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THE USE AND APPLICATION OF INFRARED THERMAL IMAGING SYSTEMS IN FORENSIC ENGINEERING

ABSTRACT

Under the right conditions, electrical equipment can self destruct rapidly even when carrying less than rated load in the event of "hot spots". The melted down mass of metal that remains after sustained electrical arcing often leaves few apparent clues of the real cause of the problem.

One of the most efficient methods of actually "seeing" the incipient fault conditions develop is to pass a current through a similar piece of equipment in apparently good working order and to examine the thermal expression through an infrared thermal imaging camera. The growth of potentially catastrophic hot spots can become readily apparent in a short time.

INTRODUCTION

Right or wrong, the cause of many fires is often attributed to faulty electrical wiring or equipment since in a major conflagration, little evidence can be found to dispute the statement. The task of the forensic electrical engineer is to discover the actual cause of the problem and to support his opinion with as much evidence as possible.

In the past, gathering data was difficult because most of the evidence was destroyed in the blaze and testimony was often reduced to statements of conjecture. It was not hard to simulate operating conditions on a similar piece of equipment in working order, but it was virtually impossible to monitor all the potential points of failure to determine how, and where, the fault started.

Now science has come to the aid of the forensic electrical engineer in the form of a thermal imaging camera. This electronic device can generate a heat picture (or thermal expression) of the equipment on a TV monitor under actual or simulated load conditions and indicate by means of a gray or coloured scale its temperature profile similar to a contour map. Thus points of high or low temperature are immediately visible on the monitor screen for analysis.

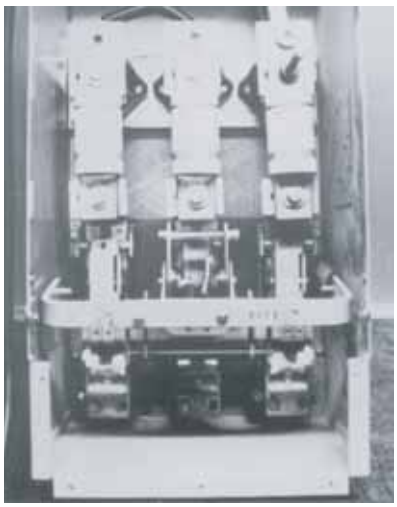
Thermal Imaging System (cart mounted)

CASE HISTORY

A recent case is a typical example of the use of a thermal imaging camera to determine the cause of a fire in the electrical room of the recreation centre of a large condominium complex.

The forensic engineering analysis concluded that the fire started in a 600 VAC, 400 A, three phase fused switch controlling the heating cables buried in the access ramp leading to the underground garage. The switch contained three 250 A, NEMA Class CJ, HRC fuses.

The intense heat generated by the electric arc destroyed most of the internal components of the switch making a meaningful examination impossible. The other devices in the switchboard were examined and a switch of similar make, model and rating was selected for detailed study. A manufacturing/design flaw in the main contact and arcing contact area leading to overheating was found and deemed to be the most likely cause of failure.



MATERIALS AND METHODS

An infrared thermal imaging camera is similar in operation to the small video cameras that are now on the market, except that the device is sensitive only to the infrared part of the electromagnetic spectrum. The camera is highly portable and is hand carried.

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Black and white thermogram in the 'cross-hair' mode indicating a hot spot temperature of 59.8°C on the centre phase arcing contact.

A typical system consists of:
- thermal imaging camera
- 12 V battery
- computer controlled electronics
- video monitor
- recording device

There is no physical contact with the object being scanned and by means of appropriate lenses a wide range of subjects can be examined at any distance, from overheated printed circuit boards, to the heat loss in large buildings caused by poor installation of the insulation or badly fitting windows.

The sensitive camera enables the forensic engineer to examine electrical and other equipment under actual operating conditions and to pin point immediately potential fault locations. The cameras are used extensively by electrical utilities in the routine inspection of their indoor and outdoor substations and overhead lines to detect hot connectors. The camera can also be used to detect overheated bearings on rotating mechanical equipment. Medical Forensic Engineers view soft tissue injuries in order to try to quantify pain.

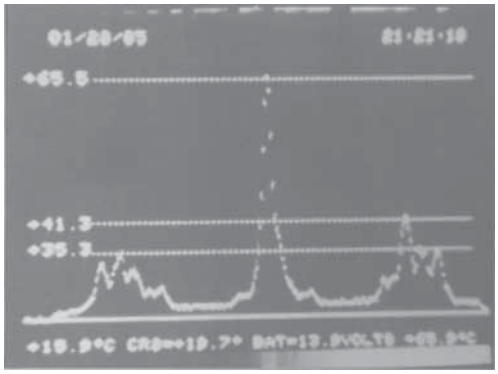
Computer control of the camera increases the analytical capabilities of the system considerably. The instrument is able to provide images in black and white or in colour, each with a selectable scale range to suit the application. Thus hot spots, or cold areas, can immediately be brought to the attention of the operator.

For accurate determination of actual operating temperatures, the operator can select a "line scan" across the screen. The computer will then produce a graph indicating the temperature of every point along that line. In the "cross hair" mode, the computer will indicate the temperature of that selected location.

The results of the examinations can be recorded on the tape recorder or by a film camera. Being transportable, the infrared system can be moved to any location which, with the assortment of lenses available, enables a wide range of situations to be studied without difficulty.

In a typical examination, a similar model of the burnt out equipment is mounted on a framework to simulate the installation. A current is then circulated through the conducting parts. The actual value of this current is not critical since a high resistance joint will generate heat at almost any current level which will be detected by the camera. In the laboratory, the current is supplied by a small power source, rated at 0-100 amps DC, and is connected to the object with all three phase components in series.

After a few seconds operation, hot spots will be readily observed on the video monitor. These are then examined with the aid of the various black and white and colour operating modes selected in the camera and recorded on the video tape recorder.



'Line scan' mode. Note left phase arcing contact is operating at 35.3°C, centre phase arcing contact at 65.5°C, and right phase arcing contact at 41.3°C.

OBSERVATION RESULTS

During the electrical test, it was soon observed that the arcing contacts were carrying the full load current and as a result were overheating. Normally in any switch, the main contacts are designed to carry the load. The arcing contacts are easily replaceable and carry the current for a short time only when the switch is being closed or opened. Thus the main contacts are not subjected to the damaging effects of pitting caused by the opening and closing arcs.

Infrared examination of the switch disclosed that the main current carrying contacts were not carrying current at all. The main contacts were prevented from properly closing by interference from the arc chutes. Arc chutes assist in extinguishing the arc by forcing it into separate channels of cool insulating material by the magnetic forces created by the arc itself. The arc is thus rapidly cooled and lengthened until it is extinguished.

In the test switch, the arc chutes had been installed incorrectly, thus preventing the main contacts from closing properly and carrying the load. As a result, the arcing contacts were burning away and it would be only a matter of time before this switch failed.

Close examination of all other switches on the switchboard revealed similar defects. The misaligned arc chutes were preventing the main contacts from closing properly. This would cause the eventual destruction of all the switches.

CONCLUSIONS

The cause of the problem was obviously due to a combination of poor assembly methods, design and quality control procedures at the manufacturer's plant. The report of the forensic engineer backed by thermal imaging evidence recommended the replacement of all the switch interiors by the manufacturer. The manufacturer stood behind his product.

The ability of the high resolution thermal imaging system to provide instant visual indication of overheated contacts is a particularly valuable investigative tool in the hands of the forensic engineer. The importance of well documented evidence provided by the camera and the video recorder is vital to the expert witness and is acceptable to many courts.

PHOTOS COURTESY OF INSTITUTE OF FORENSIC ELECTRO-PATHOLOGY