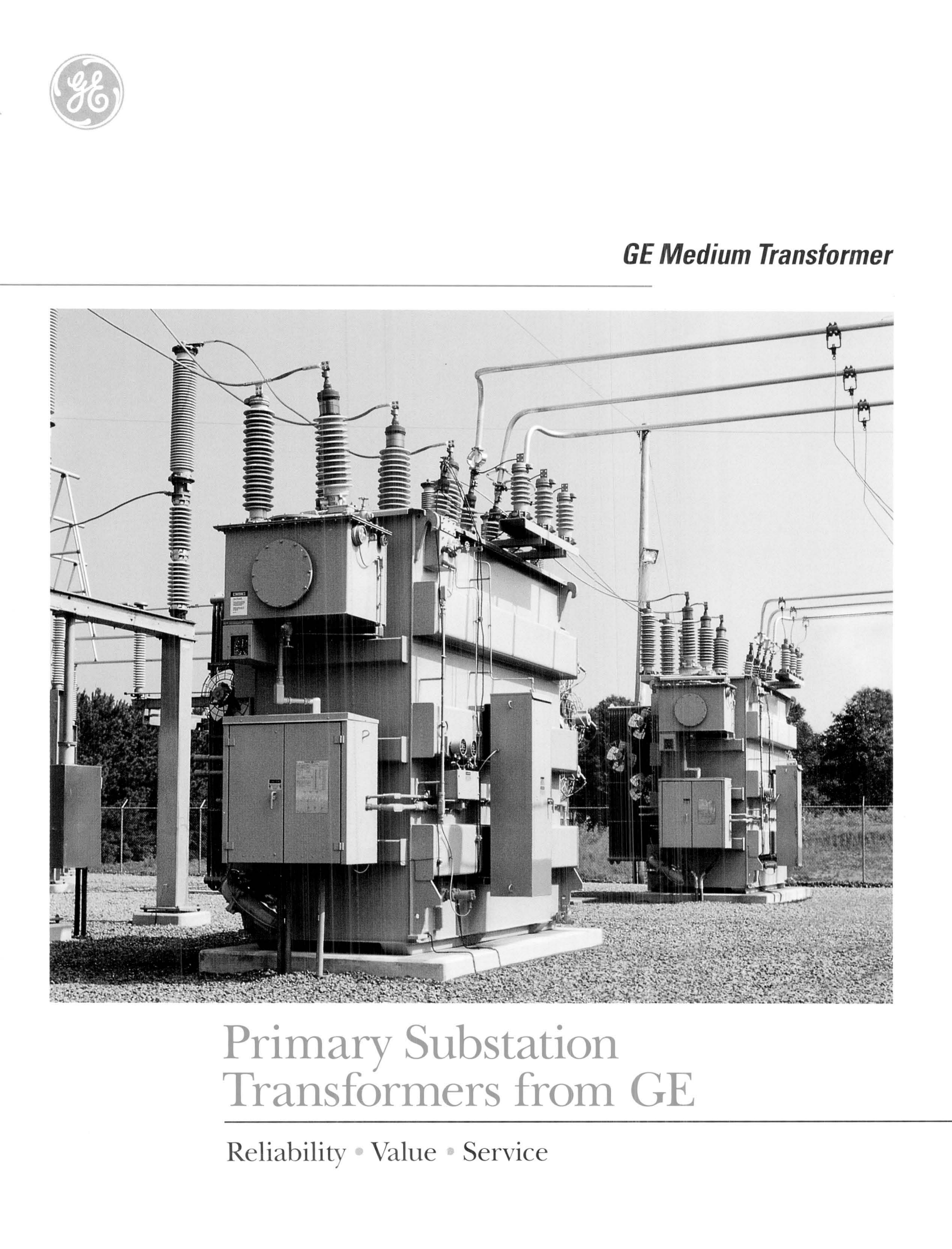

GE Medium Transformer

Primary Substation Transformers from GE

Reliability • Value • Service

History, Future, Commitment

With a broad spectrum of available products and nearly a century of operating experience, GE leadership in standards, availability, and service is well documented. Today, GE customers face new, complex issues when selecting engineered capital equipment such as primary substation transformers:

- Tight capital availability dictating lowest evaluated cost
- Requirements for transformers to communicate more effectively within "smarter" substations used in power system networks
- Highly efficient operation, more overload capability, simpler installation and service
- Shorter decision cycles that require faster cycle times on drawings and transformer delivery
- Highly responsive customer service and parts availability
- Product features and enhancements that solve customers' unique requirements

GE Hall of History Photo
Cover: RDC27,033-33-10

▲ A very early GE transformer. GE has the longest history of transformer manufacturing in the United States.

▶ Knowledge is passed to our new people, our investment in the future.

RDC27,033-23-4

Rome's cadre of manufacturing personnel build quality into each primary substation transformer every step of the way.

GE Medium Transformer is poised to answer these challenges with new management focus, millions of dollars of investments in engineering and manufacturing tools, and a vigorous program of employee involvement in all aspects of the business. In Rome, the result is paying off in improved productivity, quality and customer service.

From integration of all the most critical materials and processes, to investments in machinery such as the special Georg "E-Stacker", to fully computerized test bays, our Rome, Georgia factory is the premier plant for production of a broad line of substation transformers. While GE continues to upgrade its capability to respond to changing customer needs, it is also advancing transformer product technology with new materials and processes, electronic monitoring equipment, fiber optic development, and state of the art equipment and procedures.

This brochure describes many of the qualities and features of GE primary substation transformers; how they are engineered and manufactured, and how they can meet customer transformer needs. Technical bulletins are available for a more in-depth view of many of the features of these primary substation transformers.

Investing for Better Products and Services

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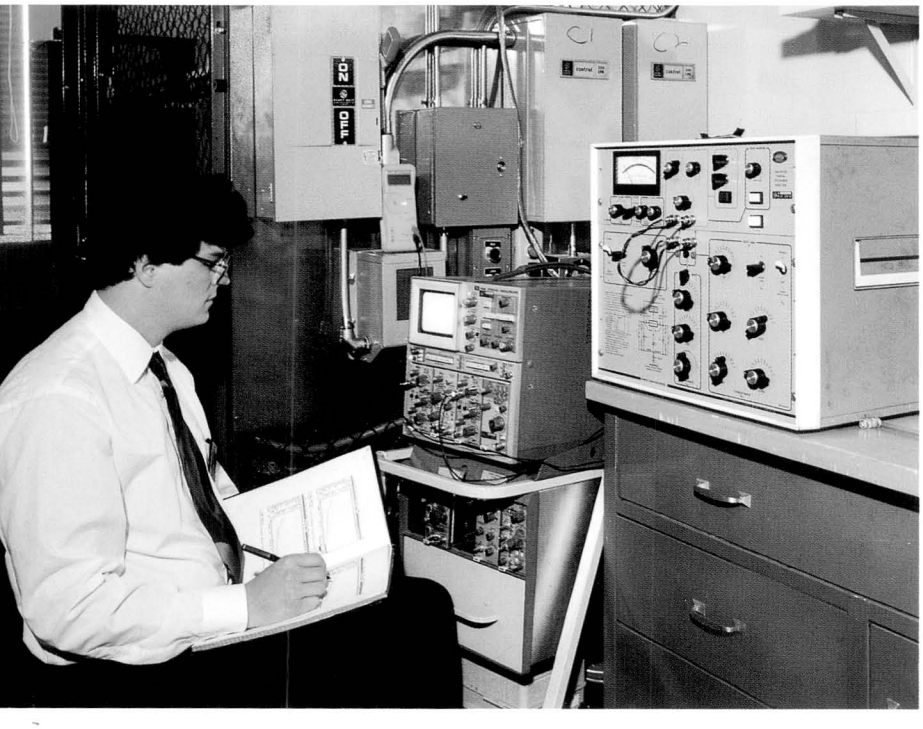
RDC27,033-B

Engineering and production concerns are collectively resolved in cross-functional meetings.

A chemist at GE's Corporate Research & Development Center reviews measurements during an experiment with insulation material.



Leadership is sustained by understanding customer needs and responding to them precisely, quickly and economically. Designing and manufacturing highly engineered equipment presents formidable – and often opposing – challenges. GE understands this better than anyone in the industry, and has been regularly investing millions of dollars in capability solutions. By listening to our customers, to our field service engineers and to our own craftspeople, we can now:

- Choose an optimum design from many alternatives and precisely integrate transformer size, loss and cost criteria while at the same time shortening engineering cycle times
- Computer-link engineering and manufacturing so engineering data is directly translated into the bill of material and shop orders needed to convert the design into a completed transformer
- Continue research and application of new developments in insulation, metallurgy, electrical characteristics and network communications.

Exclusive, Powerful Computer Tools To Improve Transformer Performance, Cost and Delivery

Economics and the environment are dictating that transformers conform to tougher requirements. Space for substation construction, sound levels, cost of installation, cost of operation, and shortened design and installation cycles are having a major impact in today's business world. GE has invested in artificial intelligence-based programs which allow our design engineers to tap the unequaled amount of data GE has

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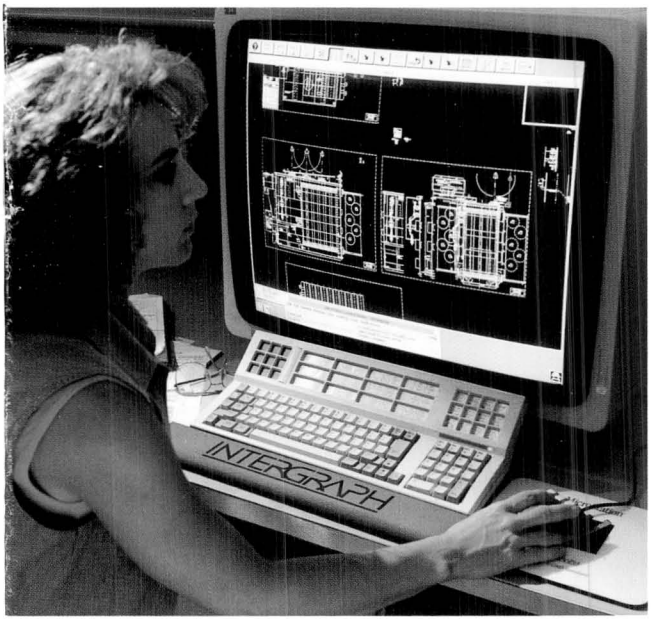
The knowledge-based engineering system integrates all customer requirements and depicts the optimum mechanical design in 3D. The engineering system is linked to the Manufacturing Resource Planning program.



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Final drawings are executed on one of many newly installed and networked CAD systems.

already compiled on transformer applications, and apply the data to quickly compare many design options. This high-speed process makes numerous comparisons and selects the optimum design for each application. Multi-million dollar investments were made in the engineering workstations used by GE design engineers to apply these programs to mechanical and electrical design parameters.

Electrical Design

GE's Corporate Research and Development Center developed Engineous® as the state of the art design tool for multiple applications in which a very large number of variables must be considered simultaneously. It is this software GE transformer engineers use to integrate the electrical design characteristics of primary substation transformers. The sophisticated artificial intelligence-based program makes direct use of GE's database while capturing the combined experience of the engineering staff. Electric and magnetic fields, for example, are calculated in multiple dimensions for optimum insulation structure and optimum loss performance. Engineous, using information from the mechanical design processes, reconciles weight, sound level, electrical parameters, size, capacity, losses and overall economic values . . . all in a fraction of the time it took before.

Mechanical Design

GE Medium Transformer has chosen a knowledge-based engineering system as the software platform for mechanical design. To increase accuracy and shorten cycle times, three-dimensional, object-oriented models of each transformer are developed to address the mechanical, electrical and manufacturing rules and limitations. Superior three-dimensional visualization helps solve complex criteria more efficiently. This system allows greater design flexibility and links to both the upstream and downstream processes from engineering through manufacturing and shipment.

The People In The Process

More employee involvement through workshops, critical production and engineering meetings, greater understanding of the entire business picture and more involvement in decision making are paying off. This total-scope employee participation breaks down barriers and speeds the flow of information throughout the business. Daily priorities can be adjusted to respond faster to business needs. An acute understanding of customer needs permeates the organization.

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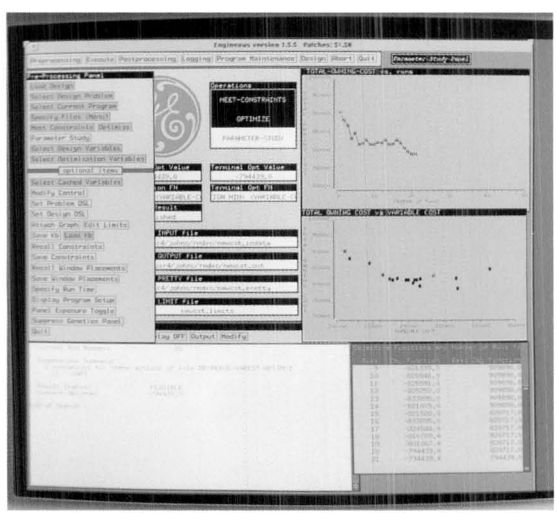


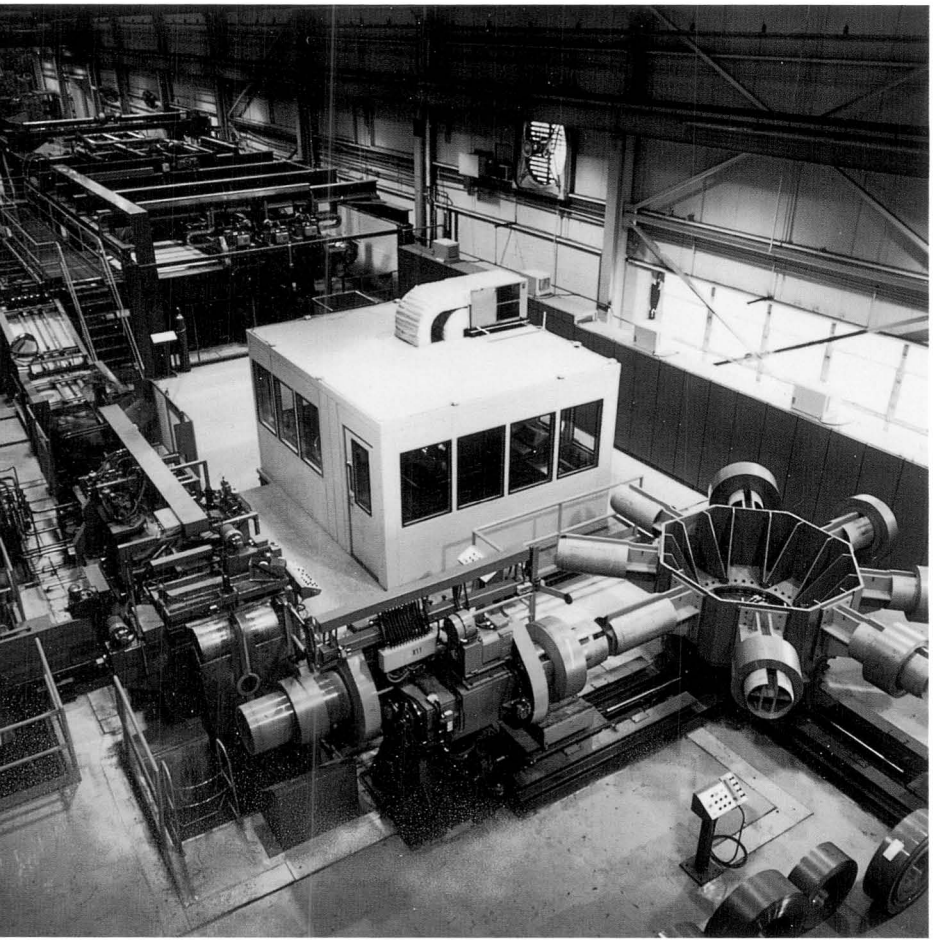
This engineering screen is running iterations to optimize lowest total owning cost.

At the same time, GE continues to take a leadership role in setting industry standards for electrical system and component design, including transformers, through its participation in ANSI, EEI, EPRI, IEEE, and other organizations. GE Medium Transformer benefits from the Company's long and comprehensive involvement in all phases of transmission, distribution and power delivery.

Efficient, Quality Execution of Quality Designs

GE's combination of experience and manufacturing engineering guide our processes to assure world-class quality and performance in our transformers. Communication between engineering, manufacturing and quality control has maintained control over materials, insulation, coatings, tooling, procedures, test, and shipment. The integration of these functions is being dramatically enhanced by a multi-million dollar investment in a Manufacturing Resource Planning (MRP) system. MRP accelerates GE capabilities by :

- Generating a bill of material and shop orders for every transformer order being manufactured. MRP takes input directly from the data generated by engineering design systems. This shortens the manufacturing cycle.
- Integrating all separate files and documents used by manufacturing into a closed loop system. Gaps and inaccuracies are immediately revealed. One repository contains all materials and schedules for each individual customer order.



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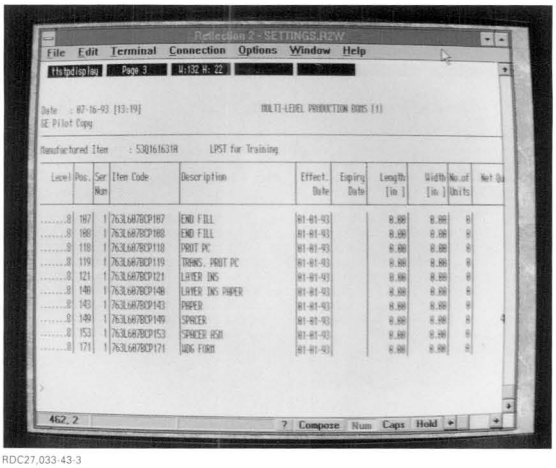

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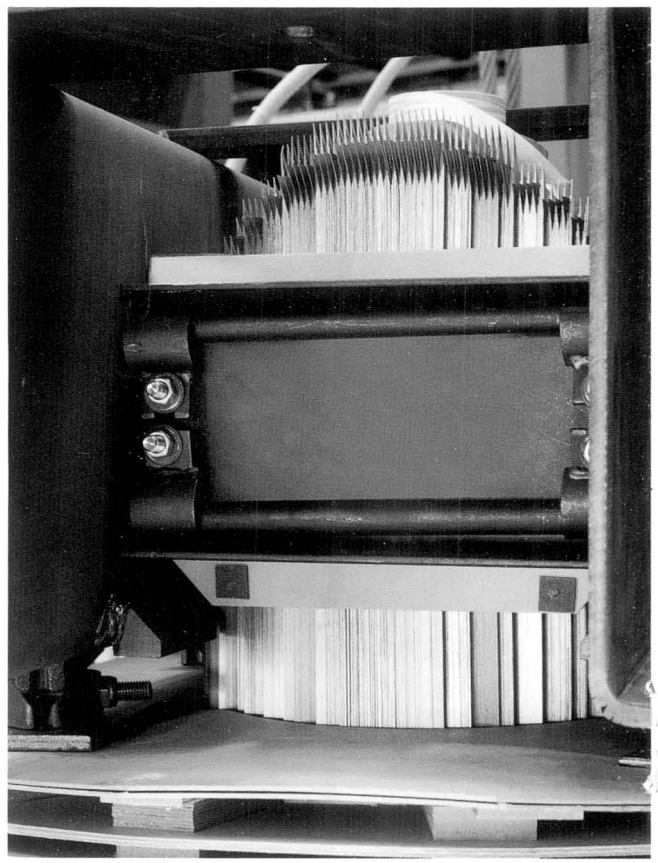
The computer controlled Georg "E-Stacker" ensures productivity and precision in the manufacture of the core.

These unique, GE-designed core cam plates clamp from both directions for extraordinary rigidity.

The Manufacturing Resource Planning program consolidates and integrates all manufacturing files for each transformer being built. It is linked downstream and upstream to other programs.



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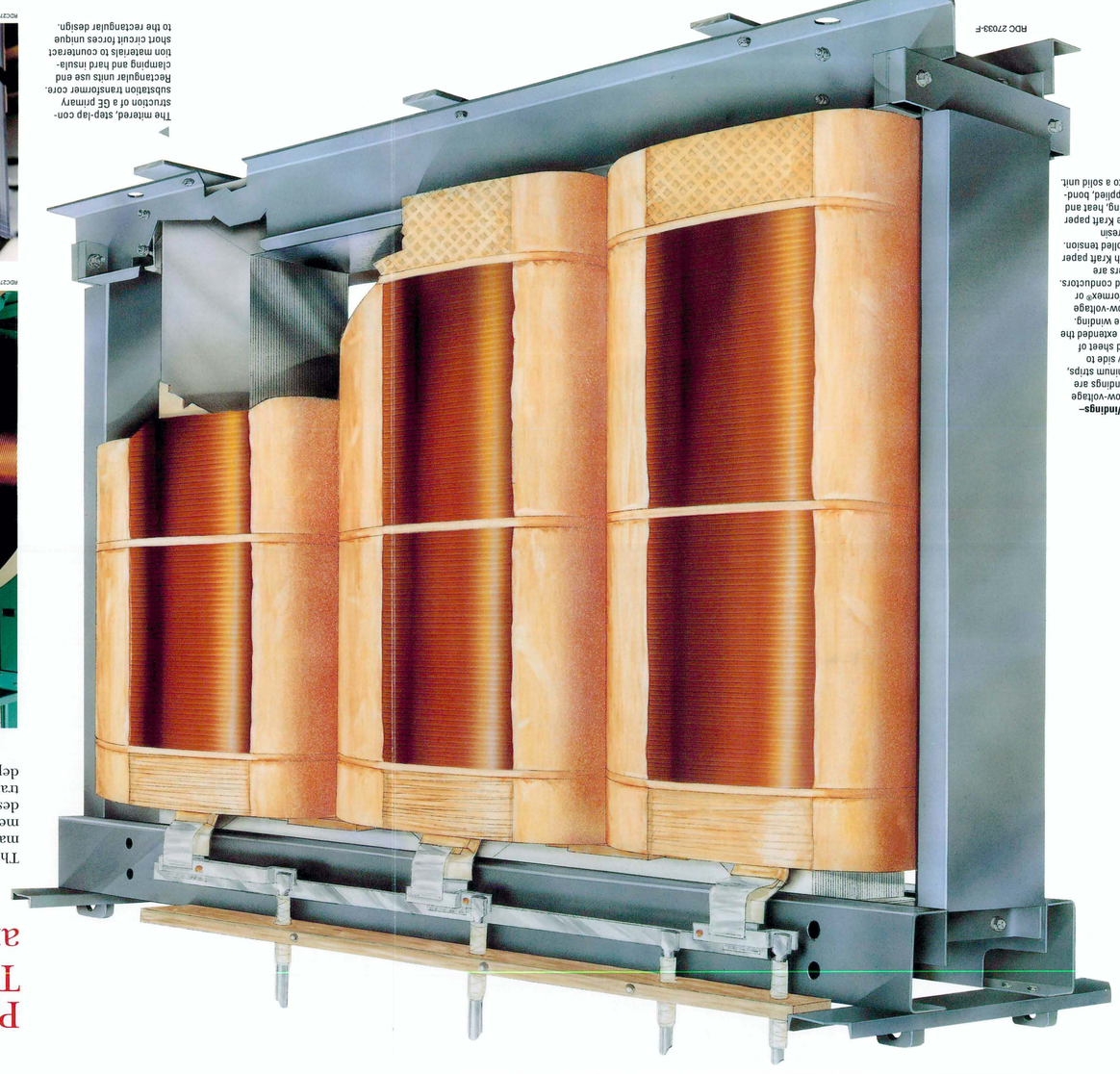

RDC 27033-F

Rectangular Windings– High-current, low-voltage rectangular windings are copper or aluminum strips, layered side by side to simulate a solid sheet of conductor, and extended the full height of the winding. Low-current, low-voltage windings use Formex® or epoxy-insulated conductors. Conductor layers are interleaved with Kraft paper in tightly controlled tension. Thermosetting resin impregnates the Kraft paper and after winding, heat and pressure are applied, bonding the coils into a solid unit.

The mitered, step-lap construction of a GE primary substation transformer core. Rectangular units use end clamping and hard insulation materials to counteract short circuit forces unique to the rectangular design.

RDC27,033-1-10

Rectangular Winding Forms– Adhesive bonded, rectangular winding forms are made of high-quality electrical-grade Kraft paper. The high- and low-voltage windings are combination wound and separated by Kraft paper insulation to provide maximum efficiency and to minimize axial forces. Duct spacers are added when needed to increase the circulation of insulating liquid.

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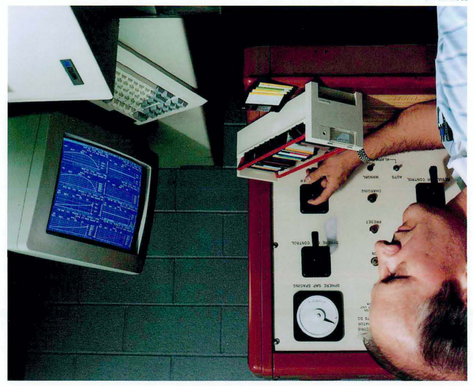

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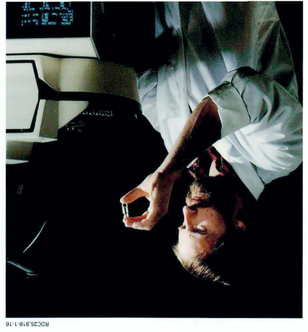
The latest test equipment measures and records test results. These results are stored on disk, and hard copies can be printed when needed.

GE insulating oil tests are the most comprehensive and stringent in the industry.



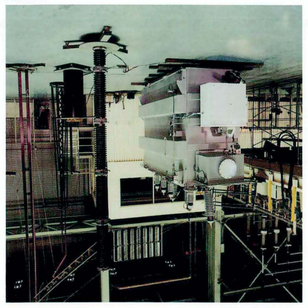
RDC28,918-1-16

Primary Substation Transformers 10MVA and Below 3Ø

The same care and quality of design and manufacture apply to all GE transformers. Our highly-efficient rectangular design is shown here. Many of these transformers also have electrostatically deposited epoxy powder insulation.

Testing is the Ultimate Quality Control

GE conducts a large array of tests on primary substation transformers. Numerous in-process quality control tests are conducted throughout the manufacturing process and prior to final test. Major final test facilities consist of over 30 test bays, including high-voltage impulse test bays, heat run test facilities and an anechoic chamber for sound testing. Every primary substation transformer is tested according to ANSI Standard Test Code for Transformers C57.12.90. State-of-the art equipment is used, with accuracy and calibration traceable to the National Institute of Standards and Technology. Test results are retained for future use. The following tests are conducted on every GE Primary Substation Transformer.



RDC27,033-8-8

One of the fully-equipped test bays at the Rome plant.

Standard Tests

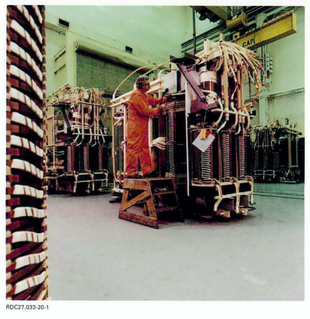
- Resistance measurements
- Ratio
- Polarity and phase-relation
- No-load loss
- Exciting current
- Impedance and load loss
- Applied potential
- Induced potential

RDC27,033-42-8

RDC27,033-6-7

New insulation systems are being applied with this new machine. Precise amounts of the insulating materials adhere electrostatically to the conductor and are then bonded by thermosetting.

The Schuler-Leuhart automated press locks coils in place with more force – by design – than any through-fault can exert.



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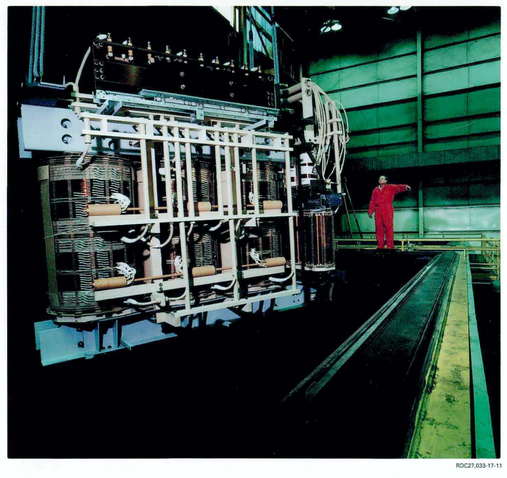
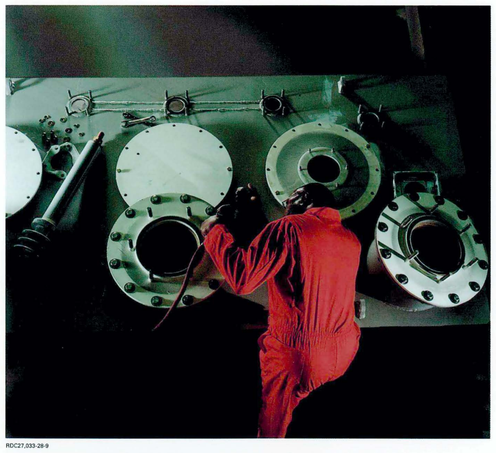
In the dry room, ≤2% humidity is maintained to prevent reabsorbtion of moisture and to allow final adjustment, tightening and quality inspection.



RDC27,033-17-11

Moisture is removed from the core and coil assembly during manufacture by a vapor phase drying process in specially-designed tanks.



RDC27,033-28-9

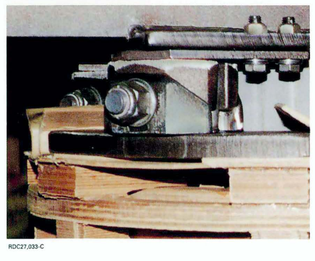
RDC27,033-13-2

Raised flanges help protect both bushings and tank interior from moisture.

Attention to detail builds quality into every GE transformer.

Many small design and assembly steps developed over the years help keep CTs in the correct position relative to the bushings.

GE's wedge-type coil clamping devices maintain uniform pressure around the coil.



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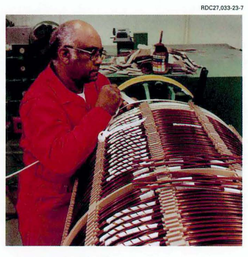
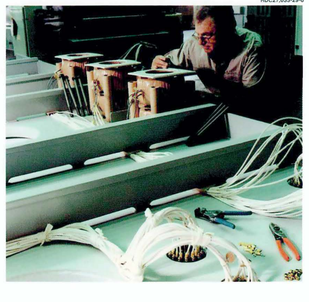


RDC27,033-23-7

Multiple winding machines staffed with our most experienced people help ensure quality and conformance to design rules.

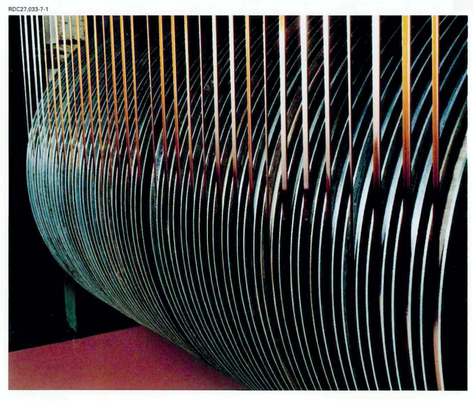


RDC27,033-29-6

Customer service can provide quicker answers to customer questions concerning the status of your order in the factory and provide real-time access to the status of all operations. The MRP system is shortening manufacturing cycles, optimizing material flow through the factory, increasing productivity, improving customer service, and improving transformer quality.

On the factory floor, automated tooling and equipment brings precision to insulation application, core assembly, and coil assembly. For example, electrostatically applied epoxy insulation is being used in selected low-voltage applications in GE transformers. Significant progress has been made in expanding the use of this insulation into higher voltage applications. GE pioneered Vapor Phase Drying to effectively remove moisture from the core and coil assemblies. Final spacing, adjustments and tanking are completed in a room where humidity is controlled to less than 2%. When complete, the transformer is filled with insulating oil under vacuum.

Quality assurance begins with the care that each employee takes in building a GE transformer. Attention to detail helps build reliability into a GE transformer every step of the way.



RDC27,033-7-1

The Formex insulation system has been proven by decades of use. The application system maintains precise thickness and bonding.

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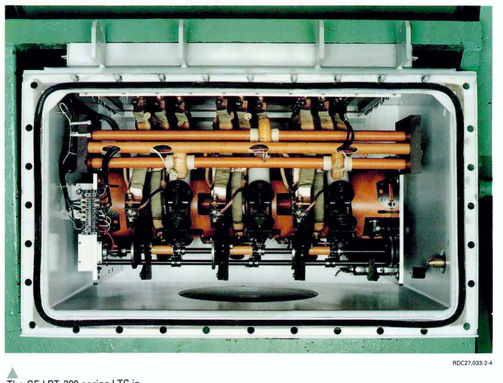
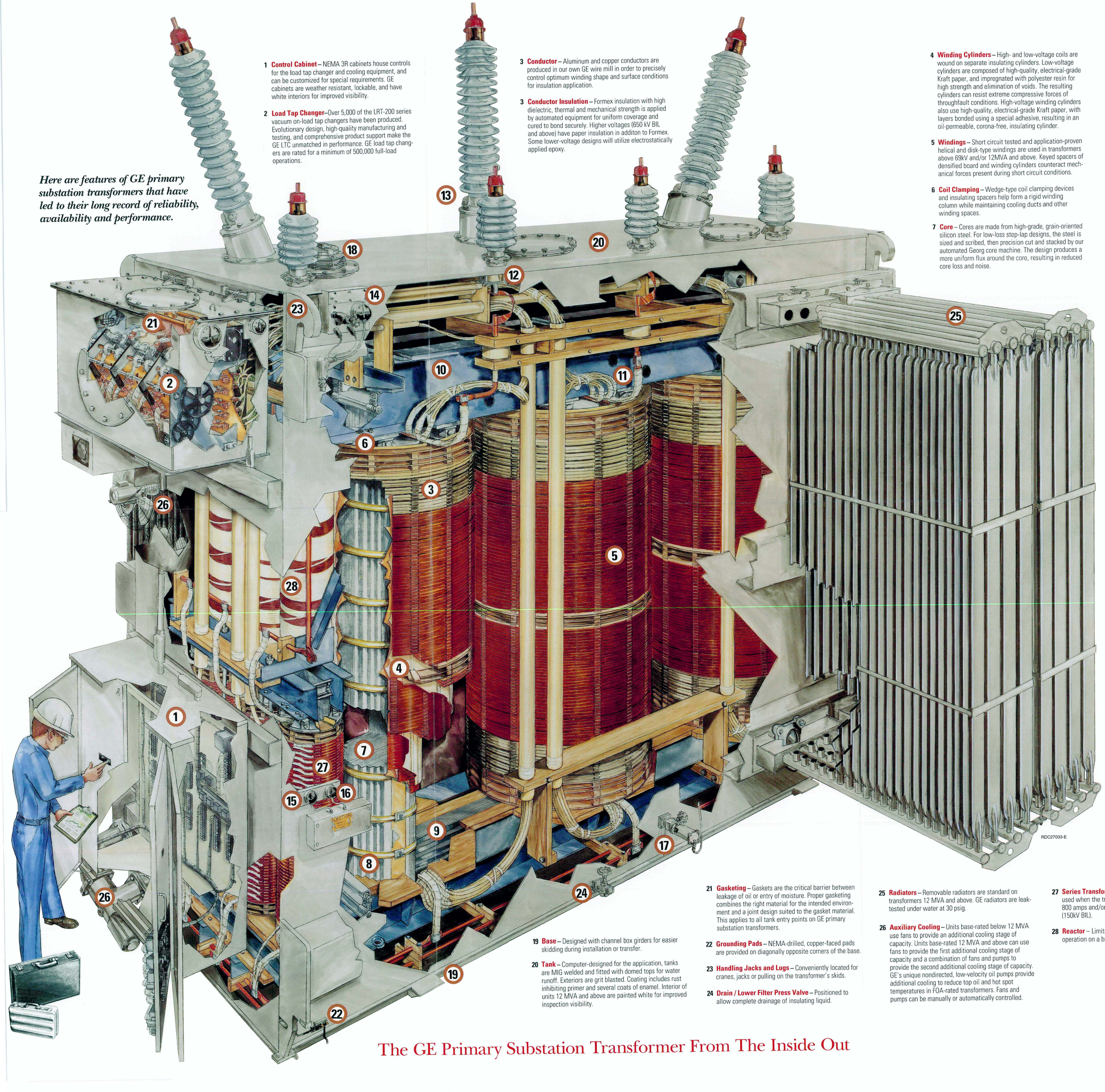
Many coats of paint, starting with primer, are sprayed or flow-coated, depending on the transformer.



RDC27,033-2-4

The GE LRT-200 series LTC is manufactured with precise attention to detail.

Here are features of GE primary substation transformers that have led to their long record of reliability, availability and performance.



1 Control Cabinet – NEMA 3R cabinets house controls for the load tap changer and cooling equipment, and can be customized for special requirements. GE cabinets are weather resistant, lockable, and have white interiors for improved visibility.

2 Load Tap Changer–Over 5,000 of the LRT-200 series vacuum on-load tap changers have been produced. Evolutionary design, high-quality manufacturing and testing, and comprehensive product support make the GE LTC unmatched in performance. GE load tap changers are rated for a minimum of 500,000 full-load operations.

3 Conductor – Aluminum and copper conductors are produced in our own GE wire mill in order to precisely control optimum winding shape and surface conditions for insulation application.

3 Conductor Insulation – Formex insulation with high dielectric, thermal and mechanical strength is applied by automated equipment for uniform coverage and cured to bond securely. Higher voltages (650 kV BIL and above) have paper insulation in additon to Formex. Some lower-voltage designs will utilize electrostatically applied epoxy.

4 Winding Cylinders – High- and low-voltage coils are wound on separate insulating cylinders. Low-voltage cylinders are composed of high-quality, electrical-grade Kraft paper, and impregnated with polyester resin for high strength and elimination of voids. The resulting cylinders can resist extreme compressive forces of throughfault conditions. High-voltage winding cylinders also use high-quality, electrical-grade Kraft paper, with layers bonded using a special adhesive, resulting in an oil-permeable, corona-free, insulating cylinder.

5 Windings – Short circuit tested and application-proven helical and disk-type windings are used in transformers above 69kV and/or 12MVA and above. Keyed spacers of densified board and winding cylinders counteract mechanical forces present during short circuit conditions.

6 Coil Clamping – Wedge-type coil clamping devices and insulating spacers help form a rigid winding column while maintaining cooling ducts and other winding spaces.

7 Core – Cores are made from high-grade, grain-oriented silicon steel. For low-loss step-lap designs, the steel is sized and scribed, then precision cut and stacked by our automated Georg core machine. The design produces a more uniform flux around the core, resulting in reduced core loss and noise.

8 Legs and 9 Yokes – Stepped identically for electromagnetic balance.

10 Clamps – Core legs and yokes on the circular core design transformers are held rigidly by unique locking plates and bosses. Top clamps are box type, pre-bowed for uniform pressure along length. Bottom clamps have long flanges for extra strength. Both top and bottom clamps employ GE-exclusive cam plates for longitudinal rigidity.

11 Leads and Cables – Based on the current-carrying requirements, insulated cables, solid rods, or bars complete the winding connections. Leads pass through supported insulating tubes or channels for support and stability.

12 Current Transformers – Available for relaying and metering applications in a variety of ratios and accuracy classes.

13 Bushings–Oil insulated bushings rated 23 kV and above have external connections for power factor testing. Bushings are furnished in accordance with the latest ANSI standard.

14 Pressure Vacuum Gauge – Provided on both main and LTC tanks for field monitoring of pressure or vacuum conditions.

15 Winding Temperature Gauges – Measure and indicate winding hot spot temperatures. Output from these gauges are used to control fan and pump operation. These gauges are standard on 12 MVA and above transformers and are available as an option below 12 MVA.

16 Liquid Temperature Gauges – Standard on all primary substation transformer designs.

17 Fault Pressure Relay – Optional for both main and LTC tanks. Mounted low on tank to detect pressure waves initiated by internal faults.

18 Pressure Relief Device–Provided on both the main and LTC tanks, these devices are designed to relieve pressures that exceed tank limits.

Not Shown

Gas Sampling Valve – Conveniently placed for sampling gas, manual release of pressure, or nitrogen blanketing.

Pressure Vacuum Bleeder – Standard. Regulates internal pressure and vacuum for both main and LTC tanks.

Insulating Oil – Oil refined to GE specifications undergoes dielectric testing upon receipt in GE's oil processing system, and is then dehydrated, deaerated, filtered and constantly monitored. GE's standards on insulating oil are the most stringent in the industry.

Oil preservation – GE's standard design is a sealed tank with an air space over the oil. Also available as options are:

- An automatic gas control design supplying a pressurized nitrogen blanket between the oil and the cover.
- An atmoseal system which employs a flexible air cell over the oil reservoir.
- A conservator system without the air cell over the oil reservoir.

Tube Type Cooling – Transformers with self-cooled ratings of 10 MVA and below are provided with non-removable cooling tubes. These tubes make the transformers smaller, and easier and faster to install. Tubes are tested at 30 psig before being welded on the tank. Removable radiators are available as an option.

19 Base – Designed with channel box girders for easier skidding during installation or transfer.

20 Tank – Computer-designed for the application, tanks are MIG welded and fitted with domed tops for water runoff. Exteriors are grit blasted. Coating includes rust inhibiting primer and several coats of enamel. Interior of units 12 MVA and above are painted white for improved inspection visibility.

21 Gasketing – Gaskets are the critical barrier between leakage of oil or entry of moisture. Proper gasketing combines the right material for the intended environment and a joint design suited to the gasket material. This applies to all tank entry points on GE primary substation transformers.

22 Grounding Pads – NEMA-drilled, copper-faced pads are provided on diagonally opposite corners of the base.

23 Handling Jacks and Lugs – Conveniently located for cranes, jacks or pulling on the transformer's skids.

24 Drain / Lower Filter Press Valve – Positioned to allow complete drainage of insulating liquid.

25 Radiators – Removable radiators are standard on transformers 12 MVA and above. GE radiators are leak-tested under water at 30 psig.

26 Auxiliary Cooling – Units base-rated below 12 MVA use fans to provide an additional cooling stage of capacity. Units base-rated 12 MVA and above can use fans to provide the first additional cooling stage of capacity and a combination of fans and pumps to provide the second additional cooling stage of capacity. GE's unique nondirected, low-velocity oil pumps provide additional cooling to reduce top oil and hot spot temperatures in FOA-rated transformers. Fans and pumps can be manually or automatically controlled.

27 Series Transformer – The series transformer is used when the transformer's rated current exceeds 800 amps and/or the rated voltage exceeds 25 kV (150kV BIL).

28 Reactor – Limits the circulating current during LTC operation on a bridged position.

The GE Primary Substation Transformer From The Inside Out

Pull Out >

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Conductor and insulation bonding quality control tests are regularly conducted and recorded.

Quality control test screen for the GE load tap changer.

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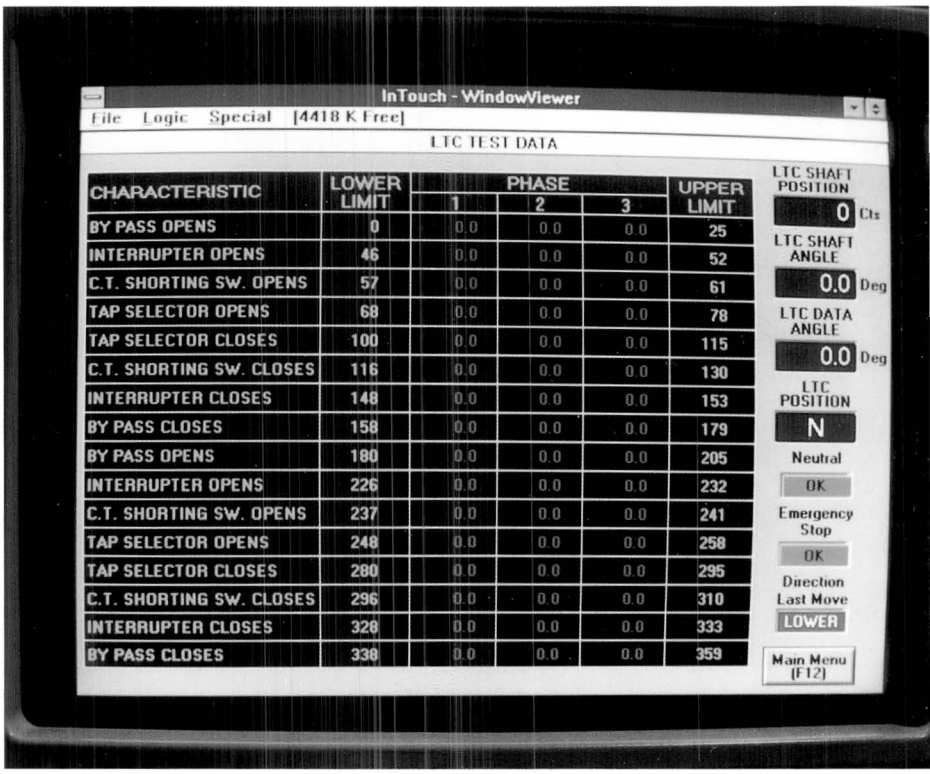
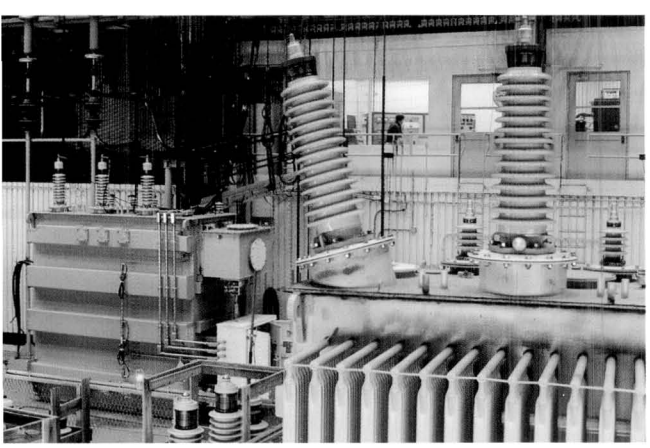


Additional Tests

Dissolved Gas in Oil Analysis is performed on all Class II transformers following standard tests. An oil sample is taken according to ASTM 3613 and tested according to ASTM 3612. Results are compared to our database for any required action.

ANSI Impulse Tests are performed on all Class II and higher transformers. This test consists of one reduced wave, two chopped waves, and one full wave on each phase bushing per ANSI C57.12.90. A digital analysis of the results provides superior test evaluation by the test operator.

Corona Tests are made on all Class II and higher transformers during the special one-hour induced test. The GE test consists of an RIV test in conjunction with an ultrasonic test to pinpoint the location of any corona present. Corona is a symptom that the transformer's insulation system is being over-stressed. Corona can permanently damage the liquid and solid insulation systems in a transformer. Standard tests have proven inadequate in predicting corona failures.



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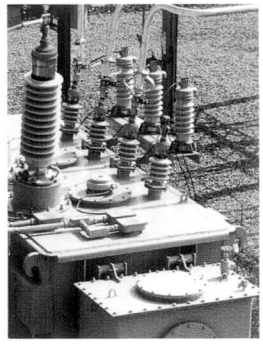
Corona tests are conducted on all Class II and higher transformers.

Optional Tests

- Front-of-wave impulse tests to be conducted along with the standard impulse tests
- Audible sound tests per ANSI/IEEE C57.12.90
- Temperature rise and overload heat run tests
- Insulation power factor test on the transformer and bushings

Accessories and Services That Help You Install, Operate and Maintain Your GE Transformer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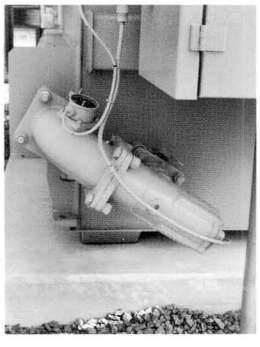
GE offers many accessories that help owners make the most of their investment in transformers. GE can incorporate new control and communication technologies to better integrate the transformer with other equipment in the power system. Emerging technologies such as fiber optic hot spot detection are being studied for integration into transformer protection.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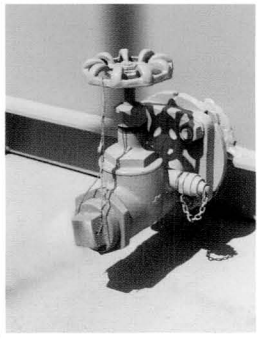
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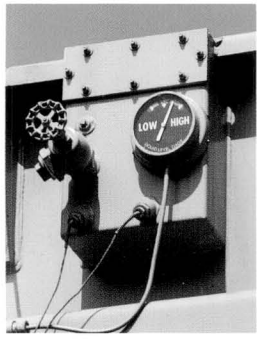
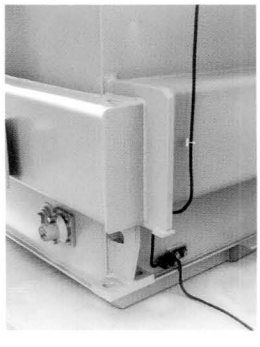
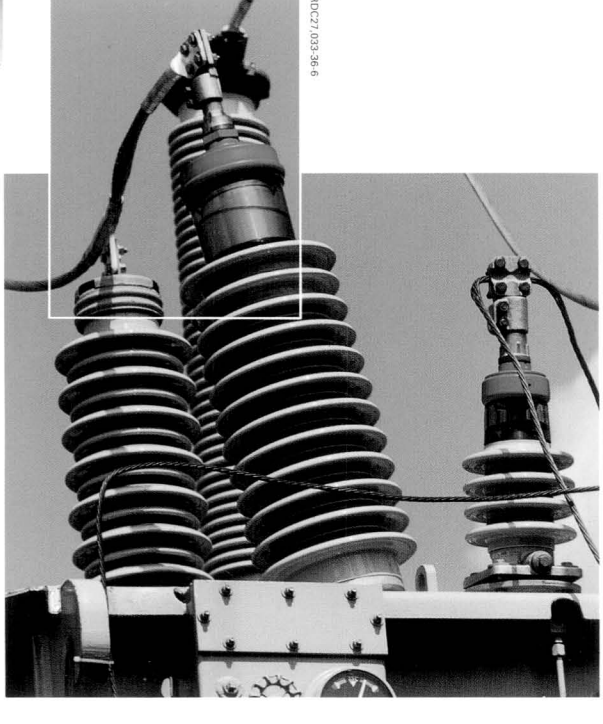


RDC27.033-36-7


RDC27.033-37-3

The GE Protection Group is designed to protect your investment from damaging conditions, protect a damaged transformer from more catastrophic and expensive damage, and protect the remainder of the system from shutdown in case of transformer failure.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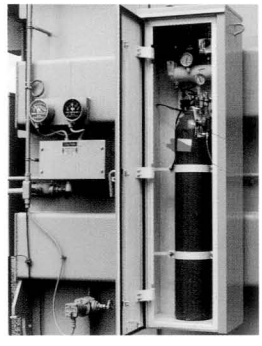
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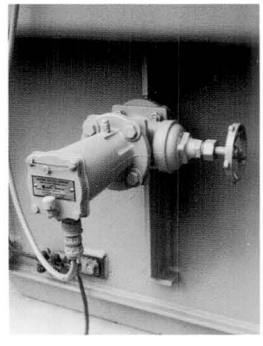
RDC27.033-37-7

Fault Pressure Relay– detects fault by sensing pressure wave. When connected to a circuit breaker, the relay can take the transformer off line.

Liquid Level Gauge & Liquid Thermometer– Both parameters must be monitored for reliable operation. Gauges can be equipped with optional contacts for alarm and trip functions.

Winding (Hot Spot) Temperature Thermometer– critical to the condition of the transformer, these sensing devices are provided for visual indication at the transformer. Switch contacts are provided for cooling equipment control, alarm and trip functions. Optional remote temperature indication is available through a resistance temperature detector (RTD) or thermocouple, either alone or with temperature transmitters.

Surge Arrestors– GE metal oxide technology provides excellent protection and temporary over-voltage capability. The gapless construction is based on a simple, reliable and economical design.

Differential Protection– This is the fastest, therefore, most effective early warning system available today. Differential relays fed by current transformers in the high and low leads detect any imbalance between high- and low-voltage windings, or reverse current flow. The relays signal the primary circuit breaker to remove the transformer from the system and limit the damage caused by any initial failure.

Shipping & Installation

GE primary substation transformers are shipped as securely and economically as possible. Standard practice is to ship FOB factory. FOB destination is available on request. Lifting lugs and jacking points also serve as tie down points for shipment. GE transformers are designed for easy and efficient installation. Detachable components, such as radiator assemblies and bushings, are equipped with lifting lugs. Tank bases have channels to make skidding easier.

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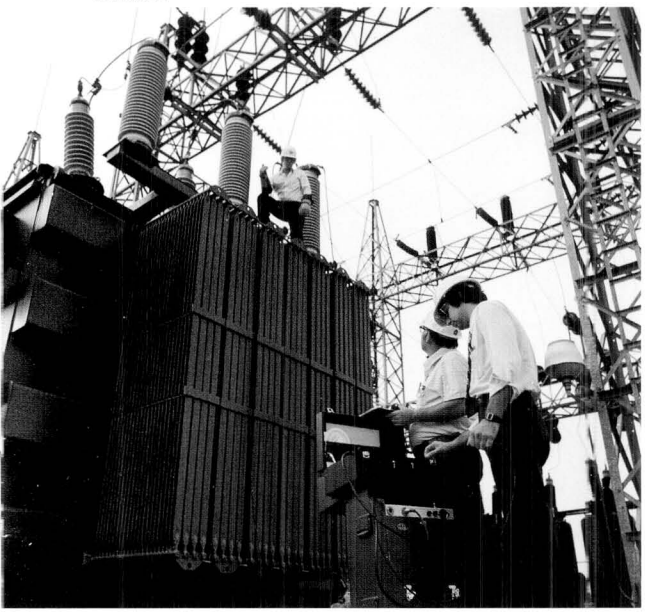

GE's Installation and Service Engineering group provides a variety of on-site services from over 80 offices strategically located nationwide. Some of these services are:

- Transformer installation and startup
- Substation design and construction
- Appraisals
- Predictive and preventive maintenance
- External repairs

GE's Apparatus Service group has specially equipped centers to provide repairs, uprates, and modernizations. Some of these services are:

- Rewinds
- Insulation, Impulse and Oil Testing
- Through-fault Analysis/Upgrade
- Leak Repair
- Gasket/Bushing Repair
- On-site Testing/Maintenance

GE maintains spare parts documentation on every transformer ever shipped, and our spare parts service is without equal. A number of parts packages are available to help you add performance by retrofitting components.

GE's transformer service network is second to none in the industry. GE's factory product service team is geographically organized to provide the best service possible through integration with field sales and service organizations.

▲ GE ships for maximum security of the product at least shipping cost.

◀ On-site testing conducted by a GE field engineer. GE's on-site engineering organization has more offices and more trained electrical engineers than any other transformer manufacturer; support that can be invaluable.

▼ Nationwide network of service locations.

RDC27,033-D

At GE Medium Transformer, these investments in people and processes continue to pay off in an ever-improving product, on-time shipments and responsiveness to changing technical and commercial needs. Our Rome, Georgia manufacturing facility is the largest of its kind in the world, and continues as a vital and productive center for primary substation transformers.

For more information about primary substation transformers and what GE Medium Transformer can do for you, contact your nearest GE Sales and Service Office.

GE Medium Transformer

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