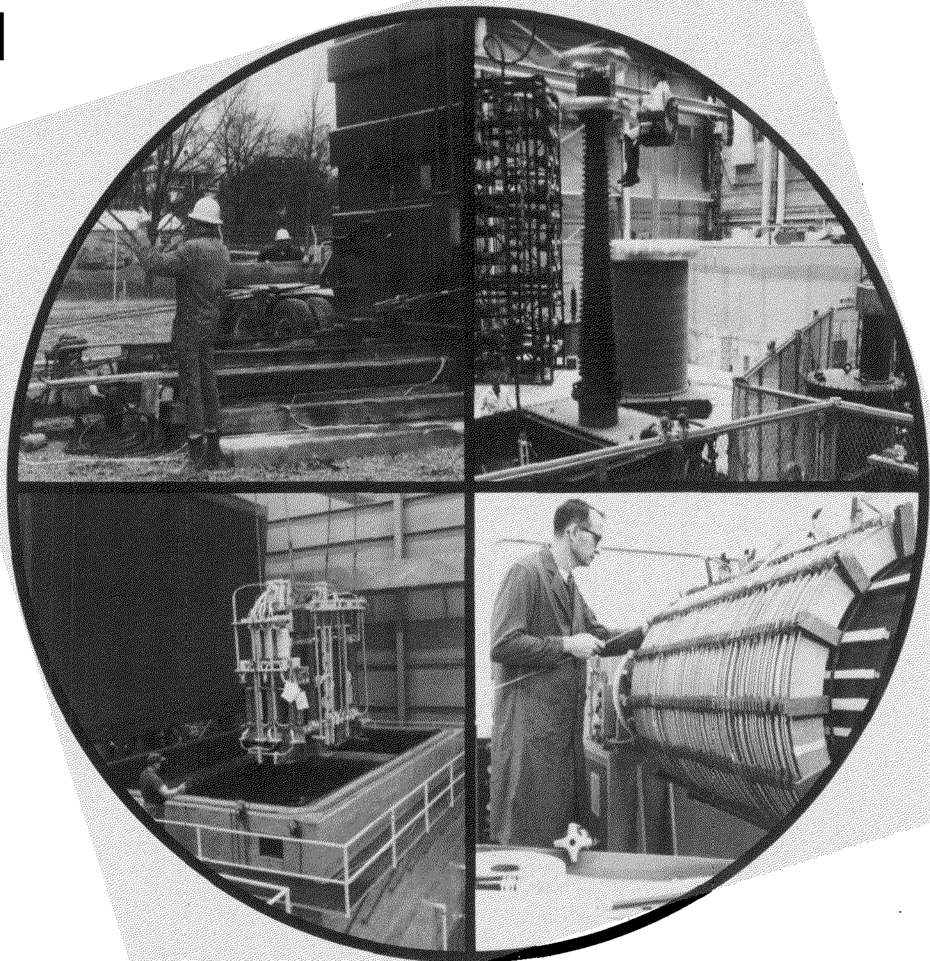
GEA – 11047-A

Primary Substation Transformers

12,000 thru 30,000 kVA 3 Ø
with & without LTC

GENERAL ELECTRIC

INTRODUCTION



This publication covers those Primary Substation Transformers manufactured at the Rome, Georgia plant of General Electric that are rated from 12,000–30,000 self-cooled kVA, three-phase. They deliver rated kVA with a winding temperature rise over ambient of 65°C, in accordance with ANSI Standard C57.12.10–1977 and C57.12.00–1980.

High voltages range from the 110 kV BIL, 15 kV voltage class, to 650 kV BIL, which may include 230 kV voltage class with modern surge arrester protection. Low voltages range from 120 volts to 69 kV class.

General Electric Primary Substation Transformers have won an enviable reputation for reliability. It's natural that they should. Years of experience have given General Electric extra insight into substation performance requirements. General Electric researchers and engineers have attacked these requirements with innovative transformer designs. Unparalleled manufacturing and testing facilities carefully translate these designs into transformers that will meet your specific substation applications.

The information and data on the following pages will give you specific details on "what we do" and "how we do it" concerning the design, construction and testing of Primary Substation Transformers.

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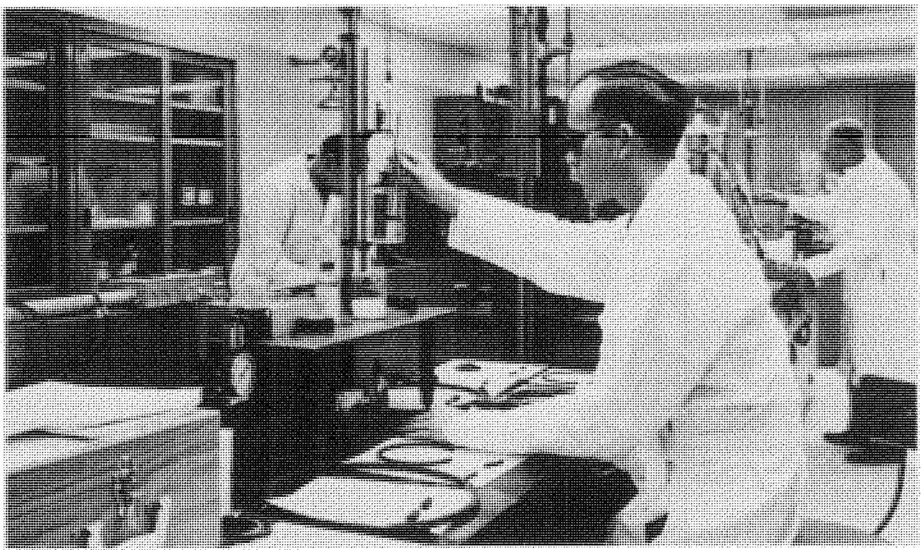
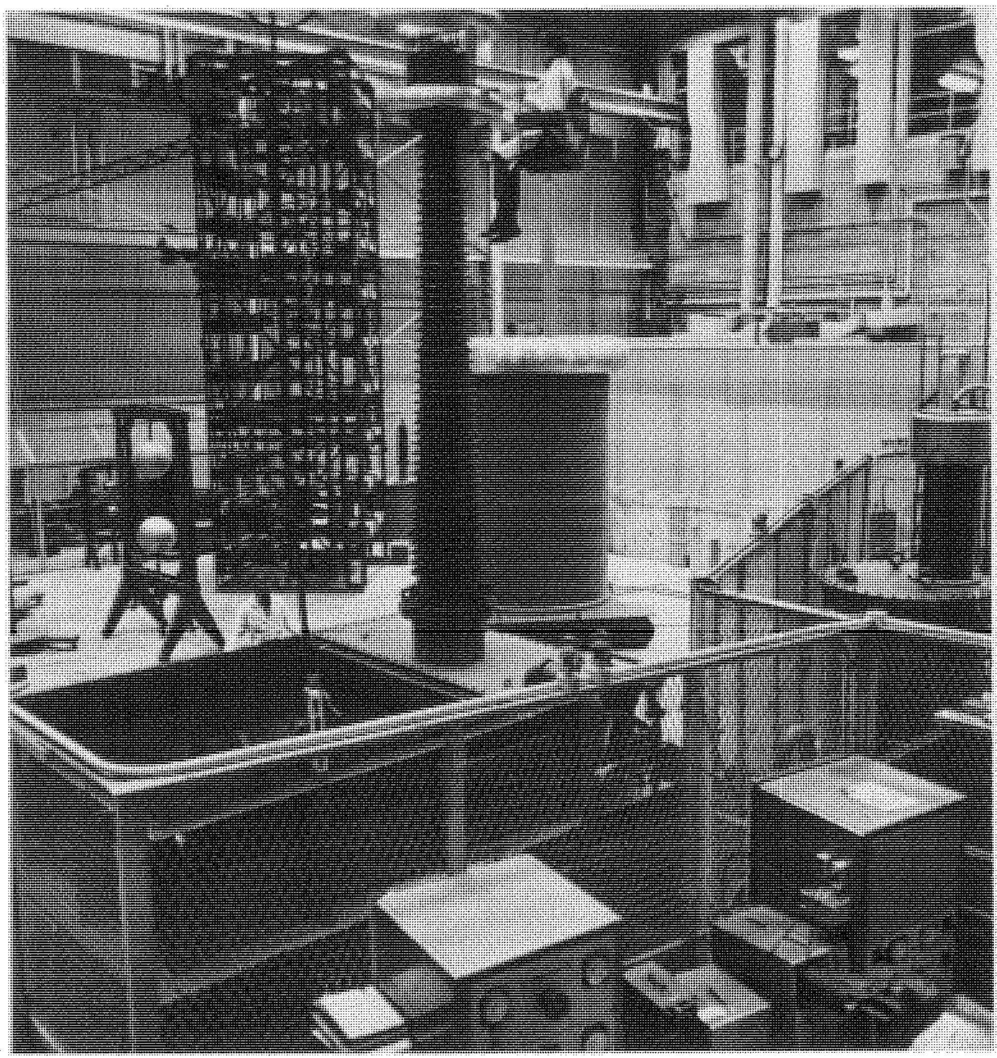
PERSONNEL AND RESEARCH

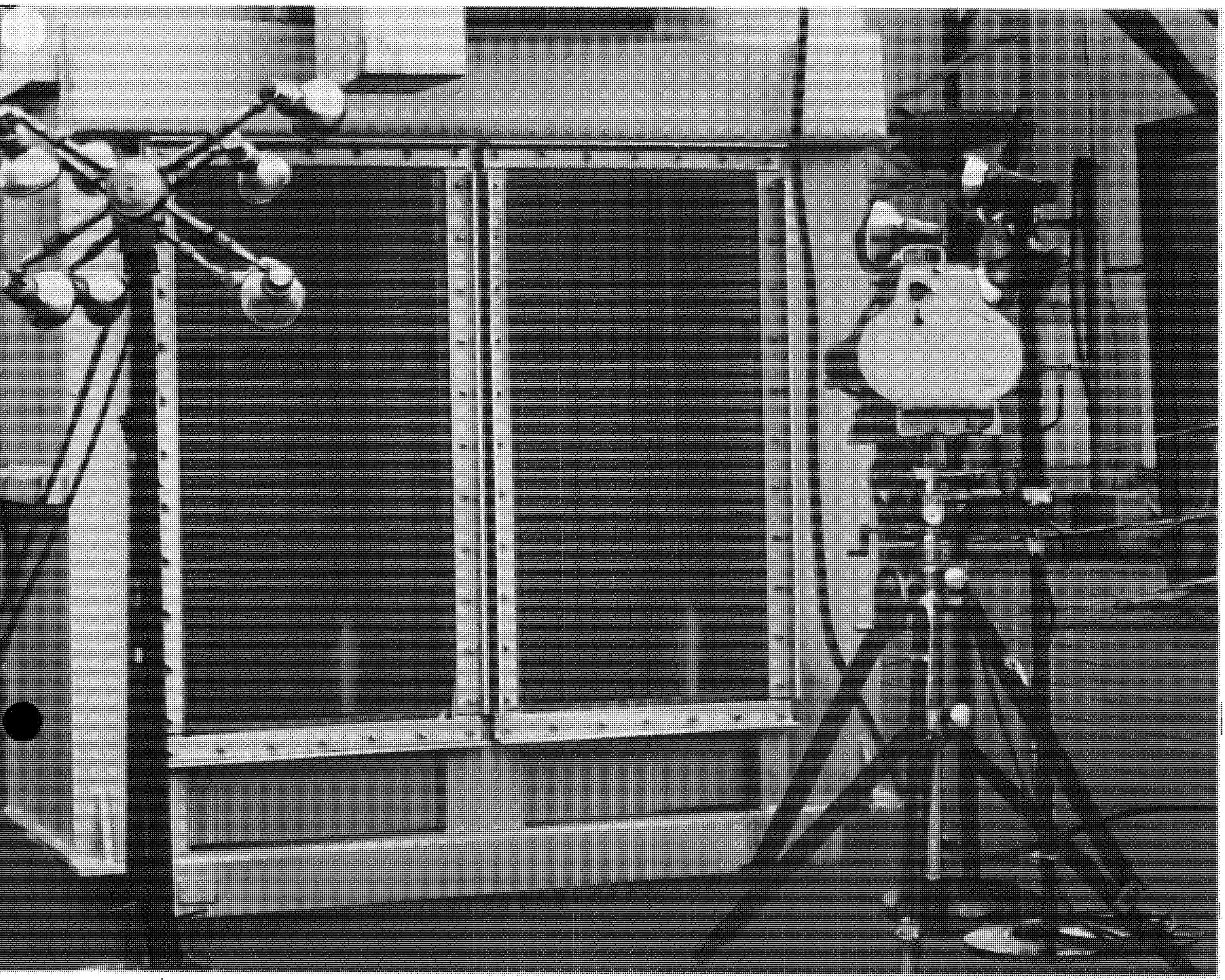
Modern manufacturing facilities, coupled with the skills and know-how of experienced personnel, bring you the utmost in product quality and performance reliability. Working with the most sophisticated equipment, GE scientists and engineers probe deep into the behavior of metals, insulating liquids, paper and other transformer materials. This sustained research allows GE engineers to utilize the best combination of materials and methods when designing your transformers.



There are many possible designs which will meet a particular transformer specification; only one will be better than all the others. An individual engineer could not exhaust all the possibilities, and therefore might miss the best design. The design logic of General Electric's best transformer engineers is stored in computers. This tool enables the engineer to design the optimum transformer quickly and accurately, enumerate the detailed drawings required, prepare templates for parts and tapes for the control of automatic fabrication equipment, and schedule the transformer through the factory. This is the kind of professional engineering and manufacturing know-how that gives General Electric transformers added reliability and the ability to meet your delivery requirements with on-time shipments.



SHORT CIRCUIT STRENGTH AND TESTING



Transformer in short circuit test cell, High Power Laboratory

In order to assure satisfactory service, power transformers must be designed to withstand anticipated short-circuits and the effects of internal electromagnetic forces they will generate. Through the years this aspect of design and in-service performance has gained increased attention as larger systems resulted in higher magnitudes of short-circuit currents; as new operating techniques and breaker operating practices evolved; and as transformers themselves became more complicated.

With the announcement of its Proposed Short-Circuit Test Code in 1970, General Electric committed its research, development, engineering and production facilities to the design and manufacture of power transformers that are second to none in reliability. A continuous program of short-circuit testing of full-size production units has yielded valuable data that is used by our design engineers to shape transformer designs for maximum short-circuit capability, optimum performance and long life. For years designers had to deal with short-circuit forces empirically, but today—with sophisticated computer programs—utilizing the data from the GE short-circuit testing program—they are able to minimize and control these forces in every transformer design.

When this design expertise is coupled with the latest in materials, manufacturing processes, testing and quality control procedures, the resulting Primary Substation Transformers have a built-in short-circuit strength and capability unsurpassed in the world.

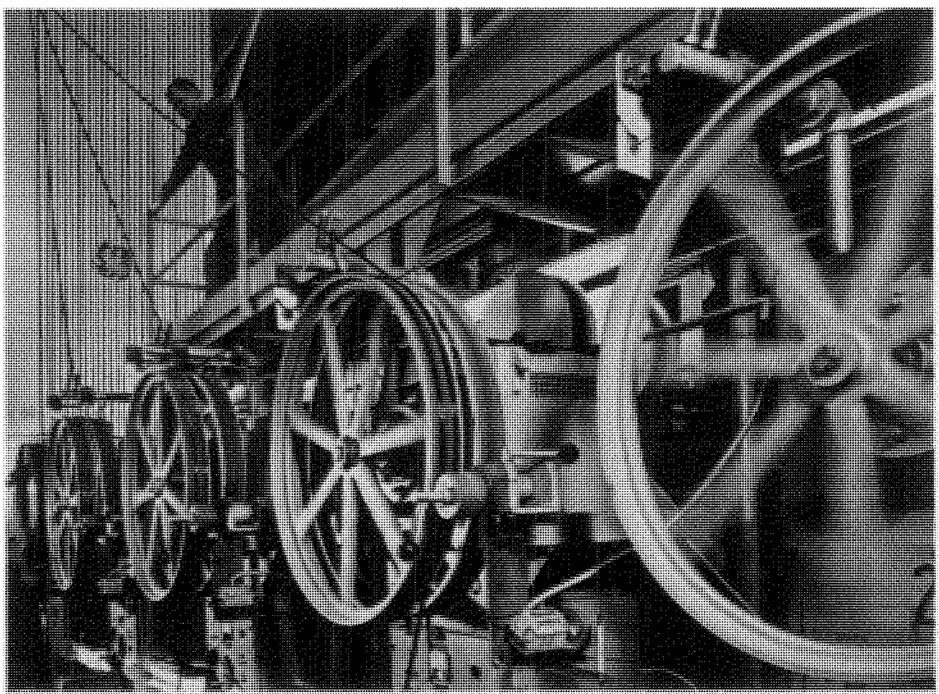
All transformers built in the General Electric Rome, Georgia plant are designed and manufactured to meet the demanding requirements of ANSI Short-Circuit Standards: C57.12.00 – 1980 – Section 7 and Test Code C57.12.90 – 1980.

INSULATION SYSTEM

All Primary Substation Transformer core-and-coil structures are designed with the aid of a computer. Design requirements for flux density, winding type insulation, cooling, sound levels, and structural integrity are accurately computer calculated. In addition, optimum weight, size and configuration for each core and coil is computed. Result: a structure which is both physically and electrically designed to your specifications.

The insulation system is the most important system within the transformer. Its design is a major consideration in the overall design of the transformer. Sufficient strength must be built into the insulation system to withstand normal operating voltages, as well as abnormal over-voltages caused by lightning and switching surges. Since the insulation system is under continual electrical stress, even under normal operating conditions, it must be designed to withstand this stress in order to prevent breakdown and interruptions in service.

The Insulation System's useful life can be greatly curtailed by moisture created from the decomposition of cellulosic materials. Generally, these materials are the paper parts used in the insulation system near and in the windings where higher temperatures cause more rapid aging. Moisture from decomposition reduces the tensile and dielectric strength of the paper from which it was generated, and accelerates the rate of decomposition. It also reduces the dielectric strength of oil and other insulations as they absorb the moisture that is produced. To minimize these effects, General Electric uses a "thermally uprated" insulation system. Model transformers, built to scale and using the same materials that are in production transformers, are life tested. By carefully controlling the temperature, it is possible to run accelerated life tests on proposed designs and various configurations of insulation systems and materials in order to locate and eliminate possible weak spots in each particular system and structure.



Automatic equipment apply Formex® insulation to conductor wire.

1. CONDUCTOR INSULATION

Raw aluminum or copper rod is drawn, rolled and annealed to be rectangular wire, completely uniform and burr free.

Formex® film insulation is applied by special equipment which uniformly covers, totally cures, and securely bonds the film to the wire. Formex has high dielectric strength and is practically immune to damage by bending, stretching, or scraping. Transformers rated up to 550 kV BIL use wire insulated with Formex.

For higher stressed turns, and for entire turns on high-voltage windings above 550 kV BIL, several wrappings of thermally-uprated paper are used in addition to Formex.

Each winding is formed on a separate insulating cylinder for sturdy mechanical foundation. The cylinders also serve as major insulation between core and windings and between the low- and high-voltage windings.

High-quality winding insulation aids short-circuit protection.

General Electric controls the quality of its conductors by special processing done completely in our own plant. Rod is first shaved to remove surface irregularities and impurities, then drawn to proper diameter, and finally rolled into rectangular shaped wire. Conductor corners are rounded during the rolling operation to eliminate sharp edges and to provide a surface that will permit the uniform application of film insulation. The wire is finally annealed to remove stresses encountered in the drawing and rolling processes.

2. WINDING CYLINDERS

Each winding is wound on a separate insulating cylinder which supports the winding and serves as major insulation between the core and low-voltage winding and between the low-voltage and high-voltage windings.

The **low-voltage** winding, which experiences crushing compressive forces under short circuit, is wound on a special insulating cylinder of high physical and dielectric strength. These cylinders are constructed of Kraft paper impregnated with polyester-resin. This bonding polyester-resin is a modified thermo-setting material that is applied in a continuous dip process to heated paper and provides cylinders that are free from voids with a modulus of rupture averaging 25,000 psi.

Since any breakdown of the insulation system can be detrimental to the operation of the transformer, special care is taken during manufacture to produce a cylinder free of inclusions and voids.

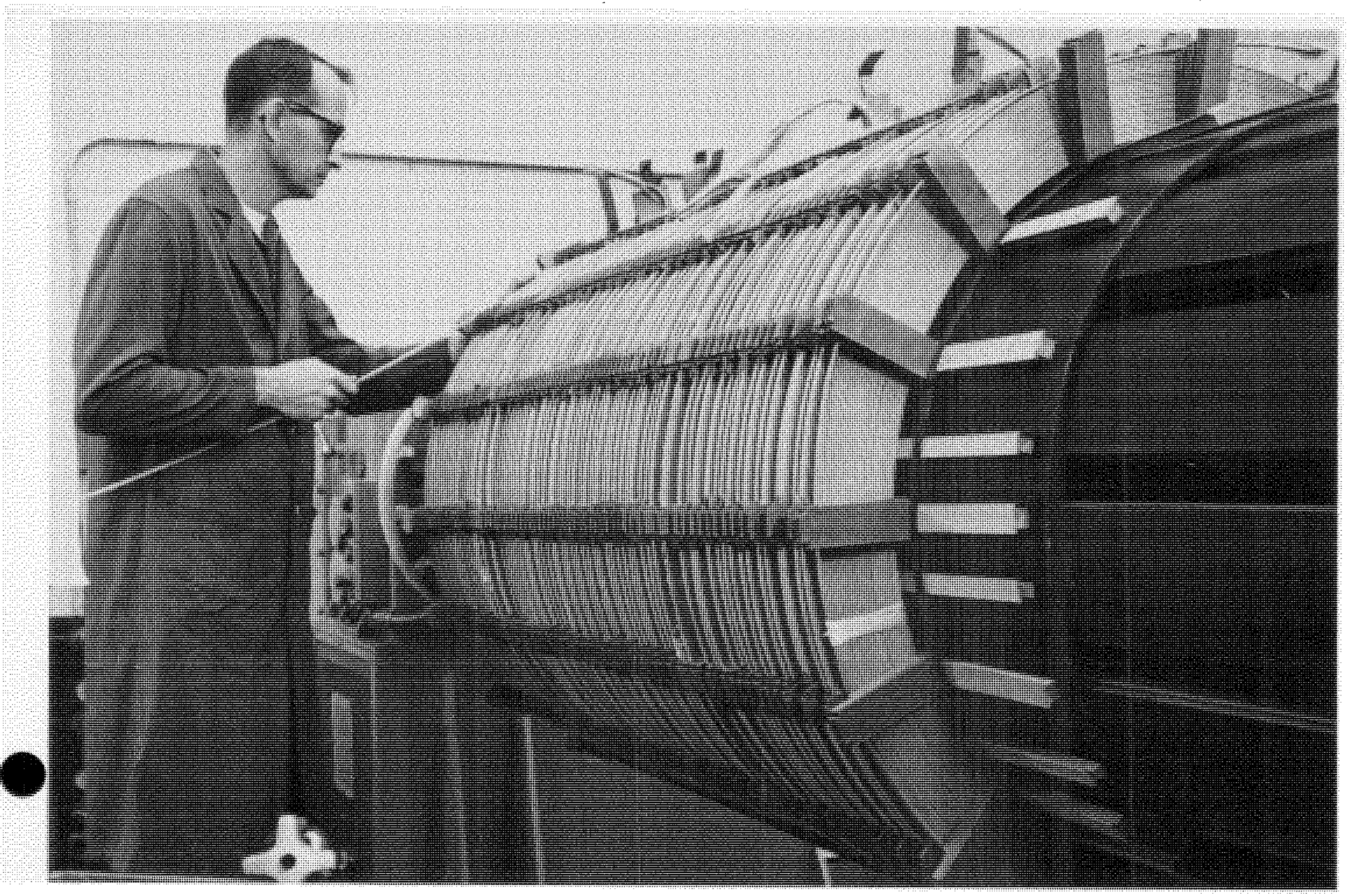
High-voltage winding cylinders are constructed of heavy electrical grade Kraft paper. Individual turns are bonded during manufacture by the use of a special adhesive, resulting in a rigid cylinder free of voids and capable of absorbing the insulating oil.

3. ELECTRICAL GRADE KRAFT PAPER

One of the other components of the high temperature insulation system used in General Electric transformers is electrical-grade Kraft paper ("Electrical-grade" signifies the best in both chemical and mechanical qualities of paper insulation). Purchased from long-established suppliers, this material is subjected to a continuing quality control program of "aging tests" to provide both initial design data and information on the ability of the paper to withstand the operating demands of time and temperature inside the transformer.

4. INSULATING OIL

Refined especially for this application, the oil is desiccated and deaerated upon receipt at the factory. Each incoming batch is routinely tested for dielectric strength and for the presence of impurities. Further, the product of each supplier is subjected to a continuing program of screening tests to provide initial design data and aging characteristics.



CORE AND COIL STRUCTURE

All Primary Substation Transformer core-and-coil structures are designed with the aid of a computer. Design requirements for flux density, insulation, cooling, sound levels, and structural integrity are accurately computer calculated. In addition, optimum weight, size and configuration for each core and coil is computed. Result: a structure which is both physically and electrically designed to your specific application.

Start with quality steel for flat laminations

Cores are built of high-grade, grain-oriented, silicon steel laminations. The steel is first subjected to rigid quality tests. It is then slit to width, cut to length, and built into high quality cores having the desired performance characteristics.

Form a superior magnetic circuit to reduce sound, improve performance.

Laminations of the core legs and one-piece yoke are interleaved in mitred joints. This construction improves flux distribution, reduces losses and sound emission.

Core legs and yokes are stepped identically. The resulting electro-magnetic balance reduces transformer noise and losses. It also enables General Electric to include as many vertical ducts as necessary to cool the core by natural oil flow.

The massive core (Fig. 1) must be securely and tightly contained to assure that the designed loss and sound levels are maintained, and to reduce the possibility of damage during shipping.

Core legs are held rigid by tie plates on both sides, banded to (but insulated from) the core legs. These tie plates are locked to the top and bottom core clamps by a unique combination of a reinforcing plate boss and locking method.

The top core clamps are sturdy box-type, pre-bowed to give positive and uniform clamping pressure over the entire length of the core yoke. The bottom core clamps have large flanges for extra strength. On the ends of the bottom and top core clamps are installed Rome-designed adjustable core cam-plates. (See Fig. 2.) These unique cam-plates exert a holding pressure against the ends of the core legs in a direction parallel with the long dimension of the core. Firmly adjusted end clamps help prevent a loose core, which could result in high losses and sound levels.

This combination of core clamps, tie plates and core cam-plates forms a mechanical structure that will maintain its position and form even under the severe stresses which may be encountered during shipment and during the coil-clamp tightening operation required to prevent winding movement during short circuits.

Once the assembled core and coil has been placed in its tank, additional bracing is installed. Tanking wedges are positioned between the tank wall and the top core clamps in all four corners. These wedges rigidly brace the internal assembly within the tank to prevent damage in shipment and handling. The bottom core clamps have locating holes that fit over locating pins welded to the inside bottom of the tank.

This extra care in clamping and bracing means that the design loss and sound levels are maintained and that in-transit damage is prevented.

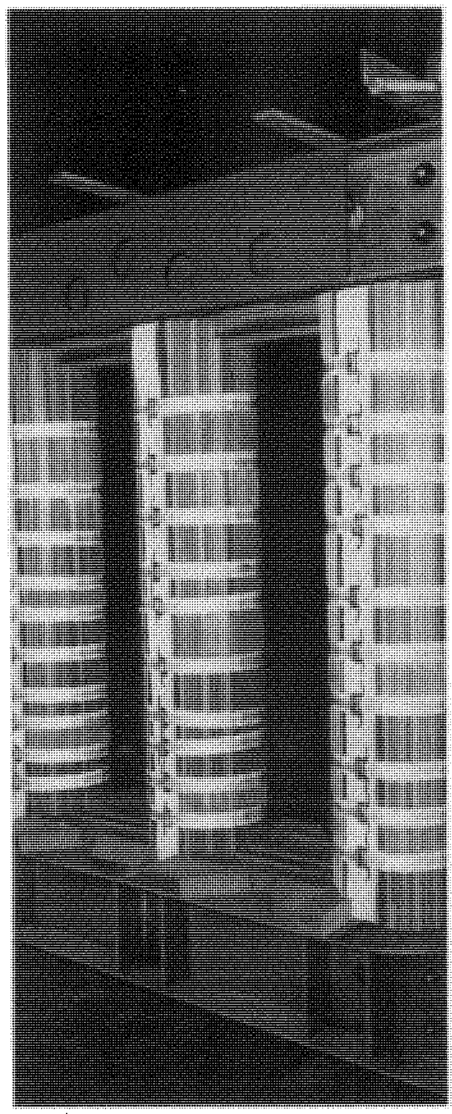


Fig. 1 — All cores are securely locked in place by core clamps

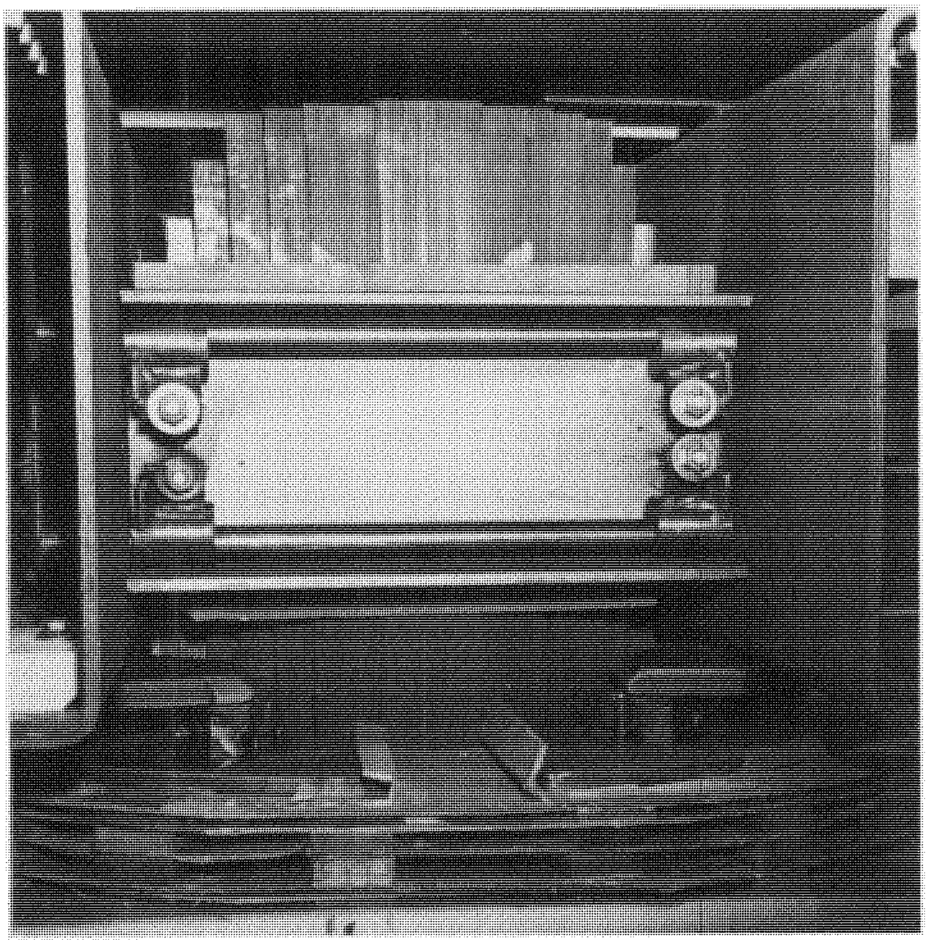


Fig. 2 — Unique core cam-plates help hold core in place.

Winding types match application requirements

General Electric employs two basic winding designs: helical, and disc. Although different, these designs have certain basic performance parameters in common.

For each kVA and voltage classification of transformer, there is a particular value of winding-rise over oil temperature at which the winding should operate for maximum service. For each application, General Electric engineers select the one winding design that meets the electrical and overall size requirements at the lowest operating cost and loss levels.

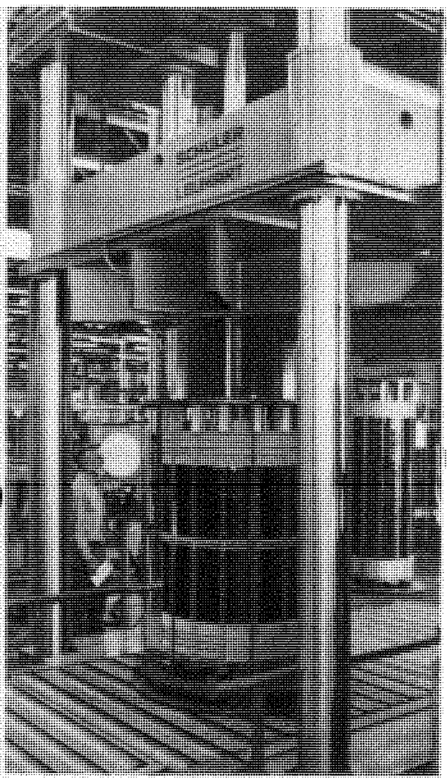


Fig. 4 — Special equipment lock coil assembly in place.

A transformer winding must initially be both tight and strong and must remain so in service. In order to help maintain this quality in General Electric windings, *keyed spacers* are employed between coil sections (Fig. 3). *These spacers are mechanically locked in place* so that they cannot turn or slip out of position under the shock and stresses of operation (Fig. 4). They are made of very dense precompressed pressboard and the edges are rounded to prevent damage to the conductor. Being vertically "in-line", they provide rigid supporting columns for the winding, and assure that clamping forces will be evenly distributed throughout the coil.

RIGID COIL CLAMPING HELPS PREVENT DAMAGE DURING SHIPMENT AND UNDER OPERATING STRESSES

Adjustable coil clamping devices distribute clamping forces evenly around the coil stack. Pre-densified, compression-resistant insulating spacers maintain cooling ducts and other spacings in the winding and help form a rigid, mechanically strong column.

At the heart of the clamping system are wedge-type clamps that apply force directly to the major insulation at the upper end of the coil. The clamping force of this system is up to eight times that of conventional jack-screw arrangements commonly used. (Fig. 5).

Short-circuit stresses can cause improperly supported leads to move, resulting in failures from reduced strike distance, lead disconnection or other breakage. To prevent this, leads and cables in General Electric transformers are passed through insulating tubes or channels which in turn are securely held in an insulating superstructure.

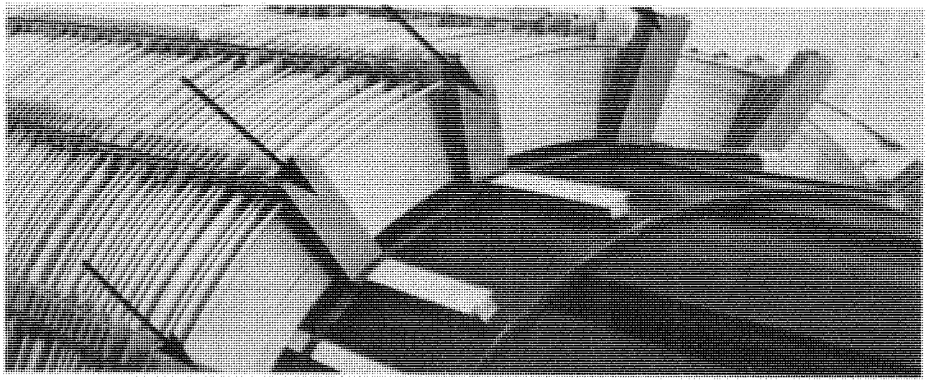


Fig. 3 — Keyed-spacers are used to give windings extra strength.

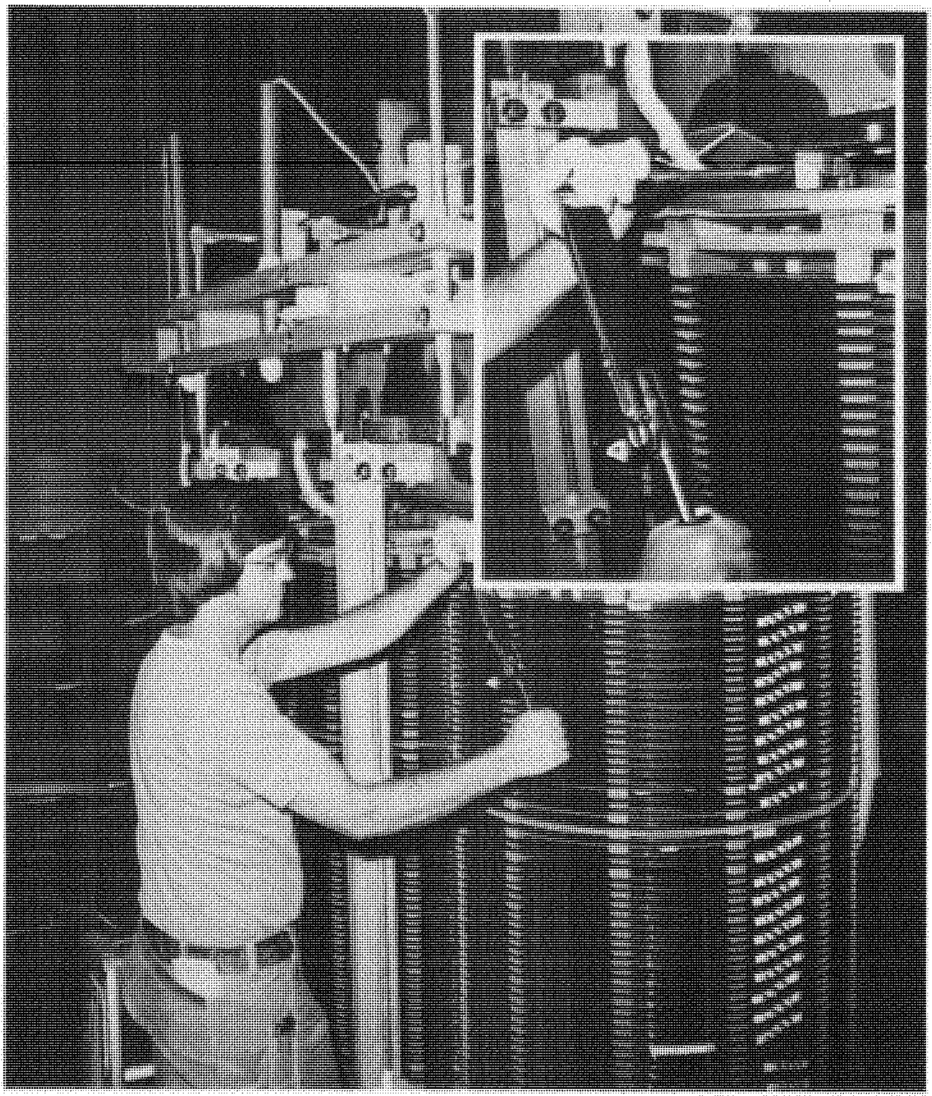
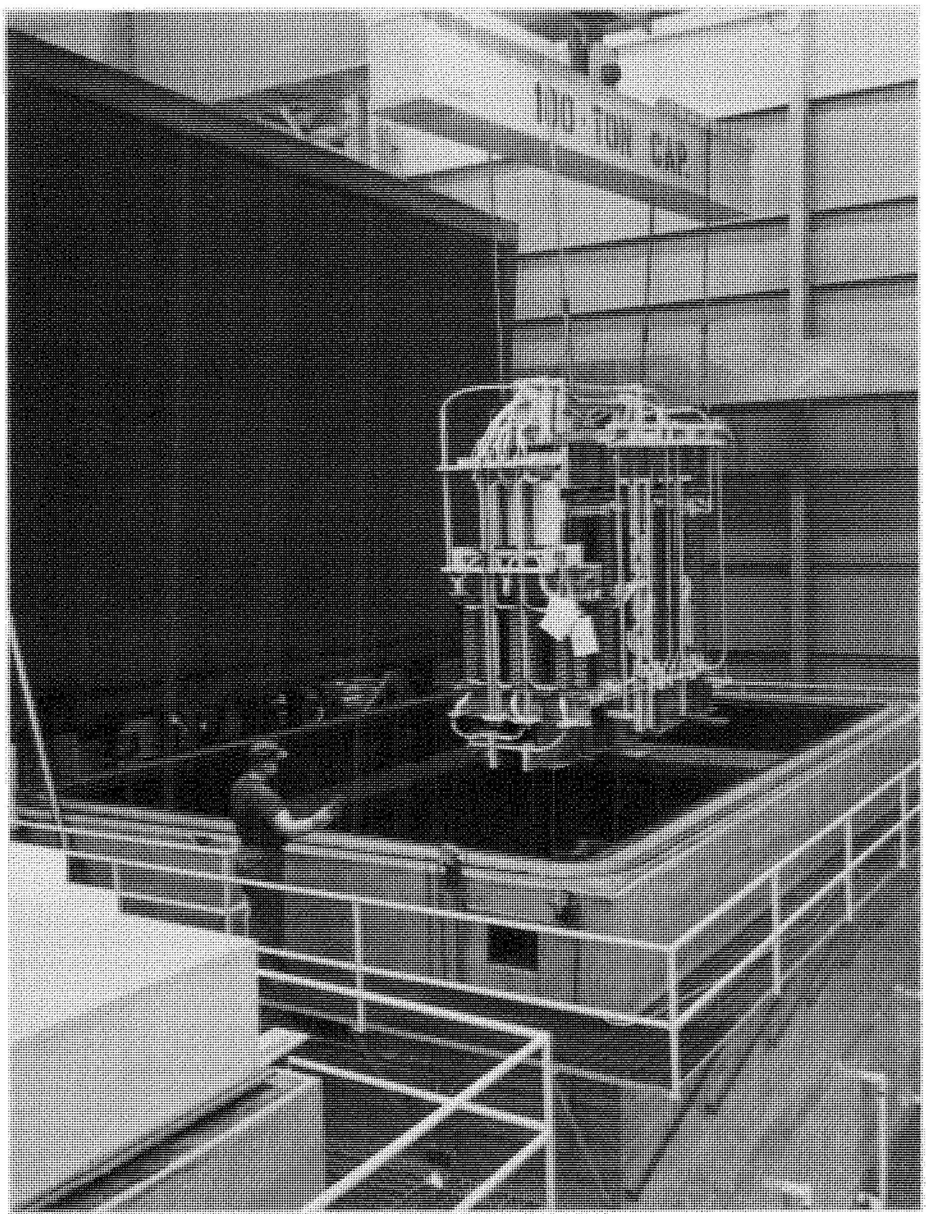


Fig. 5 — Wedge-type clamping system applies force directly to major insulation.

DRYING & MOISTURE CONTROL

Excess moisture can severely curtail transformer life. General Electric removes moisture from the core and coil during manufacturing by a special Vapor Phase Drying Process. Hot oil vapor is released into a specially designed compartment containing the core and coil assembly. When the hot oil vapor condenses, its heat vaporizes any moisture in the insulation. A vacuum system then draws off the moisture leaving a moisture-free core and coil assembly. Drying of the completed core and coil assembly is superior to the drying of individual components that could absorb damaging moisture during assembly.

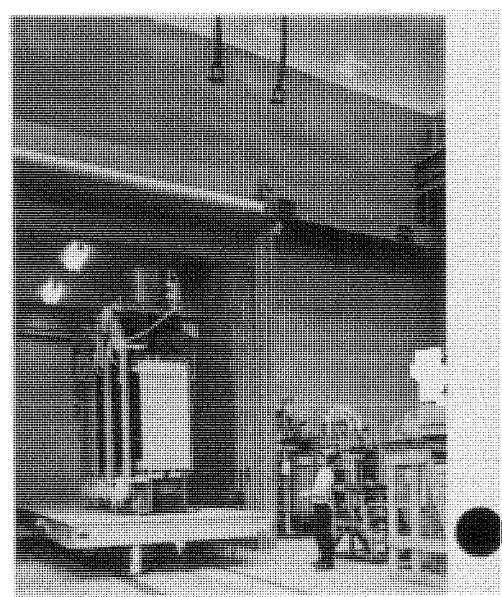
In contrast to conventioanl oven heating, the completely automatic Vapor Phase Process permits internal drying by its ability to circulate hot oil vapors through cooling ducts and other internal passages.



Vapor phase drying takes place in these specially designed tanks.

Upon completion of the Vapor Phase Process the core and coil assembly is immediately moved to a dehumidified room where the relative humidity is maintained at 2 percent maximum. Here the final finishing, tightening and clamping operations are performed prior to tanking without the risk of moisture entering the assembly. When the internal assembly is complete, it is placed immediately in its tank. The tank is then filled, under vacuum, with deaerated oil.

From initial design through final assembly and drying of the internal structure and its insulation system, each GE Primary Substation Transformer is the product of the skills and dedication of the hundreds of engineers, designers, production craftsmen, quality control inspectors and test technicians in the Rome plant. Each of the hundreds of steps taken to complete your transformer is done with pride, and the final result is a transformer of exceptional quality and reliability.



The Dry Room, at the Rome, Georgia facility where relative humidity is maintained at 2%.

TANKS & RADIATOR DESIGN, CONSTRUCTION AND FINISHING

At General Electric each Primary Substation Transformer tank is designed to permit optimum heat dissipation, to protect the insulating liquid and to minimize maintenance routines once the unit is in operation.

1. BASIC TRANSFORMER TANK

On units rated above 10 mVA the tank is fitted with removable radiators that permit economies in handling, shipping and installation of these larger units.

It is a standard procedure at General Electric to thoroughly leak test, under pressure, every tank assembly and radiator unit, during the production cycle. To compliment this thoroughness in the manufacturing cycle, great care is exercised in the selection and application of all gaskets and seals. A variety of materials as well as joint and seal designs are utilized to meet specific environmental and operating requirements.

A. TANK DESIGN AND CONSTRUCTION

The design engineer, working with numerous computer programs, formulates the best tank configuration for each application. Placement and size of external braces are accurately determined and help assure a rigid tank capable of withstanding the many stresses to which it will be exposed. Structural joints are welded, using the flux cored CO_2 shielded process, for deep penetration and uniform strength. After fabrication all tanks are thoroughly leak tested. Since one of the primary functions of the transformer tank is to protect the core and coil assembly from moisture entering the tank, forming and attaching the cover is an important step. Covers are specially "domed" so the moisture runs off. Attaching the cover by welding is the standard method. To prevent weld spatter from entering the tank during the welding operation, a glass-rope gasket is cemented to the tank flange inside the weld area. When a bolted cover is specified, both the cover and the tank flange are drilled simultaneously to assure hole alignment and a tight fit. A continuous nitrile rubber gasket is cemented to the tank flange and properly "stopped" to prevent over-compression during tightening.

The selection and appliction of gaskets is an integral park of tank design procedures. Where separate connections enter the tank from outside, it is necessary to seal the opening to prevent leakage of insulating oil, as well as to prevent moisture from entering the tank.

Transformer gasketing procedures must maintain a leak-tight seal for the life of the unit under conditions of exposure to hot dielectric liquids, weathering, sun light, ozone attack, and mechanical disturbances caused by changes in operating temperatures and pressures. In many cases, dimensionally stable gaskets are required to prevent failure from excessive swell. Thus, proper gasketing is a combination of selecting the right material for the intended environment and designing a joint which is adequately suited to the physical properties of the gasket material.

B. TUBE HEADERS AND RADIATOR DESIGN AND CONSTRUCTION

To achieve the design requirements for transformer cooling, units rated OA/FA/FOA are equipped with removable radiators. Radiator construction consists of four tube header units welded into a common manifold that is fitted with a mounting flange. The individual radiator units are then mounted on the tank. This arrangement permits removal of each radiator unit for shipping and field maintenance. Bracing, in the form of tube straps, is provided on each tube header section or radiator unit to further strengthen their ability to withstand handling, shipping and operating stresses. As a part of the manufacturing cycle radiators are leak tested under water using 30 psi air pressure. Each unit is inspected for leaks again after final assembly, once the unit has been filled with oil.

2. FINISHING & PAINTING

All external surfaces are coated with special enamel to prevent rust and to minimize maintenance. Internal tank surfaces are also painted.

Before painting, the tank surface is cleaned by steel-grit blasting to remove all traces of scale or dirt.

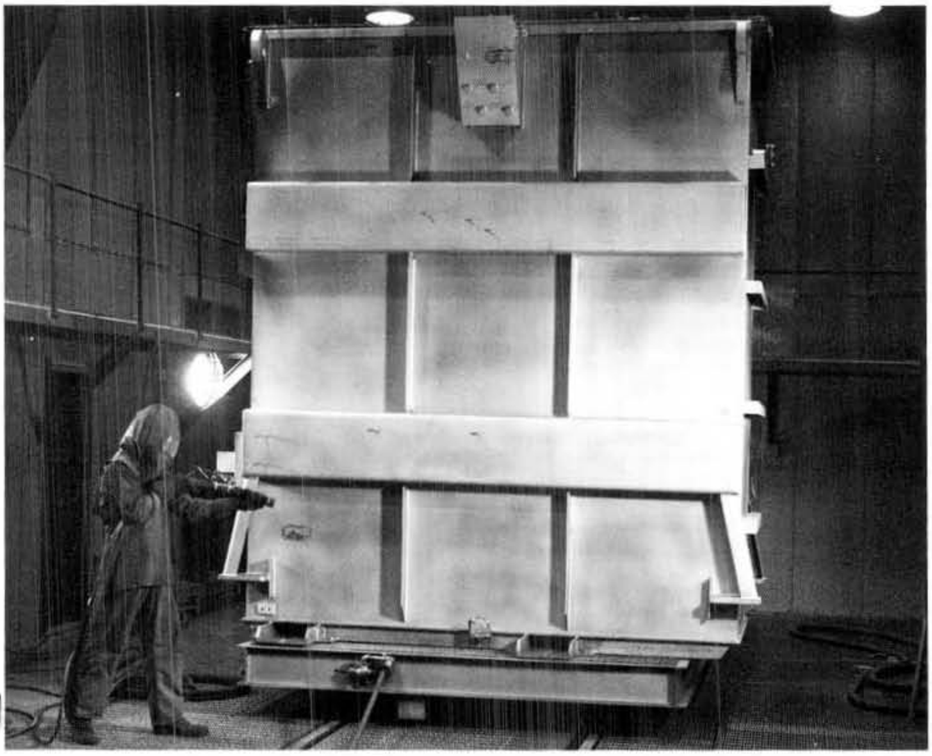
A primer coat of modified alkyd enamel is then applied to protect against corrosion and provide a sound base for the subsequent body coat. The body coat of alkyd enamel has mechanical strength to resist abrasion and chemical resistance to avoid fading and chalking. These are followed by a final appearance coat of modified alkyd enamel, sprayed and air-dried, to eliminate any minor blemishes.

The standard paint color for Primary Substation Transformers is light grey ANSI #70 (Munsell No. 5.0BG 7.0/0.4).

Optional colors available are:

Dark Blue-Grey ANSI #24 (Munsell No. 10B2.40/1.18)

Medium Green - I.S.C.C. - National Bureau of Standards Color No. 150 (Munsell No. 9.0G4.5/1.8)



Steel-grit blasting of the tank surface removes scale and dirt.

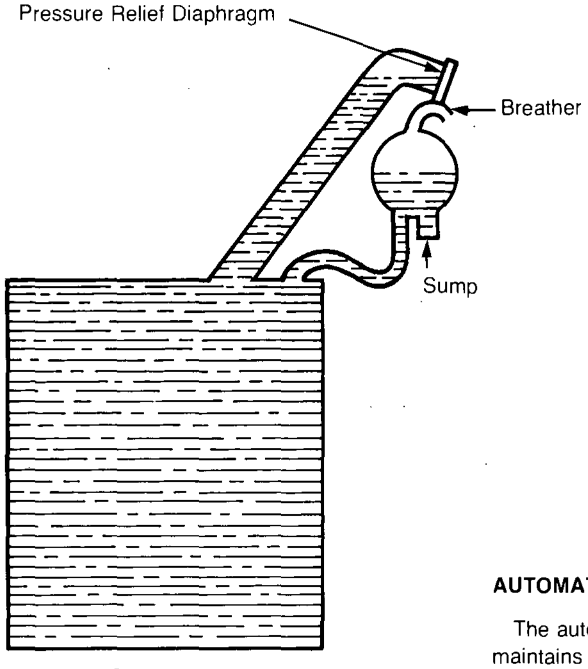
OIL PRESERVATION SYSTEMS

Once the transformer has been installed, temperature changes due to weather and load variations cause the oil to expand and contract. If the tank were completely sealed, excessive positive and negative pressure would result. On the other hand, if the tank were freely vented, moisture-laden air would be drawn into the transformer when the oil contracted during cooling. Such moisture intake, occurring on every cooling cycle of every day, would seriously deteriorate the insulation system in a very short time, and result in greatly reduced transformer life. To minimize moisture intake during these expansion and contraction cycles, many types of oil preservation systems have been developed. ANSI standards describe three methods of preservation. The sealed tank method is standard for all General Electric Primary Substation Transformers.

SEALED TANK (STANDARD DESIGN)

Sealed-tank transformers are provided with a gas space above the insulating liquid. This space serves to cushion the tank against changes in pressure created by expansion and contraction of the liquid. Under normal operating conditions the space remains sealed from the atmosphere, thus protecting the insulating liquid against contamination and maintaining its dielectric strength at a high value over a long period of time. When the space available in the main tank is limited, additional space is sometimes provided by piping down to the channel braces, or, occasionally, by the use of a separate expansion tank. Liquid-filled units are equipped with a pressure-vacuum bleeder which maintains the internal pressure or vacuum within the operating limits shown on the transformer nameplate.

Further information on the sealed-tank transformers is available in GEI-54008.



Conservator

CONSERVATOR

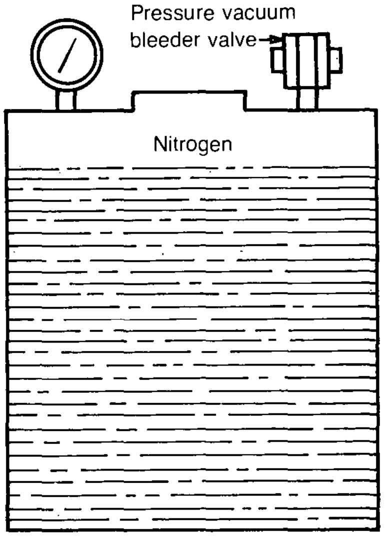
Conservator-type transformers are equipped with an oil expansion tank which provides a head of oil above the main tank and keeps the transformer completely filled at all times. A "U"-tube connection between the conservator and main tank permits the expansion and contraction of oil in the main tank, but does not allow thermal circulation of oil between the tanks. A breather is provided to maintain the oil in the conservator at atmospheric pressure. Any condensation occurring in the conservator will collect in the sump provided at the bottom of the tank and can be drawn off.

For additional information on the conservator transformers refer to GEK-5654.

AUTOMATIC GAS CONTROL

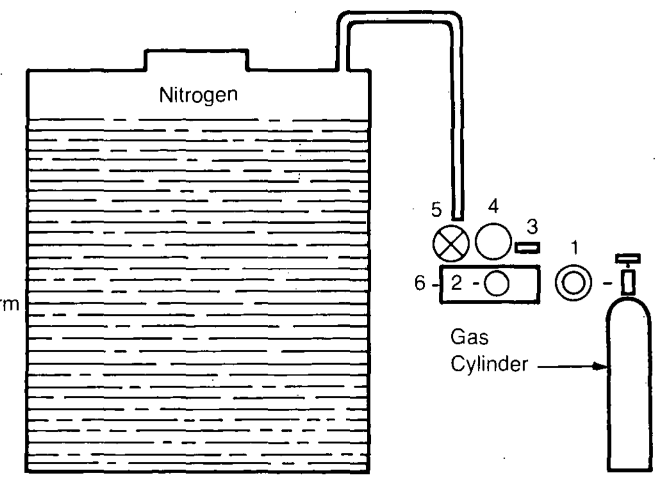
The automatic gas-control equipment maintains an atmosphere of dry nitrogen under a slight pressure between the top oil surface and the transformer cover. This isolates the oil in the transformer from the outside air preventing oxygen, moisture and other contaminants from being absorbed. The nitrogen is supplied from a gas cylinder and is admitted to the transformer through a three-stage automatic gas regulator. The transformer gas space is sufficiently large to allow for normal expansion and contraction of the oil. An automatic bleeder is provided to relieve any excessive pressure which may occur as a result of seasonal high temperatures or heavy load conditions. As lower temperatures are encountered and the pressure drops off, the gas regulator will automatically add gas to maintain a positive pressure.

For additional information on the automatic gas control transformer refer to GEI-54035.



Sealed Tank

1. Gas Regulator
2. Relief Valve
3. Low Pressure Alarm
4. Pressure Gage
5. Shut-off Valve
6. Sump



Automatic Gas Control

COOLING EQUIPMENT

INTRODUCTION

Auxiliary cooling equipment is designed to supplement the self-cooled characteristics of Primary Substation Transformers. While the transformer is operating within its self-cooled rating, natural convection carries the oil up through the windings, out the top manifold, down through the radiators, and back into the tank through the bottom manifold. As the load and/or the ambient temperature increases, additional cooling is provided by the auxiliary cooling equipment. This equipment is desirable under any of the following conditions:

1. When occasional heavy overloads or wide seasonal load variations occur.
2. Where economic considerations favor forced-air cooling over self-cooling for present or future loads.
3. In locations which have the highest ambient temperatures over long periods of time.
4. Where future load growth is unpredictable.

Auxiliary cooling equipment can consist of a pump with liquid flow gage, fans, shut-off valves, and controls. A wide variety of control functions are available beyond the activation of fans and pumps—alarm contacts, remote indication and other options can be supplied to meet specific requirements.

The following table shows the various cooling classes and the resultant increase in load carrying ability available for each:

TYPE OF COOLING	SELF-COOLED kVA (INCLUSIVE) THREE-PHASE	*PERCENT OF SELF-COOLED kVA WITH AUXILIARY COOLING
OA/FUT FA	12000-30000	133
OA/FA/FOA OA/FUT FA/FOA	12000-30000	133/166

*Continuous capacity @ 65°C average winding temperature rise, and 80°C winding hottest-spot rise.

COOLING FANS

Fans are controlled either automatically from the winding hottest spot temperature, or manually. Winding temperature control and alarm contacts are standard equipment. When OA/FA (or OA/Future FA) cooling is specified the control is set for *single stage cooling*. That is, as the load and/or the ambient temperature rises above the OA rating, the control switch activates the cooling fans.

Fan blades are carefully balanced to keep sound levels to a minimum and to ensure long trouble free life. Fans are furnished with water tight connections.

The following data summarize the important physical and electrical characteristics of GE cooling fans.

FAN SIZE — 24"
POWER SUPPLY** — 230 volts, 60 hertz, single-phase
FAN SPEED — 1075 RPM, 60 hertz
TYPE OF MOTOR — permanent split capacitor — TENV
HORSEPOWER — .333
NAMEPLATE CURRENT — 2.7 amperes
OVERLOAD PROTECTION — Thermal protectors with automatic reset
FAN BLADE MATERIAL — Aluminum
LUBRICATION — Motors are lubricated and sealed at the factory and, therefore, require very little maintenance. Under normal operating conditions (running approximately 12 hours per day in an average ambient of 30°C) the bearings should be relubricated at 10-year intervals.
WEIGHT — 50 lbs.

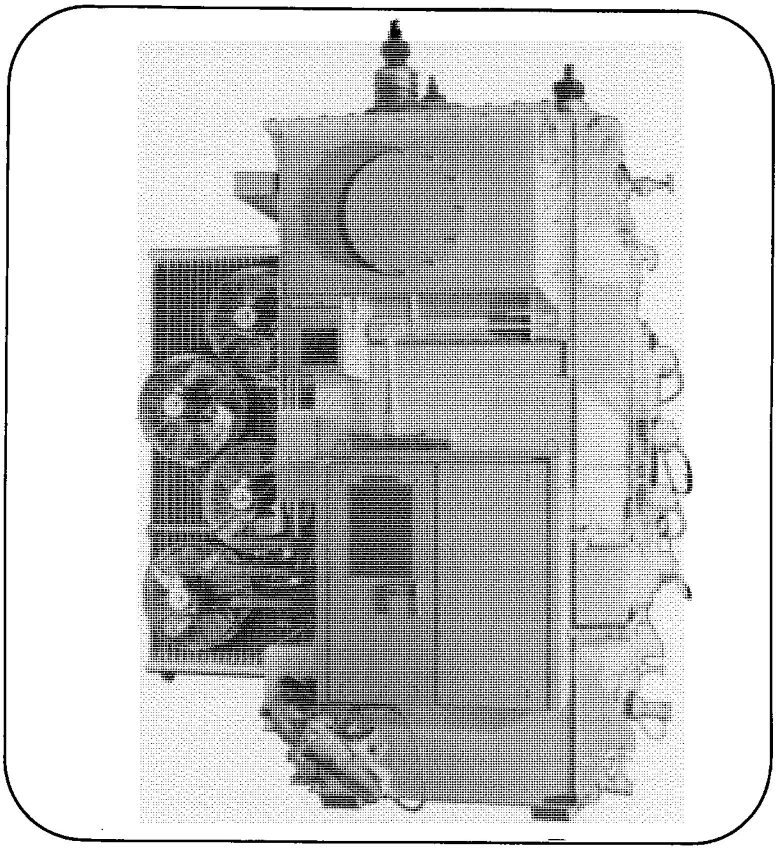
**Motors for other voltages are available when specified.

OIL PUMPS

When an oil pump is included in the auxiliary cooling package (OA/FA/FOA cooling class) *two additional stages of cooling* are made available. The first stage activates a portion of the fans as the temperature nears the limits of the self-cooled rating. The second stage activates the remainder of the fans and the oil pump as the temperature and load increase. The primary reason for utilizing a pump is to maintain a more uniform oil and winding temperature from the bottom to the top of the transformer. Also, when a pump is used, the number of fans required is reduced for cooling at the top rating. This results in a more compact cooling package, lower power requirement and reduced maintenance, as well as a lower sound level.

The oil pump is located between the bottom cooling-bank manifold and the bottom oil inlet to the transformer. It uses the circulating oil as a lubricant and has electrical leads brought out through oil-tight terminals. Power requirements for the pump are 230 volts, single-phase, 60 hertz. Both pumps and fans are furnished with water-tight connections. The pump can be readily removed after closing two butterfly valves. One valve is between the pump and the bottom manifold. The other is between the pump and the bottom oil inlet to the tank.

An oil flow indicator is located on the elbow connecting the pump bottom oil inlet to the bottom cooling bank manifold. It is mounted on the top of the elbow so it can easily be observed. It comes equipped with a LEXAN® face to prevent breakage. The indicator operates an alarm switch when oil flow drops to approximately 50 percent of normal forced flow. A time-delay relay prevents momentary false alarms when pumps are started.



TAP CHANGING EQUIPMENT

ON-LOAD TAP CHANGER

LRT-200 LOAD-VAC Load tap-changing equipment is available on all three-phase Primary Substation Transformers 1000-30,000 kVA. The LRT-200 load-vac tap-changing equipment, which utilizes the *reactor limiting method* of switching, is designed to change transformer voltage ratios under load. The standard design (Fig. 1) provides a plus or minus 10 percent voltage regulation in 32 approximately 5/8 percent steps; 16 above and 16 below rated voltage. Vacuum interrupters (Fig. 2) are used to break the load current when changing tap positions. Their long contact life, a minimum of 500,000 operations at full load, means less maintenance is required over the life of the transformer. The clean oil switching they provide allows maintenance inspection schedules to be established at 10 year intervals.

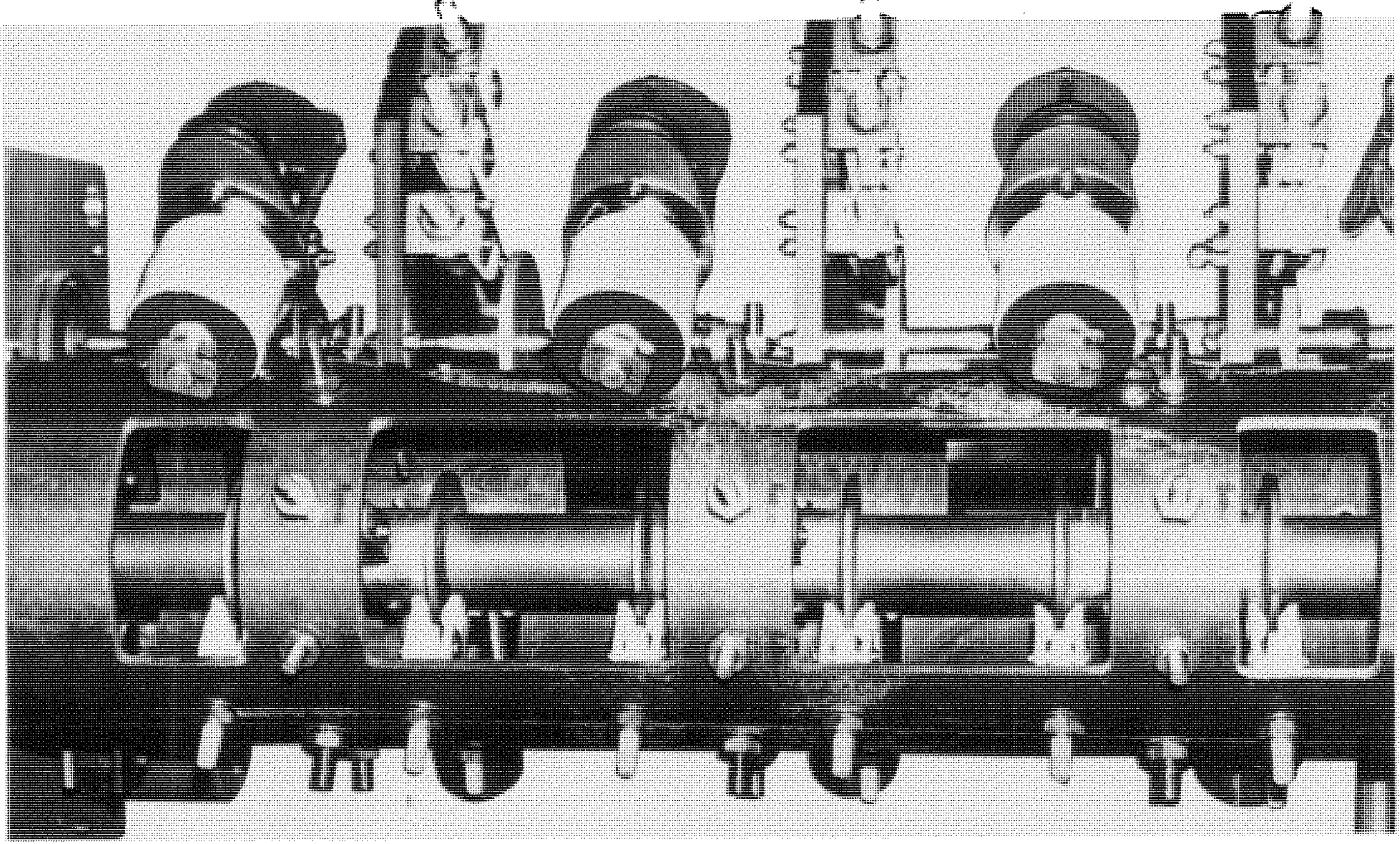
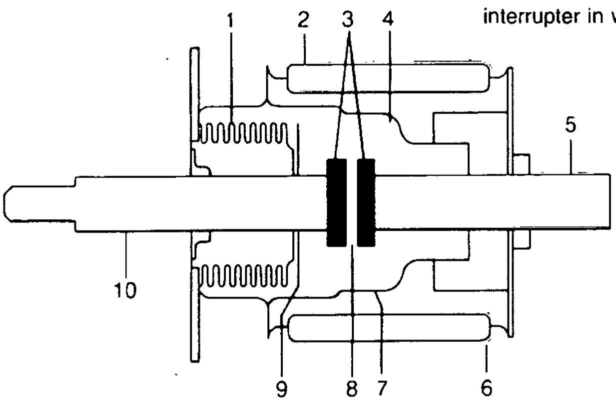


Fig. 1 — The LRT-200 switch mechanism

Heart of the LOAD VAC tap changer is the vacuum interrupter in which all arcing takes place.

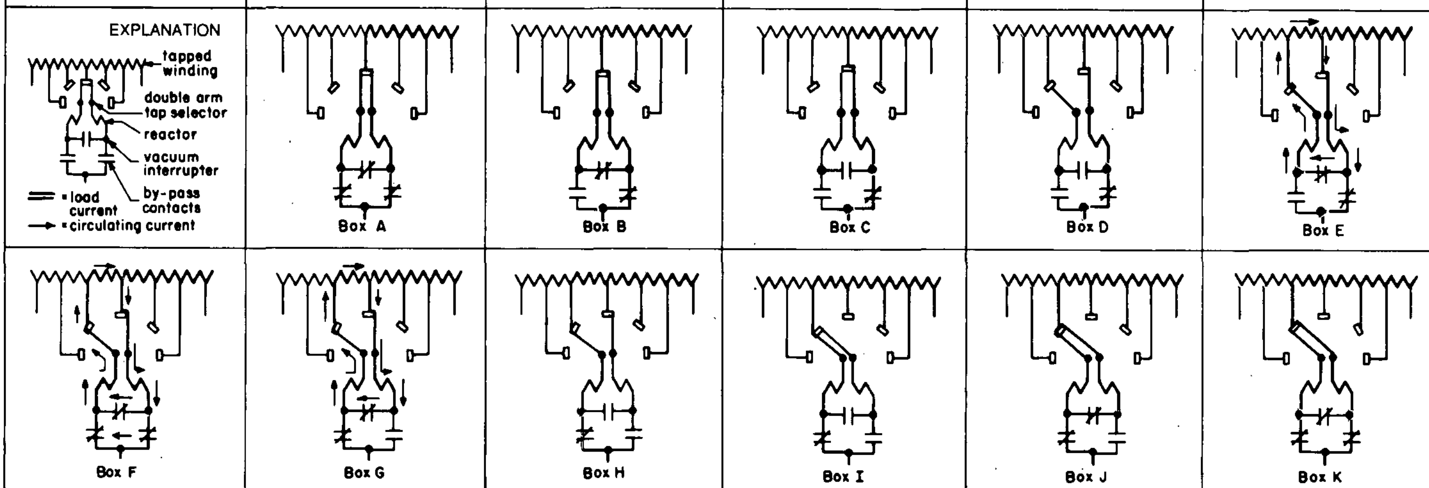


Cutaway view of POWER/VAC® vacuum interrupter

1. Flexible metallic bellows assembly
2. Insulating vacuum envelope
3. Arcing contacts
4. Vacuum chamber
5. Stationary electrical terminal
6. Metal-to-insulation vacuum seal
7. Metal vapor condensing shield
8. Electric arcing region
9. Bellows shield
10. Operating rod (movable terminal)

Fig. 2

	Full-cycle position	The left-hand side of the current carrying or by-pass switch opens and current flows through the right-hand side of the by-pass and the vacuum interrupter, into the tapped winding.	The vacuum interrupter has opened the circuit of the left-hand side of the load tap changing switch. All current is now flowing in the right-hand side.	One tap selector finger moves to the left stationary contact, the next position.	The vacuum interrupter has now closed and current flows into the right-hand side of the by-pass switch and through the interrupter to the interrupter to the tapped windings.



The left-hand side of the by-pass switch closes. This is the half cycle switch position.	The sequence repeats as in the preceding steps: however, during this next half-cycle, the right-hand side of the current carrying or by-pass switch opens and current flows through the left-hand side of the by-pass and vacuum interrupter, into the tapped winding.

Fig. 3 — Tap Changing Sequence (Boxes A and K show the full cycle starting and finishing positions. Box F is the half-cycle position. Boxes A, F and K are operating positions. Circulating current, as shown by the arrows, flows in the tapped section of the winding back through the vacuum interrupter. At full cycle position, Box K, the tap selector fingers have moved to the left stationary contact.)

SOLID-STATE STATIC CONTROL FOR LTC IS SIMPLE, PRECISE AND TROUBLE-FREE

General Electric's solid-state static control system for LTC offers simple adjustment of significant control functions, such as voltage level and band-width, with dial-type controls on the front panel.

The control panel is mounted in an air-filled compartment readily accessible from ground level. This solid-state control is maintenance-free, eliminating problems associated with moving electrical contacts and sensitive rotating devices. The control package is immune to shock or vibration, providing reliable service in various environments without maintenance (Fig. 4).

POSITION INDICATOR AND OPERATIONS COUNTER

A position indicator is provided with drag hands to record the range of operation of the load tap changer. The drag hands have an electrical reset button located in the control compartment to allow resetting the maximum operating range indicator hands from ground level. An operations counter is provided in the control compartment to record the number of load tap changes.

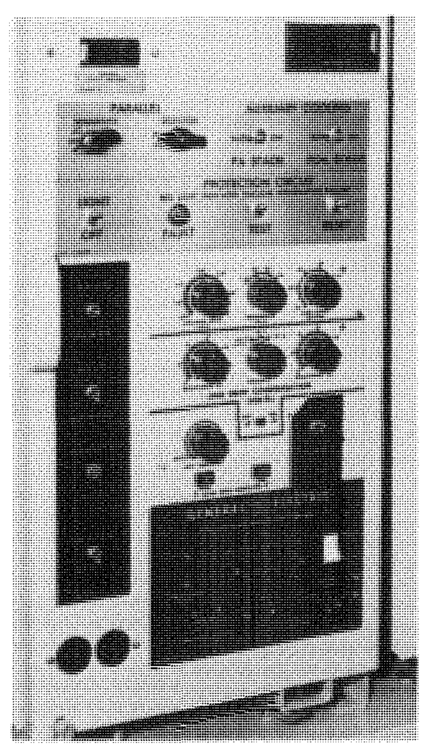


Figure 4 — Solid-state Static Control.

TAP CHANGING EQUIPMENT

CONTROL CIRCUITS FOR PARALLEL OPERATION OF LTC TRANSFORMERS

Optimum load sharing between transformers operating in parallel with automatic voltage control is insured through use of circulating current control circuits (Fig. 1). In the circulating current method of paralleling, the circulating current component is separated from the load current component and is applied to the LDC in a direction opposite to that of the load current. This reversed compensation effect causes the tap-selecting equipment to operate in a direction to reduce the circulating current to a minimum. Although any number of units can be paralleled using this method, only the corresponding phases of two units are shown. The circuit for each transformer includes a current transformer (CT), potential transformer (PT), voltage sensor (VS), and auxiliary transformer (LCT), paralleling reactor (XTR), and a line-drop compensator with adjustable resistance (RLDC) and reactance (XLDC) elements. Note that for proper parallel operation the CT's and PT's must be connected in the corresponding phases of each unit and produce voltages and currents of the same polarity.

To illustrate the function of these devices, Fig. 1 depicts the case where the no load output of unit number 1 is higher than that of unit number 2. The solid arrows indicate normal load currents and the dashed arrows indicate the circulating current which will result from the difference in output voltages. By virtue of their secondary winding interconnections, the auxiliary current transformers (LCT's) permit free flow of load current through the line drop compensator elements but block the flow of circulating current. The circulating current is forced through the paralleling reactors (XTR's). Note that the effect of the circulating current through the paralleling reactor is to oppose normal compensation on the unit with the higher output, unit number 1, and to add to the normal compensation on the other unit. This will result in voltage corrections in the direction which will reduce circulating currents. The reduction of circulating current is independent from the magnitude of load current and line drop compensator settings.

By responding to current rather than tap-changer position, the circulating current method of paralleling provides extreme flexibility in the parallel operation of similar transformers. Transformers with variations in kVA rating, number of on-load taps, time required to complete a single tap change, and relative impedance with tap position, can be controlled to optimally share their combined loads. Provision is also made for

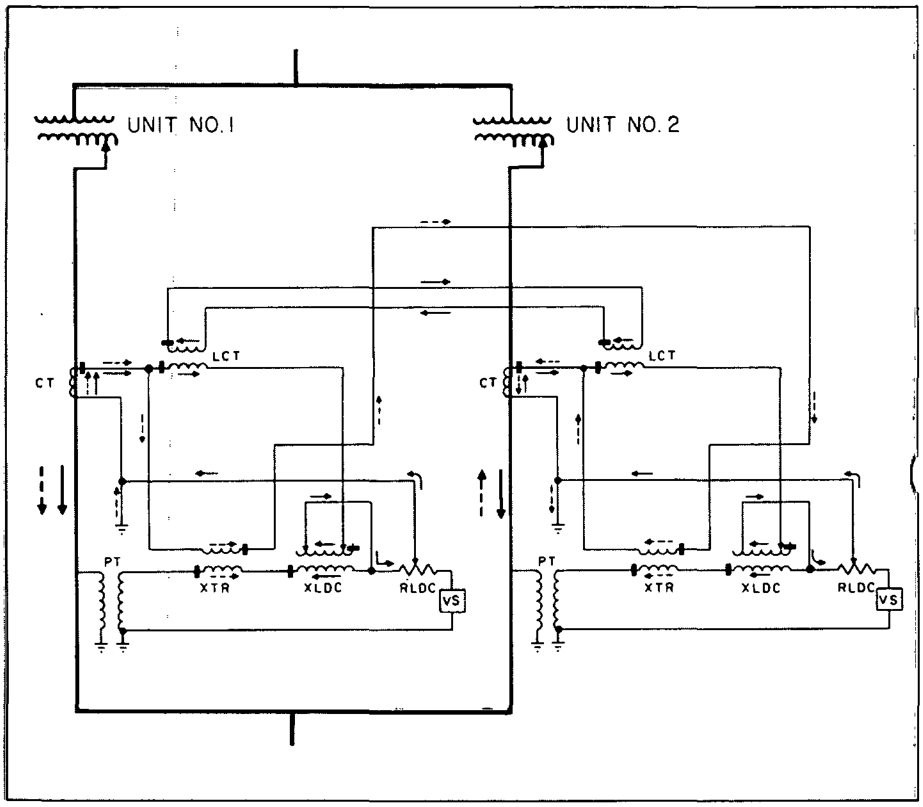


Fig. 1 — Circulating current method allows paralled operation with existing transformers of either the resistance type of reactance type located in either the low voltage or high voltage windings.

switching units in and out of parallel without having to make control adjustments to maintain a constant bus voltage. This is accomplished by using a second set of auxiliary current transformers to force a division of load current among all parallel line drop compensators even when some units are out of service. Existing transformers with no provision for circulating current type paralleling can normally be adapted to its use by addition of two auxiliary current transformers, a paralleling reactor and the necessary interconnections between units. It is necessary that a current source which is in phase with the automatic control sensing voltage at unity power factor load be available. In some cases an additional auxiliary current transformer may be required to make the level of this current source compatible with the current sources provided on other transformers in the parallel bank. These current sources must be equal when all transformers are carrying their rated outputs.

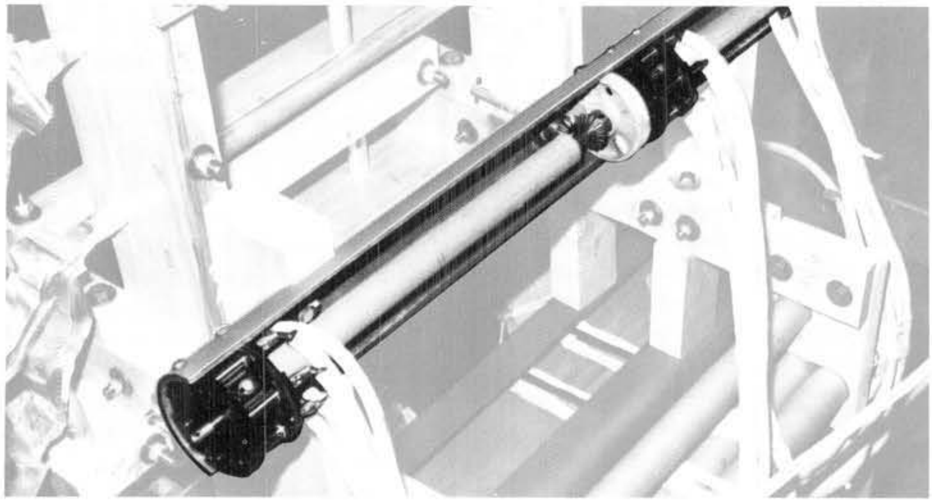
While the described method of paralleling is on the basis of transformers directly in parellel between two buses, this is not essential. The same devices may be used in parallel transformers in which long feeders are used to connect the transformers to the paralleling bus or network. These paralleling devices will operate satisfactorily even though the feeders are of different lengths and require different degrees of line-drop compensation. This may result in the transformers operating, under load, on different taps to provide correct voltage through the different feeders.

DE-ENERGIZED TAP CHANGERS

General Electric's wedge-type de-energized tap changers are used to change the voltage ratio when the transformer is de-energized.

The standard wedge-type tap changer has six contacts providing five operating positions, and features self-aligning contacts, high current-carrying ability, high dielectric and mechanical strength, and low contact temperatures. Contacts operate with a wiping action which assures a low-resistance contact.

Wedge-type changers for de-energized operation have an operating mechanism which protrudes through the tank wall at a convenient height, and provision is made for padlocking the mechanism.



Gang operated 3 ϕ tap changer mounted in superstructure above core and coil assembly on ratings 69 kV high voltage and below.

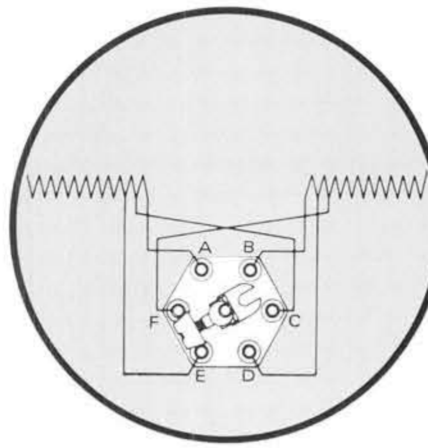
External Operating Mechanism with cover on and lock in place.

The wedge-type tap changer provides a means of changing the voltage ratio of a de-energized transformer without breaking the transformer seal. It is shipped in place, and is set on the position corresponding to the rated voltage shown on the transformer nameplate.

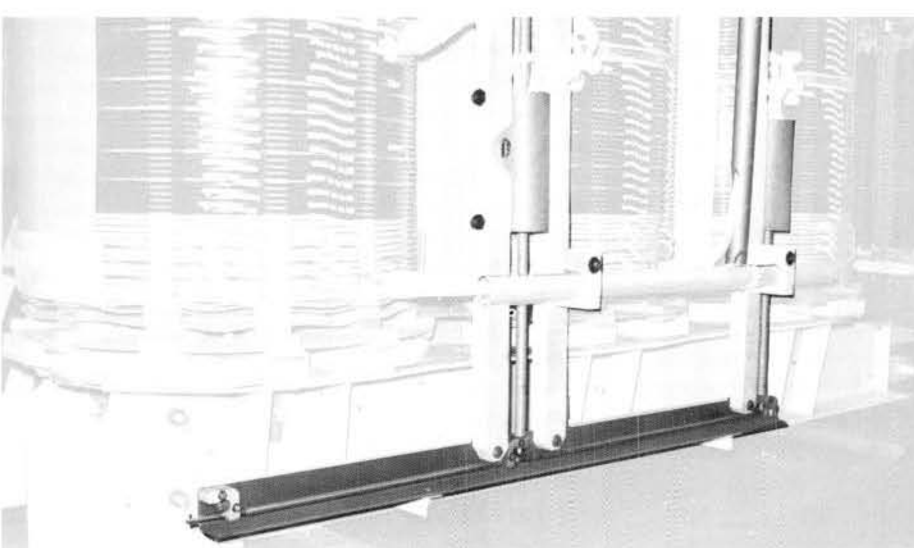
Tap leads from the transformer windings are connected to a circular group of nickel-plated copper rods which are held together between two insulating heads. A wedge in the middle can be moved by a crankshaft to wedge between any two adjacent rods. A spring between the wedge and crankshaft maintains a high-pressure line contact between current carrying components.

When the crankshaft is turned to move the wedge from one operating position to another, pressure is gradually reduced on the spring and the wedge is withdrawn from between rods. A "U"-shaped guide on the opposite side then pivots the wedge around to the next set of rods. As the crankshaft continues to turn, pressure is again applied to the spring and the wedge is forced into position with a wiping action, insuring positive contact.

Typical connection of a wedge-type tap changer.



HIGH-VOLTAGE CONNECTIONS LINES ON		
VOLTS (Percent)	DIAL POS.	TAP CHANGER CONNECTS
105	1	A to B
102.5	2	B to C
100	3	C to D
97.5	4	D to E
95	5	E to F



Gang operated 3 ϕ tap changer used in transformers above 69 kV high voltage.

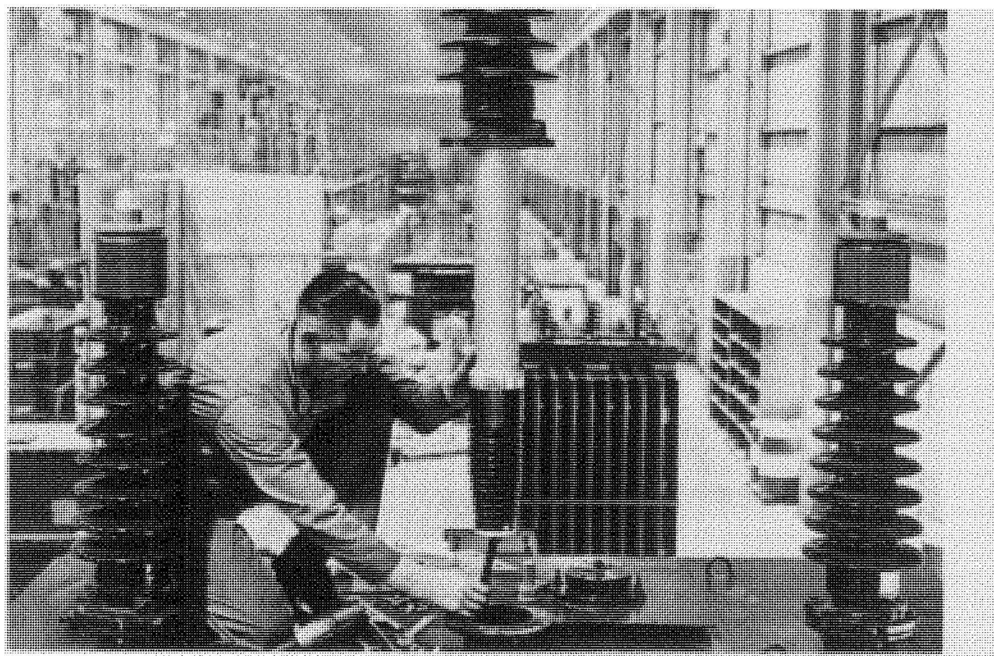
BUSHINGS

The major components of high voltage oil-insulated bushings are:

- Core, consisting of a hollow copper tube
- Internal, solid insulation consiting of oil-impregnated paper wound on the tubular core
- Oil expansion chamber or dome
- Exterior procelain
- Mounting flange and ground sleeve
- Interior procelain

The internal solid insulation consists of altenate layers of plain kraft paper and kraft paper printed with stress equalizers in the form of a herringbone pattern. This paper is wound onto the tubular core in the form of two continuous sheets. Near the outer surface of the insulation, a foil metal layer is included with a lead running to an external connection which is used for power factor testing of the bushing. This connection is, in effect, a type of "capacitance tap" that provides sufficient capacity for operating a bushing potential device only on bushings rated 115 kV and above.

Cover-mounted bushings are standard for both high-and-low-voltage windings. Side-wall bushings are supplied where necessary for terminal compartments, connection to switch-gear, or when specified by the purchaser.

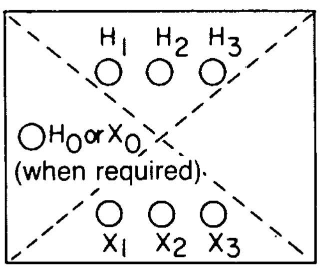


High voltage leads are drawn up through the bushing core and clamped to the bushing terminal, greatly reducing the time required for installation.

STANDARD TERMINAL ARRANGEMENT FOR COVER BUSHINGS ON THREE-PHASE TRANSFORMERS IS AS FOLLOWS:

Segment 3

Segment 2

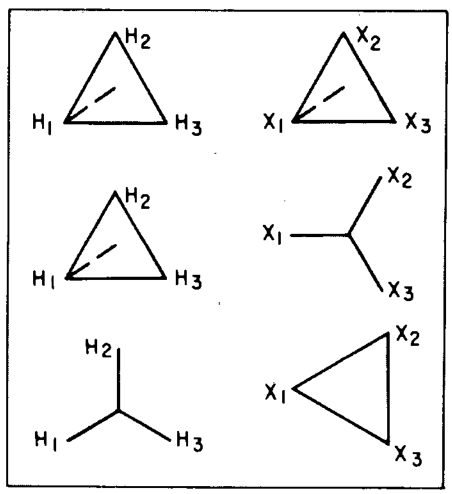


Segment 4

Segment 1

POLARITY, ANGULAR DISPLACEMENT, AND TERMINAL MARKINGS

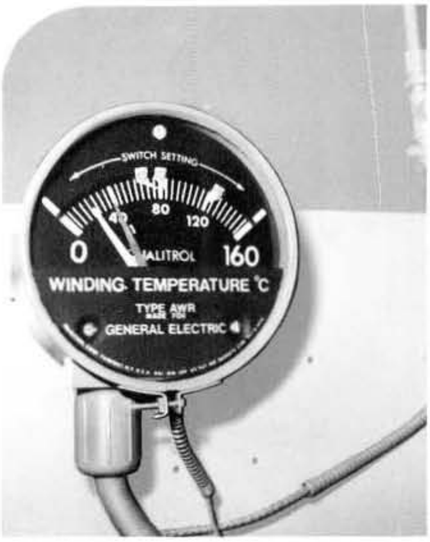
Three-phase vector relations are as follows:



Bushing Ratings and External Creepage Distance
Per ANSI
C76-2

BUSHING BIL-kV	BUSHING VOLTAGE RATING kV	MINIMUM CREEPAGE DISTANCE (INCHES)	EXTRA-CREEPAGE BUSHINGS DISTANCE (INCHES)
110	15	11	USE NEXT HIGHER RATED BUSHING
150	25	17	
200	34.5	26	
250	46	35	
350	69	48	66
550	115	79	92
650	138	92	114

FEATURES AND ACCESSORIES
OPERATING ITEMS

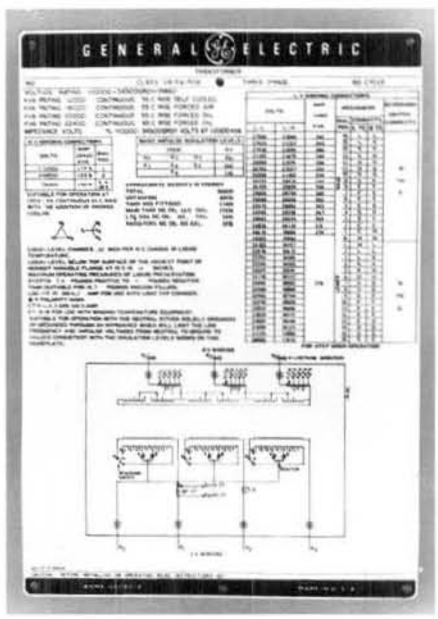


★ **Winding-temperature unit** indicates winding hot-spot temperatures. The indicator relay has snap-action switches, two for fan units and a third for pump units, enclosed in a sealed instrument case. A detector for remote indication is also available.

★ **Dial-type liquid thermometer** indicates the top-oil temperature. It is factory calibrated and has a maximum reading pointer with an external reset. Dial readings range from 0° to 120°C. Alarm contacts are included when specified.

All standard accessories and gages are centrally located on a panel where they can be safely reached even when the transformer is energized.

Dial indicators, mounted on one panel, are easily read from the ground. All gages have tempered glass faces to resist breakage. Temperature indicators are tipped 30 degrees from the vertical when mounted at heights greater than 96 inches. Years of testing and constant use have proved the reliability of General Electric instruments and gages.



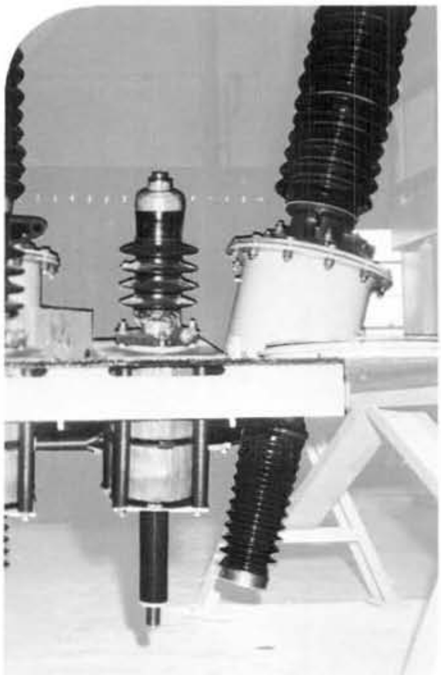
★ **Diagrammatic nameplate** shows kVA rating, voltage rating, operating temperature, and power circuit diagrams and other data specified in ANSI standards.

★ **Magnetic liquid-level gage** indicates the change in liquid level. Dial markings show the 25°C and the maximum and minimum levels. It can be furnished with alarm contacts which actuate when the liquid level approaches a point too low for safe operation.

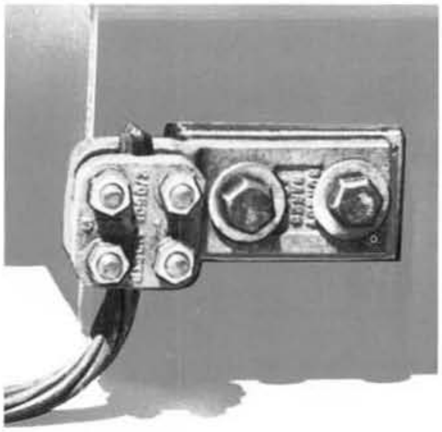
★ **Pressure vacuum gage** is standard on all transformers with sealed-tank oil preservation systems. It has a scale range of plus or minus 10 psi and provides a means to continually monitor the sealed system.

★ STANDARD ACCESSORIES ● OPTIONAL ACCESSORIES

FEATURES AND ACCESSORIES
PROTECTIVE ITEMS



• **Bushing-type current transformers** can be supplied on request. Relay-type current transformers have accuracy classes in accordance with ANS C57.13 and NEMA Standard SG-4. In some cases, their accuracy may be acceptable for metering, as well as for relaying.



★ **Grounding pads** are on diagonally opposite corners of the tank base for ground connections.

• **Model 900-1 fault pressure relay** signals a faulted condition. It responds quickly to internal faults by reacting to the primary shock wave transmitted through the insulating oil.

★ **Pressure vacuum bleeder** maintains the internal pressure within predetermined operating limits and is equipped with a sampling valve. It is factory calibrated to function at the operating pressure shown on the nameplate.

★ **Pressure relief device** is mechanically operated, self-resetting and reclosing, and has a visible operating signal. Alarm contacts (shown) for remote monitoring are optional.

• **Surge arresters** provide protection from excess voltages resulting from externally generated sources. Depending upon the application: station, intermediate, or distribution-type arresters are available.

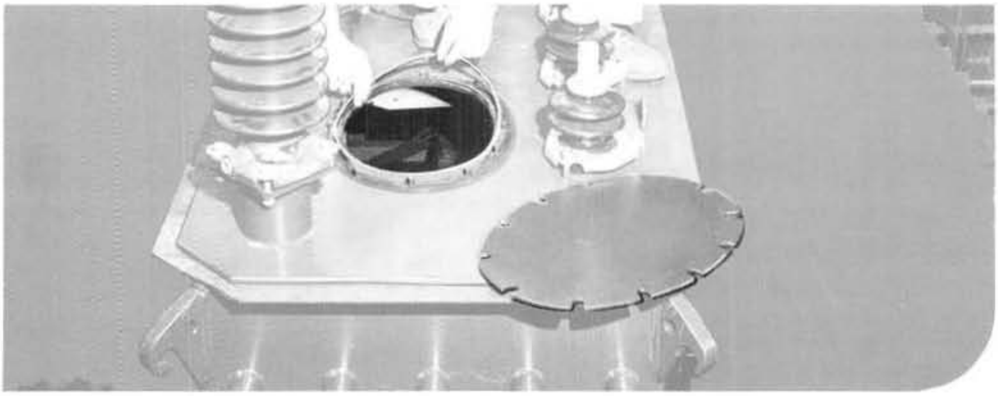
★ STANDARD ACCESSORIES • OPTIONAL ACCESSORIES

MAINTENANCE ITEMS

★ **Upper filter-press valve** is globe-type.

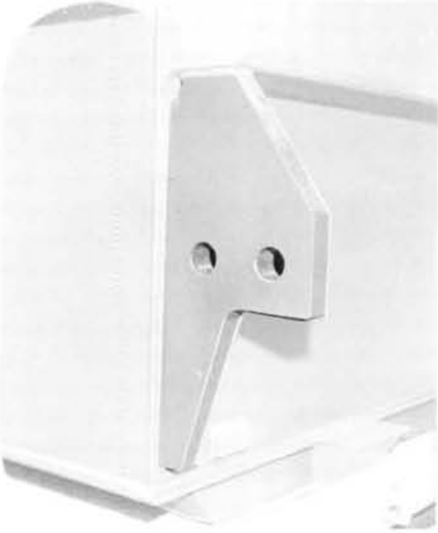
★ **Combination drain and lower filter-press valve** is globe-type with drop-seat construction that allows full drainage. The integral sampling device is designed for easy testing and sampling of the insulating liquid.

★ **Gas sampling valve** vents gasses from the transformer tank.

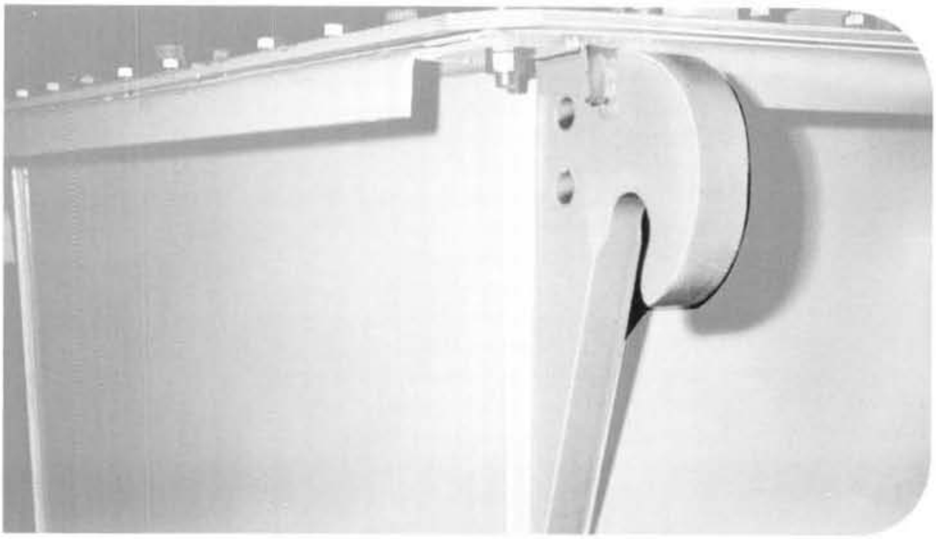


★ **Handholes or manholes** on cover provide access to the interior of the transformer.

INSTALLATION ITEMS



★ **Jacking facilities** located at all four corners of the base, have a minimum ground clearance of 13 inches on units rated 12,000–30,000 kVA.



★ **Lifting lugs** for cover and lifting lugs on tanks are strong. Slings and cables can be easily connected.

★ STANDARD ACCESSORIES • OPTIONAL ACCESSORIES

APPLICATION DATA, WEIGHTS AND DIMENSIONS

TRANSFORMER RATINGS

Self-cooled, forced-air-cooled, and forced-air forced-oil ratings are continuous and are based on not exceeding 65°C winding temperature rise by resistance or an 80°C hot-spot temperature rise at altitudes of 1000 meters or less. The thermally upgraded insulation system is a high temperature system designed to provide reliable service life.

The transformers are designed to operate at nameplate rating in ambient temperatures of 40°C maximum, with an average temperature for any 24 hour period not exceeding 30°C.

OA/FA/FOA Ratings

65°C Self-cooled	65°C Fan-cooled	65°C Forced-air Forced-oil-air
12000	16000	20000
15000	20000	25000
20000	26667	33333
25000	33333	41667
30000	40000	50000

Additional ratings available to purchasers' requirements

Standard bushing current transformers

Bushing Class-kV	PRI/SEC amp	Accuracy Class*
23 and 34.5	600/5	C200
	1200/5	C400
	2000/5	C400
	3000/5	C400
	4000/5	C800
	5000/5	C800
46	600/5	C200
	1200/5	C400
	2000/5	C400
	3000/5	C400
69	600/5	C200
	1200/5	C400
115 and 138	600/5	C400
	1200/5	C800
	2000/5	C800
161	600/5	C400
	1200/5	C800
196	600/5	C400
	1200/5	C800
230	600/5	C400
	1200/5	C800

*Applies to maximum current rating only

NOTE: Since each transformer is individually designed for optimum electrical characteristics consistent with requirements of the particular application, there can be no tabulation of fixed characteristics. However, for planning and estimating purposes, these tables are included to illustrate typical specifications and representative ratings.

THREE PHASE 60 HERTZ TRANSFORMERS **WITH** LOAD TAP CHANGER

RATING kVA	HIGH VOLTAGE (kV)	LOW VOLTAGE (kV)	DIMENSIONS (Inches) Height Over Bushings	Width	Depth	Tank Height	WEIGHT (lbs.)
12,000	34.5	15 or below	161	170	173	142	78,000
	69	15 or below	183	229	123	151	83,000
	115	15 or below	207	239	123	158	91,000
15,000	34.5	15 or below	166	220	177	146	82,260
	69	15 or below	184	179	177	151	87,230
	115	15 or below	211	190	177	160	96,160
20,000	34.5	15 or below	173	229	180	154	98,030
	69	15 or below	191	238	180	158	103,420
	115	15 or below	218	197	180	168	113,250
	138	15 or below	233	259	135	174	127,070
25,000	69	15 or below	196	242	182	164	118,780
	115	15 or below	224	251	182	173	130,330
	138	15 or below	237	210	186	178	143,330
30,000	69	15 or below	201	248	184	169	135,780
	115	15 or below	228	259	184	177	147,470
	138	15 or below	242	220	189	183	163,940
	161	15 or below	256	218	195	189	177,960

THREE PHASE 60 HERTZ TRANSFORMERS **WITHOUT** LOAD TAP CHANGER

RATING kVA	HIGH VOLTAGE (kV)	LOW VOLTAGE (kV)	DIMENSIONS (Inches) Height Over Bushings	Width	Depth	Tank Height	WEIGHT (lbs.)
12,000	34.5	15 or below	160	114	157	141	50,000
	69	15 or below	182	124	161	150	56,000
	115	15 or below	206	183	135	157	65,000
15,000	34.5	15 or below	166	154	158	146	54,225
	69	15 or below	184	162	162	151	59,640
	115	15 or below	211	123	173	160	72,120
20,000	34.5	15 or below	172	160	160	152	67,275
	69	15 or below	191	170	164	158	71,970
	115	15 or below	218	178	174	167	86,460
	138	15 or below	232	138	183	213	98,835
25,000	69	15 or below	196	176	167	164	83,830
	115	15 or below	222	184	176	172	98,240
	138	15 or below	237	193	184	178	112,655
30,000	69	15 or below	201	185	170	169	98,784
	115	15 or below	228	188	178	169	110,380
	138	15 or below	242	202	187	183	129,680
	161	15 or below	255	200	193	188	142,030

STANDARD AND OPTIONAL ELECTRICAL TESTS

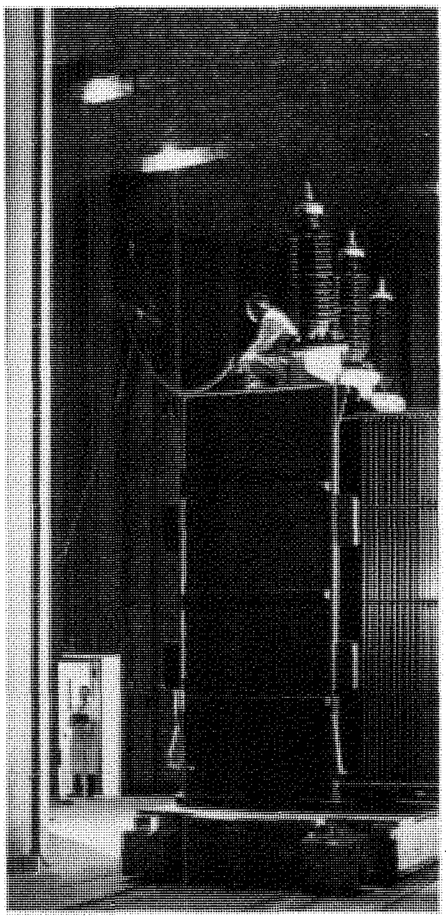
STANDARD TESTS

The following tests will be made on all transformers except as specifically stated below. The numbers shown do not necessarily indicate the sequence in which the tests will be made. All tests will be made in accordance with the latest revision of ANSI Standard Test Code for Transformers, C57.12.90.

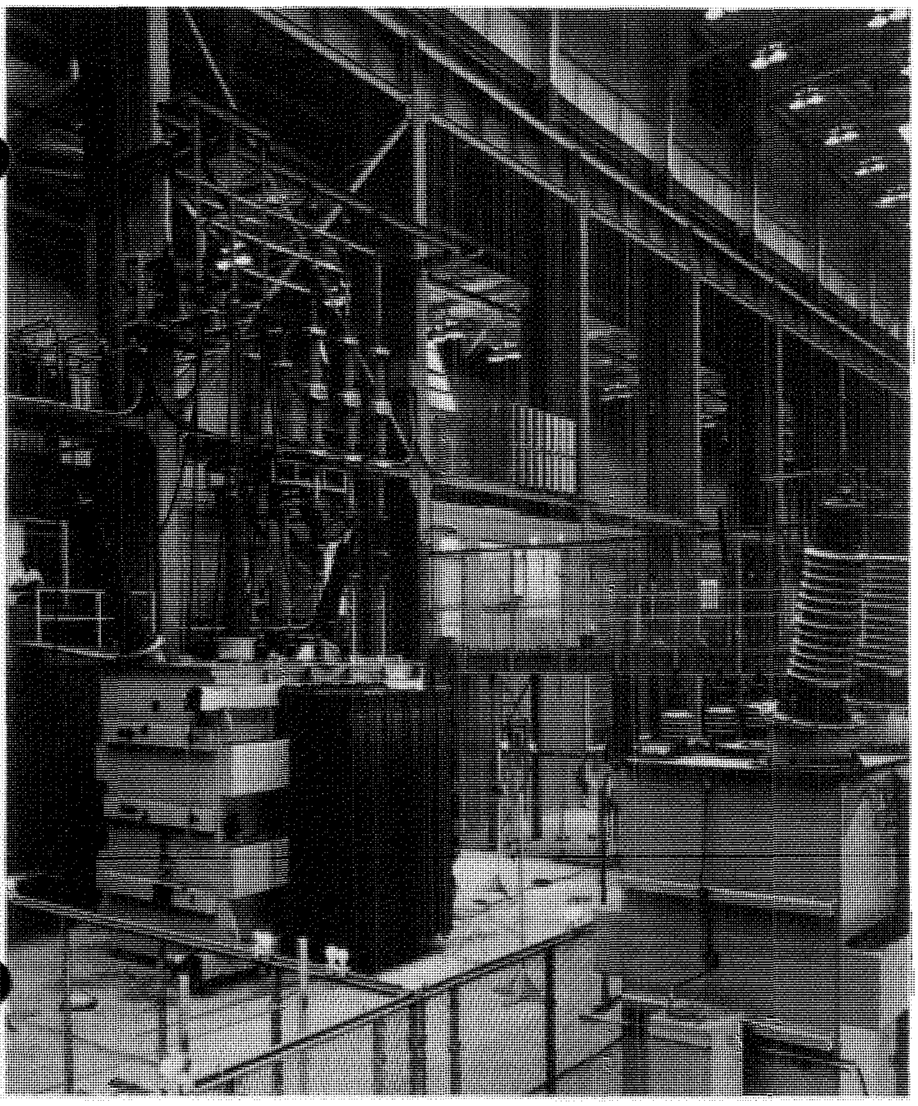
1. Resistance measurements for all windings on the rated voltage connection of each unit and at the tap extremes of one unit only of a given rating on an order.
2. Ratio tests on the rated voltage connection and on all tap connections.
3. Polarity and phase-relation tests on the rated voltage connection.
4. No-load loss at rated voltage on the rated voltage connection.
5. Exciting current at rated voltage on the rated voltage connection.
6. Impedance and load loss at rated current on the rated voltage connection of each unit and on the tap extremes of one unit only of a given rating on an order.
7. Temperature Test

   Winding temperature rise for standard transformers will be determined from basic design data which has been verified by test results of similar transformers.

   Temperature test or tests will be made only when specified. Customer must specify the exact ratings and number of units on which heat runs will be made. Tests, when made, will be made under conditions specified in ANSI Standards for Transformers.
8. Applied potential tests.
9. Induced potential tests.



Separate sound testing laboratory at General Electric–Rome, Georgia



Impedance

Impedance guarantees at rated voltage and 65°C self-cooled kVA ratings are shown in the following Table. These values are subject to 7.5 percent tolerance per ANSI C57.12.00.

HV BIL kV	LV BIL kV	Impedance—percent*
110	45 60-110	6.75 6.5
150	45 60-110	6.75 6.5
200	45 60-150	7.25 7.0
250	45 60-200	7.75 7.5
350	60-250	8.0
450	60-350	8.5
550	60-450	9.0
650	60-550	9.5

*For LTC transformers, add 0.5 to impedance values listed.

Standard audio sound levels

Each transformer will be so designed that when energized at rated voltage and frequency at no load and under standard test conditions and measurement procedure, the average sound level in decibels will not exceed the limits given in the following table (in accordance with NEMA Standards, TR-1).

Equivalent Self-cooled kVA	Sound Level—Decibels		
	Without Fans	With Fans	With Fans and Pump
Three-phase kVA			
	350 kV BIL and Below		
12000	69	71	72
15000	70	72	73
20000	71	73	74
25000	72	74	75
30000	73	75	76
	450-650 kV BIL		
12000	71	73	74
15000	72	74	75
20000	73	75	76
25000	74	76	77
30000	75	77	78

OPTIONAL TESTS

- **IMPULSE TEST**
  With trend toward reduced insulation levels it is important that transformers be able to withstand the voltage surges that will occur in service. The ANSI Impulse test will give user this assurance. The ANSI Standard Impulse test consists of the following: one reduced full wave, two chopped waves and one full wave.

- **AUDIBLE SOUND TEST**
  The trend to higer kVA substations (but smaller in physical size) and the closer proximity of residential areas require that audible second level of transformers be closely monitored. The NEMA Standard Sound test will do this and the details of the test can be found in NEMA STD TRI-1980.

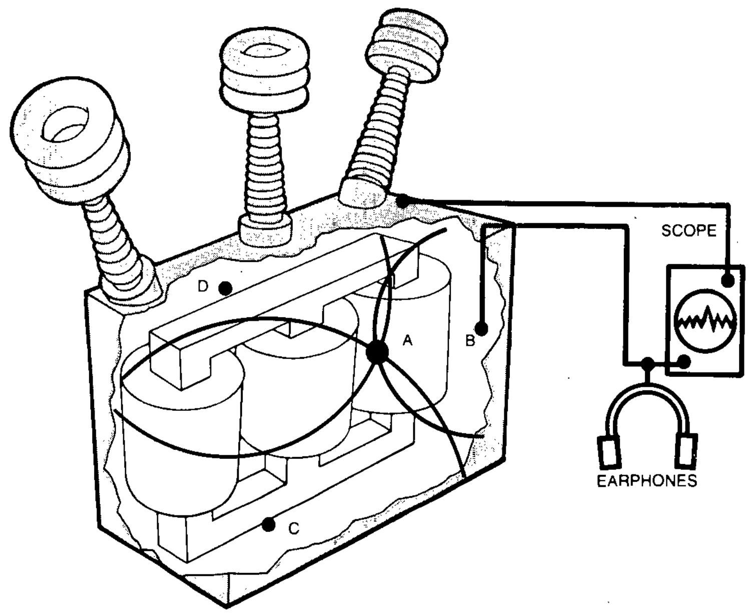
- **CORONA TEST**
  With today's higher operating voltages and reduced insulation levels, the need for insulation system reliability is doubly important. The General Electric ultrasonic corona detection system offers this assurance and consists of a combination of two basic methods:
  (1) Ultrasonic Test:
    a. Observation by oscilloscope of the voltage pattern produced by a sensitive transducer located in or attached to the transformer.
    b. Observation by ear phones or loudspeaker of the audible portion of the output of the transducer.
  (2) RIV Test:
    Measurement of the radio influence voltage which appears in a sensitive coupling circuit connected to the capacitance tap on the high-voltage bushings.

CORONA TESTING

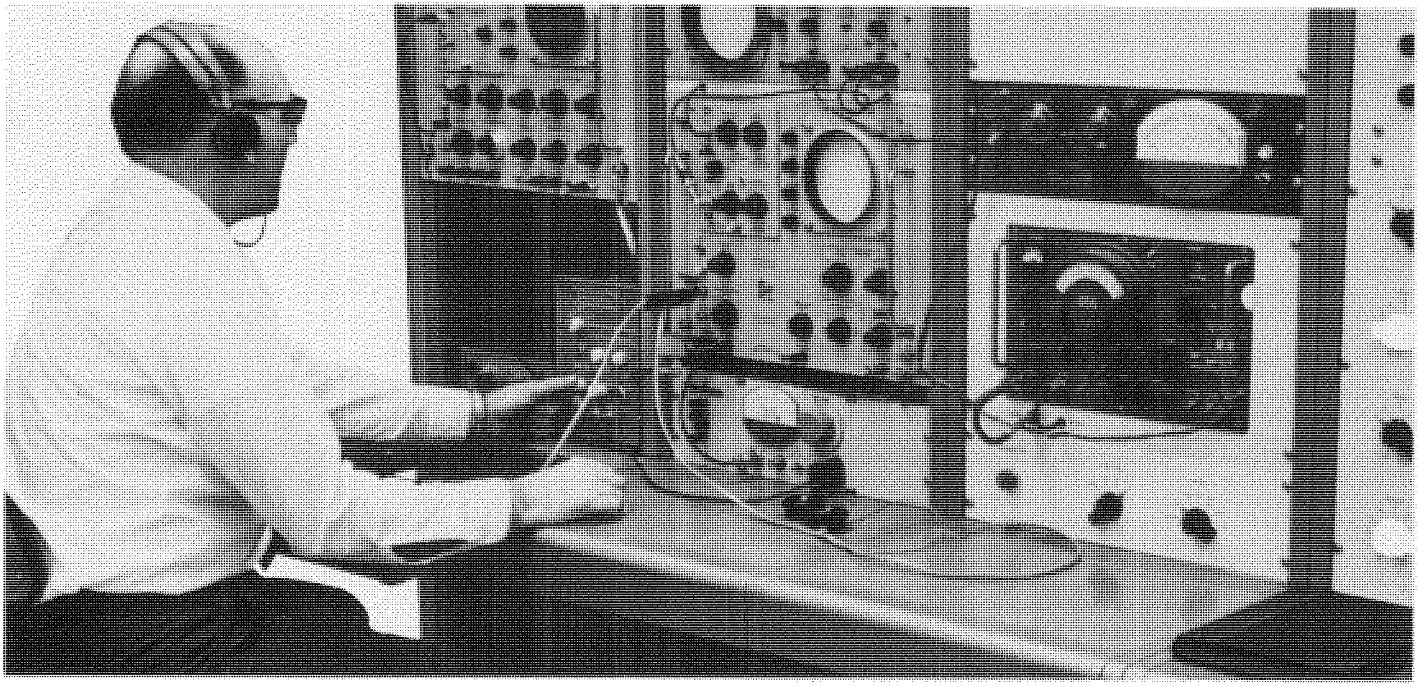
Corona is a warning symptom that the transformer's insulation system is being over-stressed. Without immediate and positive means of detecting and locating the damaging portion of this discharge, the transformer's insulation system can be totally destroyed. What are some of the effects of corona on insulation?

- Corona has an abrasive effect on transformer insulation. It scars and tracks and can eat into and physically erode insulations.
- Corona can cause chemical decomposition which degrades solid insulation and makes it brittle due to depolymerization of the cellulose molecules.
- Corona can decompose oil. Gas bubbles can then be carried by the oil throughout the insulation system and increase hazards elsewhere.
- Corona-generated RIV (Radio Influence Voltage) can interfere with carrier current communications.

Whatever its form, corona is capable thermally, chemically and mechanically of doing permanent damage to liquid and solid insulation materials.



Corona source is located by ranging from locations B, C, D. Oscilloscope measures time lapse between instantaneous electrical signal (via the bushing capacitance tap) and the slower sound signal heard by the transducer. Lapsed time indicates distance from transducer to corona source. Arcs drawn with these radii from each point intersect at corona location A.



CORONA— AN INCREASING NEED FOR DETECTION AND PREVENTION

The increasing emphasis on corona detection and prevention is brought about by two additional factors:

(1) Today's transformers are being specified with reduced insulation levels and better lightning protection. This reduction in insulation level permits the manufacturer to make units smaller, lighter and less expensive, by decreasing the amount of insulation. This means that operating and test voltage levels are getting closer together.

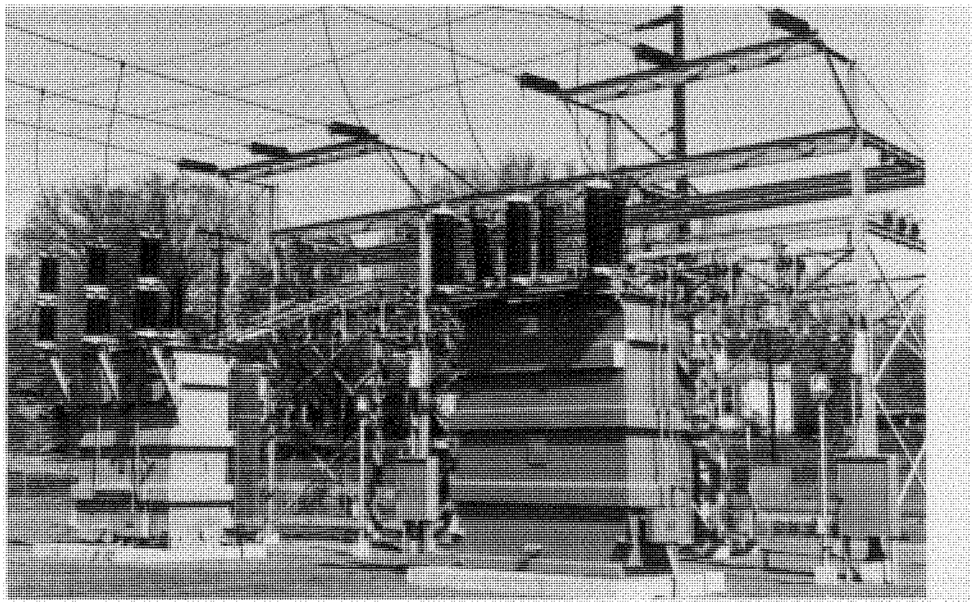
(2) Operating voltage levels on the other hand have increased. These additional factors make it doubly important that transformer manufacturers verify the integrity of the insulation system before the transformer is shipped from the factory. Standard industry insulation tests have proven inadequate in coping with all possible corona failures in transformers. The applied potential tests, induced voltage tests, etc., can, in themselves, initiate corona if a weak spot exists in the insulation system. Therefore, passing all standard tests is no assurance that a transformer is free of damaging corona.

TRANSFORMER PROTECTION

Transformer protection has three objectives:

1. To protect the transformer from conditions that can lead to damage or failure.
2. To protect a failed transformer from further damage that will increase the cost and time of repair.
3. To protect the remainder of a system from shutdown caused by a transformer failure.

In order to meet these objectives, GE offers a number of standard and optional transformer protection systems that are available to the purchaser, based on the relative importance of the transformer installation and the cost of providing such protection.



FAULT PRESSURE RELAY

Once a fault begins to progress in a transformer, a pressure wave is set up in the liquid. A fault pressure relay will sense this disturbance and quickly signal the removal of the transformer from the system, thus sparing the unit the extensive damage that might be incurred if additional fault energy is allowed to flow. This simple and inexpensive device is usually mounted on the tank wall below the liquid level in a location that provides optimum sensitivity and reliability by placing the relay sensor near the winding which it is intended to protect. For adequate transformer protection a circuit breaker is used to disconnect the transformer from the power system.

LIQUID-LEVEL GAGE AND LIQUID THERMOMETER

The oil is a vital component of the insulation system of the transformer, and it is essential that it be maintained in adequate supply and at satisfactory temperature. A warning signal by either the liquid-level gage or the liquid thermometer is an indication that a potentially harmful condition exists in the transformer and steps should be taken to correct the situation. Alarm contacts are provided in these devices when specified by the purchaser to actuate the warning signal.

WINDING TEMPERATURE EQUIPMENT

While voltage and current are the system characteristics most important to the operator, the condition of the transformer is closely related to the temperature of the windings. The life of the winding insulation is a function of its temperature, and continued useful service from the unit requires that insulation temperature be kept within clearly defined limits. Winding temperature accessory equipment is available to allow the operator to monitor this condition so that corrective action may be taken when needed. Equipment is available in three forms:

1. Local gages mounted on the transformer for visual indication.
2. Local relays that may be used to turn on transformer cooling fans or to sound an alarm, either locally or at a remote location.
3. Temperature-sensitive resistors which can be used in a bridge circuit to actuate a remotely-located gage for visual indication.

While winding temperature is a function of current carried by the winding, it is also affected by voltage since core loss affects the oil temperature, ambient temperature, and external environmental conditions such as the presence of wind or the operation of cooling fans. Winding temperature equipment integrates all of these factors through a simulation network to provide an accurate indication of the temperature of the hottest-spot in the transformer windings of two-winding transformers. For three-winding transformers where division of the load may vary between two output windings a separate device is required in each winding for accurate indication.

SURGE ARRESTERS

Voltage surges may appear on electrical transmission and distribution systems as a result of lightning strokes on or near a line or because of switching of the current carried by the system. Damage to a transformer winding may occur if such a voltage is allowed to reach the transformer, and surge arresters are available for application to the system to prevent such an occurrence. The surge arrester provides a temporary low impedance path to ground allowing the electrical charge associated with the voltage surge to reach earth harmlessly and then re-establishes the insulation between the circuit and ground so that system voltage can not produce a flow of "follow current" after the transient disturbance has passed. Surge arresters are selected for application to the electrical system based on system characteristics, and then transformer BIL (basic impulse insulation level) is specified to allow sufficient margin of protection between surge arrester operating characteristics and transformer insulation strength.

DIFFERENTIAL PROTECTION

In this most sensitive and reliable of all systems, internal current transformers monitor the current in the high-voltage and low-voltage circuits and instantly detect any unbalance caused by a beginning failure. A relay immediately signals a primary circuit breaker to remove the transformer from the system even before the conventional overcurrent relays can operate. Potential internal damage to the transformer is held to an absolute minimum, and the system is generally spared any harmful disturbance. General Electric's Primary Substation Transformers can be provided with bushing mounted current transformers to detect the magnitude and flow of current through the transformer.

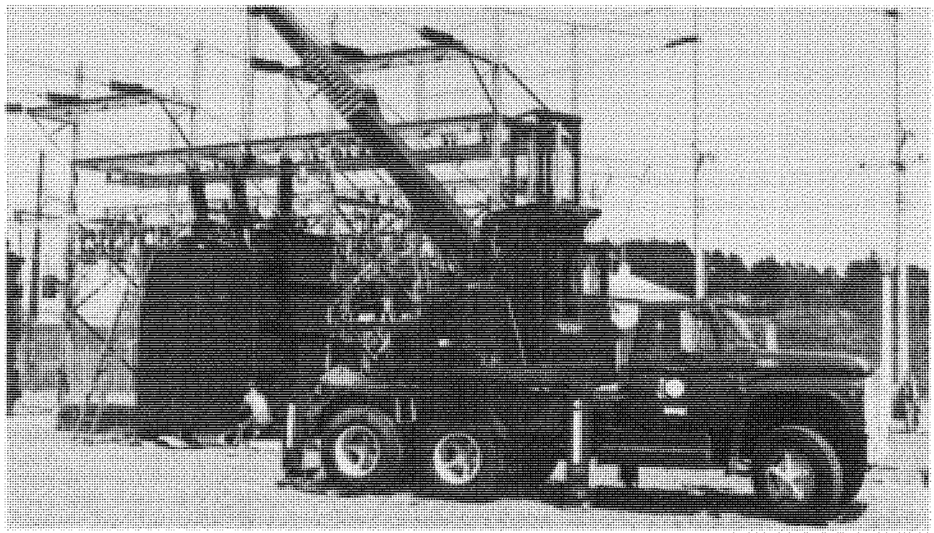
INSTALLATION

General Electric Primary Substation Transformers are designed and prepared for shipment to simplify the installation process in order to minimize cost to the user and minimize delay in getting the unit into service. Transformers are shipped as completely assembled as shipping limitations will permit—oil-filled with side-wall bushings in place if at all possible.

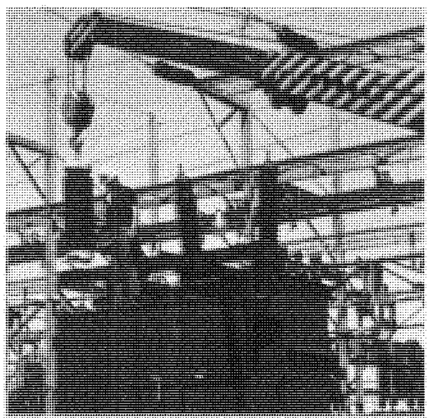
A variety of mechanical features facilitate the process of moving the trasformer from the conveyance to the operating site. The base is designed to allow skidding the unit in any direction on any firm surface or for rotating the unit in place. Pulling eyes at the four corners of the tank near the base are available for the attachment of pulling lines. Jack bosses at the four corners near the base allow raising the unit evenly so that supporting or skidding members may be inserted under the base.

Lifting lugs at the four corners of the tank near the cover provide for the lifting of the entire unit including oil. Tie-down holes are incorporated into the lifting lugs and the jack boses so that the unit may be securely fastened to a conveyance if it is to be moved any significant distance.

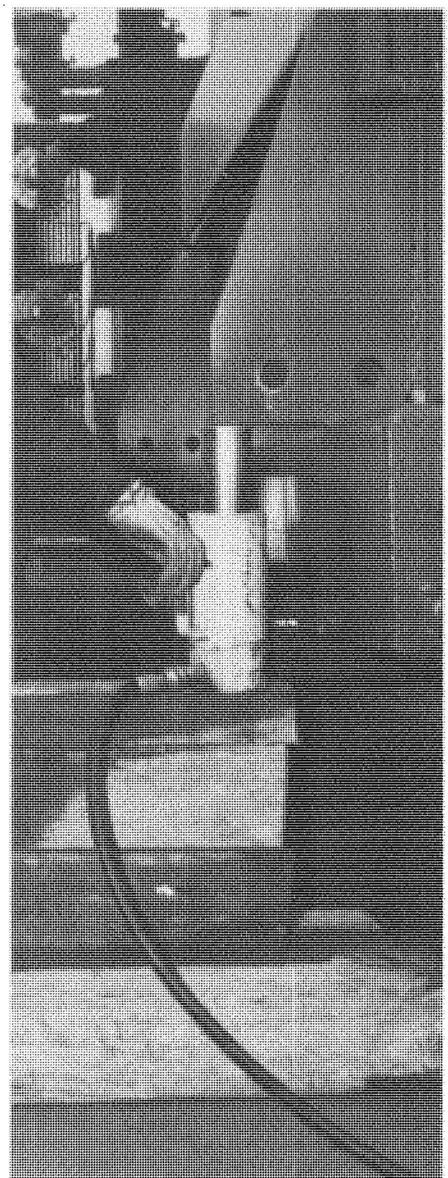
Finally, any large component attached to the main tank is provided with a set of lifting eyes to facilitate installation and possibel future maintenace. These lifting eyes are also used during factory assembly and will be found on the tank cover, bushings, Load Tap Changing equipment, junction boxes, radiators, terminal compartments, etc.



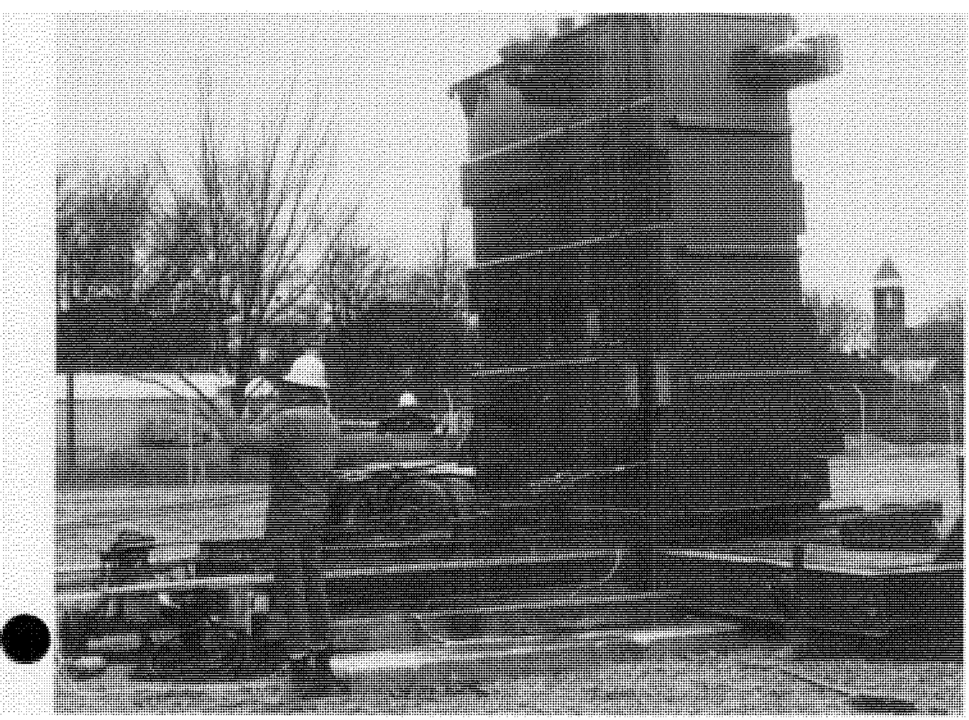
Removable radiators are easily positioned for mounting on the transformer tank.



Lifting eyes facilitate installation of surge arresters.



Jack bosses allow smooth installation and positioning on the transformer pad.



Pulling lines attached, the unit is skidded off the conveyance.

Keeping pace with your needs for improved, reliable primary substation transformers

Early in 1954, General Electric opened the Medium Transformer Department in Rome, Georgia to produce primary substation transformers in the 504 - 7500 kVA range, and a full line of secondary substation transformers for industrial applications. This plant, on a 265 acre site, was built with future expansion in mind.

Over the years expansion of facilities and modernization of equipment have kept pace with the increased demands for dependable electric power across the nation.

Our most recent expansion and modernization program added new Research and Development capabilities, and increased our capacity for designing, building and testing of primary substation transformers with self-cooled ratings through 30,000 kVA. Increasing the plant facilities, although significant, is only **one** step in accomplishing our primary goal of furnishing the best and most reliable transformer to meet your particular requirements.

Research and Development, computer technology, design engineering, quality control, manufacturing innovations, testing techniques and improved safe-shipment practices all play an important part in reaching this goal. And each is significant in establishing General Electric's Medium Transformer Department as a leader in transformer reliability.

GENERAL ELECTRIC

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