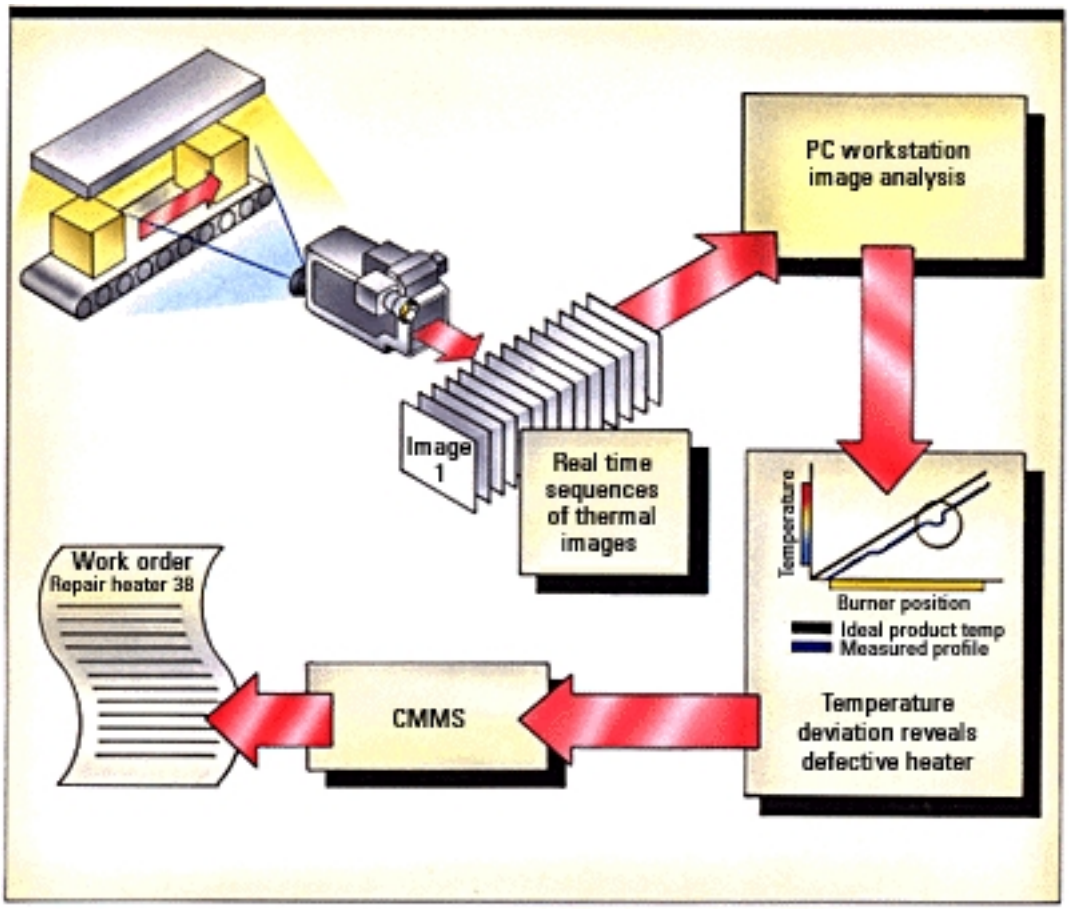

Over the past three years, the latest generation of handheld focal plane array (FPA) infrared (IR) imaging cameras have become widely used as temperature measurement tools in condition monitoring programs. Increased usage stems from significant improvements in image resolution and the ease of use accompanied by major reductions in camera size and weight. These cameras are now being integrated with personal computers (PC) and Windows software to provide real-time imaging capabilities that extend the value of these tools for condition monitoring.

Advanced thermal systems are as simple to use as a camcorder. They can save hundreds of thousands of dollars a year by revealing temperature abnormalities that, if left untreated, cause process inefficiencies or line outages. Traditionally used as handheld systems that capture individual images to PC cards for later analysis on a personal computer, infrared cameras can now be connected to PC-based systems for continuous capture and analysis of temperature data at up to 60 frames/sec.

Maintenance technicians have traditionally used IR cameras to detect high temperatures that often indicate a pending electrical failure. However, thermal imaging is increasingly used to find

potential problems in mechanical processes. Routine inspections of motors and bearings can reveal out-of-range temperatures caused by lubrication or alignment problems. Furnaces, vessels, and piping also can be imaged. Worn or decaying insulation in these areas can be detected as greater amounts of heat escape to the outer surface.

Modern thermal imaging systems clearly reveal defects with images and temperature data that can be interpreted and acted upon quickly. Improvements in software for image tracking, image analysis, and report generation permit data to be integrated into maintenance programs, from basic to advanced.

Infrared technology

Today's advanced infrared camera is literally a handheld PC that measures temperature with an advanced focal plane array detector. The most powerful cameras provide 12-bit recording, enabling users to view and measure a scene that contains very hot and very cold temperatures without losing the ability to measure thermal variations of less than 0.1 deg C.

Camera options, such as bar code readers for image tracking, have extended the functionality of IR imaging systems to match the needs of computerized maintenance management systems (CMMS). Bar code tracking offers accurate, operator-independent data entry that adds pertinent condition comments directly to the stored IR image. Even where bar codes are not used to identify equipment, the bar code standardizes all inspection comments associated with the image.

At the completion of an inspection task, stored images are usually transferred to either a stand-alone thermal analysis and reporting software package, or to the main CMMS. Regardless of the type of maintenance management system at a facility, the primary task at this point is to archive collected data and generate work orders for corrective actions. When required, a full range of image analysis software features allow the user to extract temperature values from the stored images on any PC with the Windows operating system.

Real-time infrared

IR system suppliers are delivering real-time IR workstations that can measure dynamic temperature changes in equipment and processes. Although single, static IR images of moving machinery or a dynamic process are useful for recognizing many problems, real-time thermal imaging systems allow machine cycles to be recorded and analyzed easily. This capability speeds accurate problem recognition while eliminating potential misdiagnoses that could lead to

costly delays or inappropriate remedies.

The call for more sophisticated application of IR imaging is often initiated after production and engineering departments have battled quality or efficiency problems. The problems may range from poor adhesion of hot-set glues to quality variations in plastic films or poor uniformity in glass products. Invariably, the production equipment has been designed to provide a uniform level of heating to one or more components. Heat is supplied using a system that maintains temperatures based on a simple control mechanism.

It is not uncommon that as management pushes for increased quality, the new levels cannot be maintained over time. At other times, the equipment may have been tuned for a higher level of performance, but the product has recently deviated for reasons not explained by the existing process data. Attaching a thermocouple is seldom an option because the equipment moves too fast, or there are too many points to measure.

In these production situations, the new real-time IR thermal imaging systems are most useful. The systems consist of two primary components: a portable Pentium PC with a digital recording system and Windows 95 software integrated to acquire real-time digital video and to display it in color, extract temperature information, and record the real-time sequences for extended analysis, and a handheld, high-resolution FPA camera.

A key feature is the digital video interface, which transmits every temperature measurement pixel generated by the camera. The camera also can be disconnected from the system and used in traditional snapshot mode.

What makes these workstations so useful for troubleshooting dynamic manufacturing problems is their ability to acquire, store, and analyze sequences of real-time IR images of the equipment under investigation. The system analyzes, displays, and stores up to 60 calibrated IR images every second. The systems use off-the-shelf components to make upgrades possible and ensure compatibility with traditional Windows software.

A 200 MHz Pentium PC with its high-speed PCI bus makes an excellent platform for thermal imaging. A digital frame grabber accepts the digital video transmitted by the camera and transfers it to the high-bandwidth PCI bus. High-capacity hard disk subsystems designed for

multimedia applications store the data for subsequent review and further analysis.

Windows 95-based software analysis tools give the system a VCR-like user interface for controlling the digital video recording and playback. Users first position the camera and adjust the viewing temperature range and then select the rate and length for which images are stored to the internal drive, ranging from 60 Hz for as long as 20 minutes, or as slow as one image every hour for weeks. Storage of the video can be initiated from the keyboard or a signal from the device under observation. Once data have been recorded, viewing controls (such as play, fast forward, rewind, slow motion, and time lapse) can be used to review the process, equipment, or event under study.

The software provides a full range of tools for extracting temperature data from the collected thermal image sequence. They range from simple points, areas, and lines to complex regions that help the user measure only specific components of interest. If live sequences reveal dynamic trends, a tool automatically extracts data from a sequence of images and generates a graph for review.

When the system is operated within a network computing environment, video and data can be shared with other users. Sequences that are transferred through this method can be reviewed and analyzed at remote sites, making the thermal imaging system available for monitoring other equipment.

Captured data can be exported to other systems so maintenance managers can integrate all maintenance test data into a CMMS.

Applications
The following examples represent some of applications where these systems have assumed an important role in condition monitoring programs.

- Furnaces and dryers. A range of products including gypsum, chemicals, and agricultural products pass through dryers and heaters of various types. Clogged burner nozzles, misdirected airflow, or malfunctioning radiators can drastically affect performance of the line. Diagnosis can be extremely difficult or impossible with contact temperature sensors.

Glass production. Bottles, cathode ray tubes, and electric lamps are examples of glass products monitored with real-time systems. Because these products are often produced at fast

rates, accurate temperature of the product is critical to high yield and reduced waste.

- Paper production. Many paper mills use production equipment that is more than 80 years old. These large, complex systems operate continuously. The condition of the dryers is critically important to the quality of the process. Real-time IR systems image the rotating dryers to create a map of the dryer surface. Post-processing allows the inspector to rapidly identify deviations in temperature across the drum surface.
- Molding processes. The quality of molded plastic and glass components is strongly influenced by the temperature of the material as it flows in the mold and the way the cool-down cycle is controlled. The steady-state thermal characteristics of a mold depend strongly on the flow of product, as well as the condition of the heaters. Static assessment of the molds does not yield the necessary information. Recording dynamic sequences allows the inspector to quickly capture images of either the molds or the released part without interrupting the production process.
- Robotic welders. The condition of welding systems installed on robotic workstations can be easily monitored by analysis of dynamic real-time IR images. Abnormalities in the cooling cycle of welding tips also can be recognized using real-time digital IR recording.
- Advanced semiconductor processing. Many semiconductor processes are sensitive to deviations in the temperature of the wafers during processing. Errors created by foreign matter, heater abnormalities, and product delivery can be readily characterized. Recording real-time sequences gives the user the best available data.
- Web processes. Processes such as application or curing of adhesives or the preheating of paper coatings depend on the proper operation of both application equipment and curing systems. Real-time IR workstations allow the maintenance professional to view temperatures on both the dynamic equipment and the moving product. The high-resolution thermal data captured by the camera allows users to identify defective equipment easily. **MT**

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