Placing a tag on hot spots

Generator condition monitors, or core monitors, provide generator protection through early detection of overheating. Although overheating can reliably be detected, determining the location of the hot spot has proved more difficult. To improve the effectiveness of the monitoring function, chemically and thermally stable tagging compounds have been devised that enable the specific area of overheating to be identified. Tests carried out by Environment|One and Ontario Hydro confirmed that the tagging compounds can be successfully identified.

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Most of the electrical power utilized in the USA is produced by large, steam turbine generators. The value of power produced by one machine can exceed $1 million per day. It is therefore important that any fault which might occur in the machine be detected and corrected promptly. The generator condition monitor (GCM), or core monitor (CM), was developed to provide such detection through early warning of hot spots or arcing in hydrogen cooled generators.

The GCM (see Figure 1) is a sensitive real-time detector of submicrometer particles created by arcing or the thermal decomposition of generator coatings and insulation. Particles are detected by means of an ionization chamber through which the hydrogen cooling gas is circulated using the differential pressure produced by the generator fan(s). Upon detection of overheating or arcing, the GCM initiates an alarm verification sequence, triggers alarm contacts and indicators, and collects a particulate sample for lab analysis. A typical generator overheating record is shown in Figure 2.

Figure 1. Generator condition monitor on-line

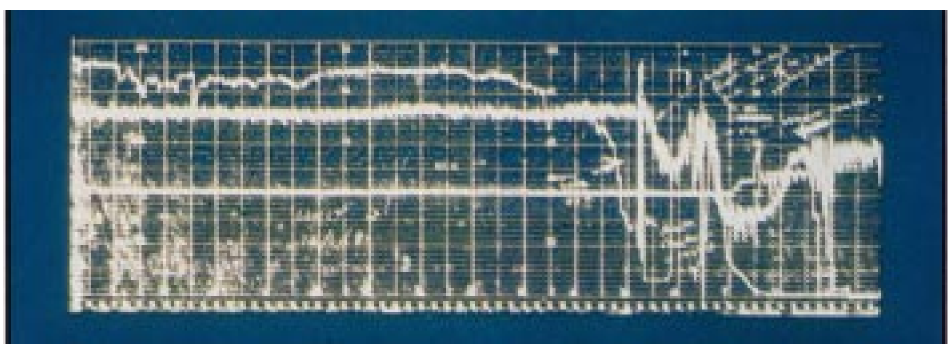

Figure 2. Strip chart recording of a generator overheating.

Hot spot location

To determine the precise location of the hot spot, extensive work has been done attempting to identify the specific products of thermal decomposition. This is a difficult task since many of the materials used in the generator (such as epoxy and varnish) give off similar thermal decomposition (pyrolysate) products as determined by gas chromatography and mass spectrometry analysis.

To overcome the difficulty experienced when attempting to characterize the pyrolysates of existing generator materials, a new system employing tagging compounds has been devised by USA firm General Electric which provides a positive means of identification of pyrolysate products. Different chemical tags are incorporated in trace quantities in color-coded coatings which may be applied to critical areas in the generator.

The tagging compounds are designed so that the physical and chemical properties of the gen-

Figure 3. The tagging compunds, their colour codes and destined generator locations

PART NO. A-1012A-	GEN-TAG COMPOUND	COATING MEDIUM	GEN-TAG COLOR	APPLIED AREA
273	N-DODECYL IMIDE	EPOXY PAINT	SUDAN YELLOW	COLLECTOR END END WINDINGS
274	CYCLO-DODECYL IMIDE	EPOXY PAINT	SUDAN ORANGE	TURBINE END END WINDINGS
275	CYCLO-OCTYL IMIDE	EPOXY PAINT	SUDAN IRISOL	CORE I.D.
276	DIHEXYL AMIC ACID	ALKYD PAINT	IRON BLUE	ROTOR SURFACES EX.RETAINING RINGS
277	ADAMANTYL IMIDE	EPOXY PAINT	GREEN	BUSHINGS AND LOWER LEADS
278	CYCLO-HEPTYL IMIDE	EPOXY PAINT	SUDAN BLUE	TRANSFORMERS AND REACTORS (APPLICABLE)

Figure 4. Encapsulated Gen-Tag 2766 (dihexyl amic acid) for application to rotor surfaces

erator materials are not affected. Produced in encapsulated form, tagging compounds are designed to be thermally stable, allowing them to function over the service life of the generator.

The different chemical compounds, their color coding and the associated region of the generator to which they are applied, are shown in Figure 3. A sample of one of the tags is shown in Figure 4.

When overheating occurs in the generator the GCM automatically collects a sample of the overheated pyrolysate for laboratory analysis. Using a gas chromatograph with an electron capture detector, the tagging compounds can be identified easily and the location of the overheating therefore determined. Figure 5 shows the application of tagging compounds.

However, while tagging compounds can readily be overheated and accurately identified in the laboratory, field tests were deemed necessary to satisfy questions concerning their actual performance in a hydrogen cooled generator. A testing program was performed by Environment|One in conjunction with Ontario Hydro to determine the effectiveness of the chemical tags.

Test programme

Before tagging compounds could be added to the generator condition monitoring system with confidence, certain questions had to be answered:

- Would the generator condition monitor initiate an alarm when the tagging compounds were overheated in a hydrogen cooled generator?
- Could the sampling system of the generator condition monitors be redesigned to permit enough tagging compound to be captured for laboratory analysis?
- Could the tagging compounds be easily identified in a laboratory?

Ontario Hydro has been performing operational field testing of generator condition monitors since 1974. The company has performed overheating tests using generator insulating materials within a hydrogen cooled generator at their Nanticoke thermal generating station.

Overheating of an insulating material was accomplished by circulating currents through a 100 W ceramic resistor that is coated with a thin layer of the test material. In the case of a tagging compound, the resistor was coated with a thin layer of epoxy paint that contained trace amounts of a tag.

Early tests proved that the generator condition monitor responds very rapidly to the overheating. However, when the pyrolysate sample was analyzed in the lab, no tags could be identified. It was decided that a special sampling system would be designed and constructed that would allow the capture efficiency of various flows and filters to be tested to determine the most effective configuration.

After considerable testing, it was determined that a flow of hydrogen through the collectors of 200 l/min was needed and that the filter should be of a glass fiber construction. Several successful tests were then conducted to confirm that the sampling system parameters would indeed enable tags to be sampled and analyzed.

To prove that the sampling system used in the generator condition monitor could be modified to incorporate the new parameters, a blind test was conducted by Ontario Hydro. After modifying the sampling system in the GCM, a resistor coated with epoxy containing a tag was overheated. The identity of the tag was known only by Ontario Hydro.

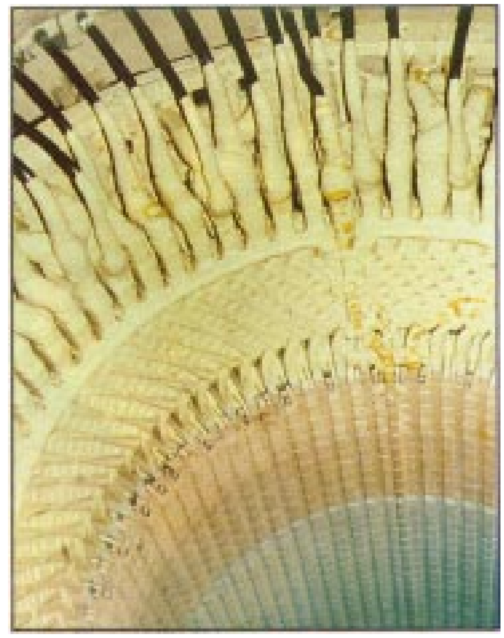

Figure 5. Tag applied to a generator

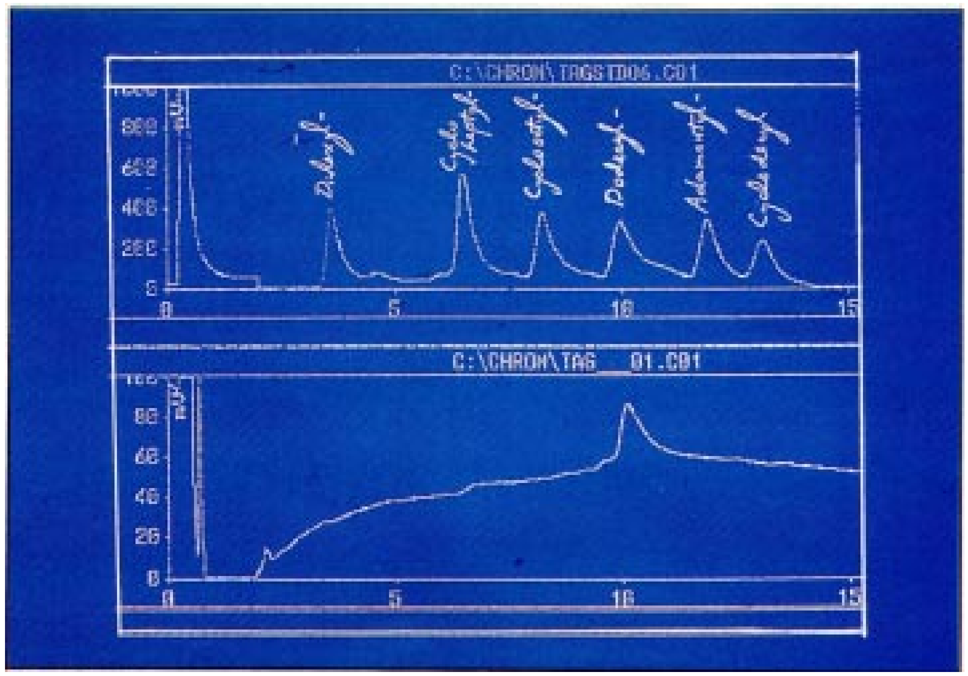

Figure 6. Upper: gas chromatograph print of the six tagging compounds
Lower: analysis of sample taken at Ontario Hydro Nanticoke station during blind test

Within a minute after the start of the test, the GCM detected overheating and initiated sample collection. (It should be noted that the GCM output, with no particulates present, is set at 80 per cent. When the output drops below 50 per cent the unit will initiate an alarm). The overheating of a 100 watt resistor, with a surface area of approximately 10 cm, caused the GCM output to drop to 15 per cent, well below the alarm level. Sample collection continued for a period of 10 minutes. When the sampling was complete the sample collector was removed and taken back to Environment|One to be analyzed.

The glass fiber filter was removed from the collector and the tag adhering to it extracted by washing it with methanol. The extract was then analyzed using a gas chromatograph with an electron capture detector (GC/EC).

The upper part of Figure 6 shows the gas chromatograph print out of all six tagging compounds that are used as standards. The lower part of the same figure is the analysis of the sample taken at the station. The results indicate that the sample tagging compound is N-dodecyl imide or the tag that would be applied to the end windings. Ontario Hydro confirmed that the laboratory results were correct.