*GEI 53945D*
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***GE Power Systems***
*Generator*

# Description
# Hydrogen–Cooled Turbine–Generators
# Axial Fan–Conventionally Cooled

**Electrical and Mechanical Features**

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# I. GENERAL DESCRIPTION OF GENERATORS

The hydrogen-cooled turbine–generator is completely enclosed for operation with hydrogen gas as the cooling medium. The ventilation system is completely self-contained, including gas coolers and fans, thus preventing the entrance of dirt and moisture. The separately excited rotating field, driven by the steam turbine, rotates inside the stationary armature and is supported by bearings located in the end shields mounted on the generator frame.

The machine is designed to operate continuously, delivering power from the armature terminals, provisions being made for maintaining the hydrogen pressure and purity and for supplying cooling water and lubricating oil. Temperature detectors and other devices are installed in, or connected with the machine to permit the measurement of the winding and hydrogen temperatures, and the hydrogen pressure and purity. The generator is constructed to withstand all normal conditions of operation including three-phase short circuits and suddenly applied loads without harm. Also, as explained later, the stator casing is made strong enough to limit the destructive effects of an explosion of the hydrogen contents to the generator casing and enclosed parts.

## A. Stator Frame and Spring Mounting

The construction of the stator frame and spring mounting is shown in Figures 1 and 2. The stator frame consists of a gastight cylindrical casing of welded plate construction, reinforced internally in the radial direction by stationary web plates, and in the axial direction by spring bars and braces.

A series of floating web plates are welded to key bars which support the stator core. The key bars are fastened at their ends to the spring bars (see Figure 2) through floating web plates. The spring bars are supported by the fixed web plates. This spring mounting of the core isolates both radial and tangential magnetic vibration of the stator core from the outer frame and results in low frame vibration and quiet operation. The motion of the core is limited to safe magnitudes by means of stop collars on several of the spring bars. The stator core punchings are held under pressure axially by flanges bolted on the ends of the key bars.

The stator frame is supported on the foundation by feet attached to the side of the frame. Heavy end shields which contain the generator bearings are bolted to the ends of the frame. The frame also serves as the support and enclosure for the gas coolers. All end shields, coolers, hand-holes, etc., are carefully sealed to prevent leakage of hydrogen from the generator.

## B. Stator Core

The stator core is made up of segmental, annealed, insulated punchings of preferred grain-oriented, high-quality silicon steel to give minimum electrical loss. These punchings are assembled in an interleaved manner on key bars (ribs) and are separated into packets by space blocks to provide ventilation ducts. The punchings are stamped from thin steel sheets and contain open-end slots for the armature bars with dovetail slots for wedges to hold the armature bars in place. Other dovetail slots at the back of the punchings are for assembly and locking of the segments on the key bars. The assembled punchings are clamped into a stiff cylindrical core by pressure applied through ductile cast-iron end flanges by means of the stator key bars. Pressure is applied to the teeth by non-magnetic steel fingers located under the end flanges. See Figure 3. In order to reduce end heating from end leakage flux and its associated electrical losses occurring at the ends of the stator core, the end packets of punchings are stepped back to increase the gap between the punchings and the rotor. The punching insulation is a thermo-setting varnish containing “Santocel” which maintains its insulating value at temperatures above the normal operating range.

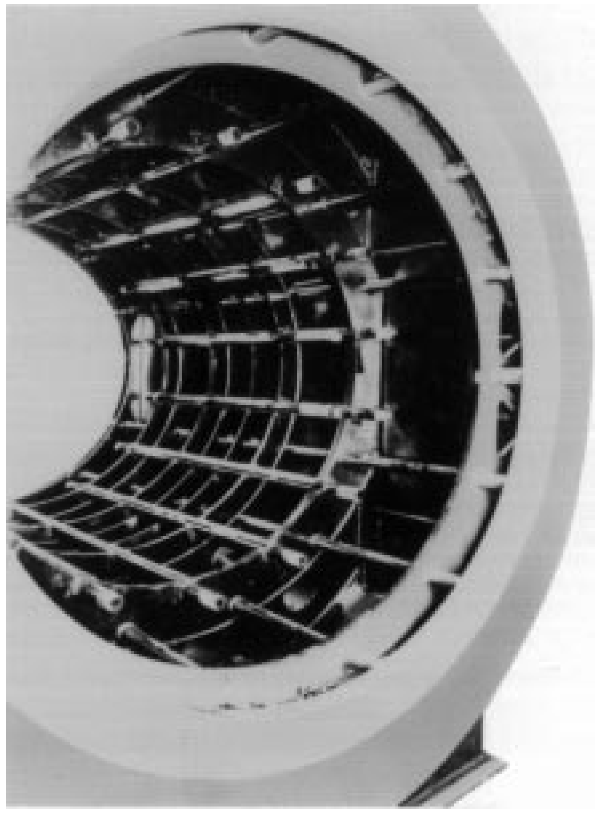

**Figure 1. Typical Stator Frame for Hydrogen–Cooled Turbine–Generator**

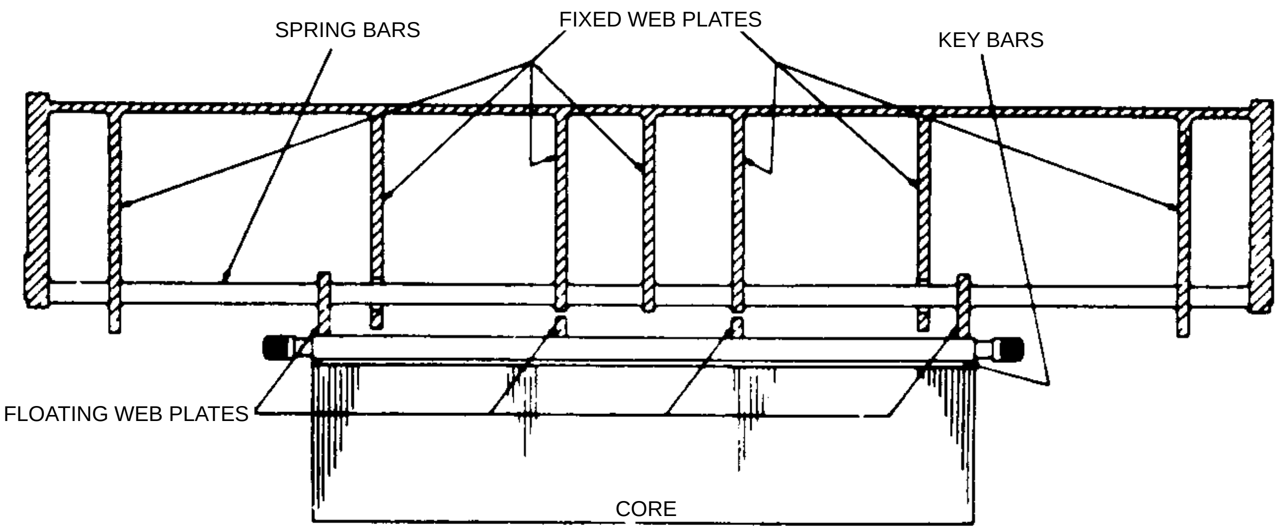


**Figure 2. Spring–Bar Mounting of Stator Core**

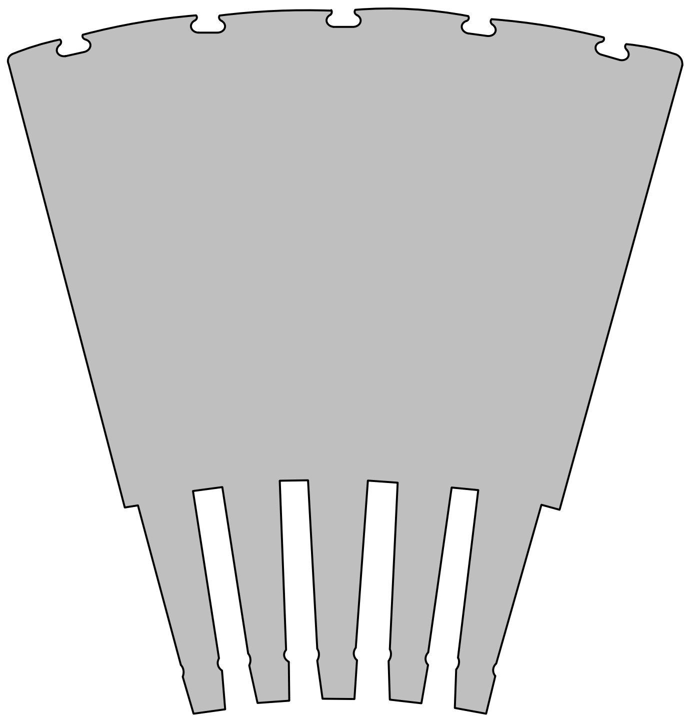

**Figure 3. Stator Punching**

## C. Stator Winding

The stator winding, Figures 4 and 5, is composed of insulated bars assembled in the stator slots, joined at the ends to form coils, and connected in the proper phase belts by bus rings. Each phase is split into groups of coils 180° apart. The stator bars are composed of insulated copper conductors (strands) transposed by the “Roebel’ method so that each strand occupies for an equal length along the bar every radial position in the bar, or by a twisted lead transposition for multiturn bars. This arrangement avoids circulating current loss which would otherwise be present under load conditions due to the self-inductive distribution of magnetic flux in the coil slot. See Figure 6 for details of the transposed bar.

The bars are insulated with several layers of mica tape and impregnated with a bonding compound. At several different stages of the taping process, the bars are placed in a tank and subjected to heating, vacuum, and pressure cycles. This process removes moisture and solvents from the insulation and eliminates any voids.

An outer covering of asbestos tape is applied to the core portion to protect the bar from abrasion in the slot. In order to minimize the effect of corona, slightly conductive paint (containing graphite) is then applied to the bar in the slot portion and extending several inches beyond the core.

Stator coil ends are covered with an outer layer of tape to bind and protect the mica insulation after which they are sprayed with oil-resistant varnish. These end turns are securely laced with treated glass cord to the binding bands, which are molded fiberglass rings supported from the stator core flanges. See Figure 7. The armature bars are held in the coil slots by Textolite* wedges driven into the dovetail slots.

* Registered trademark of the General Electric Co.

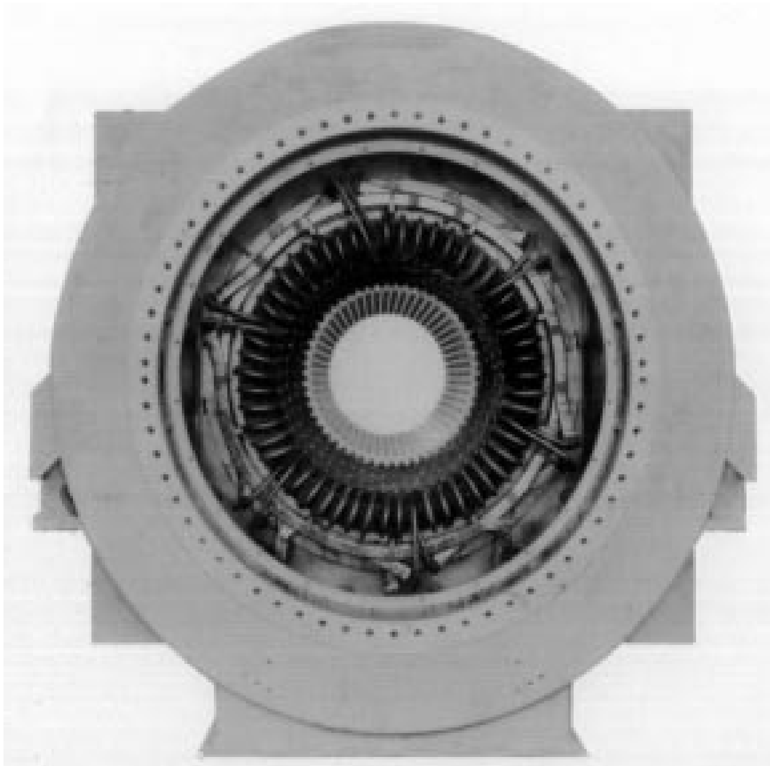

**Figure 4. Stator Core End Windings for a Two–Pole, Spring–Bar Mounted Hydrogen–Cooled Turbine–Generator**

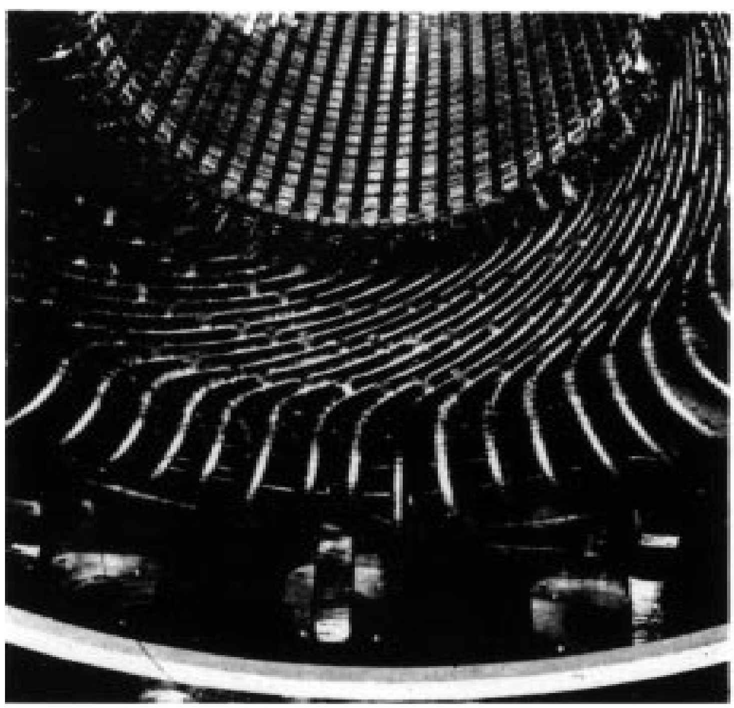

**Figure 5. Stator Winding End Turns and Connections for a Two–Pole, Spring–Bar Mounted Hydrogen–Cooled Turbine–Generator**

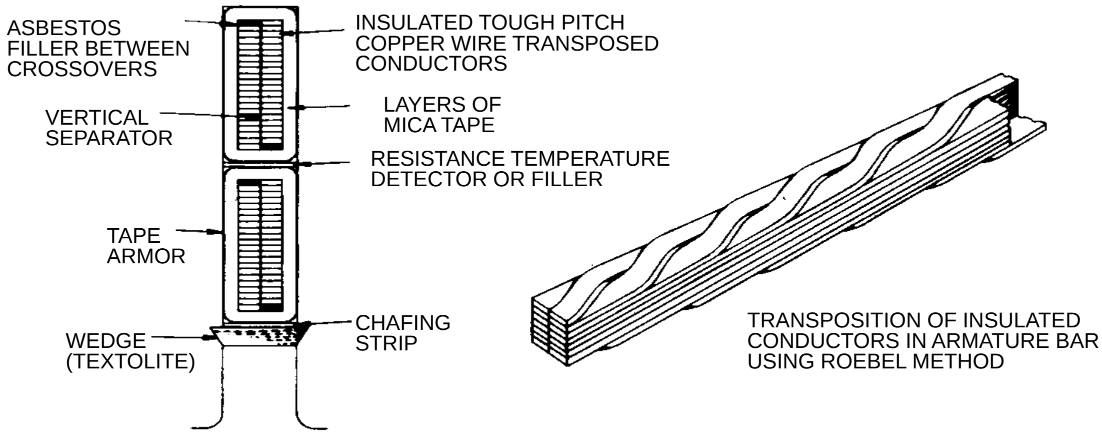


**Figure 6. Armature Conductors Assembled in a "Roebel Bar"**

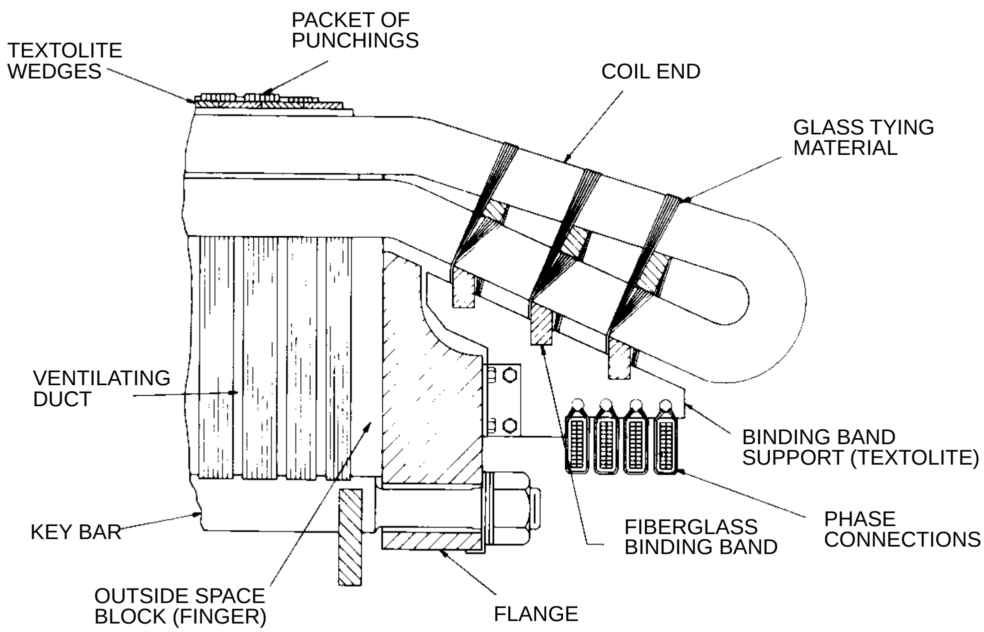


**Figure 7. Sketch of Stator End Winding Structure**

## D. Resistance Temperature Detectors and Terminal Boards

Six or more temperature detectors of the resistance type are located between coils in each phase of the armature windings to measure the temperature of the windings at the points of highest normal temperature.

Eight gas temperature detectors are provided to measure the inlet and outlet gas temperatures of each of the four coolers. The leads from the detectors are brought out through a gastight gland in the generator frame and connected to terminal boards for connection to temperature meters or relays. The locations of the resistance temperature detectors, the arrangement of connections at the temperature terminal board, and details of connections of a temperature detector to the customer's leads for a temperature meter are shown on the connection outline drawing. A description of the detector terminal boards is given in the instruction on TERMINAL BOARD, RESISTANCE TEMPERATURE DETECTORS. A description of the detectors and circuit is given in the instructions for RESISTANCE TEMPERATURE DETECTORS.

### E. Generator Terminals and Terminal Plates

The main armature leads are brought out at the bottom of the generator casing through the generator terminal plates, Figure 5, at which point connections are made. On most generators, connections are provided at the collector end (opposite the turbine coupling). To minimize induced current losses and heating caused by load current in the leads, the terminal plates are made of non-magnetic material. Drains are provided in the terminal plates to prevent accumulation of oil or water around the connections. Gaskets are provided between the terminal plates and the stator frame to prevent hydrogen leakage.

### F. High–Voltage Bushings and Current Transformers

The armature leads are brought through the terminal plates by means of gastight, high-voltage bushings (see Figure 8). These bushings consist of one-piece porcelain insulators containing a copper conductor. Silver-plated terminal studs are provided at each end of the bushings for making the connections.

Many machines are provided with longer bushings on which bushing-type current transformers are assembled. A description of these transformers and instructions for their assembly is given in the BUSHING CURRENT TRANSFORMER instructions. (This reference is furnished only if the generator to which these instructions apply is provided with bushing-type current transformers.)

### G. Gas Coolers

Generator gas coolers are mounted vertically in the cooler towers at the four corners of the frame on cooler supports. The section VERTICAL COOLERS gives a description of the coolers. Water pipe connections are made externally at the bottom of each cooler. Hydrogen seals are made by gaskets compressed between the generator frame and the cooler tube sheets, at the top and bottom of the coolers. A complete description of these seals and the method of assembly is given in the section on MAINTENANCE.

**CAUTION**

**Servicing or repairing the cooler while the generator is operating with hydrogen in the casing is extremely hazardous and should not be attempted.**

### H. Stator Ventilation

The rotor fans provide for the ventilation of the generator. They are the axial flow type with individual blades fastened to fan hubs near the ends of the rotor. The entrance and exit conditions of the gas to and from the fans is controlled by an inlet nozzle.

The stator ventilating circuit is shown in Figure 9. Hydrogen is forced by the fans into the gas gap, and also around behind the stator core. The stator is divided axially into sections by the web plates and outer wrapper so that in some sections cold gas is forced from the outside of the core toward the gas gap through the radial gas ducts, and in other sections it passes from the gas gap toward the outside of the core through the radial gas ducts. The cooling gas is conducted through tubes or ducts to the proper section, and hot gas is directed to the coolers. After the heat is removed, cold gas is returned to the rotor fans and recirculated.

**Figure 8. High Voltage Bushing**

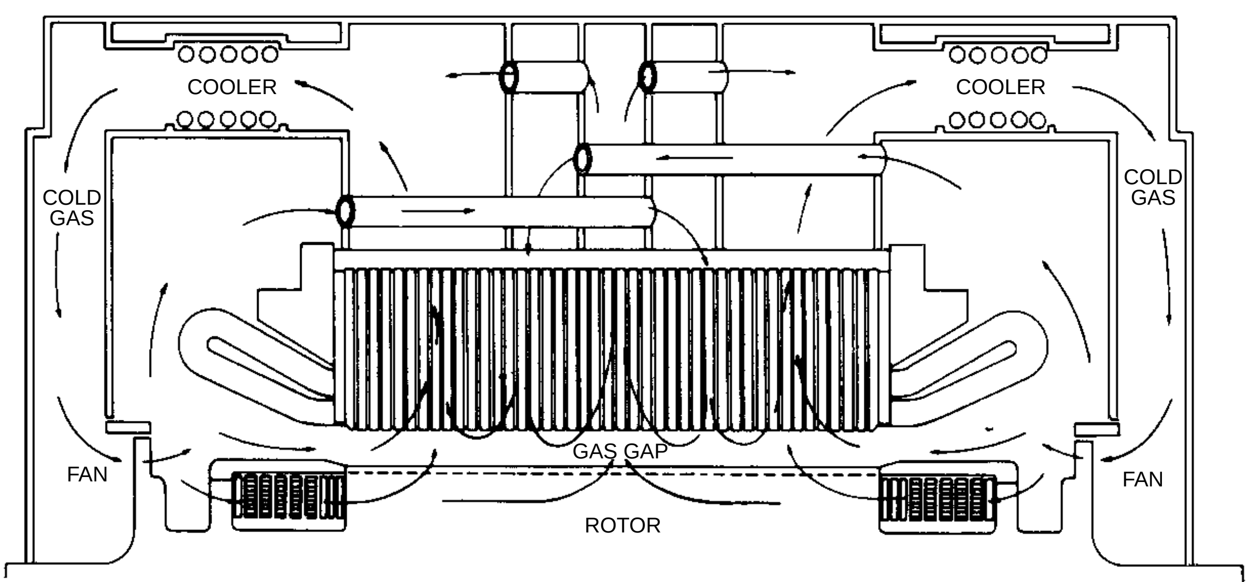


**Figure 9. Ventilating System for Hydrogen–Cooled Generator**

The arrangement of alternate inward and outward gas flow in the stator core results in a substantially uniform cooling of the core and windings, thus avoiding excessive local heating and reducing stresses caused by temperature differentials.

## J. Generator Rotor (Mechanical and Ventilation)

The construction of the generator rotor is illustrated in Figures 10 and 11. The rotor is machined from a single alloy steel forging which has passed extensive tests to assure that the forging meets the required physical and metallurgical properties.

Longitudinal slots, machined radially in the body, contain the field coils. Additional slots, machined in the teeth, provide ventilation for the rotor body. The field coils are held in the slots against centrifugal force by steel wedges, both magnetic and non-magnetic types being used to secure proper flux distribution. These wedges are individually fitted and driven into dovetail openings machined in the rotor slots.

The rotor fans, provided for the ventilation of the generator, are assembled near the ends of the rotor. The rotor is cooled externally by the gas flowing along the gap over the rotor surface, and internally by gas which passes under the rotor end windings, through the rotor vent slots, and radially outward to the gap through holes in the ventilating slot wedges.

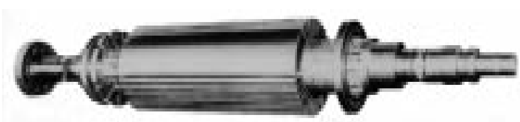

**Figure 10. Machined Rotor**

**Figure 11. Completely Assembled Rotor**

## K. Field Winding and Retaining Rings

The field winding consists of rectangular copper bars, edgewise bent and formed into coils. Several turns in one pair of slots around one pole form a coil. Several coils are assembled around each pole to form the winding. The individual turns are insulated from each other. The coils are insulated from the slot wall in the body portion by molded slot liners. To provide maximum ventilation and cooling, the end portions of the field coils are left bare except for turn insulation on alternate turns. Molded ring insulation is provided between the coils and the retaining rings, and Textolite blocking is provided in the end windings to separate and support the coils and restrict their movements under stresses from temperature and rotational forces.

The end turns are held in place against centrifugal force by heavy retaining rings machined from high–strength, heat-treated alloy steel forgings which are shrunk and locked onto the centering rings. The centering rings may either be forged integral with the shaft or shrunk and keyed onto the rotor shaft.

## L. Collector and Collector Connections

Current is supplied to the field windings through the collector rings which are connected with the winding through insulated copper bars assembled in the bored-out center of the rotor forging and connected electrically to the field winding. At one end of the connection bars, terminal rods, or studs, assembled in radial holes in the rotor shaft, connect the winding with the bars; at the other end, the bars are connected to the collector.

The collector is a built-up assembly consisting of a forged steel shell, a molded mica shell for insulation, and two pairs of grooved, forged steel rings (see Figure 12).

The mica is molded and baked on the steel shell and the collector rings are shrunk over the mica. A binder of reinforced plastic supports the mica insulation between collector rings and at the end of the shell. The complete assembly is shrunk on the generator shaft.

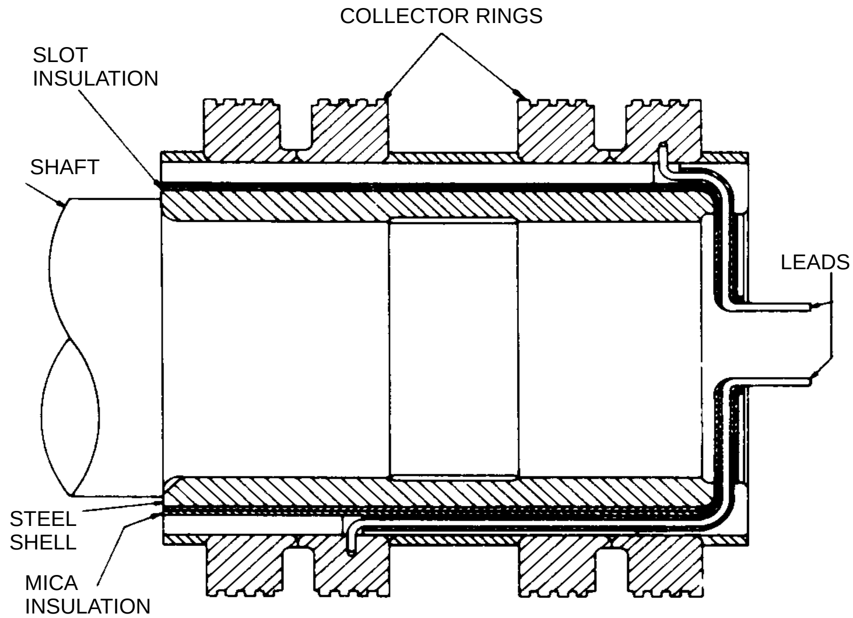


**Figure 12. Collector Assembly**

The mica shell insulates the collector rings from the steel shell and, therefore, from the shaft. Because of the large shrink fit between the rings and the shell, it is very nearly impossible to remove the rings without destroying the mica. For this reason the entire collector assembly should be treated as a unit and no attempt should be made to remove an individual ring. A more complete description of the collector and instructions for its maintenance is given in the instructions, INSTALLATION AND MAINTENANCE OF BRUSH RIGGING AND COLLECTOR RINGS.

## M. Brushes and Brush Holder Rigging

A description of these devices through which current is supplied to the collector, together with their operation and maintenance, is given in the instructions, INSTALLATION AND MAINTENANCE OF BRUSH RIGGING AND COLLECTOR RINGS.

## N. End Shields and Bearings

The generator rotor bearings, the hydrogen shaft seals, and oil passages for supplying oil to these parts are contained in the outer end shields. The end shields are split on the horizontal center line to facilitate their removal. The joints between the shield halves and between the shields and the stator frame are fitted and provided with grooves for the insertion of sealing compound to seal the gas in the machine.

The rotor bearings are provided with ball seats. A detailed description of the bearings is shown in separate instructions listed in the Table of Contents of the composite book for the set.

The escape of hydrogen from the generator along the shaft is prevented by a shaft seal attached to each outer end shield, inboard of the bearing. This arrangement permits inspection of the generator bearings without removing gas from the machine. The design of these seals is shown in detail in the instruction book on the SHAFT SEALING SYSTEM.

Both the bearing and the shaft seal housing at the collector end of the machine are insulated from the generator frame to prevent the flow of shaft currents. When a direct-connected exciter is attached to the generator shaft , insulation is provided for the exciter coupling to insulate the shaft from the exciter.

Inner end shields are located between the ends of the armature windings and the outer end shields to separate the gas discharged from the fans from the gas entering the fans. Gas seal rings are attached to the inner end shields to prevent gas leakage from the fan discharge back to the fan inlet.

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