Article for Association of Facilities Engineering

Infrared Thermography: Recommended Maintenance Practices for the Facilities Engineering Professional

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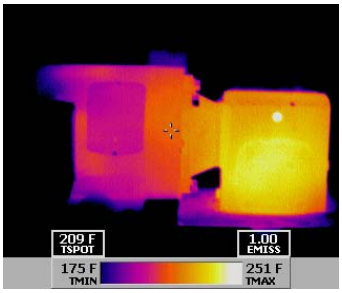
The issues of the economy, what wages we earn, how much things cost and our standard of living are issues that apply to each of us. While prosperity means different things in different cultures, the basic rules of economy govern: lower cost goods and services combined with higher quality expand the market. Market expansion results in more work, which translates into more jobs, improving our level of prosperity and our standard of living.

What does infrared thermography and maintenance practices have to do with our economy and our standard of living? Maintenance and especially predictive/preventive maintenance is the cornerstone of the infrastructure that supports all of our industrial and commercial enterprises. The prevalent attitude about maintenance is "if it ain't broke, don't fix it".

In the photograph (left), the drive motor and gearbox appears to be working properly, but the infrared image (right) the gearbox is clearly overheating, indicating a pending mechanical failure!



Management decisions regarding controlling and cutting costs compounds the problem because the maintenance budget is an easy target. Maintenance can often be delayed, or skipped altogether. Management shrugs the issue as if simply saying, "Who is John Galt!" The result increases the frequency and severity of failures, undermining our facility infrastructure like a silent cancer.

To compete globally (and we must!), organizations must strive to become lower cost producers of higher quality goods and services. Our ability to reduce costs and improve quality is directly impacted by the effectiveness of our maintenance function.

ADHERING TO CODE

Industrial and commercial facilities have a great deal in common with living bodies: one of the first signs of a developing problem in each is a fever. This is especially true with electrical and mechanical equipment even to the degree that when our equipment fails, we commonly say it burned up. Electrical equipment burns up. Motors burn up. These

failures are not products of spontaneous combustion. The equipment usually fails gradually over time. In electrical equipment problems are accompanied by a rise in temperature proportional to the increase in electrical resistance associated with loose connections, corrosion, and component failure. The same occurs with electric motors, gearboxes, bearings and mechanical drive assemblies. The problems waste electricity, cause unexpected downtime and create unsafe conditions. The result is poor productivity (higher costs!) and lower quality products. What can we do?

Infrared thermography involves the use of an infrared camera that produces a picture that displays thermal differences. Infrared inspections are highly endorsed by the insurance industry and the National Fire Protection Association (NFPA). The insurance companies' experience in reduced losses is so significant that some provide infrared electrical inspections at no direct cost to their policyholder. Many others offer premium discounts to policyholders who have infrared electrical inspections performed in their facilities. Considering how frugal the insurance industry is, their actions are a strong endorsement of the value of infrared inspections.

Without exception, every facility engineer must be familiar with the National Electric Code (NEC), which is written by the National Fire Protection Association (NFPA). Most

are also familiar with NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces since safety is of paramount importance. NFPA 70E is extremely pertinent in regards to infrared thermography since infrared thermography inspections are performed on electrical power distribution systems that are operating and under load. Infrared electrical inspections are not a simple matter of walking around with an infrared camera and looking for hot spots. Infrared thermography requires that the protective covers and panels be removed from operating equipment in order to perform the inspection. This places the thermographer in direct exposure to hazardous arc flash from the energized equipment. NFPA 70E offers specific safety requirements for personal protective equipment for persons working in the vicinity of energized electrical equipment.

Arc flash is a major concern with electrical systems and NFPA is moving towards requiring all electrical cabinets to be identified and labeled in terms of arc flash exposure risk when the panel covers are removed. Infrared cameras cannot see through metal panels but a new infrared window, the IRISS VPF®-series is now available that can be easily installed in high voltage cabinets. This window, IP-65 rated, allows the interior of the cabinet to be examined without opening the cabinet, enabling a qualified thermographer to perform more frequent inspections quickly and efficiently.

These infrared windows are available in 2, 3 and 4 inch

diameters (2" / 50mm at right) and work with both long and short wavelength infrared cameras enabling the thermographer to maintain a safer distance from the inspected equipment. This minimizes your risk of arc flash exposure, and without locking you into a particular camera manufacturer or service provider, enabling you to achieve improved safety and productivity. Considering their low cost and easy installation, these certified performers (UL approved) greatly enhance the value of your electrical P/PM program by protecting people and profitability.

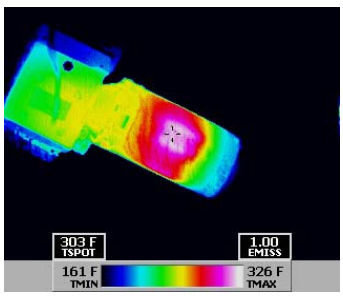
NFPA has another extremely useful document that every Facility Engineer should have - NFPA 70B. This is NFPA's Recommended Practice for Electrical Equipment Maintenance. It includes specific guidance on establishing an electrical preventive and predictive maintenance program as well as specific recommendations on using infrared thermography to inspect the electrical power distribution equipment.

NFPA 70B recommends that every facility should have an infrared inspection performed on its electrical power distribution system ***at least annually***. Critical equipment should be inspected semi-annually or more often as deemed appropriate for safety and productivity.

An example of the benefit of this is a client who contracted our company to provide monthly inspections of their soft drink bottling facility. This client's production line runs 24x7 with scheduled maintenance days. The client could essentially sell as much as they could produce, so unexpected line breakdowns not only idled the production crew, it also directly reduced their gross revenue since their production capacity was reduced.

This client understood the efficient application of infrared thermography to their whole operation. While the electrical power system was inspected semi-annually, the pump motors, electric drive motors and gear boxes, and other rotating machinery was inspected monthly. Charting the health of the equipment (baseline trending) requires the collection of the operating temperatures, emissivity (the power of a surface to emit heat by radiation) values, load and ambient conditions. This information is necessary in order to develop the understanding of the changing condition of our equipment and establish the baseline trend of each piece of equipment in accordance with the recommendations of NFPA 70B and ASTM E1934's Standard Guide for Examining Electrical and Mechanical Equipment with Infrared Thermography for predictive and preventive maintenance.

Electric motors are designed to operate at specific temperatures based on a rated load. When a motor is operated in excess of the rated load, it runs hotter. As little as a 17°F temperature rise will shorten a motor life expectancy by 50%. A particular motor was observed running much hotter than similar motors under similar load, and the temperature was increasing at each observation. On a scheduled maintenance day, the motor was replaced and the observed temperature dropped to normal, but the following month the temperature was back up higher than before. The next maintenance day the motor was more closely examined and the actual problem



was identified as foreign material that became lodged in the conveyor drive, overloading the motor. The situation was corrected and foreign material removed on scheduled downtime, avoiding burning up another motor and saving a substantial amount of lost production.

More than just "a good idea," this client applied the principles of ASTM E1934 Standard Guide for Inspecting Electrical and Mechanical Equipment Using Infrared Thermography. This standard outlines the recommended procedure for inspecting electrical equipment, motors, gearboxes, bearings, and all rotating equipment with infrared thermography, and applies the principles of the NFPA standard to mechanical equipment as well as electrical power distribution.

Today, data management is an essential part of our facility management and there are several issues that require serious consideration. Traditionally, when infrared inspections are performed, printed reports are produced with the report containing a page with a visual photograph and a thermal image describing each problem observed. I have visited many facility managers who have shelves or bookcases full of thermography reports. In order to compare the condition of a piece of equipment today with its condition last year or, say, the last 3 times it was examined to review its history, you need to pull the old reports and look up the piece of equipment to compare it.

The NFPA and ASTM standards offer basic guidance on data management and infrared predictive/preventive maintenance programs. A comprehensive program should begin with a detailed cataloging of the individual pieces of equipment, with significant nameplate data and load rating, the location and the route that is to be monitored. Considerable thought and planning should go into establishing the predictive/preventive maintenance (P/PM) program, as it is not cost effective to try to examine everything continuously. Much equipment should be inspected annually. Some equipment should be inspected semi-annually, some quarterly, some monthly, and some mission critical equipment may be appropriate to monitor continuously.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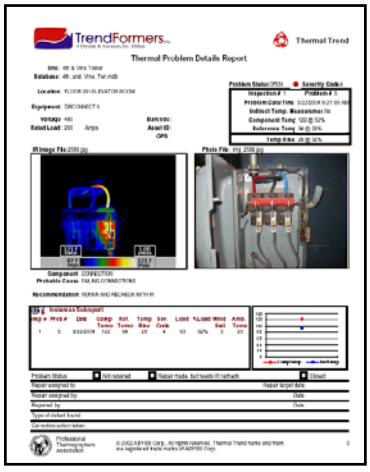
Inventory Report

Open Problem	Status	Barcode	Location \ Equipment
No	Not Tested		ELEVATOR LOBBY A/C ROOM
No	Tested		LOBBY CLOSET
No	Tested		HOUSE 108
No	Tested		OFFICE #1
No	Tested		OFFICE #2
No	Tested		SUITE 1160 HILLTOP
No	Tested		NORTH COPY ROOM
No	Tested		HILLTOP MAIN (RIGHT)
No	Tested		PANEL LEFT
No	Tested		FLOOR 12
No	Not Tested		A/C ROOM SOUTH
No	Tested		CABINET NORTH
No	Tested		HOUSE
No	Tested		CLOSET SOUTH
No	Tested		HOUSE
No	Tested		ELEVATOR LOBBY
No	Not Tested		A/C ROOM NORTH
No	Tested		FLOOR 13
No	Tested		A/C ROOM NORTH
No	Tested		HOUSE
No	Not Tested		A/C ROOM SOUTH
No	Tested		CLOSET SOUTH
No	Tested		HOUSE
No	Tested		FLOOR 14
No	Tested		14B
No	Tested		A/C ROOM SW
Yes	Tested		SUITE 1420
No	Tested		SEC 2 GROUP 22
No	Tested		FLOOR 15
No	Tested		A/C ROOM NORTH
No	Tested		150 AMP DISCONNECT
Yes	Tested		15-A
No	Not Tested		AC-15J

Example 1 (left) illustrates the first requirement – a complete equipment list.

Example 2 (right) illustrates a comprehensive problem report including an infrared image of the problem and corresponding photograph, detailed information about the observed temperatures, electrical load, and a history charting the condition of the equipment.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Thermal Trend

Thermal Problem Details Report

Maintenance is about three functions: 1) Repair what breaks, 2) Prevent things from breaking, and 3) Extend the life and effectiveness of our assets. The objective is not perfection, but efficiency, productivity, and low total maintenance cost per unit.

Reality is that equipment sometimes breaks and undoubtedly wears with use. In order to get the best value out of our investment in equipment, we must monitor its condition over time and perform repairs and maintenance on scheduled downtime to obtain the best value for our investment. NFPA 70B refers specifically to charting the condition of the equipment over time and establishing baseline trends so that developing problems can be observed and corrective action taken before equipment unexpectedly breaks down. This form of condition monitoring is the crystal ball that enables us to predict our future and increase total productivity.

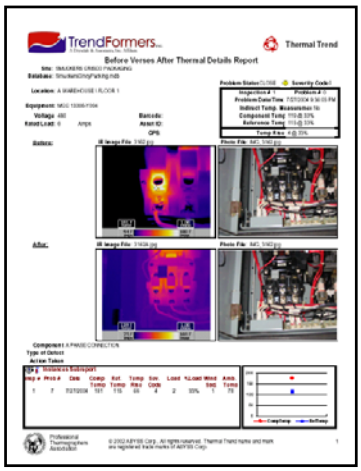
USING INFRARED INSPECTION SERVICE PROVIDERS

With the advance of the computer age, many infrared inspection service companies now provide services in accordance with NFPA and ASTM guidelines. When utilizing these services, it is critical that you establish ownership of the data when you issue a contract or purchase order for inspection services. The issue of data ownership is somewhat complicated, since you would expect that if you contract for an inspection, obviously you "own" the data that is developed. To the contrary, infrared thermography reports are generally considered more like professional photography where the photographer collects numerous images. Although he delivers the final copies that you want printed, the photographer "owns the proofs" from the shoot.

In thermography terms, unless you specify ownership of the database in the contract when you purchase an infrared inspection, the service provider is obligated to deliver "a report" while they own the raw data that was collected for the report. If you decide to change service providers, your historic data may be lost or relegated to collecting dust on someone else's bookcase.

Software today is inexpensive and easy to use and Microsoft Office® is readily available on the majority of office computers. Microsoft Access, part of the Microsoft® Office suite of products, can be used to create a database program to manage an infrared P/PM program. If you do not have the resources for setting up your own database program, an excellent approach is to use a commercial MS Access based program such as ThermalTrend®. This software is relatively low cost and also independent of infrared camera manufacturer and allows for efficient data collection and analysis. Using the MS Access platform ensures easy analysis of data and a means of migration to other CMMS programs. ThermalTrend® runs on your desktop computer and also comes with a data collection version that runs on a PocketPC®. Whether you perform your own infrared inspections or contract for the services, you can have the data entered directly into your system as the inspection is performed.

A critical function of an infrared maintenance program (example 3, next page) is verification that problems have, in fact, been corrected. Thermal Trend provides an excellent problem verification report in the database so that you have a record of the original problem, the correction, the history of the problem, and analysis available at your fingertips instead of collecting dust on the shelf. At a glance you may be able to identify repeat breakdowns so that the real source of failures can be identified and corrected.



Infrared thermography is a complex science and there is a significant difference between looking for hot spots with an infrared camera and conducting a preventive/predictive maintenance program. Infrared thermography is essentially the analysis of thermal differences in materials.

There is a significant difference between true thermal differences and observed thermal differences. Observed thermal differences occur partly due to temperature, but also due to surface finish and emissivity differences, thermal reflections, and a variety of other effects.

For example, if you place a cast iron skillet and an aluminum skillet on identical burners on the stove, apply the same amount of heat to both and examine them with an infrared camera, the shinny aluminum skillet surface will appear significantly cooler than the cast iron, even though they are both the same actual temperature.

On the other hand, if you hold the hot cast iron skillet above the aluminum skillet, you can see a hot spot on the aluminum skillet. This is the reflection of the cast iron skillet on the aluminum surface. The shinny aluminum surface acts like a mirror, giving a false indication of temperature. These emissive and reflective characteristics are prevalent in infrared thermography and require a thorough understanding to apply the technology properly.

Infrared cameras have a great deal in common with visual cameras. They are both very easy to use, and even easier to mis-use. Not every hot spot indicates a problem and not every problem is indicated by a hot spot. NFPA offers specific temperature guidelines and recommendations established by the National Electronics Testing Association (NETA) in assessing the severity of electrical problems. These guidelines along with your own knowledge of infrared inspection standards, operating conditions and criticality of your equipment establish the basis for intelligent prioritizing of maintenance and repair work and allocation of your resources.

CHOOSING A THERMOGRAPHER

Simply having an infrared camera and performing infrared inspections does not make one a qualified infrared thermographer. Both ASTM and NFPA specify the importance of qualified individuals in the performance of electrical work and infrared inspections.

Infrared thermography requires extensive knowledge, experience, and education. Whether you choose to perform your own inspections or contract for services, certification in infrared thermography is essential. Certification in infrared thermography is defined in terms of training, education and experience by the American Society for Nondestructive Testing (ASNT).

In order to establish a common understanding among the industry, ASNT offers

Recommended Practice No. SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing. This document is not a standard. It is intended as a guideline to establish your own written practice for defining the qualifications for someone to perform infrared thermography in your facility, and to establish a common definition of understanding between companies and service providers. As a guideline, it is intended to be flexible, and there are only two specific items that are essential in order to "comply" with SNT-TC-1A:

1. You must have a written practice
2. You must keep records.

The actual content of your written practice is solely your responsibility. Therefore, when contracting with a service company to provide infrared thermography (or other NDT) services for your facility, just as you would commonly require proof of liability insurance and a workers compensation certificate, it is important that you review a copy of the service company's written practice or reference the pertinent text of SNT-TC-1A to validate to what standards their personnel are held. It is your responsibility to ensure that your thermographer or service provider is properly trained and qualified to perform services in your facility.

ASNT offers another document ASNT/ANSI CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel. As an ANSI document, CP-189 establishes a strict comprehensive requirement for compliance for Levels I, II and III with additional specificity. For example, CP-189 requires a person certified as level III to pass the professional exam requirements of ASNT. This certification is reviewable on-line at www.ASNT.org where you can look up every person who is ASNT Level III certified.

Why does it matter if your thermographer or service provider is certified to some standard? Why is a certified professional recommended? What value is it to be a CPE Certified Plant Engineer or a CPMM Certified Plant Maintenance Manager?

Certification establishes a standard of competence. When we talk of a thing having value, the measure is "of value to whom and for what." Our values are reflected in the choices we make. Neither low cost or high quality by itself is an indicator of value, but standards

of performance like NFPA 70B, ASTM E1934, ASNT SNT-TC-1A and CP-189 establish the gradients on the measuring stick so that real value assessments can be made.

This applies directly to those individuals whom you entrust to examine your facility, help reduce your unexpected equipment failures and extend the life of your equipment. The entire purpose of maintenance is to maximize the value of your investment in your facility for today **and tomorrow**.

Footnotes:
ASNT standards may be found at www.asnt.org
ASTM standards may be found at www.astm.org
NFPA standards may be found at www.nfpa.org

About the author

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President of TrendFormers, Inc. TrendFormers provides infrared inspection services for predictive and preventive maintenance and consulting engineering services on both spectral and thermal analysis of materials and processes. Consulting services also include designing and implementing facility P/PM programs. Mr. Clausing is a registered professional engineer and is ASNT NDT Level III certified in infrared and thermal non-destructive testing methods.

A graduate of the University of Cincinnati with a BSME and Xavier University with an MBA, Mr Clausing teaches industrial sensor technology and thermal imaging at Cincinnati State Technical College in the Industrial Maintenance department.

Mr. Clausing serves as the chairman of ASTM committee E07.10.04 infrared methods for non-destructive testing, and serves as chairman of ASNT infrared methods committee.

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