidence in your competence and professionalism. Certification is a mark of distinction and lets them know you are the expert when it comes to the subject matter.

I never use the word "camera" when referring to an infrared imager. A "camera" is a consumer item which can be purchased at any big-box store. Cameras employ "point-and-shoot" technology and are simple and easy to use. In the not too distant past even the most basic thermal-imaging equipment could easily weigh around a hundred pounds and was hauled around on carts. While modern imagers come in a form very similar to cameras, that is where the similarity ends. It may be true that almost anyone can pick an imager up and record an image, but will it be a useful image? Will the user be able to properly interpret and gain any kind of useful information from that image?

A common misconception with thermography is that infrared imagers measure the temperature of an object. They do not. Every object in nature emits varying amounts of infrared radiation. The amount of radiation emitted will be influenced by object temperature, surface condition, target shape, and viewing angle. This is called emissivity. Human skin emits infrared radiation at a very high level, while shiny metals such as copper emit very little. An object can also reflect the infrared energy from its

surroundings. This is called reflectivity. Emissivity and reflectivity are linked. Objects with high emissivity have low reflectivity, and vice-versa.

The thermographer must enter the correct emittance of an object into the imager in order to get an accurate temperature. Other variables which must be considered include ambient air temperature, humidity, and distance to the target. So, the imager can be used to show qualitative thermal differences in an object. In other words, the trained thermographer is able to detect thermal patterns in an object and determine when an anomaly exists.

Remember reflectivity? A lot of electrical equipment is metal, and is highly reflective of infrared radiation. The component being imaged can even reflect the thermographers own body heat and an inexperienced or untrained thermographer can mistake that reading as the temperature of the component. And detecting a “hot spot” isn’t the only issue. Is the increased heat due to a loose connection or is the circuit overloaded? These separate anomalies have their own characteristics, and a trained thermographer can tell the difference without first sticking a screwdriver into an energized panel to check for connection tightness. Also, not all electrical breakers are the same. Some types of breakers are designed to operate at a particular temperature, which may be elevated compared to the other types of breakers found in the same panel.

Paragraph 11.17.1 of NFPA 70B states, “Infrared inspections of electrical systems are beneficial to reduce the number of costly and catastrophic equipment failures and unscheduled plant shutdowns.” The use of thermography to perform surveys of electrical equipment is not only validated by NFPA 70B, but it is also recommended. It is also recommended that the personnel conducting thermographic surveys be “… qualified and trained personnel who have an understanding of infrared technology…” Engaging a trained and certified thermographer can prevent possible errors and mistakes during imaging and interpreting data.

It is highly recommended that a Level-III certified thermographer takes part in the design, implementation, and oversight of the facility’s IR predictive maintenance program. Level-II certification should be considered the minimum level of qualification for imaging electrical equipment. A Level-II certified thermographer is qualified to interpret and evaluate the results of imaging with respect to applicable codes, procedures and specifications, as well as properly calibrate imaging equipment. Many applications of IR thermography are qualitative in nature, and Level-I thermographers are able to perform those tasks. However, the imaging of electrical equipment involves the more advanced knowledge and experience of a Level-II thermographer in order to record accurate quantitative data. Utilizing properly trained personnel reduces liability while increasing the credibility of the program.

Just because a plant or facility has their own imager or certified thermographer doesn’t mean they are not interested in contracted services. Several of my own clients have inexpensive imagers in their maintenance departments. A couple of them even have certified thermographers. However, these personnel don’t perform imaging tasks on a

daily basis and they are usually only certified to Level-I standards and are not performing their duties under the supervision of a program manager who is Level-III certified. I am usually called in to conduct specialized surveys or to perform surveys in which the documentation will be used to satisfy insurance requirements.

Insurance companies prefer to have thermographic surveys of electrical switchgear performed by thermographers certified as Level-II or higher. In many cases the insurance company may prefer that annual surveys be completed by independent contractors. This is usually seen as providing transparency; the survey and report are being provided by someone outside the organization.

It is also the view of many insurers that an independent contractor's sole job is thermographic imaging. So, the contract thermographer is a specialist and an expert in the field, while the maintenance personnel is considered a jack-of-all-trades. The maintenance person trained in thermography may do a great job of imaging, but is pulled in so many directions by other responsibilities that they can't dedicate themselves to the profession in the same way as an independent thermographer. Some insurance companies don't mind reports from in-house teams, so long as the thermographers are at a minimum of Level-II certification.

You're Not Managing It if You're Not Measuring It

The key to any successful program is proper documentation. Documentation is not done for its own sake. With a properly implemented program, the documentation serves a higher purpose and helps justify the funding of the program. The documentation is the basis for all of the metrics which allow management to make the important decisions concerning the facility.

If maintenance is simply wandering around tightening loose connections without recording or documenting anything, what does management know or learn about the condition of the facility? They may only know the cost of paying the maintenance worker and the monthly amount spent on basic repair parts. Without documentation or a report of some kind, how will anyone see a trend, or know if there is a bigger problem that needs to be solved? Are the same connections loose each time? Is the same part failing and causing production stoppages?

Let's say that over the course of a year, the facility replaces five breakers a month on average. Those repairs may go unnoticed if not documented and tied to other maintenance reports. The repairs could mean nothing if each replacement was for a different piece of equipment. But what if each replacement was for the same piece of equipment? Now we know the problem is much bigger than a bad breaker. And remember, thermography allows the maintenance team to see the early signs of developing problems.

That inexpensive imager the facility purchased that ends up sitting in a closet somewhere? It is a wonderful tool which can be used by maintenance supervisors to simply check key areas for possible problems. The problems can then be fixed before they halt production and cause unscheduled shutdowns; or they can be monitored until the next scheduled shutdown.

The information gathered by the thermographers is documented in a report. The reports are given to management with an analysis of the equipment imaged during the survey. At a minimum, the report will list what equipment was imaged, and what equipment had anomalies; along with a classification of the anomaly. There is often a report summary listing the total number of items imaged and then a breakdown of the number of anomalies by its classification.

In my own reports, I include not only the numbers, but also a pie chart displaying the criticality of the various anomalies found. This graphic is a simple way to display system "health" at a glance. The report is also used to generate work tickets for the maintenance department. The individual work tickets are also used to request energized work permits (if repairs are to be made to an energized system).

The maintenance department then makes the repairs and documents the work. The repair is verified (and documented) in either a follow-up or the next regularly-scheduled thermographic survey. With the proper documentation feeding a database, management is able to track the overall "health" of the system at any given time. The system can be as low-tech as manually created spreadsheets, or utilize a CMMS/EMS system. The point is, it allows managers to see trends or patterns in the facility's equipment through the maintenance program. They are also better able to calculate costs for maintenance and see the value of the program.

An "Ideal" Infrared Thermography Program

The ideal method is to have a dedicated predictive maintenance team. The team may perform thermographic surveys as their full-time job, or they may only perform them monthly. Having dedicated personnel, or at least using the same personnel each time, allows them to gain familiarity and expertise with not only the task, but with each other. This familiarity and experience builds competency and increases efficiency. The team may be as small as two people. One will open and close electrical panels, while the other images the equipment once it is exposed. Whoever is using the imager needs to be a trained and certified thermographer.

While the use of electricians is not required, all members of the team must be qualified personnel. A qualified person is defined by NFPA 70B as someone "who has the skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved."

Working around energized systems comes with inherent dangers, and possible emergencies and responses must be addressed. OSHA requires that capabilities for both CPR and first-aid be provided for in some fashion when performing work on electrical systems over 50 volts as stated in OSH Standards for General Industry (29 CFR, Part 1910, Subpart R).

There is no further guidance on the matter, and having trained EMS personnel on standby at the facility would satisfy the requirement. However, that is not a practical solution. If an accident occurs, every second matters and immediate help is necessary to save lives. From a practical standpoint all members of the team should be trained in first aid and certified in both CPR and the use of AEDs along with training in the proper release of individuals caught in a live circuit. While it would be easier to simply have one of the team members trained as a first responder, what happens if that individual is the one who is incapacitated in an accident?

Greater efficiency can be achieved using a team of four. In such a configuration, the first person is opening cabinets, the second is imaging the switchgear, and the third is recording anomalies and taking notes, while the final member is closing the cabinets which have already been imaged. While performing the thermographic survey, the team's sole job is conducting the survey along a predetermined route.

As previously discussed, the person taking the images should be at least a Level-II thermographer. While there are no specific skills or prerequisites (other than being a qualified person) for the note taker/assistant, this is a good position for an apprentice or a Level-I thermographer.

This is a perfect example of the company investing in the human capital of their employees. A thermographic program is more than just an imager, it is the skill and expertise of the employees trained in thermography. The team images the switchgear along the route and records their findings; which are later documented in the survey report. They do not attempt to fix any of the problems they find along the route (remember, they don't have energized work permits).

Survey routes are determined by the program manager, and are dependent on the size of the facility and the systems involved. A small facility may have only one route and can be imaged in a day. Large facilities, or facilities with several complex systems or several buildings on a large campus, may have multiple routes which could take a week or more to survey. A basic route may only need to be surveyed once a year, while others may need quarterly surveys.

In some cases, it may be a good idea to have the critical components of the facility's operation on one route, with other sections of the facility broken up into other routes. That critical route can then be surveyed as needed to provide a snapshot of system "health" to management. Such a route may get walked monthly or as otherwise directed, while the other routes get surveyed on separate schedules. The important

part is having the preplanned route. Doing so allows for repeatable surveys, which allow for easy comparisons between multiple surveys of the same route.

Conclusion

Without an electrical preventive maintenance program, management takes on a greater risk of serious electrical failure and the resulting consequences. A well run program will minimize costly breakdowns and unscheduled shutdowns as well as reduce accidents, potentially saving lives. The program has the ability to identify problems at an early stage before they become major problems that will require costly and more time-consuming solutions. These are avoided costs.

In other words, the facility is able to avoid the cost of paying for the expensive repairs or loss of operations. Any predictive maintenance program requires the support of top management. The program requires investments in not only equipment, but proper training for the personnel involved, as well as the extra resources needed for proper administration. Adding thermographic surveys to a maintenance program can bring significant cost savings to company operations, but there is more to it than simply purchasing an imager. The program must be well-planned, administered, and in compliance, just like every other aspect of the facility's operation. Properly executed, the program will save money while saving lives.