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Site Preparation

Site preparation is the first significant action to perform immediately before an inspection carried out on, or in the vicinity of, a large electrical machine. Every inspection of a large machine—scheduled or not, long or short—requires a sensible effort toward site preparation. The goal is to minimize the risks of contaminating the machine with any foreign material or object, as well as to ensure a safe environment in which to perform the inspection. Site preparation should be planned ahead of time, and it should be maintained from the moment the machine is opened for inspection until the time it is sealed and readied for operation. Neglecting to prepare and maintain a proper working environment in and around the machine can result in undue risks to personnel safety and machine integrity (see Figs. 1-1 and 1-2).

1.1 FOREIGN MATERIAL EXCLUSION

Foreign material exclusion (FME), a term originated in the nuclear industry, is the set of procedures geared to minimize the possibility of intrusion into the machine of foreign materials before, during, and after the inspection.

In principle, the definition of foreign material is anything not normally present during the operation of the machine that might adversely affect its constituent components if left there. For instance, although ambient air is not necessarily considered a foreign material, the water content of the air is. Water definitively is an extraneous element that should be kept from condensing on the machine

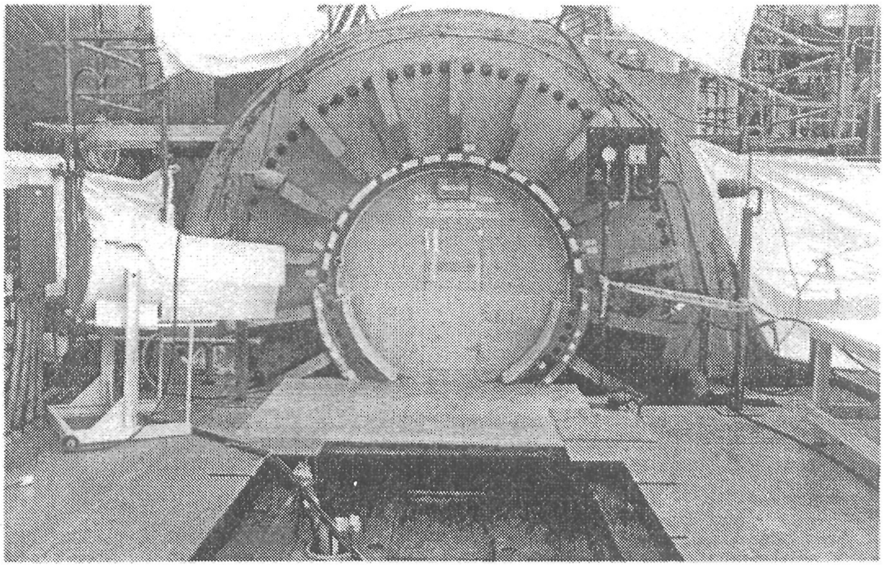

Fig. 1-1 Wooden cover with door at the entrance to the bore area (both sides). These allow control of access to the machine of personnel and tools.

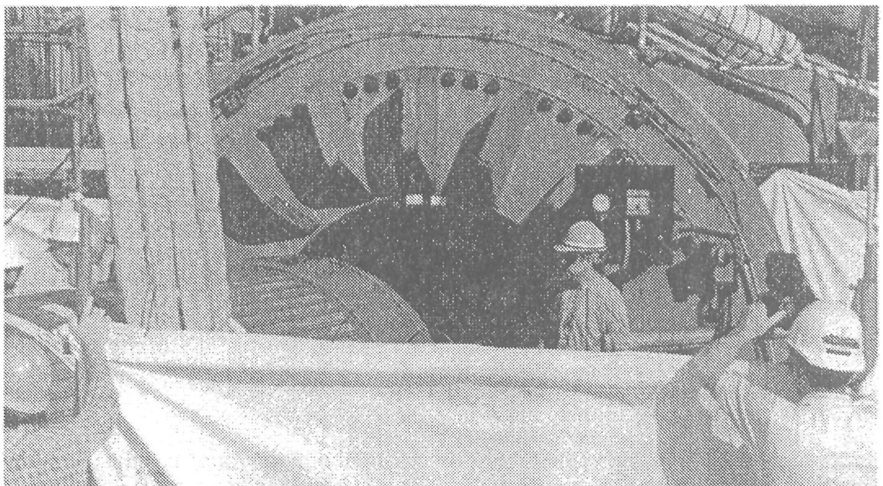

Fig. 1-2 Temporary barrier erected to keep vital components from being contaminated with foreign objects or materials.

windings, retaining rings, and other parts susceptible to mechanical failure from corrosion, or from electric breakdown of the insulation.

Keeping water from condensing onto the machine components can be readily accomplished by containing both stator and rotor under protective covers (i.e., tents), and maintaining a flow of hot air. The hot air and the positive pressure differential inside the tent eliminate the condensation of any significant amount of water (Figs. 1-3 and 1-4). Although the flow of hot air is normally suspended dur-

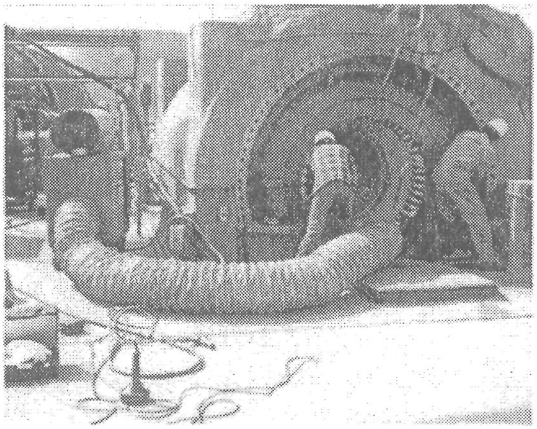

Fig. 1-3 Typical hot-air blower.

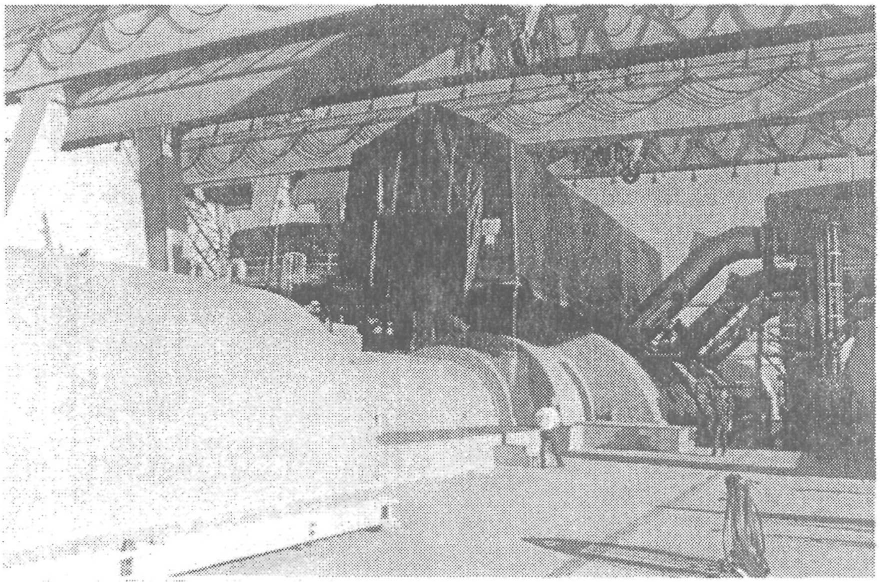

Fig. 1-4 Lowering a protective tent on the rotor of a large turbogenerator.

ing the actual inspection for personnel comfort reasons, thus allowing some condensation to occur, the subsequent flow of hot air will most probably evaporate the moisture and remove it from the containment area [1].

It is important to perform any scheduled electric tests with dry windings. Otherwise, results obtained will not be representative of the winding condition under normal operating conditions.

It is also important not to contaminate the machine inadvertently with corrosive liquids such as solvents, certain oils, and so forth. Sometimes extraneous fluids can be introduced by walking over them and then walking into the machine. Therefore, in situations where stringent FME rules are applied, paper booties are worn over the shoes. Some inspectors prefer the use of rubber booties over their shoes for better and safer grip.

Paper, rubber, or cloth booties will go a long way in eliminating the introduction of small pebbles that may be stuck to the sole of the shoe. When pressure is applied to the end-winding by walking over it, a small pebble can puncture the insulation, thus creating a region of electric-field concentration. This is worth avoiding. It is good practice not to step on the bare coils. A cloth will suffice to protect the winding from the shoe.

The worst enemies of the windings are any foreign metallic objects. They can become airborne due to the high speed of the cooling gas, and break the insulation when striking it. Magnetic particles have been known to cause failures in water-cooled coils by penetrating the insulation over long periods of time, due to the electromagnetic forces acting on the particle. Magnetic as well as nonmagnetic metallic objects may be subject to eddy-current heating, detrimentally affecting the insulation with which they are in contact. Foreign metallic objects such as nails, welding beads, or pens inadvertently left in the bore can short-circuit the laminations of the core. Continued operation under this condition may result in a winding failure due to localized temperature rise of the core. Precautions should be taken to eliminate the possibility of metallic parts or other foreign objects entering the machine. One step in that direction is masking the vent holes of the rotor where these are located outside the stator bore, and covering the rotor when not under inspection or refurbishment (see Figs. 1-5 to 1-7). Metallic objects not required for the inspection should be left outside. This entails removing any coins and other objects (such as medallions, beepers, unnecessary pens, pencils, etc.) from pockets prior to entering the machine. Inspection tools should be carried into the machine on an "as needed" basis. When using mirrors or flashlights in otherwise inaccessible areas, these should be secured by strapping them to one's wrist (Fig. 1-8). In particularly compromising situations, such as with nuclear-powered generators, taking an inventory of tools is recommended both before entering the machine and after exiting it. This is a time-consuming practice, but recommended for all large generator inspections.

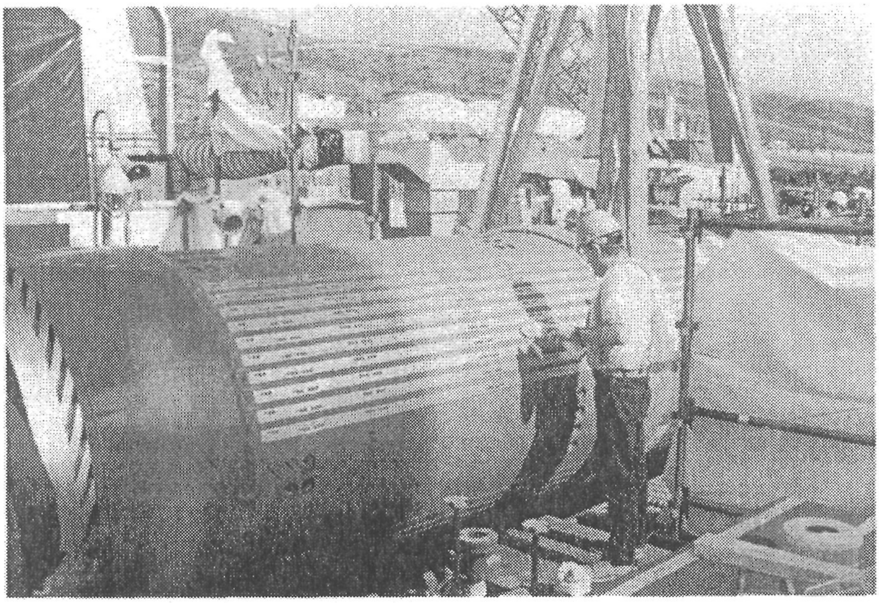

Fig. 1-5 Applying masking tape to vent holes of a large 4-pole turbogenerator rotor, with the purpose of eliminating contamination of rotor winding.

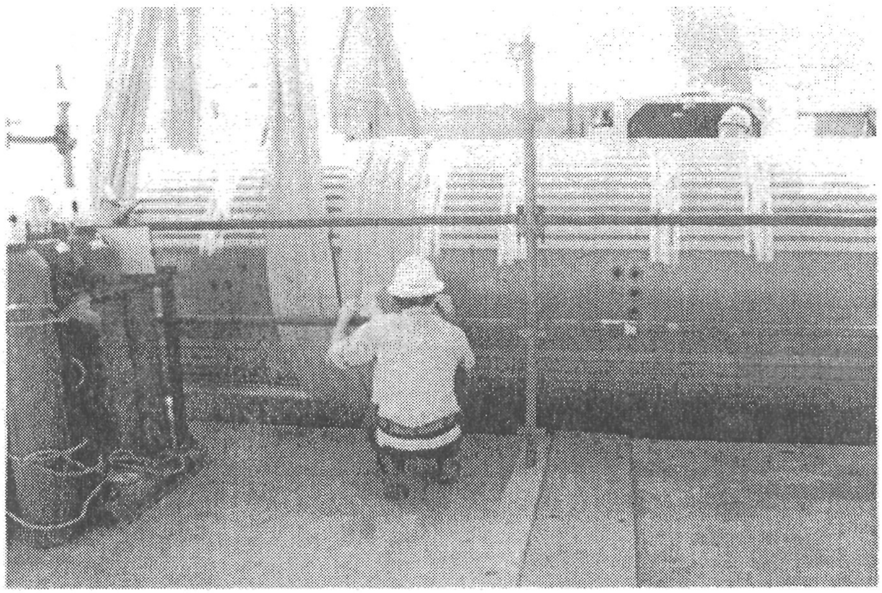

Fig. 1-6 Same rotor as previous figure, with the vents covered.

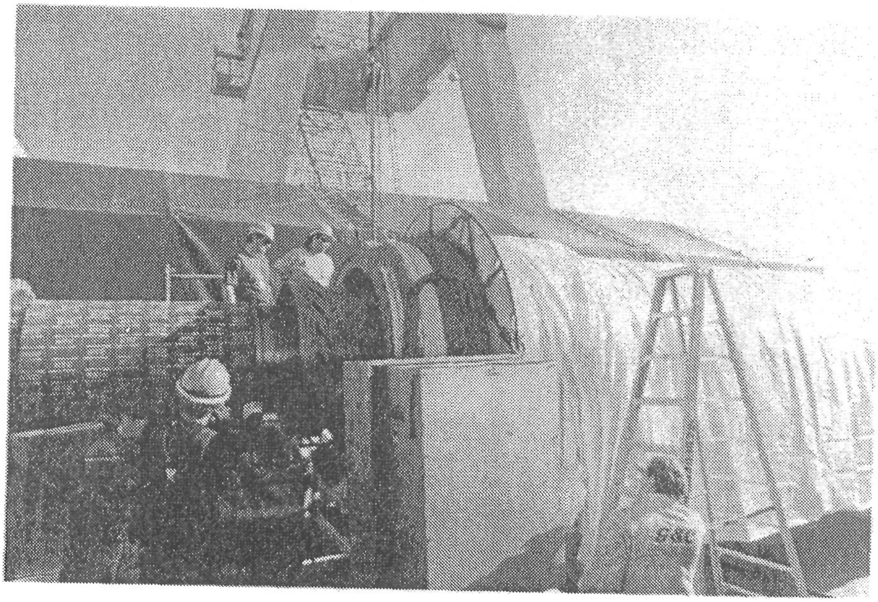

Fig. 1-7 Rotor body covered to avoid contamination while working on other areas of the rotor (end-windings).

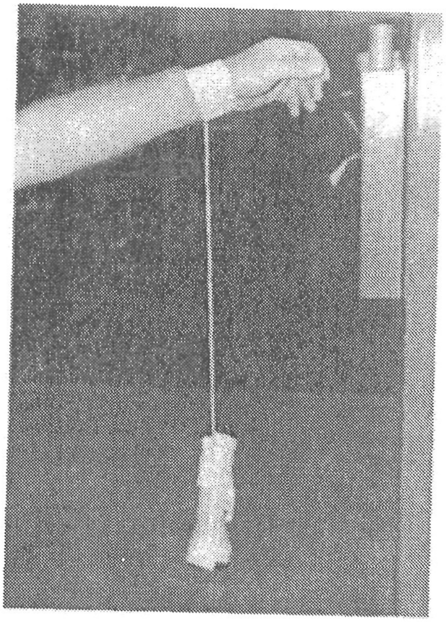

Fig. 1-8 Flashlight strapped to the wrist, to eliminate the possibility of dropping it in inaccessible places.

1.2 SAFETY PROCEDURES—ELECTRICAL CLEARANCES

When carrying out work in an industrial environment, nothing is more important than adhering to all required safety precautions. Large machines opened for inspection often present obstacles in the form of big openings in the floor surface, crevices to crawl through, rods and machine members sticking out, and so on (see Fig. 1-9). They all demand evaluation of required temporary additions to the site, such as beams over the open floor spaces, handrails (Fig. 1-10), secure ladders, and so on.

The obstacles just mentioned are all visible to the people engaged in the inspection. However, an invisible and very powerful element to contend with is the voltage potential (or range of voltages) that may be present in a machine. Although rare, electrical accidents can occur when work is performed in large machines.

A comprehensive inspection of a large machine requires direct physical contact with all windings and other elements that are normally energized during the operation of the machine. "Walking the clearance" is jargon used by some to describe the process of inspecting all breakers, cables, and connections that may be sources of electric power to any part of the machine, and making sure they are deenergized and secure. This means that none of these will be accidentally ener-

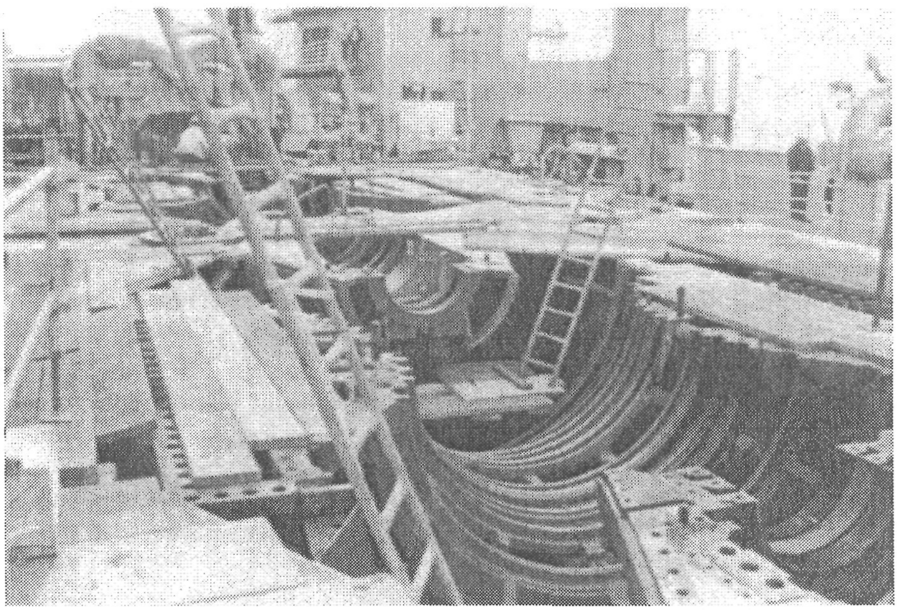

Fig. 1-9 Site of a 1350-MVA unit undergoing overhaul.

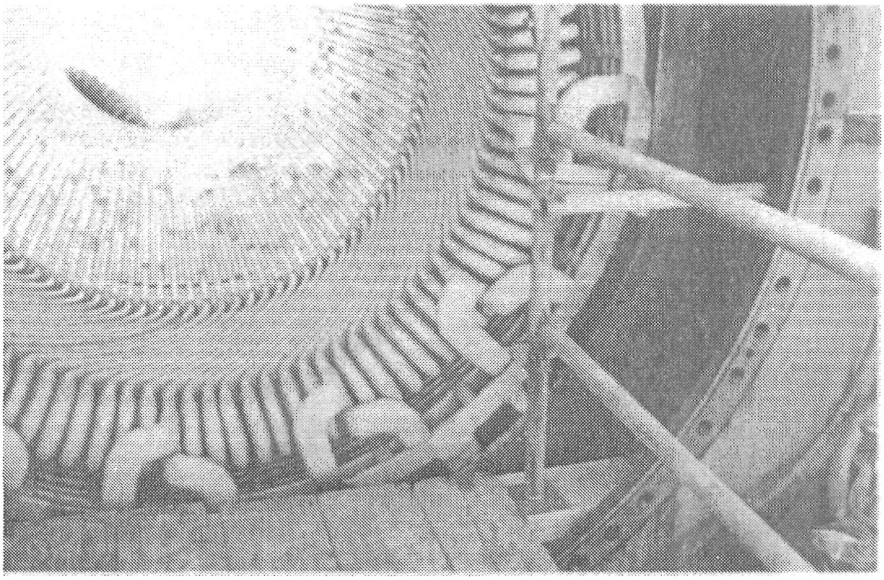

Fig. 1-10 Provisions allowing safe access to the bore of a large generator.

gized during the inspection. The following is a typical (but by no means all-inclusive) list of safety procedures:

- "Personal grounds" (grounding cables) at both ends of the winding of each phase will minimize the possibility of receiving an unexpected electric discharge (Fig. 1-11).
- Phase leads must be open.
- Neutral transformer (if present) must be disconnected, or have its leads opened.
- Voltage regulators and other excitation equipment must be disconnected.
- Potential transformers are an additional source of voltage to the main windings, and therefore they must be disconnected and secured. Space heaters are often overlooked. To keep the moisture out, space heaters are normally left "on" after disassembling the machine; thus, it is imperative to make sure they are disconnected during the inspection.
- All switches that may energize any part of the machine must be clearly tagged. A tag can *only* be removed by the person who installed the tag originally.
- When inspecting machines with direct gas cooling of the stator windings, discharge resistors are often found on the coil knuckles (see Fig. 1-12).

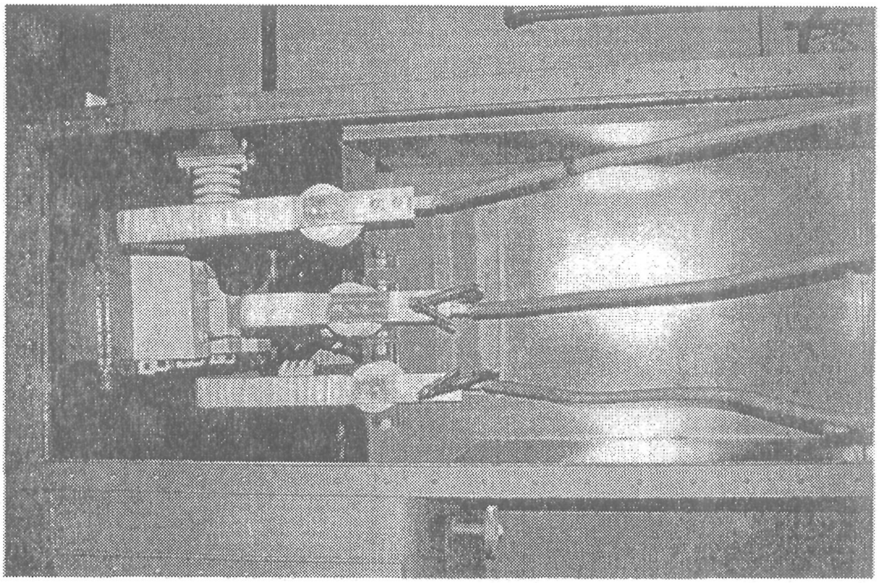

Fig. 1-11 Ground leads applied to a generator unit being overhauled.

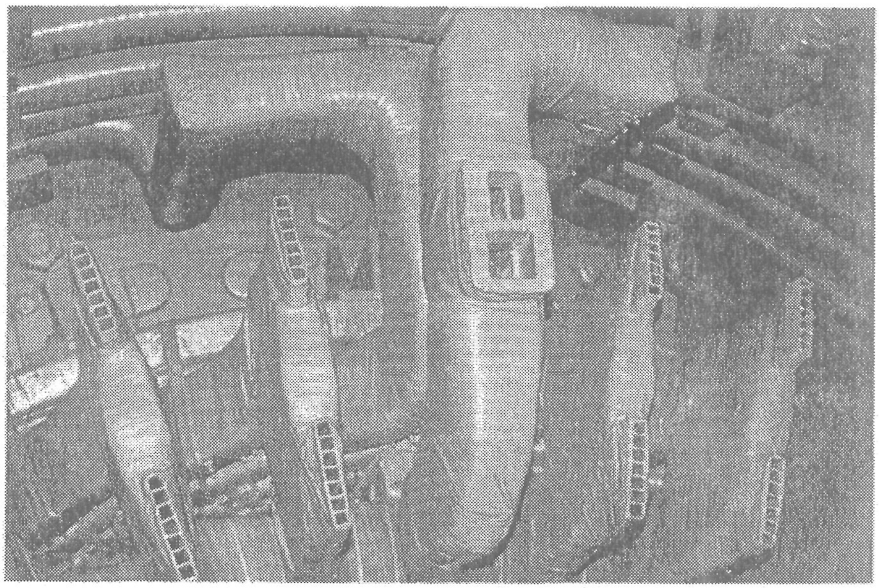

Fig. 1-12 The knuckle area of directly gas-cooled stator coils. The discharge resistors are inside the knuckle area.

When faulty, they may remain charged for substantial lengths of time. Precaution should be taken when inspecting such windings, in particular if high-voltage tests were performed before disassembling the machine. *You can never be too safety-conscious when dealing with high-voltage apparatus.*

- Turning gear must be disconnected (fuses removed) and clearly tagged when inspecting with the rotor in place.
- Gas monitors for confined areas must be used.
- When inspecting hydrogenerators, in addition to the electrical clearance walk, a mechanical clearance walk must be carried out. This should verify the water turbine and valves are locked and secure from inadvertent movement. If possible, the turbine/penstock should be de-watered.
- Additional items as each specific case warrants.
- Follow all relevant safety rules and regulations.

1.3 INSPECTION FREQUENCY

Certain components in large synchronous machines require routine inspections (and sometimes maintenance) between scheduled major outages. Other more comprehensive inspections, requiring various degrees of machine disassembly, are performed during the more lengthy outages.

However, experience has shown that a major inspection after one year of operation is highly recommended for new machines. During the initial period, winding support hardware and some other components experience harsher than normal wear. Retightening of core-compression bolts may also be required during this first outage.

Subsequent outages and inspections can be performed at longer planned intervals. How long an interval? Minor outages/inspections every 30 months, to major outages/inspections every 60 months are typical periods recommended by machine manufacturers. These major outages include removal of the rotor, comprehensive electrical and mechanical (nondestructive) tests, and visual inspections. Obviously, these intervals tend to be longer for machines spending long periods without operation. Most stations have logs containing the actual number of hours the unit was running and the number of starts/stops. This information, together with the manufacturer's recommendations, can be used to schedule the inspections and overhauls.

Large utilities that have many generators in their systems and many years of experience running these machines have formed their own maintenance and inspection criteria and schedules. Although working closely with the respective machines' manufacturers, these utilities tend to extend the periods between outages for those machines that experience has shown to have good records of operation, and shorten the periods between outages/inspections for machines that have been characterized by more frequent failures (as may be the case with old hydrogenerators and rotating condensers).

Frequently, the major outages during which the opportunity presents itself to carry out a major inspection follow the need to maintain the prime mover more than the generator itself.

1.3.1 Condition-Based Maintenance (CBM)

High equipment reliability, high outage costs, and the new competitive outlook permeating the electric power industry have resulted in a new approach to machine maintenance. Condition-based maintenance (CBM) relies heavily on sophisticated on-line instrumentation and evaluation techniques to assess the condition of the machine. In this manner, the periods between major outages/inspections can be increased beyond the fixed, scheduled intervals of the past. The main concept is to base maintenance on the actual condition of the machine rather than on a fixed schedule.

One suggested method of obtaining significant information on the condition of the machine is to retrieve temperature, vibration, PD (partial discharge) activity, air/gas-gap flux, and other readings on the machine under load (prior to shutdown), and compare them with the same test data obtained on previous occasions under similar operating conditions.

REFERENCES

[1] ANSI/IEEE Std 43-1974, "Recommended Practice for Testing Insulation Resistance of Rotating Machinery," Item A2, p. 15.