INFRARED INSPECTION

INTRODUCTION

Many loss-producing conditions, like high resistance at electrical connections and accelerated wear in bearings, cause abnormal temperatures in the area of incipient failure. An infrared (IR) thermometer or imaging system can often detect these abnormal temperatures in equipment while the equipment is in service.

IR inspection is the most effective tool currently available for detecting many electrical equipment problems. It can efficiently detect conditions such as wet or damaged thermal insulation, leaking steam traps and compressor valves, or unequally-performing cylinders in internal combustion engines and some compressors. It can support mechanical equipment maintenance tools, such as vibration analysis and lubricant wear particle analysis that detect mechanical misalignment and worn or damaged bearings in machinery.

POSITION

IR inspection is an essential part of an effective maintenance program. IR inspection is a nondestructive test (NDT) method; any such method is most effective when applied in accordance with a written procedure or protocol. SNT TC-1A provides guidance for NDT procedure development. NFPA 70B describes how to apply IR inspection within an electrical preventive maintenance program.

Using an IR imaging system or thermometer, operated by in-house staff, a centralized corporate support team or a contractor, apply IR inspection as follows:

- Perform IR inspections on facility equipment in accordance with Table 1.
- IR inspect newly installed and repaired electrical equipment while under load soon after placing it in service.
- Promptly investigate and correct any adverse conditions found during an IR inspection.
- Provide IR inspection results to maintenance engineering for analysis.

IR thermography is only one of the many tools a complete maintenance program will include. If IR thermography does not prove beneficial in a particular application, substitute another tool.

Local overheating may have more than one cause, particularly in mechanical equipment. Therefore, after correcting a condition located by an IR survey, arrange a follow-up IR survey soon after the repaired equipment is returned to service.

TABLE 1
Suggested Infrared Inspection Frequencies

Equipment To Examine	Where To Look	Initial Frequency (1)	Typical Conditions Found	Alternate Or Supplemental Tests
All electrical power distribution switchgear and transformers, 480 volts AC or higher and all DC including rectifiers	Panels; breakers and their "stabs" or connections; cables, bus ducts, and bus structures; bushings and other connections; fuses and fuse clips; transformers, including their tanks and heat exchangers	Annually	Loose or otherwise defective connections, incipient ground faults, hot spots (10 -20°C [18-36°F] rise)	None
Electrical equipment in hot atmospheres or exposed to corrosive, conducting or insulating particles such as chaff, water, corrosive chemicals, oil or carbon	As above in, for example, paper, textile or steel mills, foundries and smelters	Quarterly	As above	None
Severely exposed and heavily loaded electrical equipment	Arc furnace transformer secondaries, aluminum smelter busses	Weekly	As Above	None
Large motors and other large loads and their connections and controllers	As above, also windings and bearings	Annually	As above, also deteriorating bearings	Vibration and wear particle analysis, bearings only
Generators, exciters and their associated switchgear	As above	Annually	As above	As above
Mechanical equipment	Bearing housings, couplings, belts, conveyor drives and support rollers	Quarterly	Parts running abnormally hot or hotter than similar parts	Vibration and wear particle analysis
Compressor valves	Valve housing temperatures	Quarterly	Abnormally hot (leaking) valves	Dismantle
Engine and compressor cylinders	Compare cylinder head and exhaust temperatures	Quarterly	Cylinders hotter or colder than others	Cylinder balance or compression test
Insulated equipment (2)	Inspect outer surfaces	Monthly (3)	Hot spots; wet or damaged insulation	Surface pyrometer, strip and inspect
Primary reformer tubes	Tubes	Weekly	Over heating, unbalanced performance	None
Flat roofs	Whole roof	Annually	Leaks	None

NOTES:

1. Adjust the IR inspection scope and frequency as needed to obtain the greatest benefit.
2. Insulated equipment, particularly that in which internal refractory protects a load-bearing or pressure-containing metal structure from fire or other internally produced heat of reaction, should be IR inspected on a frequency determined by experience. A monthly frequency is suggested until experience indicates a more appropriate interval.
3. IR inspections for this type of equipment are most cost-effective for in-house IR programs but may also be effective if performed in conjunction with electrical equipment IR inspections.

Electrical equipment can be effectively IR inspected only while it is under load or within 1 min – 5 min after it is unloaded. Inspection may require removing back panels and other protective covers from energized switchgear and defeating or bypassing door safety interlocks. Appropriate personnel and equipment safety precautions are necessary, and jurisdictional restrictions may apply. Consult NFPA 70E and the local jurisdictional regulations for more information.

AXA XL Risk Consulting recommends purchasing IR equipment appropriate for the location and intended use. Operator dedication, training, experience and enthusiasm will influence program effectiveness. A management commitment to the program as well as a capital investment in equipment is necessary for success. If equipment purchase cannot be justified, or if desired for other reasons, contract IR services are available. This Property Risk Consulting Guideline should help specify services and evaluate offers of service.

DISCUSSION

IR radiation is an electromagnetic radiation similar to light. Its wavelength is longer than that of visible light. IR radiation is emitted by a body in proportion to its temperature. The amount of IR radiation emitted by a body at a given temperature also depends upon the emissivity of the body. Emissivity is a measure of the efficiency with which a body radiates. A lightly-colored, polished surface will tend to have a low emissivity and a dark-colored, dull surface will tend to have a high emissivity.

Emissivity is a number between zero and one. It is the ratio of the emissivity of a given surface to that of a perfect emitter, or blackbody. Most surfaces encountered in industrial work may be considered as having a 0.95 emissivity. If an accurate reading of absolute temperature is needed, standard tables are available to help more closely estimate the emissivity of a given surface. Some IR thermometers are designed to measure the emissivity of a surface having a known temperature. Such a device could be calibrated on a part whose temperature can be measured with a surface pyrometer, then used to accurately measure other locations having the same surface characteristics. Surfaces with an emissivity less than 0.5 generally cannot be measured accurately. Very low emissivity surfaces, such as polished aluminum, may not even reveal hot spots. Shiny surfaces may also reflect IR radiation from other sources that will make the surface appear hotter than it really is.

Most portable IR inspection devices are either thermometers or imaging systems. An IR thermometer indicates the temperature of the surface at which it is pointed. An IR imaging system produces a modified image of the object of interest. Different temperatures of the different portions of the object appearing on the display are discerned by using either a gray scale or a color scale. Either type of IR instrument is used by “scanning” all surfaces of the object to be inspected, looking for hot areas.

Temperature differences are the normal focus of an IR inspection. This is because the normal temperature of an object can vary with the applied load, ambient conditions and possibly the position of the sun and the cloudiness of the day. Hot spots are generally worth investigating regardless of their absolute temperature. If the absolute temperature is important, or for recording purposes, IR thermometers or imaging systems may need to be adjusted for object emissivity.

Other factors can influence absolute temperature measurements or the repeatability of results. For example:

- The apparent emissivity of an object varies with the viewing angle. For example, when inspecting the curved surface of a cylindrical object, only the portion of the surface directly facing the instrument can be measured accurately.
- Painted areas, rough spots, shiny spots, holes and threads all have different emissivities than the rest of an object being inspected and will therefore appear warmer or cooler than their surroundings.
- Varying insulation thicknesses can cause an object with a uniform temperature to appear to have several different temperatures.
- Wind and rain can cool an object; sunlight can heat it or be reflected from it.

Equipment Selection

IR thermometers are suitable for most loss prevention survey work, however, IR imaging systems are more versatile and are generally faster and easier to use. An appropriate IR thermometer can be obtained for between $500 and $800; fully-featured IR imaging systems generally cost between $20,000 and $60,000. To place the equipment cost in its proper perspective, consider that one hour of avoided downtime at most large facilities will pay for the finest IR instrument on the market. Further, as a bonus, a suitably accurate IR instrument may also have a variety of process or quality control applications.

AXA XL Risk Consulting strongly recommends IR imaging systems, particularly for manufacturing facilities. This type of equipment has significant advantages:

- It simplifies evaluation of the "big picture," an important advantage in applications like thermal insulation surveys.
- When combined with a recording device, it provides a permanent survey record.
- An imaging system is less likely to miss hot spots, particularly small ones.

Many options and features are available for IR imaging systems. Persons interested in more information about this equipment should contact an IR imaging system manufacturer or vendor.

If the purchase and training costs for an IR imaging system cannot be justified, consider an IR thermometer. When selecting an IR thermometer, consider accuracy and temperature range, and also the following features:

Emissivity adjustment - While not necessary for most loss prevention activities, this feature allows more accurate measurement. It is necessary if absolute temperature measurements are required, particularly in process measurement or quality control applications.

Resolution - An IR thermometer is an optical device and, like a camera, has a focal length. Resolution is generally stated as "spot size" at a given distance. The spot size is the diameter of the circular area the detector "sees." Most general purpose instruments have satisfactory resolution for loss prevention work, unless the instrument is to be used for viewing very small objects, such as circuit board-mounted parts or their connections, or objects which cannot be safely approached, such as outdoor high voltage lines or furnace internal components.

Sighting method - Unless an instrument has unusual resolution characteristics, the instrument "aiming" method is a matter of personal preference. Some instruments have "open" or "peep" sights and others have optical sighting systems. The simple sights are easier to use and possibly less fatiguing; the more complex ones are intended to be more accurate. Laser-sighted units are also available.

Ambient temperature compensation - This feature is not required unless readings will be made of objects located in areas where radiation from other objects at different temperatures may reduce accuracy. For example, accurately measuring the temperature of tubes in a furnace requires an instrument capable of compensating for the background radiation from the furnace walls.

Alarms - These may help reduce operator fatigue when large areas are to be inspected. If an alarm is set a few degrees above the "normal" temperature of the equipment being examined, the operator can direct full attention to a careful inspection without worrying about specific readings.

Latching - The ability to "latch" or retain the highest temperature found during an IR inspection may also help reduce operator fatigue.

Data logging - If many readings are to be taken on a regular tour, it may be convenient to obtain an instrument that will store a quantity of data and transfer it directly to a computer.

Auxiliary outputs - Analog or digital outputs may allow the unit to be used with a separate data logging device. They allow the instrument to monitor a piece of equipment by recording the temperature of a point of interest over time, or to act as a supplemental or backup input to an alarm or protective circuit.

Applications

Electrical equipment loss prevention surveys are an important loss prevention application of IR. Most electrical failures occur at either fixed joints, such as bolted lugs or bus connections, or at moveable joints, such as switch, controller or breaker contacts. Joint deterioration is characterized by an increase in resistance; this increase will cause a local temperature increase. The nature of electricity makes surface contact measurements hazardous to the equipment being examined as well as to the persons making the measurements.

An IR inspection may locate contacts that are slightly warmer than the associated conductors, especially if the contactors have recently operated, without causing concern. If the difference is more than 10°C – 20°C (18°F – 36°F), however, the condition should be investigated. Any detectable difference between the temperature of a fixed joint and that of the associated conductors should be investigated. A fixed joint which is 10°C – 20°C (18°F – 36°F) warmer than the adjacent conductors may be in critical condition and should be inspected as soon as possible. In contacts, temperature rises are generally caused by pitted contact surfaces or weak closing springs; in fixed joints, such rises are normally caused by looseness or corrosion.

Other electrical problems that IR inspection readily detects include phase imbalances, harmonics and overloads. If a temperature difference between phases is found, arrangements should be made to promptly obtain phase voltage and current readings that will indicate whether an imbalance or other adverse condition exists.

Although most electrical equipment is designed to operate at a temperature up to 20°C (36°F) and possibly as much as 150°C (270°F) above the ambient temperature, this much temperature rise is seldom found. Experience with a facility's equipment will determine at what value further investigation of a given object is necessary. Logging the temperatures at a series of fixed points when inspecting equipment will help develop the needed data.

In some locations, an adequate IR inspection can be performed with an IR thermometer. Operators of the severely exposed electrical equipment described in Table 1 or those with extensive electrical systems, particularly those who own and operate the high-voltage distribution system, should perform a periodic inspection with an IR imaging system.

IR temperature measurement can also help mechanical equipment loss prevention. Here are a few ways:

- In conjunction with a vibration monitoring program, IR inspection can assist a rotating machinery condition monitoring program by quickly detecting overheated or possibly overloaded bearings and couplings.
- Periodic examination of reciprocating compressors may detect leaking valves or cylinders by detecting the temperature rise caused by recompressing air or gas that leaks back into the compression chamber.
- Internal combustion engine IR inspections may conveniently detect cylinder imbalance caused by poorly performing valves or out-of-adjustment diesel injection or spark ignition equipment.
- Radiators, transformer cooling fins and coils, and other heat exchangers and cooling jackets can be easily inspected while in service for performance losses caused by clogging or fouling.
- Rolling mills can employ IR methods to prevent rolling "cold" product.

Several applications have direct economic benefits in addition to preventing losses. Fired and pressure equipment IR inspection is very likely to have a direct payback. For example:

- While internal refractory failures may only cause heat losses, they may cause a fire hazard or strength loss if they severely overheat casings and structures. In pressurized high temperature reactors, such as ammonia secondary reformers, such failures may be critical.

- Monitoring tube temperatures in boilers and fired heaters is a convenient way to detect poor performance caused by internal fouling; it may be the best way to prevent rupture of tubes carrying flammable materials. IR thermography may be employed heavily in applications, such as reformer furnaces, where heating rates as well as temperatures are important.
- Waterlogged paper dryers are readily detected.
- Steam traps, including those located in ceiling-mounted equipment, can be readily surveyed for proper performance.

An inspection with an IR imaging system can also locate leaks in a flat roof before leakage can damage the roof system, deck or structure. Such an inspection can also identify where insulation can help conserve energy. Contact the imaging system manufacturer or a specialty contractor for more information.