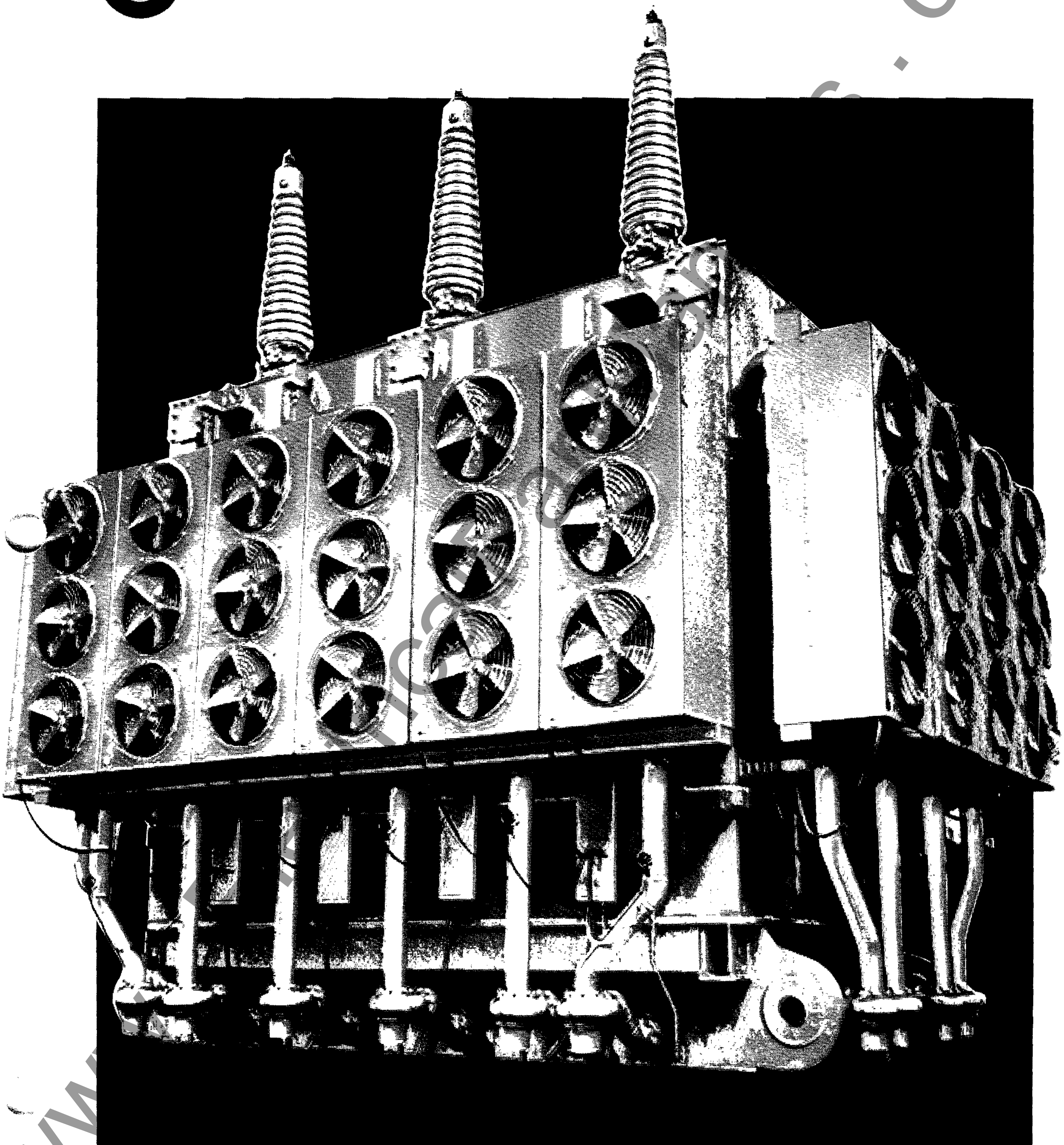
Westinghouse

Large Power Transformers



December, 1971
Supersedes DB 48-650,
dated Sept., 1970
E.D.C/2094/DB

Large Power Transformers

Westinghouse power transformers are used for transfer of electrical energy from generator to transmission system, at system interties and in large bulk power substations. Reliability is the foremost consideration in these applications.

Reliability is achieved in Westinghouse shell form power transformers without compromising economy of operation, physical size or initial cost.

General Description

A transformer design encompasses several interrelated components: An electrical circuit (coils) with proper proportions to give the necessary voltage transformation, a magnetic circuit (core) to provide magnetic coupling for the electrical circuit, an insulation system which also supports the electrical circuit, a high dielectric strength liquid (transformer oil) which also serves as a cooling medium, heat exchangers to dissipate the losses generated in the electrical and magnetic circuits, terminals for connection to an external energy system and a steel tank to mechanically support all components and contain insulating liquid.

Westinghouse transformer design satisfies the three basic criteria to assure reliable and economical service:

1. **Mechanical Strength** — The forces on the electrical and magnetic circuits due to handling, shipment and operation are supported by the insulation system and the steel tank.

2. **Thermal Capability** — Temperature is the most important factor affecting the useful life of a transformer insulation system. Hottest spot temperatures are lower in shell form transformers because direct cooling of the conductors is accomplished by oil flow over both sides of each coil.

3. **Dielectric Design** — The insulation structures are designed to eliminate excessive voltage stress, prevent ionization at test and operating voltages and eliminate corona discharges.

HV Coil Group

LV Coil Group

LV Coil Group

Core

Insulating Washer

Inter-Phase Blocking

Inter-Phase Blocking

Maple Core Blocks

Upper Core and Coil Support

Lower Core and Coil Support

Forced Oil, Forced Air Cooler

Oil Circulating Pump

High Voltage Bushings

Low Voltage Bushings

High Voltage No-Load Tap Changer

NLTC Operating Mechanism

Transformer Tank Top Section

Inner Tank Brace

Transformer Tank Bottom Section

Inner Tank Brace

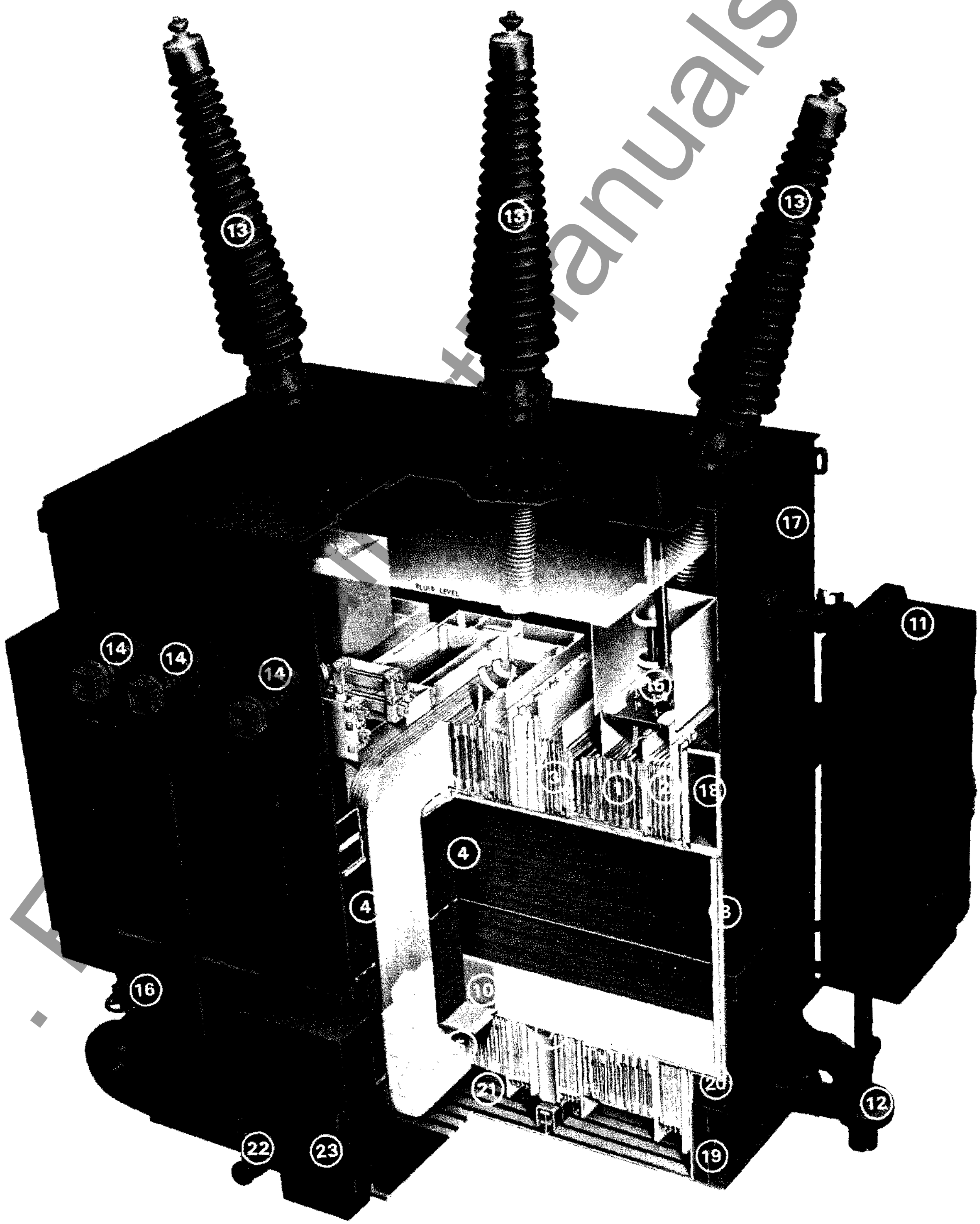
Tank Shielding

Drain Valve

Control Cabinet

Further Information

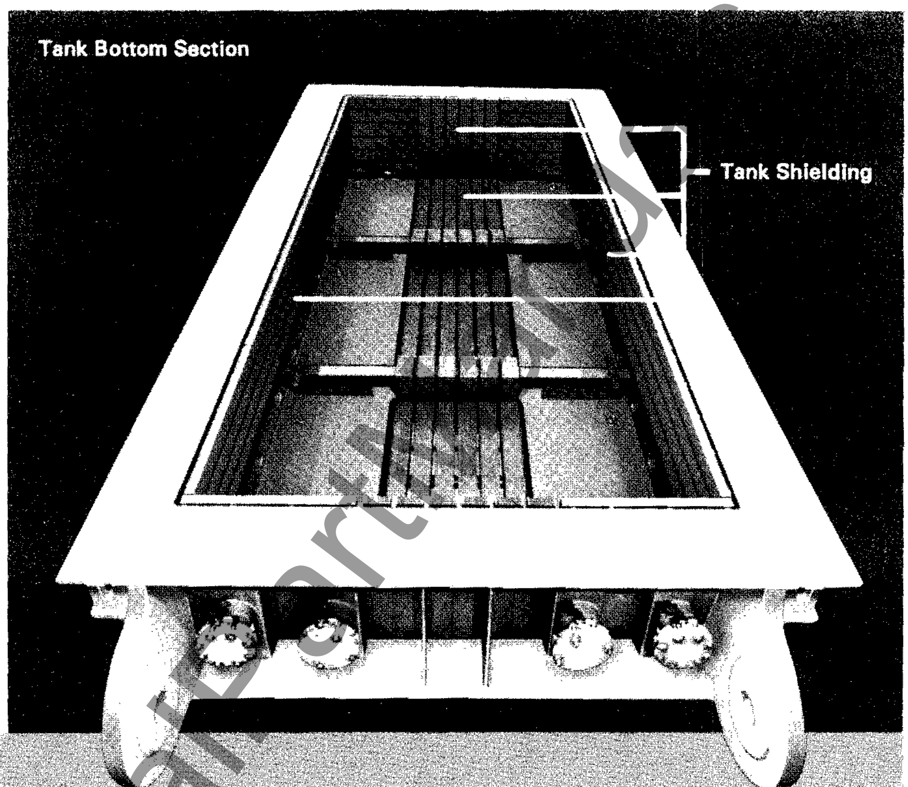
Prices — Price List 48-620
Technical Data — Technical Data 48-660

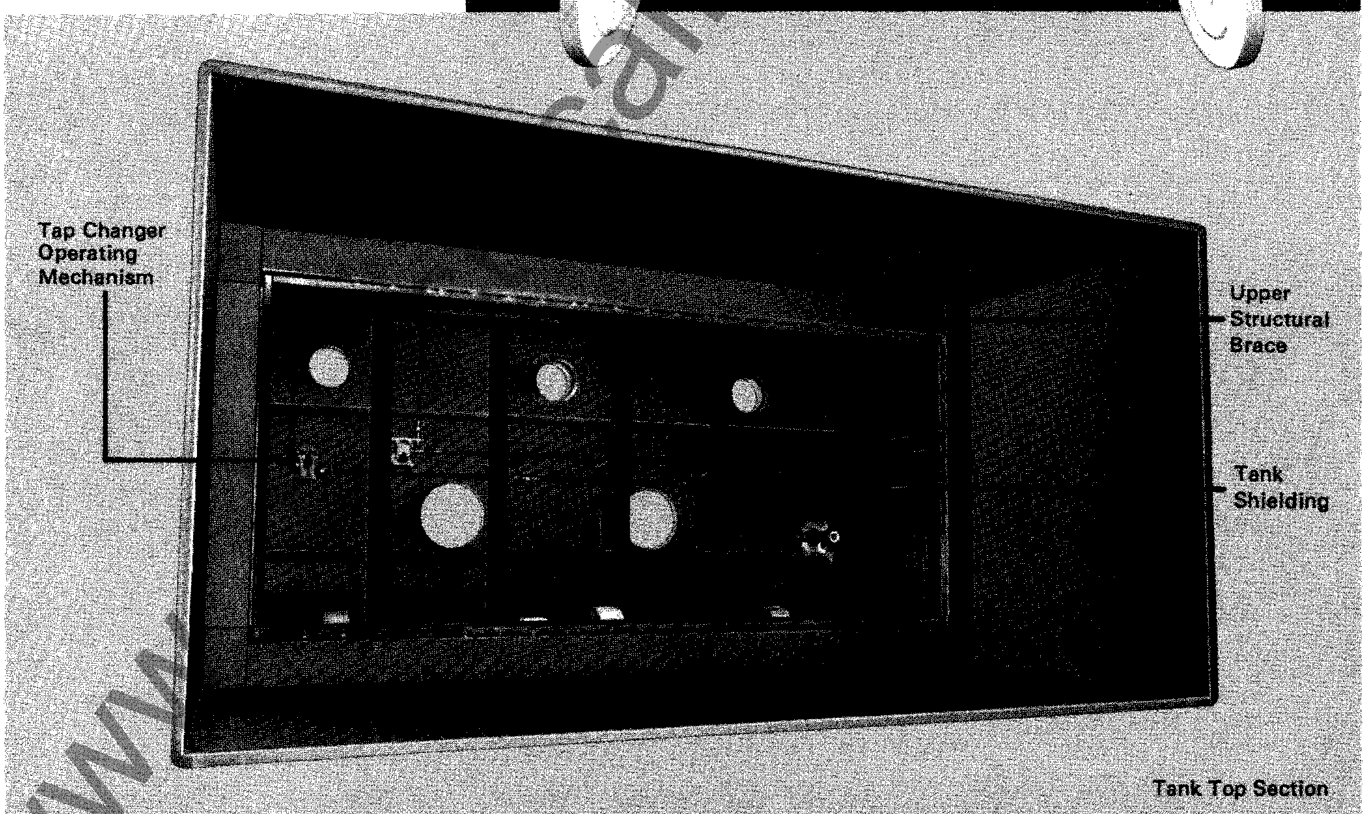

13
13
13
17
11
FLUID LEVEL
14
14
14
15
3
1
2
18
4
4
8
10
16
21
20
12
22
23
19

Mechanical Strength

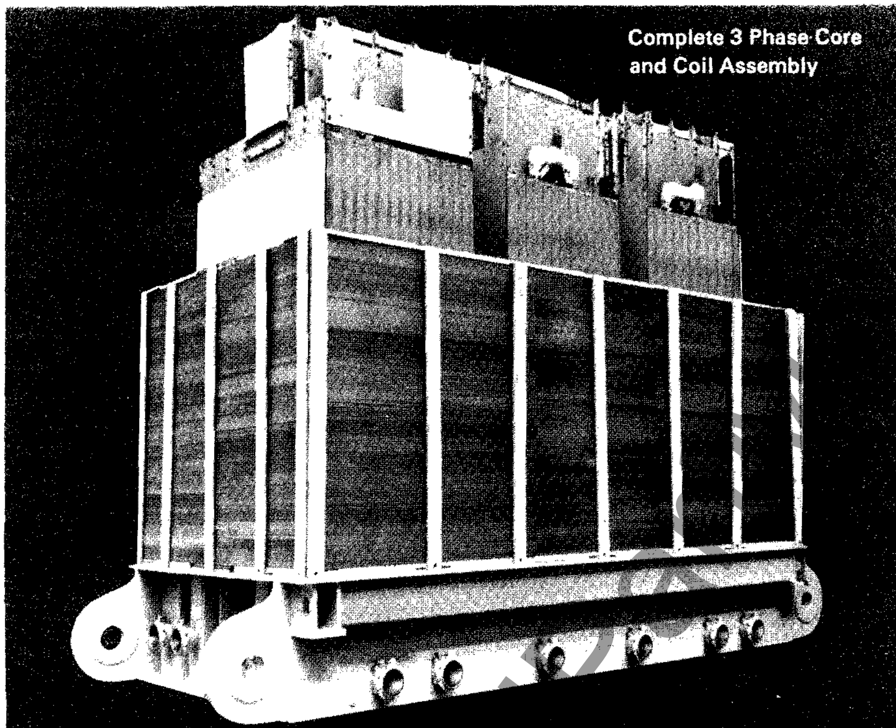
Significant benefits and advantages of the mechanical strength of Westinghouse Shell Form — Form Fit construction:

- Up to 20% reduction in weight.
- 30-40% less floor space required.
- As much as 40% less oil volume with corresponding reduction in field oil processing time.
- 10-15% reduction in total installation costs because of these factors.
- 30-40% greater mechanical strength — resulting in a through fault failure rate for Westinghouse Shell Form Transformers of only 1/5 the industry average.
- Westinghouse shell form transformers incorporate over 70 years of experience in areas of design, fabrication and knowledge of materials processing and testing to withstand the severe mechanical stresses imposed by through short circuits.
- Westinghouse has successfully applied the mechanical principals of shell form, form fit designs to transformers rated 1,300,000 KVA and to EHV units through 765 KV and 1100 KV.





Mechanical Strength

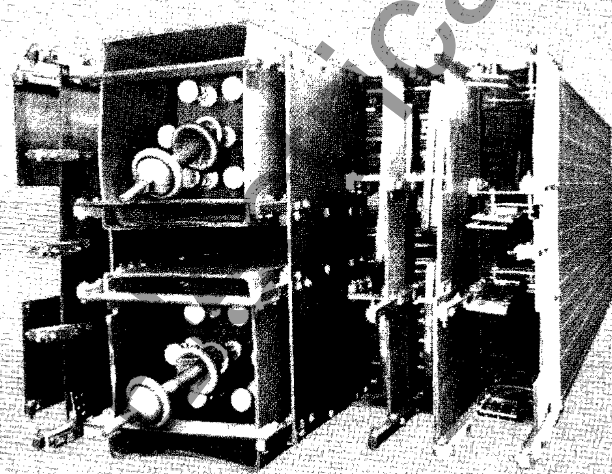


Complete 3 Phase Core and Coil Assembly

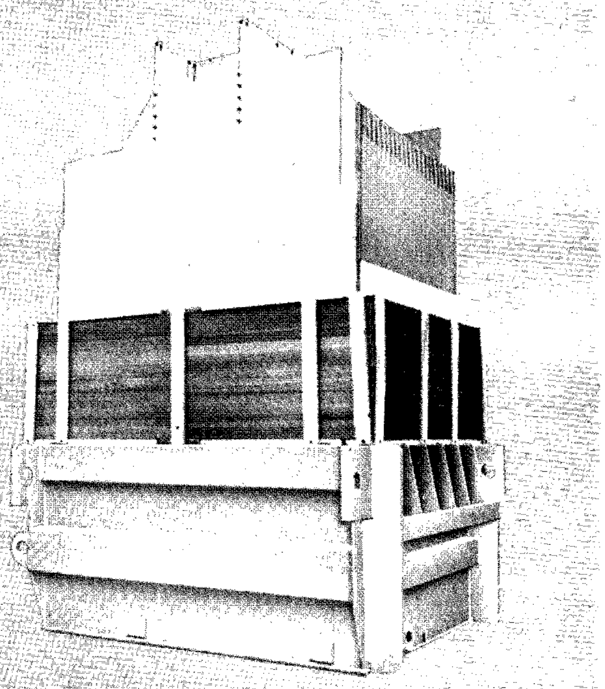
Westinghouse shell form transformers utilize a coil structure, core and a form fit tank designed and built into a unit assembly of high inherent strength.

The pancake type coils are mounted vertically and interconnected in the coil group to maintain a unidirectional current flow in adjacent conductors during all load conditions or during an external fault.

The pancake coils used in a shell form transformer are made up of multiple layers of conductor, wound into a broad rectangular configuration. A rectangular loop of wire carrying a heavy current has a natural tendency to assume a circular shape, particularly as the current and resulting forces increase. The forces causing a rectangular coil to form a circle are cancelled in a shell form transformer by the interleaving of the HV and LV windings, and the opposing current flow in these windings.



Transformer Phase Assembly



Single Phase Transformer Core and Coil Assembly

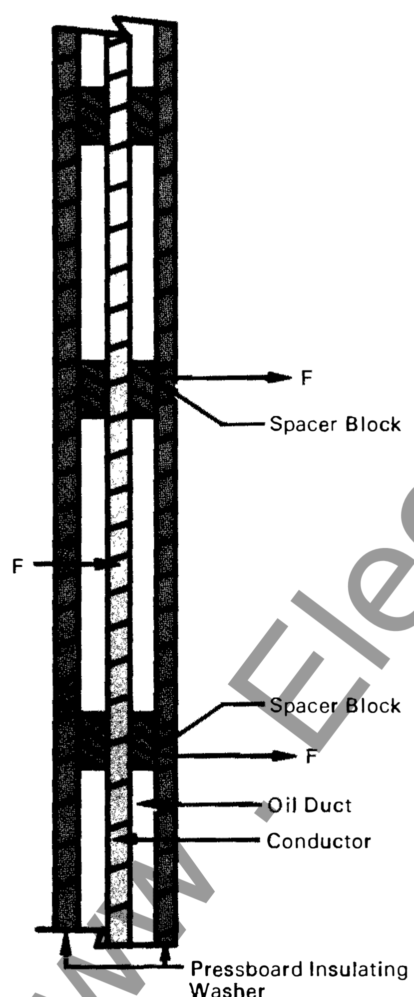
Mechanical Strength

The major mechanical force in a shell form transformer is one of repulsion from one coil group to the other (HV to LV). These forces are minimal during normal operation, however, they increase in proportion to current and are substantial during periods of fault. Each turn in the winding develops a force of repulsion to the opposing coil group, the resulting stress is supported by the turn acting as a beam across the pressboard spacer blocks adjacent to the coils. The magnitude of these forces is calculated for each transformer and the copper conductor is designed using sufficient cross-sectional area to withstand the forces without deflection.

Figure 1
The total summation of forces developed by the individual turns acts in two ways, first it tends to compress the inner, HV coil group and second, it forces the outer LV coil group outward against the core stack and and tank wall. The stress per unit area on the conductor and insulation material is kept at a low value because the forces are absorbed across the broad area of the coil face.

Figure 2
The repulsion force between the coil groups increases with KVA or current. The coil groups in the shell form transformer are divided and interleaved in order to limit these forces within the mechanical capability of the conductor and the pressboard insulation structures.

Figure 1: Cross-sectional View Illustrating Repulsion Force From Opposing Winding on Individual Turn



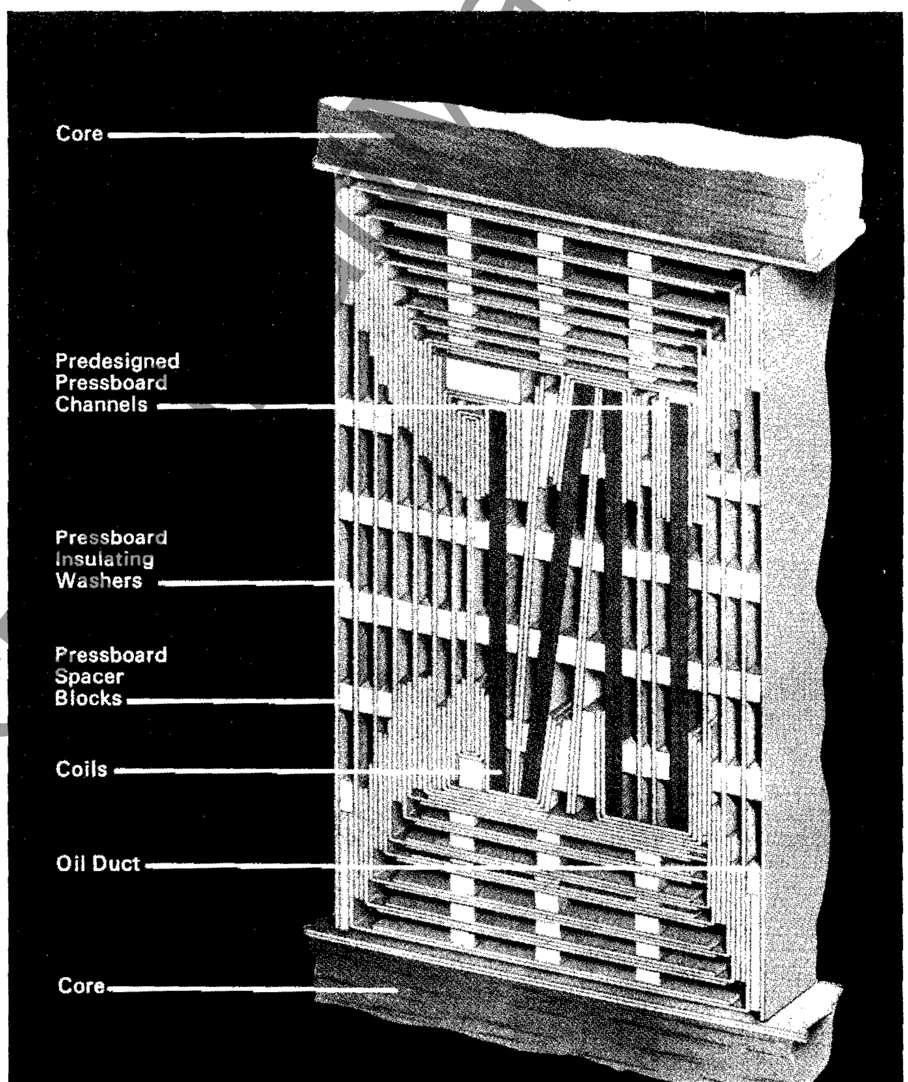


Figure 2: Cross Section of a Shell Form Winding Showing Line End Coils and Insulation Structure

Mechanical Strength

Figure 3
Interleaving is accomplished by dividing the LV winding into two groups and locating them on either end of the HV winding

The forces on the HV windings are absorbed by the pressboard and the conductor in compression and the forces on the LV windings are transmitted through the pressboard, core steel and maple core braces all in compression out to the steel tank wall. Immediately above and below the core stack a major structural steel tank brace absorbs the forces directly from the pressboard insulation, again in compression.

Figure 4
Further interleaving is used in larger transformers in order to limit the forces between coil groups resulting from faults The HV coils are divided into two groups and the LV coils are divided into three groups located between and on either end of the HV windings.

The bottom structural brace supports the entire weight of the core and coils and the top structural brace serves as a bearing surface and clamp for the core. When the two tank sections are welded together the core and coils are supported from all sides by the steel tank, forming a unit assembly. Stresses caused by shipping, handling and installation are absorbed by the tank wall without disturbing the internal structures.

Figure 3: Plan View of Standard Winding Development

F = Repulsion Forces
≶F = Summation of Repulsion Forces

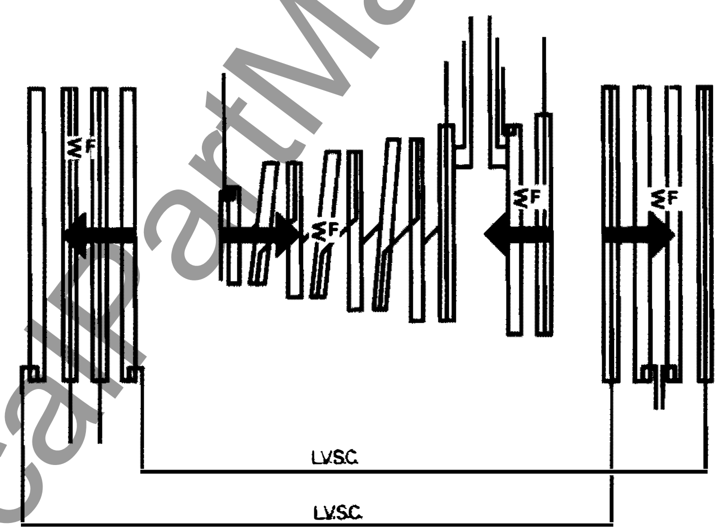
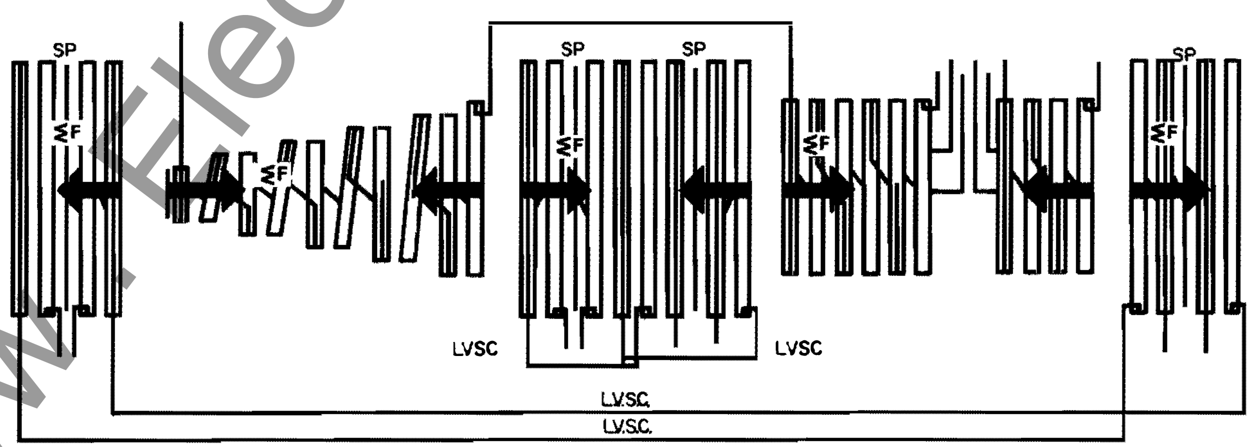
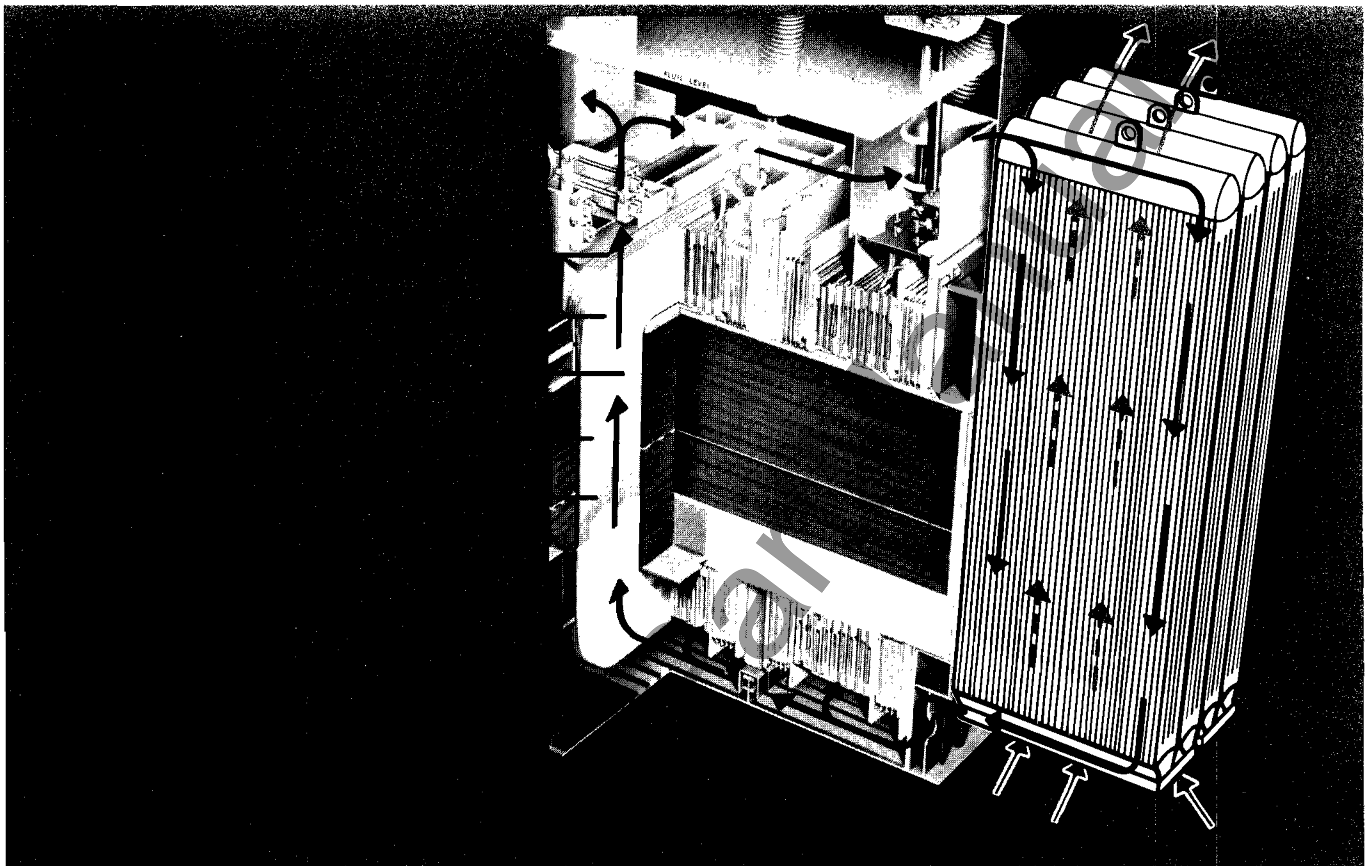


Figure 4: Interleaved Winding Development



Thermal Capability



Significant benefits and advantages of the thermal capability of Westinghouse Shell Form transformers.

- Maximum cooling efficiency because of oil flow directly over both sides of the conductor.
- 5°-10°C — Lower hottest spot temperatures during both self-cooled and forced-cooled operation.
- 3-5% — Lower I^2R loss during forced-cooled operation because of reduced conductor temperatures.
- As much as 5% — Increased insulation life because of reduced conductor temperatures.
- Up to 10% — Greater thermal capacity both for continuous loading and for short term overload capability.
- Insuldur thermally stabilized insulation system providing continuous 12% additional load capacity. ①

①Ask for SA 9025 for a complete description of the Insuldur system.

A transformer is a very efficient device, however, the losses in the electrical circuit and the magnetic circuit generate heat which must be dissipated. The transformer oil in addition to being a liquid insulator serves as a means of carrying the heat away from the working parts of a transformer to a heat exchanger where it can be dissipated to the atmosphere. The efficiency of the dispersion system determines the thermal capability and insulation life of a transformer.

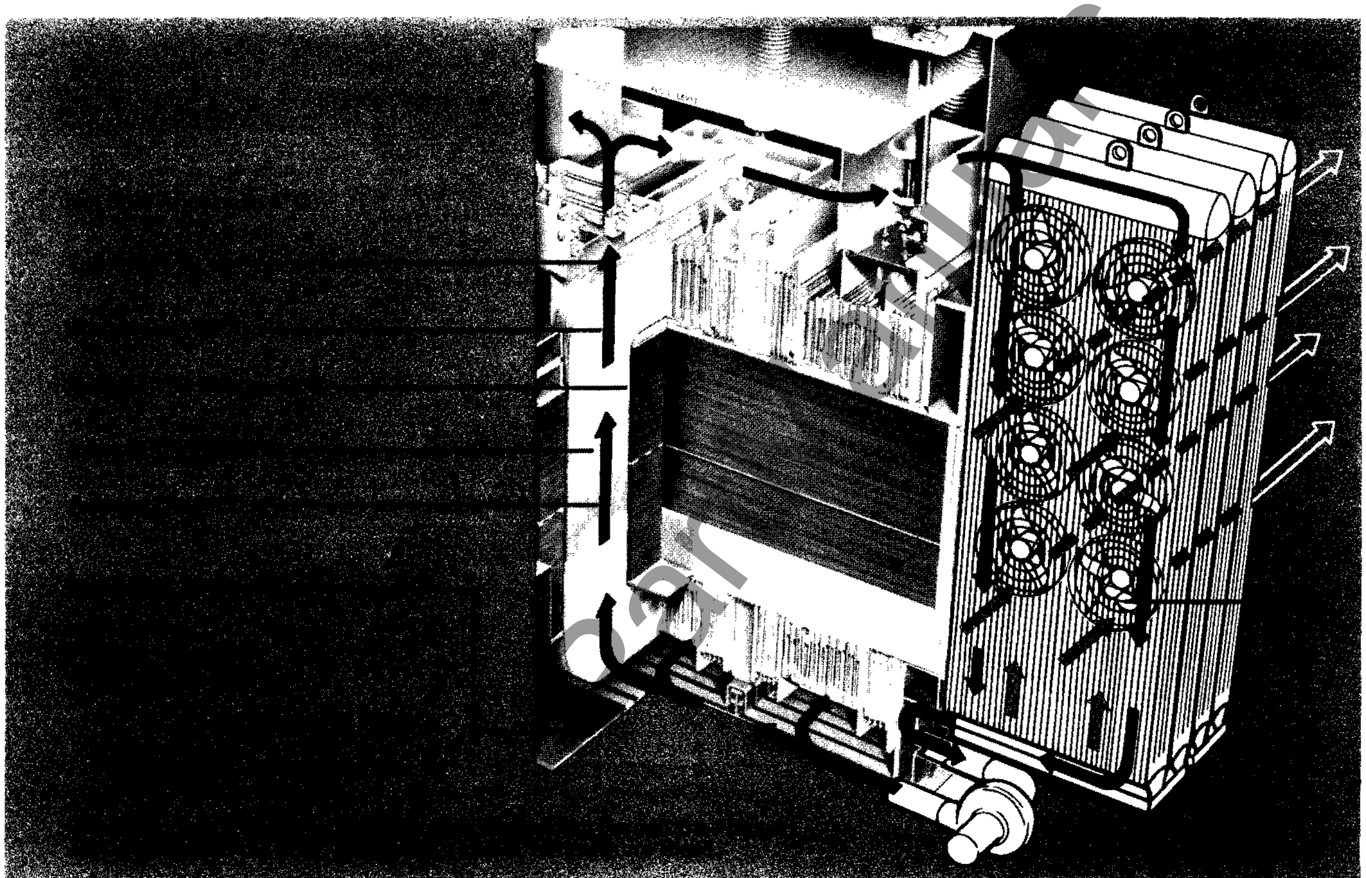
Superior thermal capability is inherent in Westinghouse shell form transformers during both self-cooled and forced-cooled operation.

A thermosiphon cooling action functions in the transformer during OA (Self-Cooled) operation because of the temperature differential between oil at the top and bottom of the transformer tank. This temperature differential, thermal head, is approximately 12°C for an OA transformer, and will support an oil flow exceeding four feet per minute over the core and coil surfaces.

The pancake coils are mounted vertically and the pressboard insulating washers with predesigned spacer block pattern are located on either side of the coil providing an ideal path for oil flow over both sides of the conductor surfaces. A large portion of the coil surface in a shell form transformer is positioned in the cool oil near the bottom of the tank where direct heat transfer is most efficient. The core construction is a relatively high stack of narrow width silicon steel punchings, thus oil flowing on either side of the core adequately cools this area and oil ducts within the magnetic circuit are not necessary.

The cool oil rises from the bottom of the tank, traveling over the conductor surfaces picking up heat as it moves to the top of the tank and then out through the heat exchanger, where it cools. The cooled oil re-enters the transformer tank at the bottom.

Thermal Capability



The typical temperature rises are as illustrated. The average copper temperature rise is set by ANSI or NEMA Standards, and for this example is 55°C. The top oil rise is 48°C, the bottom oil rise, 36°C — a difference of 12°C which is the thermal head required for oil circulation. The average oil rise is 42°C.

All temperatures at this operating condition will stabilize if the load remains constant and the difference between average copper rise and average top copper rise will be 6°C, or the same as the difference between top oil rise and average oil rise. The average top copper temperature rise then is 55°C plus 6°C or 61°C.

Hot spots will occur in the coil due to oil flow restriction by the spacer blocks. At the OA rating this allowance is 2°C, this added to the average top copper temperature of 61°C results in a hottest spot temperature of 63°C. ANSI Standards allow a 65°C hottest spot temperature for a 55°C rise transformer.

Forced cooling is applied to transformers to increase their thermal capability without adding active material. Forced cooled units can be designed with a single rating using pumps and fans for forced oil and forced air (FOA) or forced oil with a water cooled heat exchanger (FOW) Triple rated units are commonly used in application with heavy cycling loads and the forced cooling is applied in two equal stages. Pumps as well as fans are again used providing OA/FOA/FOA ratings at 100%/133%/167% with the self-cooled rating considered as the 100% base.

The OA operating data illustrates the flow of oil caused by the thermal head in the transformer, however, it is obvious that the thermal head contributes to the total hottest spot temperature of the transformer. For this reason, Westinghouse shell form transformers employ pumps to circulate the oil during forced cooled operation. Since total temperatures are also proportionate to oil volume flow, the increased oil flow made possible by the pumps further reduces operating temperatures for any given load condition.

Typical temperature characteristics of a forced cooled transformer operated at its maximum rating are illustrated above. Again using an average copper rise of 55°C, the top oil temperature is 45°C and the bottom oil temperature is 43°C — a difference of only 2°C. We have almost eliminated the thermal head because oil circulation is forced by the pumps. The average oil temperature is 44°C and after the temperatures stabilize the average top copper temperature rise will be 56°C.

Hot spots will also occur during forced cooled cycles and will increase slightly due to increased losses and restriction of oil flow. The hot spot allowance is now 4°C giving us a hottest spot temperature rise of 60°C. Similiar temperatures and operating characteristics can be obtained if the transformers are operated at 65°C average copper temperature rise.

Dielectric Design

Dielectric Performance

Benefits

Westinghouse Shell Form Fit Transformers have excellent dielectric characteristics:

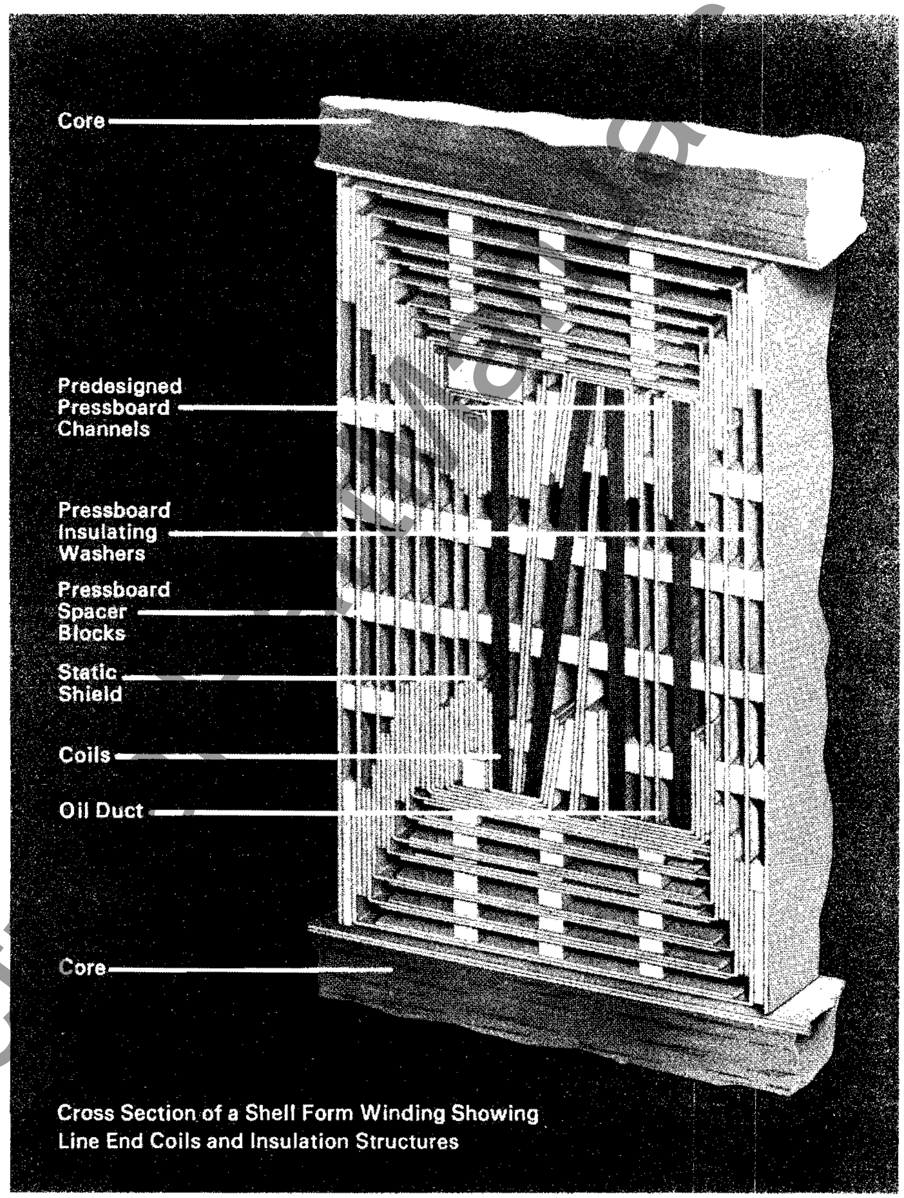
- **The high coil-to-coil and low coil-to-ground capacitance ratio provides uniform distribution of surge voltage over the entire coil.**
- **Insulation structures are predesigned and strategically placed to utilize the oil impregnated pressboard insulation in puncture rather than creep for up to 300% additional strength.**
- **Taps and line end connections are made at the top of the coil with short predesigned leads thus minimizing the effect of localized heating because of high fields.**
- **The exclusive Westinghouse modeling technique verifies the transformer reliability before manufacture.**
- **The annual trouble rate for Westinghouse Shell Form Transformers is less than 1/4 the rate of those manufactured by other companies.**

The arrangement of the coil assembly and the utilization of the insulation structures determine a transformer's ability to withstand transient surge voltages and to operate under normal conditions without stress.

The coil assembly of a Shell Form Transformer consists of a relatively few large pancake coils, resulting in high coil-to-coil

High Voltage Static Plate

and low coil-to-ground capacitance. When this ratio is high, the voltage distribution across the coil group with rapidly rising surge voltage is uniform. This ratio reduces stresses due to the initial application of the surge and also reduces the oscillations which may develop in the winding. The natural period of oscillation is long which allows the surge to decay to a low value before the oscillations develop.



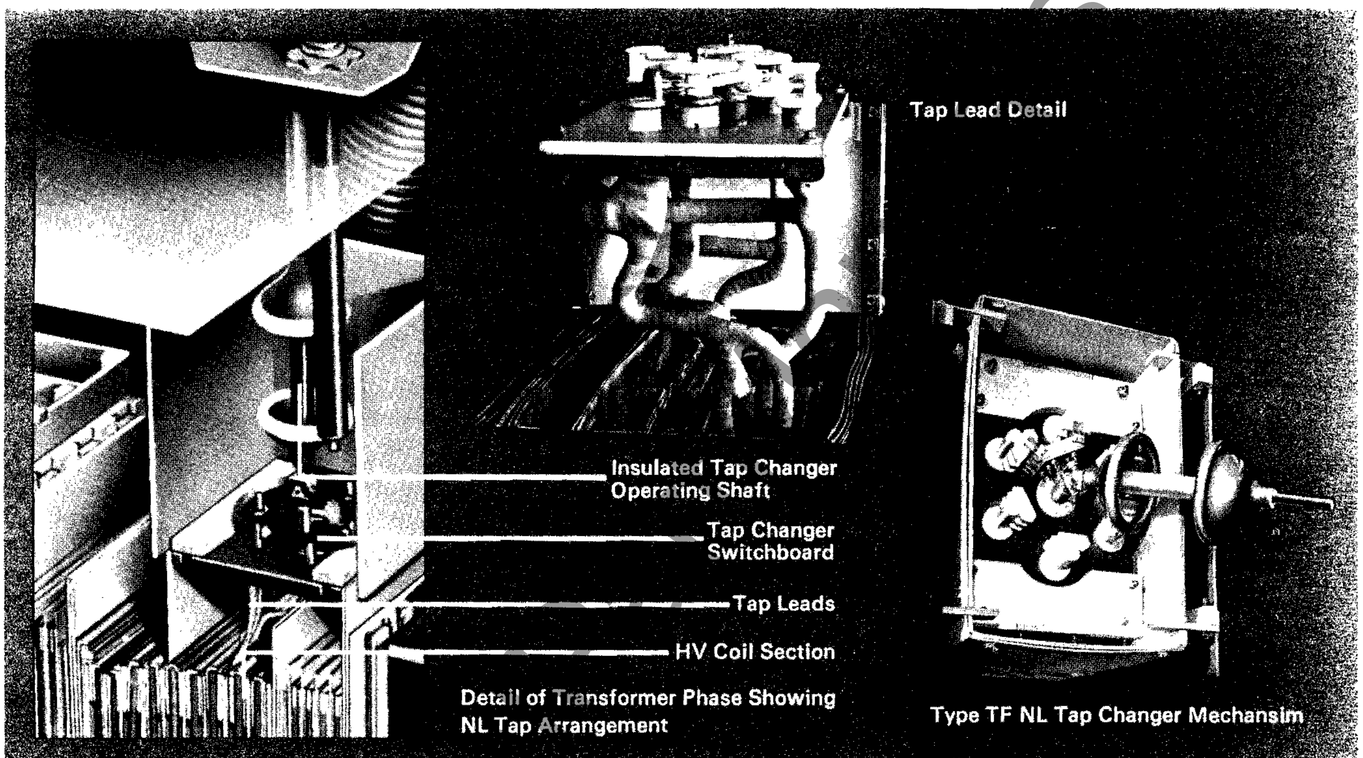
Cross Section of a Shell Form Winding Showing Line End Coils and Insulation Structures

A static shield is connected directly to the line end lead in each coil group to prevent high surge concentration on the line end turns of the coil.

Special static shields are used on coil edges, edge of the core and other sharp edges to reduce voltage stresses and prevent ionization at these points.

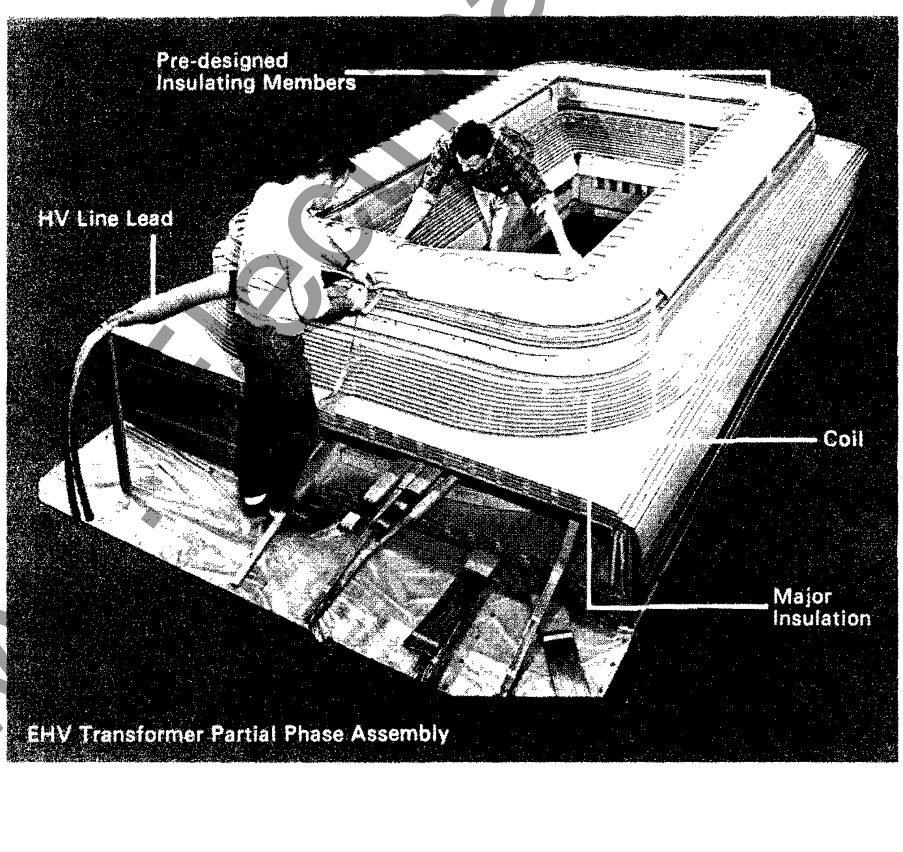
The insulation structures between coils, between coils and core and between windings are made of high dielectric strength oil impregnated sheets. Oil spaces are provided with precise relationship to the pressboard structures to control voltage stress concentrations. Special formed insulation pieces are used over the coil edges where the voltage stresses are highest. This insulation is utilized in puncture rather than creep for maximum strength.

Dielectric Design



Detail of Transformer Phase Showing NL Tap Arrangement

Type TF NL Tap Changer Mechansim

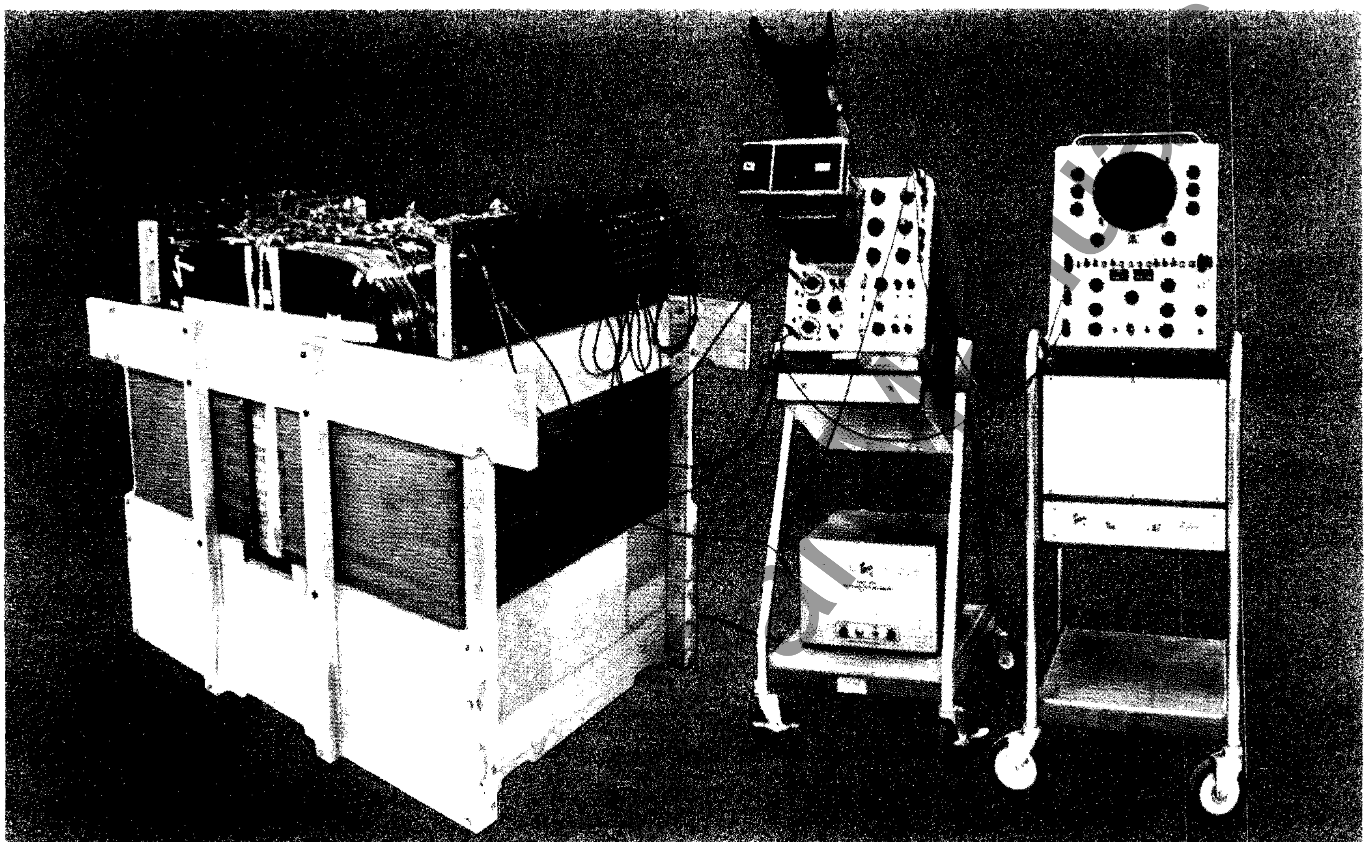


EHV Transformer Partial Phase Assembly

The Shell Form pancake coils are arranged to terminate at the top of the transformer where connections can be made with a short lead. Mechanical bracing of the lead is no problem because of the short length and the magnitude of circulating currents induced by high fields is minimum.

Increasing insulation spaces in transformers will not necessarily enable them to withstand the stresses present at EHV voltages. Insulation failure generally occurs at a stress concentration in the winding. The stresses are determined by the combination of insulation spaces, relationship to coil dimensions and by structural configurations.

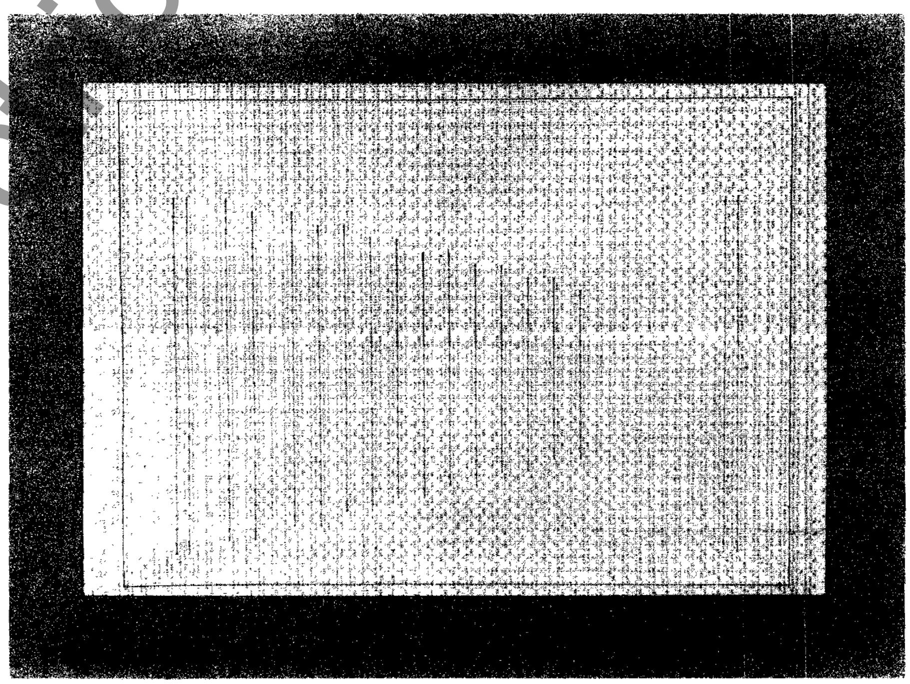
Electromagnetic Modeling



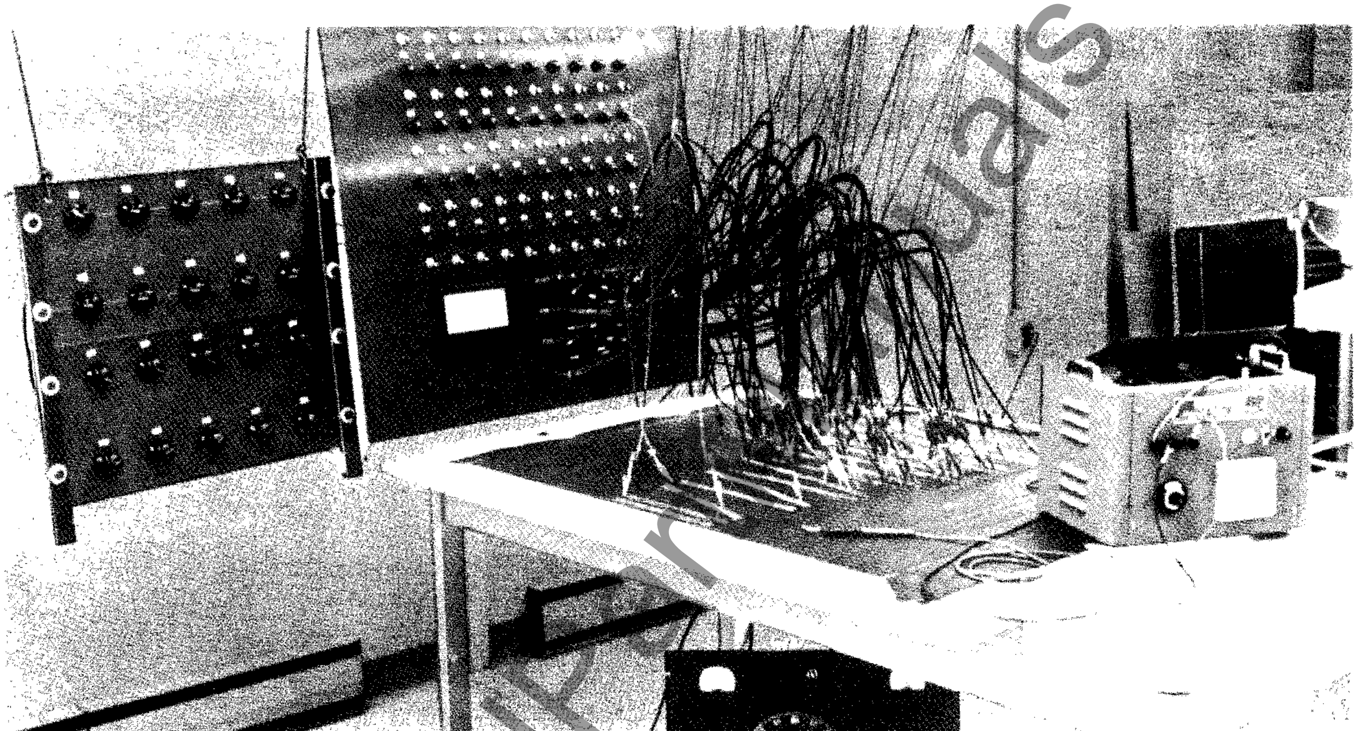
Westinghouse engineers utilize electromagnetic models of complete transformer phases to analyze the different switching surge and impulse voltage conditions. Direct readings and oscillograms can be obtained from probes placed at critical points in the model winding and actual voltage values are established.

Analog electric field plots of the winding and insulation cross section are made using the voltage values obtained from the electromagnetic model. Digital computer plots are also employed in conjunction with the electromagnetic models to accurately establish voltage conditions and magnitude of electric fields.

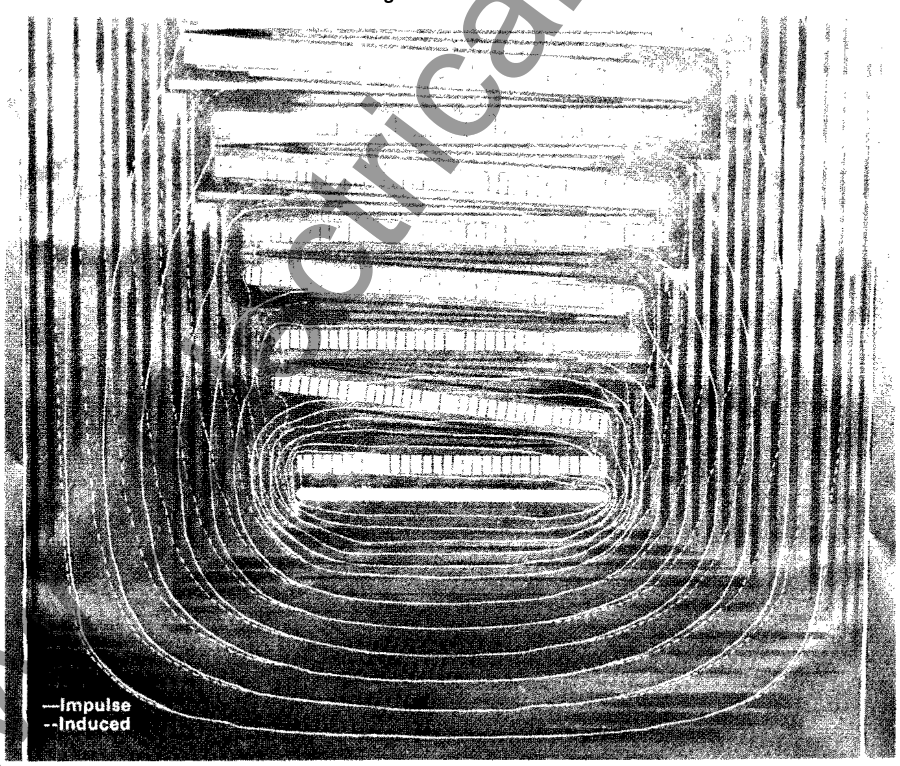
The equipotential lines for the low frequency and impulse voltages are plotted on the analog field plot, and the voltage stresses are then calculated. More efficient insulation structures can then be developed by changing insulation configurations and coil relationships. These techniques are used to investigate stresses in production units and to make development investigations.



Electromagnetic Modeling



Potentiometer Bank Used to Set Voltages on Field Plots



Analog Electric Field Plot Showing Winding and Insulation Cross Section

The field plotting techniques are further employed in making detail studies of insulation behavior under various voltage stress conditions. Full scale models of winding sections and insulation structures are made and tested based on the data developed by the field plotting techniques.

Complete full size coil, insulation and core sections are then designed and manufactured to prove the developed concepts under actual operating and test conditions. Three full scale models, at various Basic Insulation Levels, are used during this stage of the program.

The models are tested at full voltage levels using Impulse, Switching Surge and Low Frequency Tests. Overvoltage tests are also made to further verify the integrity of all components. Loss measurements, overload tests, temperature measurements and leakage flux measurements are performed to establish performance characteristics.

All new developments as well as design changes are verified in the experimental units prior to being applied to production transformers. Auxiliary equipment such as heat exchangers are also tested prior to application on production units to establish their performance characteristics.

Vapotherm Insulation Processing

The assembled transformer phase is clamped with heavy spring loaded beams, to assure dimensional stability during processing and to adjust for material shrinkage. The complete transformer phase assembly is placed in the processing vessel, the vessel is sealed and evacuated to remove all oxygen and moisture. A hydrocarbon solvent is used to rapidly and uniformly transfer heat into the insulation and raise the temperature of the entire structure, thereby accelerating moisture removal from the Kraft insulation. Overheating and preaging of the exterior insulation parts does not occur because no oxygen is present and because of the uniform heat transfer by the solvent vapor.

The heating and moisture removal continues until the system pressure reaches the solvents liquid-vapor equilibrium curve. At this time the liquid solvent is removed.

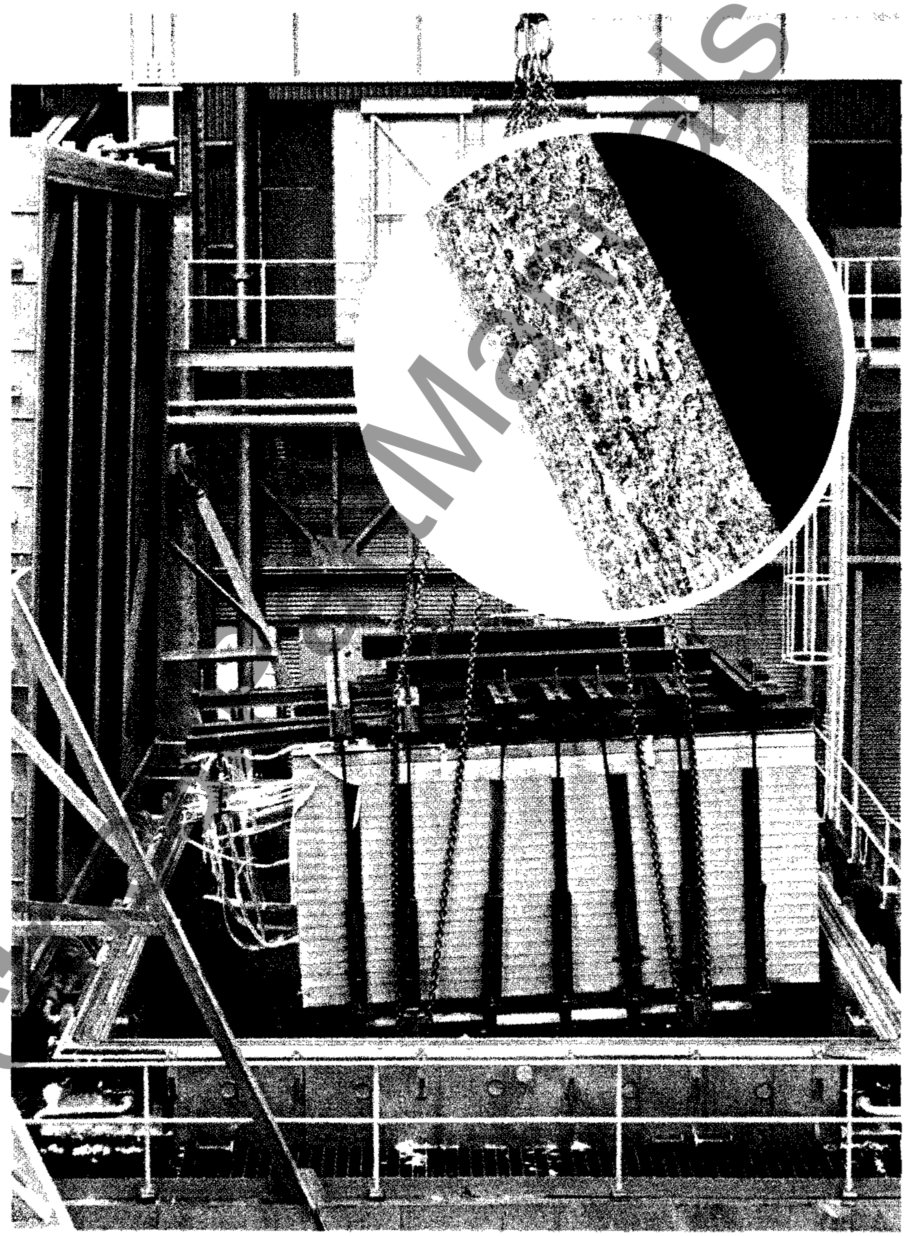
Evacuation continues until the last traces of solvent and moisture are removed from the system.

The power factor of the insulation is monitored during the entire cycle and must be at a low level as a final check at the conclusion of the drying cycle.

Insulating oil is admitted into the processing tank without relieving the vacuum to completely impregnate the Kraft paper insulation and eliminate corona producing bubbles. The oil fills the voids in the Kraft paper, assuring high short circuits strength and a dry, dimensionally stable phase assembly throughout subsequent operations. The transformer phase is then removed from the processing tank.

After assembly is completed, the transformer is processed in its own tank with hot oil under a low vacuum to remove any surface moisture from the insulation that may have accumulated during assembly.

Final control of the process is achieved by checking the insulation power factor at the conclusion of the dry out cycle, to be certain it has remained at a low level.



(Insert) Expanded End View of Kraft Insulation

Summary of Benefits:

- Dryout and oil impregnation are accomplished in a single processing vessel.
- Spring loaded clamps adjust for material shrinkage and assure a tight insulation assembly.
- Solvent heat of vaporization raises the temperature of the insulation structures at a uniform rate. Preaging and embrittlement of insulation material is eliminated.
- Insulation structures are impregnated with dry oil to prevent subsequent moisture absorption and to assure maximum dielectric and mechanical strength.
- Closer dimensional control of insulation parts is possible allowing size and weight reduction of the completed transformer.

Testing

Indisputable proof of the reliability of a transformer and confirmation of its performance characteristics is established by tests. All Westinghouse shell form transformers are tested in accordance with American National Standards Institute Test Code for Transformers.

Standard Tests applied to all units:

- Resistance measurements of 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.
- Ratio tests on the rated voltage connection and on all tap voltages.
- Polarity and phase-relation tests on the rated voltage connection.
- No load loss at rated voltage connection.
- Exciting current at rated voltage on the rated voltage connection.
- 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 of an order.
- ANSI Temperature Test.
- Applied Potential Test.
- Induced Potential Tests.
- Westinghouse Quality Control Impulse Tests.
- Westinghouse Quality Control Corona Test on all units 345 KV and above.

Tests which will be performed at purchaser's option and at additional cost:

- ANSI Impulse Tests.
- NEMA Front-of-Wave Impulse Tests.
- Switching Surge Test.
- Audio Sound Level Measurement.

Impulse Testing

The most comprehensive demonstration of transformer insulation strength is the ability to withstand low frequency tests and impulse tests. Westinghouse uses a Quality Control Impulse Test to check the adequacy of design, materials and workmanship on all shell form transformers. These tests are made in addition to the low frequency test required by ANSI Standards.

The test consists of applying a reduced full wave, two chopped waves and one full wave in this order to each line terminal. The crest values of the impulses have a minus tolerance of 5% in addition to the +5% tolerance allowed by ANSI Standards.

Westinghouse pioneered the impulse testing of transformers and began commercial use of the test in 1931.

This type of testing maintains the high degree of quality in Westinghouse shell form transformers.

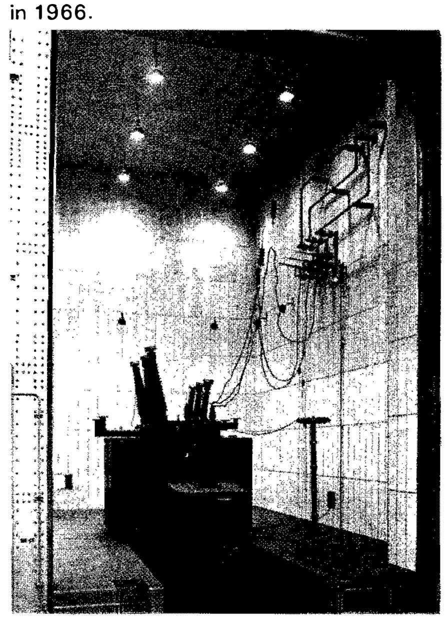
Testing Section of Westinghouse Large Power Transformer Plant

Corona Testing

The Westinghouse procedure for corona testing EHV transformers requires a RIV measurement on the HV winding during the Induced Test. The measurement procedure and instruments as prescribed in "NEMA 107 — Methods of Measuring Radio Noise" are employed, except the power supply is connected to the lowest voltage winding of the transformer being tested and the bushing capacitance tap is used to connect the RI meter to the HV terminal.

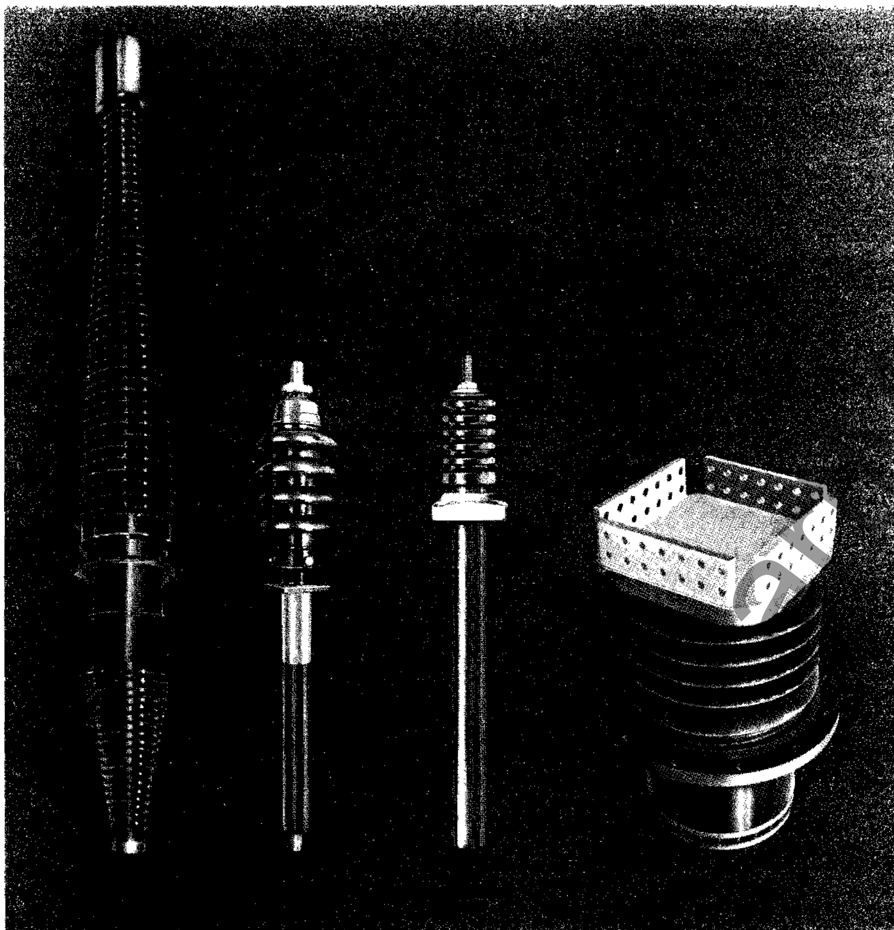
The induced voltage is raised to approximately 50% full test value, a value above operating voltage, and the RIV is measured. The test voltage is then raised to the full test value and held for 7200 cycles. An RIV measurement is taken at this voltage. After the low frequency test is completed, the RIV is again measured at 50% full test voltage. If the RIV levels at 50% induced voltage level exceeds 100 microvolts or if the RIV level at full test voltage exceeds 500 microvolts, additional testing will be performed to demonstrate the reliability of the transformer.

Westinghouse performed the first commercial corona test in 1958 and began corona testing every EHV transformer in 1966.



Isolated Chamber for Corona and Sound Tests

Bushings



Several designs of bushings are used on Westinghouse shell form transformers depending on BIL and current requirements. All designs comply with industry standards pertaining to electrical and mechanical characteristics.

RJ Bushings

RJ Bushings are applied on transformer windings 15 KV and below. This design is applied primarily on tertiary windings of autotransformers and multiple winding transformers.

This bushing uses a lead encased in a single piece wet process porcelain. A one-piece forged aluminum flange is rolled into a groove in the porcelain over a silicone rubber gasket.

OS Bushings

This bushing is applied to windings through 46 KV-250 KV BIL. The condenser is wound on the conductor tube using treated Kraft paper. Metal foil is inserted at appropriate diameters to form the condensers. A porcelain weather shield is solder sealed to the conductor tube and flange to protect the external portion of the condenser. The porcelain weather shield is filled with Wemco C Oil.

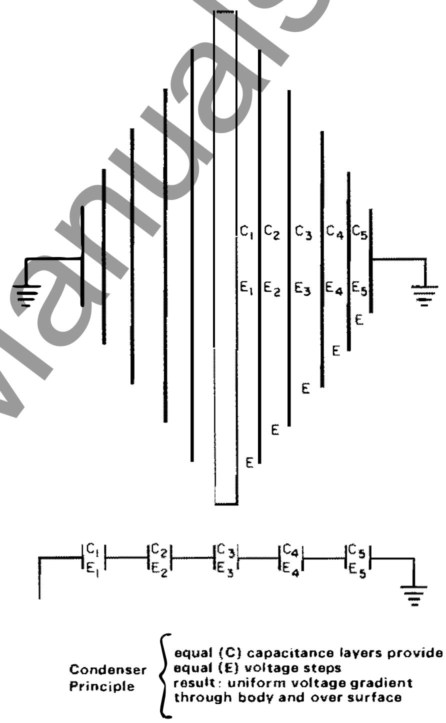
O Bushings

The type O condenser bushings are designed for transformer and oil circuit breaker applications above 46 KV.

The bushing is constructed using an oil-impregnated Kraft paper condenser in an oil filled chamber. The oil chamber consists of an expansion bowl, upper and lower porcelains and a metal flange. The assembly is sealed and held under pressure by a spring assembly.

The flange is provided with a voltage tap receptacle and an oil valve.

Condenser Bushing Principle



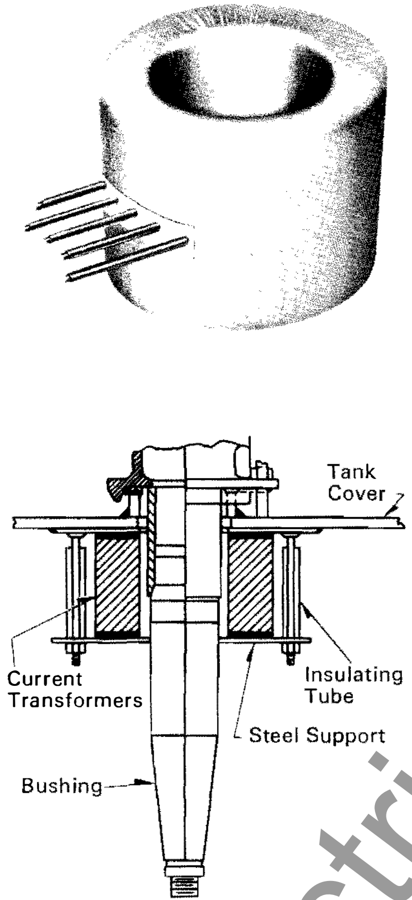
Bulk Type Bushings

Westinghouse bulk type bushings are designed for 25 KV, 150 KV BIL insulation level and are used as the primary lead connection on generator step up transformers. The design features a single piece porcelain and integral metal flange with a heavy tubular lead through the center. A spring loaded retaining ring maintains the lead and porcelain assembly under compression.

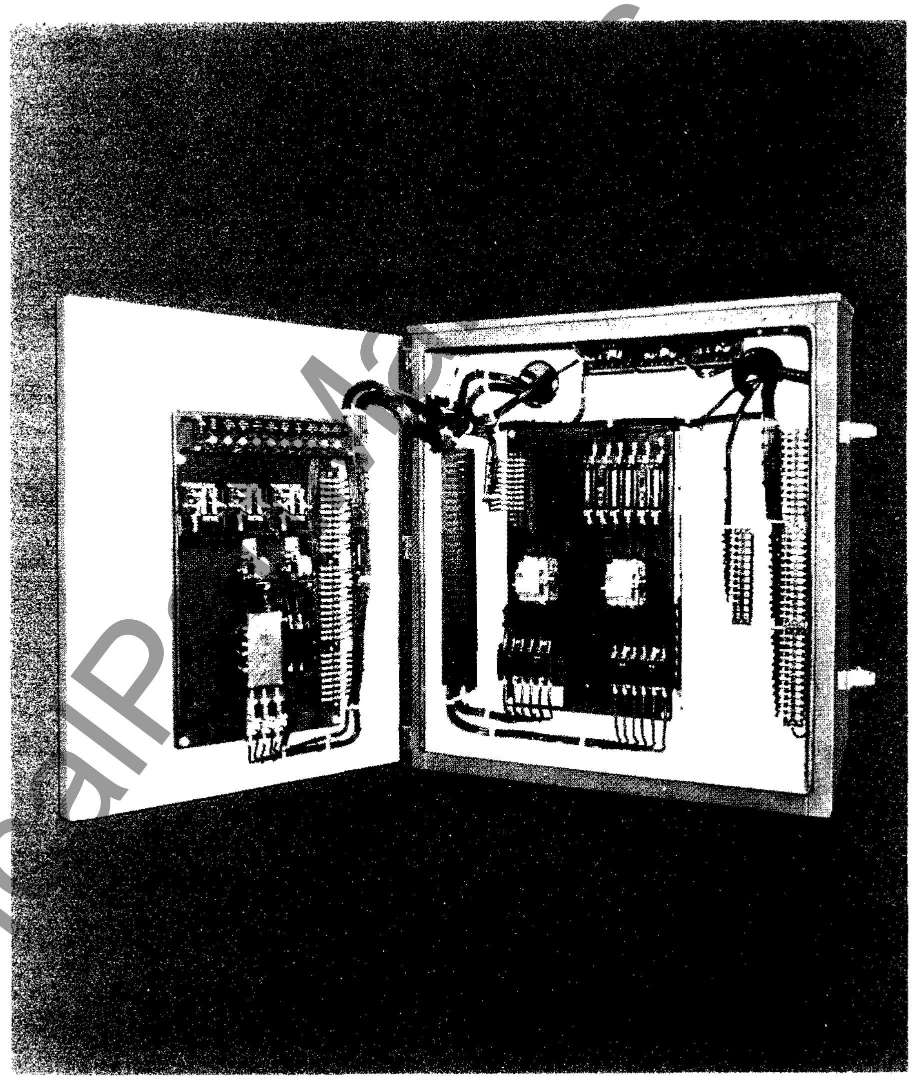
A four spade rectangular terminal is provided for external connection to bus duct leads. The inner assembly is vented to allow circulation of cooling oil from the transformer tank, and for this reason the internal end of the bushings is located below the oil level in the transformer tank.

All external porcelains for Westinghouse Bushings are available in either ANSI 70 Grey or Standard Brown.

Electrical Accessories



Typical BCT Mounting



Multi-Ratio Bushing Type Current Transformers

Ampere Rating Range 600/5 to 5000/5, 60 Hertz

Multi-ratio current transformers are used as a current source for relays and indicating instruments. The current transformers are supported by brackets on the tank cover and utilize the bushing lead as a single turn primary. Other mounting configurations such as the internal transformer bus work or the external portion of the bushing are also used. The tap ratios, current ratings and accuracy conform to ANSI Standards. Taps for multi-ratio ratings are available through 5000 amperes, ratings above 5000 amperes are generally single ratio.

NEMA Standard Ratings for Bushing-Type Current Transformers

40	50	10	20	600/5
80	100	20	40	1200/5
100	60	160	8●	2000/5

X5 X4 X3 X2 X1

100	300	200	3000/5
200	200	400	4000/5
200	200	600	5000/5

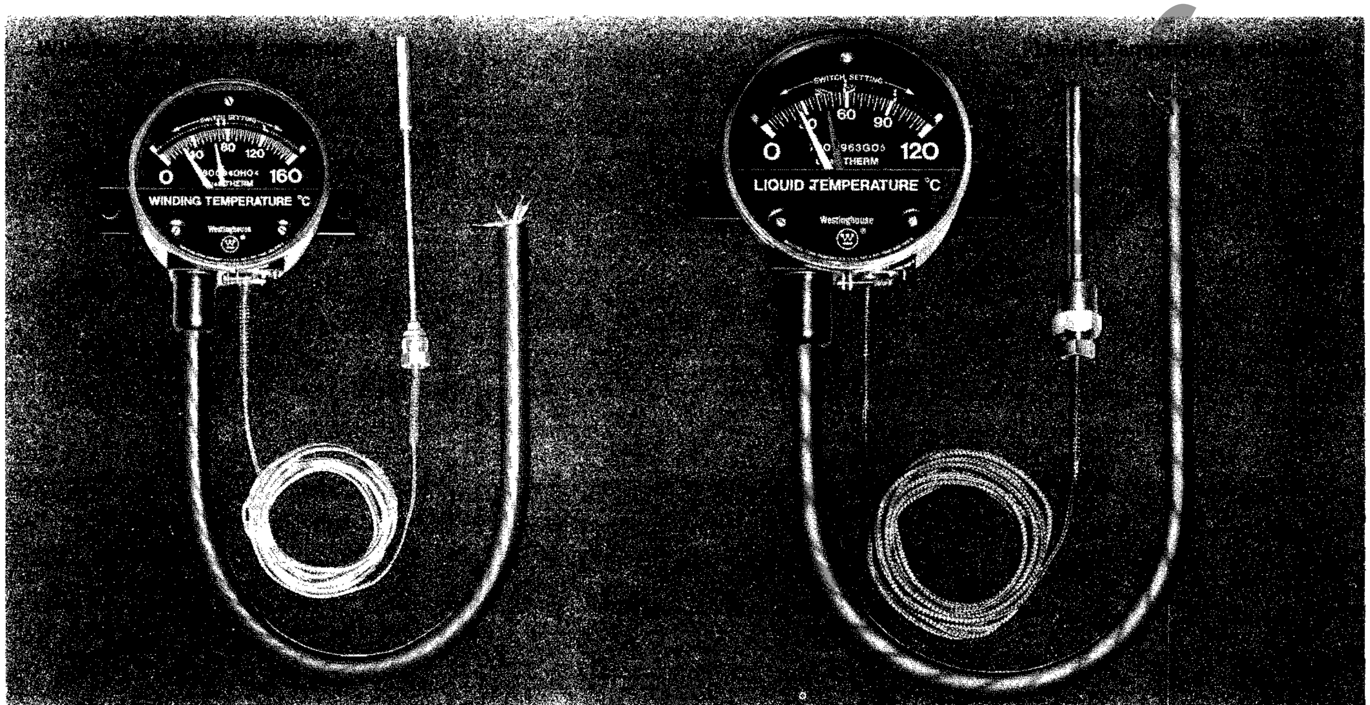
X4 X3 X2 X1

Standard Primary Current Amps	BCT Standard Ratios
600	120/100/90/80/60/50/40/30/20/10 1
1200	240/200/108/160/120/100/80/60/40/20 1
2000	400/320/300/240/220/160/100/80/60 1
3000	600/400/300:1
4000	800/600/400.1
5000	1000/800/600 1

Control Cabinet For Auxiliaries

Westinghouse transformers are equipped with a weatherproof control cabinet for termination of auxiliary equipment. Controls for the fans and pumps are actuated by winding temperature and provisions can be made for automatic or manual switching to an alternate auxiliary power source to assure continuous operation of cooling equipment.

Electrical Accessories



Winding Temperature Indicator

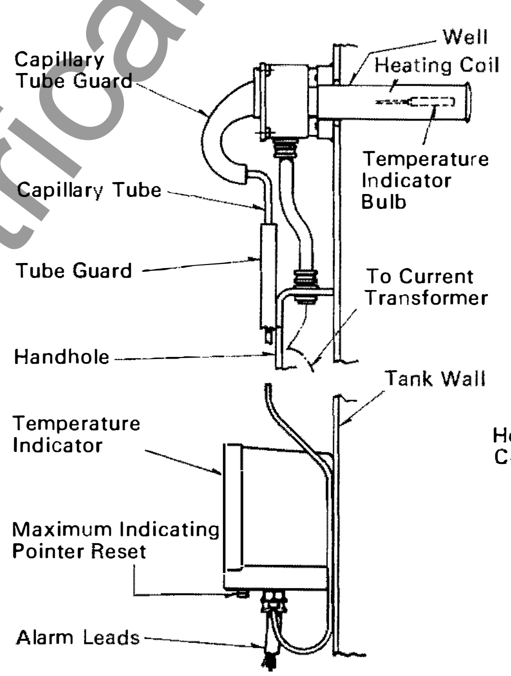
The Westinghouse hottest spot temperature indicator is an assembly utilizing a bourdon gauge, calibrated in degrees centigrade, connected to a bulb by a capillary tube. The indicator is located on the tank wall at eye level for convenient reading. The thermometer bulb and a heating coil are assembled in a well located in the hottest oil near the top of the transformer.

Current, proportional to the transformer load current, is supplied to the heating coil by a current transformer. This adds an increment of temperature to the thermometer bulb which is equal to the winding hot spot rise above hot oil temperature. Thus, the instrument indicates hot spot temperature.

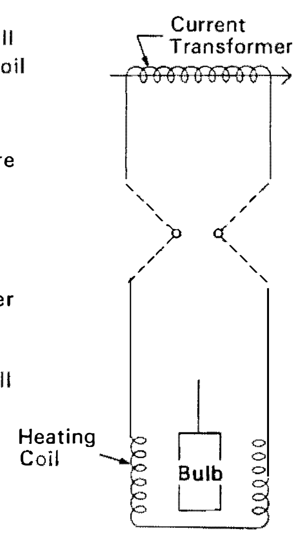
Three switches are provided in the instrument to operate forced-cooling control and alarm circuits.

Oil Temperature Indicator

The liquid temperature indicator is mounted on the transformer tank at eye level height. The assembly utilizes a bourdon gauge connected to the bimetallic thermometer bulb by a capillary tube. The thermometer bulb is enclosed in a well located in the hottest oil near the top of the tank. Two switches are provided in the instrument for operation of auxiliary and alarm circuits.

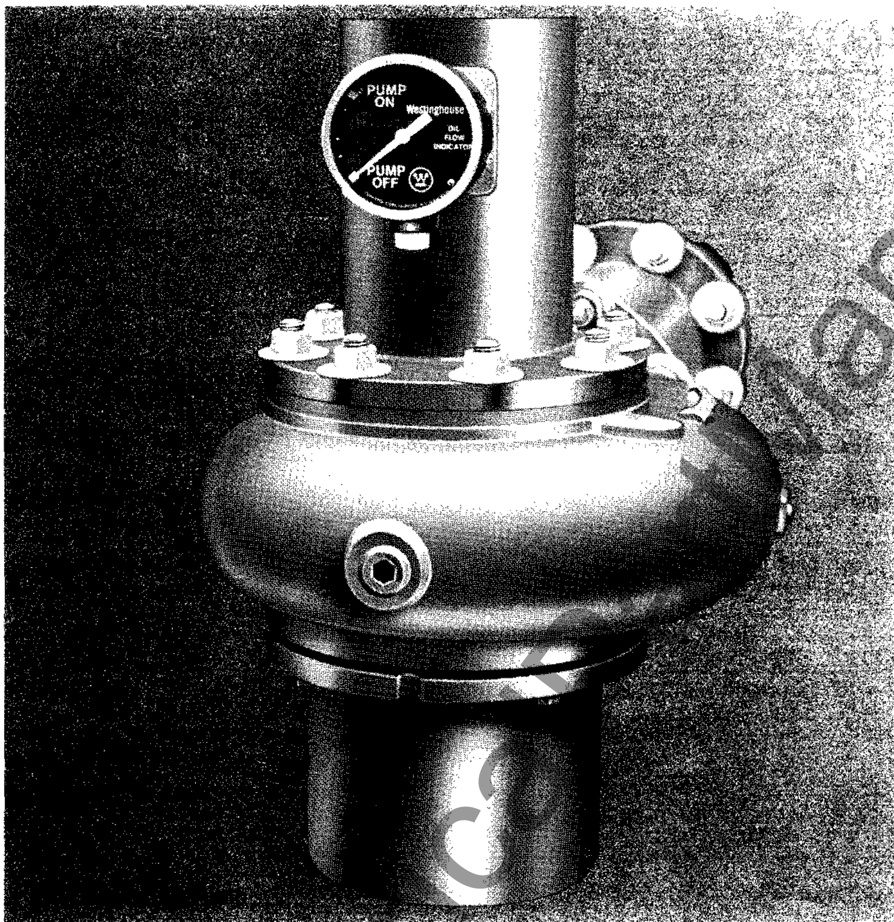


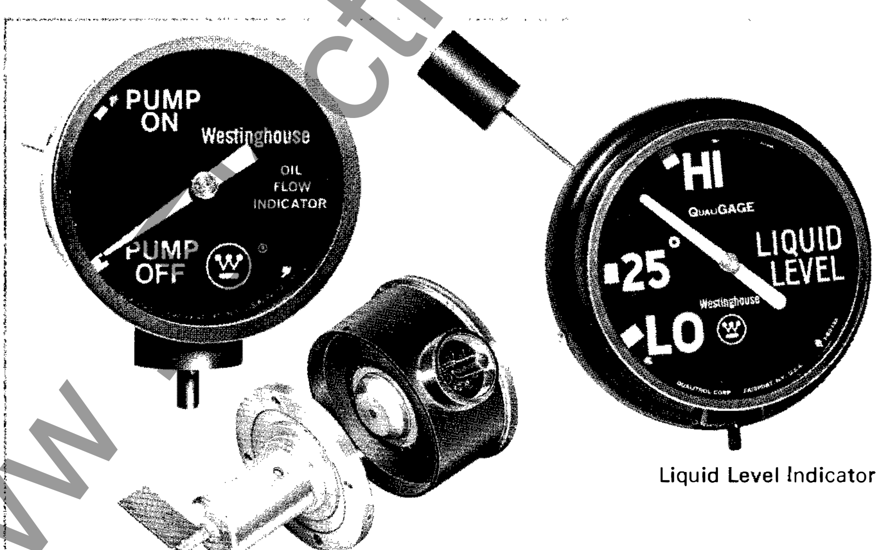
Sectional View of Transformer Showing Mounting of Indicator with Flexible Tube



Connection Diagram for Current Transfomer and Heating Coil

Thermal Accessories





Liquid Level Indicator

Oil Flow Indicator

Oil Circulating Pumps

The circulating pumps supplied on Westinghouse forced cooled power transformers are a special centrifugal design using a close coupled pump and motor enclosed in a cast iron housing. The oil flow within the pump is directed to provide bearing lubrication and cooling for the motor stator.

The pump is suitable for multiple mounting positions and can be applied to all types of Westinghouse coolers or radiators.

Oil Flow Indicator

The Westinghouse oil flow indicator is a vane operated instrument designed for use with each forced oil pump on a transformer. It provides visual indication and confirmation by electrical alarm switches, of the proper operation of the pump and adequate oil flow for cooling.

The alarm switch leads are brought out through a threaded receptacle for connection to remote alarm equipment.

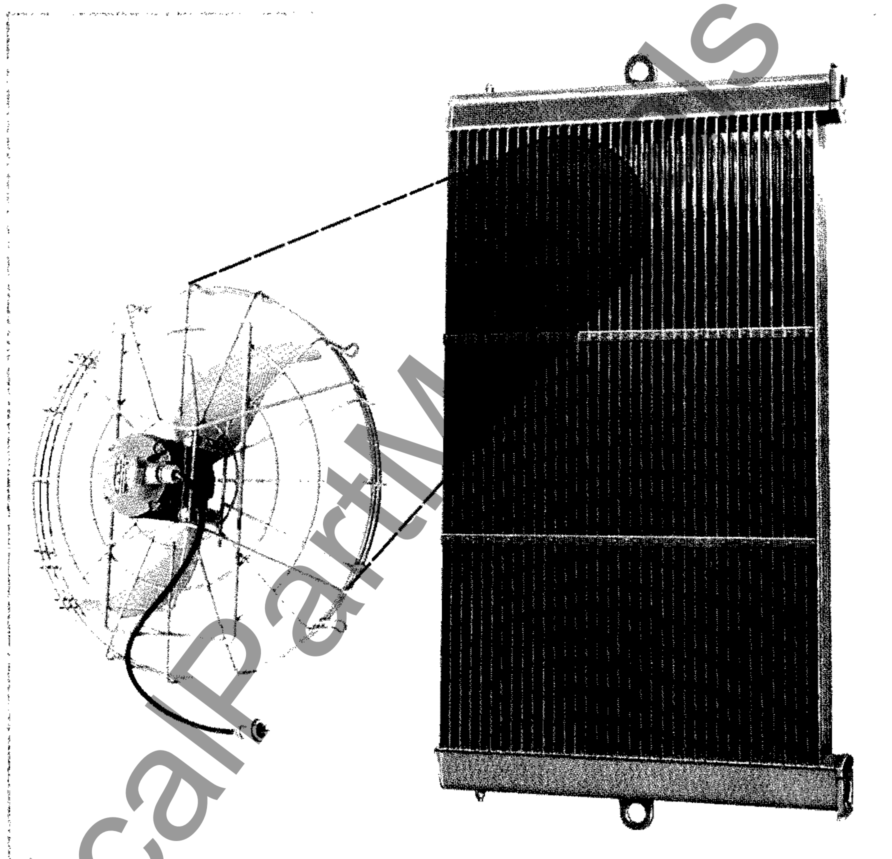
Liquid Level Indicator

The liquid level indicator designed for Westinghouse transformers is a self contained float operated instrument. The indicator is a two part assembly. The sealed body is attached to the tank wall and contains an actuating magnet shaft connected to the float arm inside the transformer. The bezel, or outer assembly, contains the calibrated dial and indicating needle. The indicating needle is directly connected to a second magnet which is positively displaced by the rotation of the magnet and float arm assembly in the sealed body. Alarm switches are enclosed in the bezel and alarm leads are terminated in a threaded receptacle from which they can be connected to remote equipment. No oil leaks can occur around the instrument because of the sealed body design.

Westinghouse Insulating Oil WEMCO "C"

Concurrent with the Insuldur development, Westinghouse was working with the various petroleum companies to develop a higher flash-point oil for additional margin of safety. Westinghouse Research, developed and provided to all of the oil suppliers the required information needed to refine a new higher flash-point oil and made it available to all the industry. The flash-point was raised from 273°F to 283°F while equalling or bettering the remaining characteristics including lower pour point.

Thermal Accessories



Radiators

The Westinghouse radiator is an efficient cooling unit designed for use on large transformers requiring a self cooled rating. The radiator is detachable and is removed from the transformer for shipment.

The radiator is all welded sheet metal construction with vertical cooling sections through which the oil circulates and cools. A formed metal header is welded to each end of the vertical fin sections and provides the fittings to attach the radiator to the transformer tank.

Fans and pumps are used in conjunction with the radiator to provide forced cooled ratings.

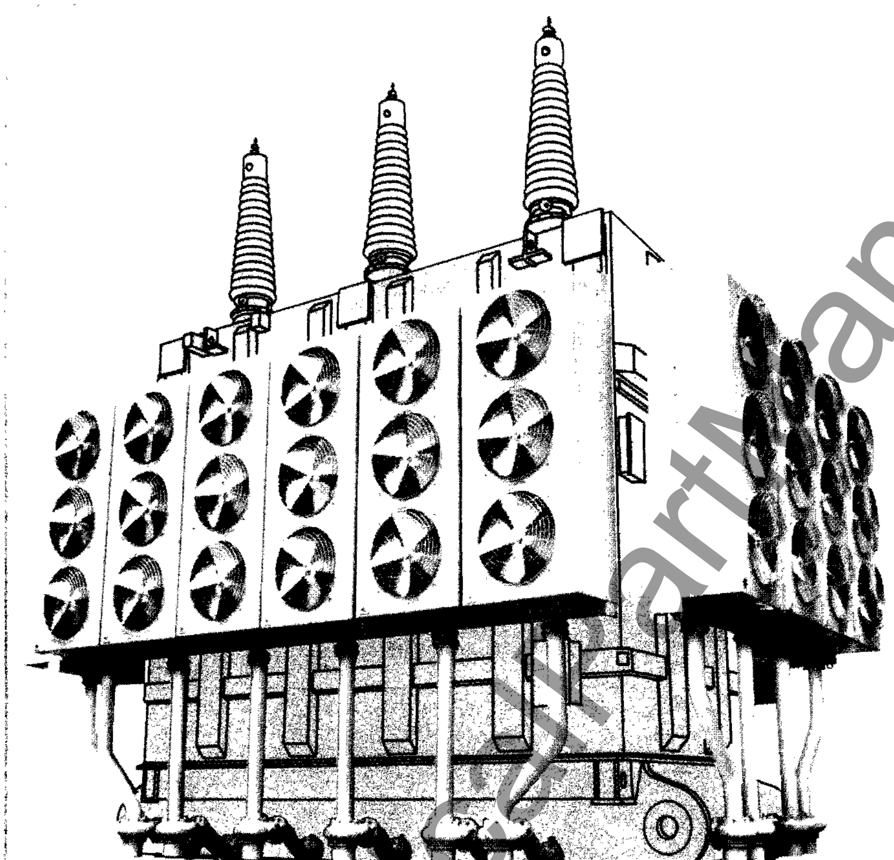
Forced Air Fans

The fan assembly is designed specifically for use with Westinghouse radiators. Groups of fans are mounted on the side of a radiator bank and provide forced air circulation through the continuous ducts formed by the parallel mounting arrangement of the radiators.

The fan assembly consists of a fractional horsepower motor and glass reinforced polyester fan blade. The motor is mounted on a steel wireform bracket, which also serves as a guard for the fan blade.

Either three phase or single phase motors are available and all motors are equipped with fittings for periodic lubrication.

Thermal Accessories



FOA Cooler

FOA Transformer Cooling Equipment
Westinghouse FOA transformers are equipped with oil to air heat exchangers.

Efficient heat dissipation occurs as oil is pumped through the tube bundle and the fans draw air across the finned tubes. The air discharged by the fans is directed away from the transformer.

The FOA cooler is an assembly of a tube bundle and fans mounted in a steel housing. The tubes have extruded fins for increased radiation surface. The fans are thermally protected to prevent motor overheating.

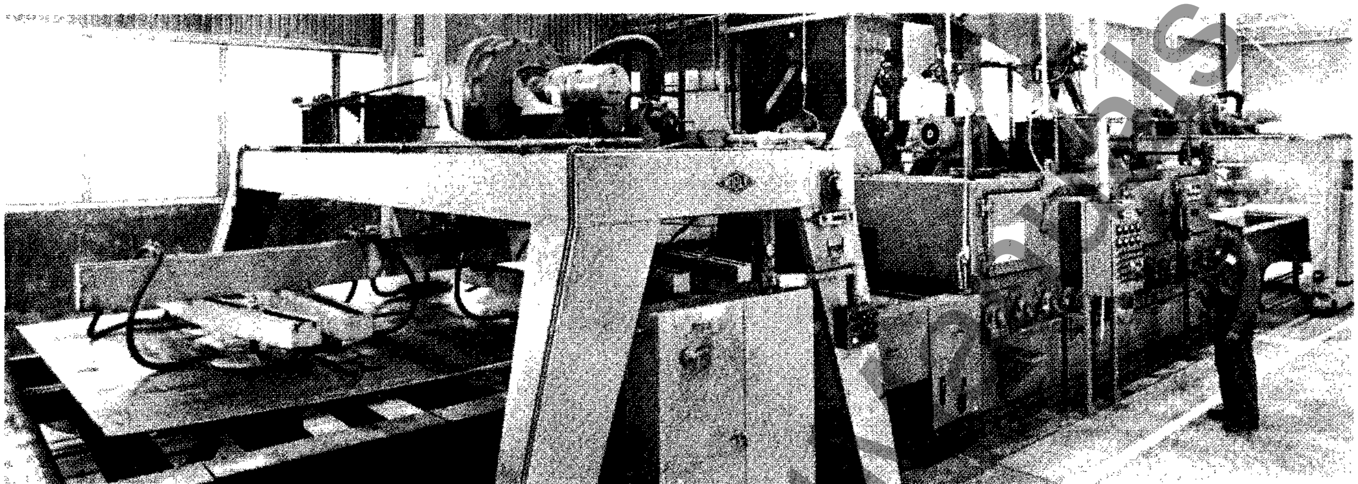
FOW Cooling Equipment

The Westinghouse oil to water heat exchanger is an efficient and compact method of cooling large power transformers and is used if a suitable source of cooling water is available. The cooler is constructed using double wall finned tubes encased in a steel shell.

Oil from the transformer is pumped through the shell around the tube bundle as water is circulated through the tubes. Heat from the oil is transferred through the cooling tubes and carried away by the discharged water.

The outer (oil side) of the cooler tubes is copper with extruded copper fins. The internal (water side) of the tubes is cupronickel alloy. The use of saline or raw river water is feasible because of this tube construction. Double wall construction between the water inlet and the oil shell prevents contamination of the oil.

Standard Paint Finish


Steel Plate Being Cleaned in Plate Blaster

The paint finish on a transformer serves two purposes — to protect the exposed metal surfaces from corrosion and to enhance the appearance of the unit. The current emphasis on beautification has increased the use of colors that help to blend the units with the background at the installation site.

Several steps are followed in painting a Westinghouse transformer and its accessories:

The steel plate used to fabricate the tank is thoroughly cleaned of mill scale and corrosion by rotary blasting equipment.

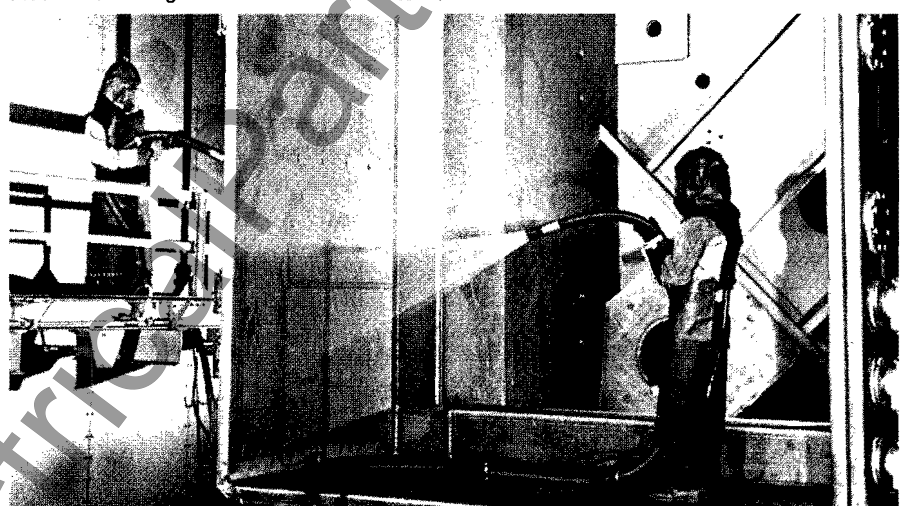
The complete tank is shotblasted for removal of weld spatter and other surface dirt accumulated during fabrication.

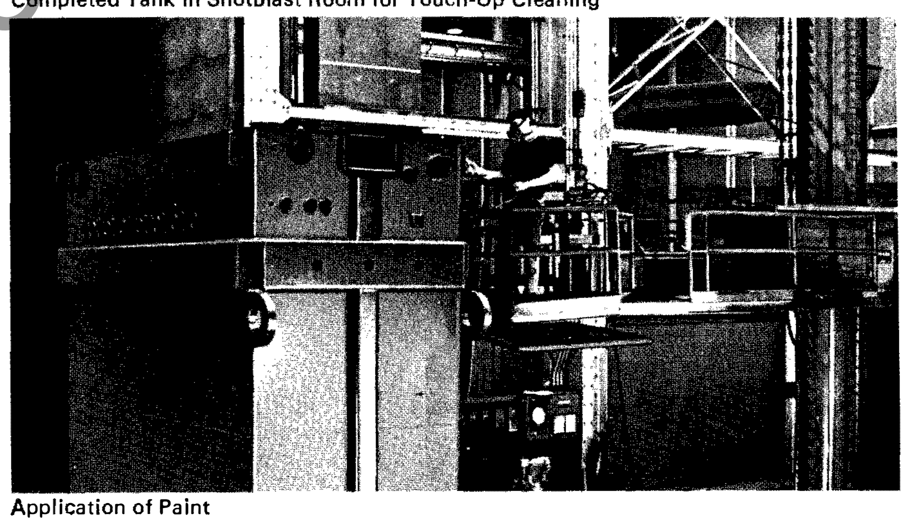
The tank is then painted using an "Airless Spray" process. A primer coat of alkyd vehicle and rust inhibitive pigment is applied followed by a finish coat of alkyd vehicle and pigments. Both coats of paint are oven-dried to assure proper curing and adhesion to the metal surfaces.

A final touch-up coat of alkyd vehicle and pigments is applied to the completed transformer immediately prior to shipment.

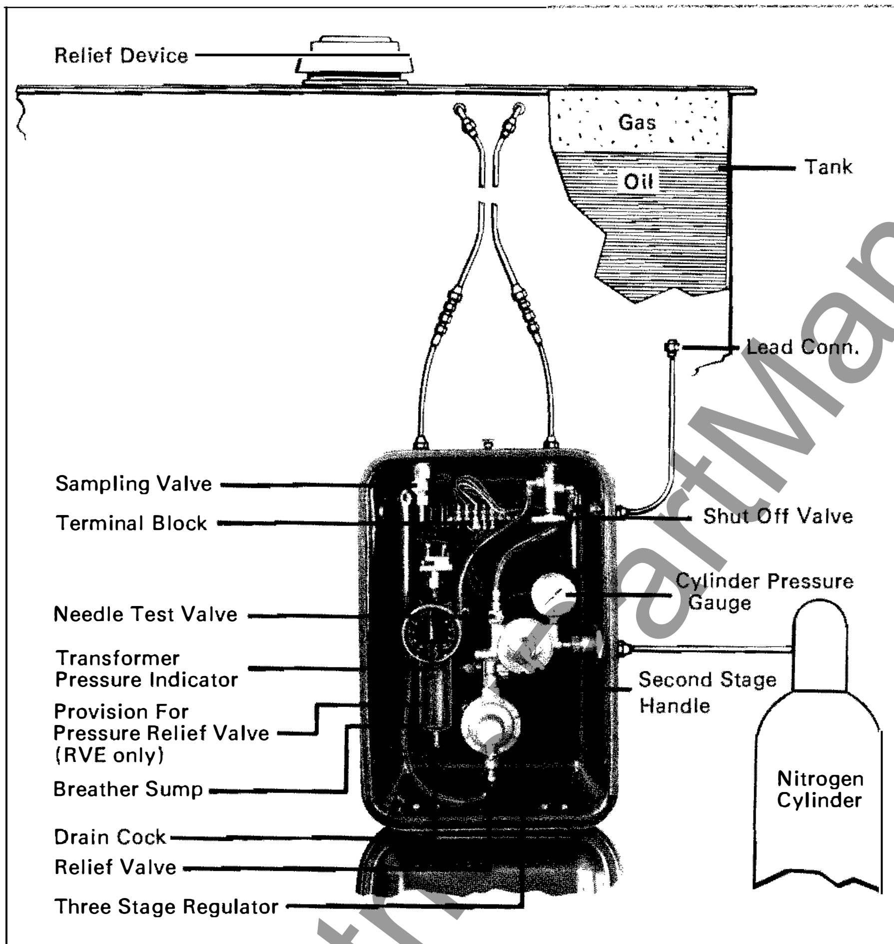
Accessory items are painted separately using a similar process.

The standard color for Westinghouse large power transformers is ANSI 70 light Grey. ANSI 24 Dark Grey and ANSI 45 Foliage Green are available at no additional cost. Nonstandard colors are also available at additional cost providing the material is compatible with Westinghouse primer.


Completed Tank in Shotblast Room for Touch-Up Cleaning


Application of Paint

Inertaire Equipment



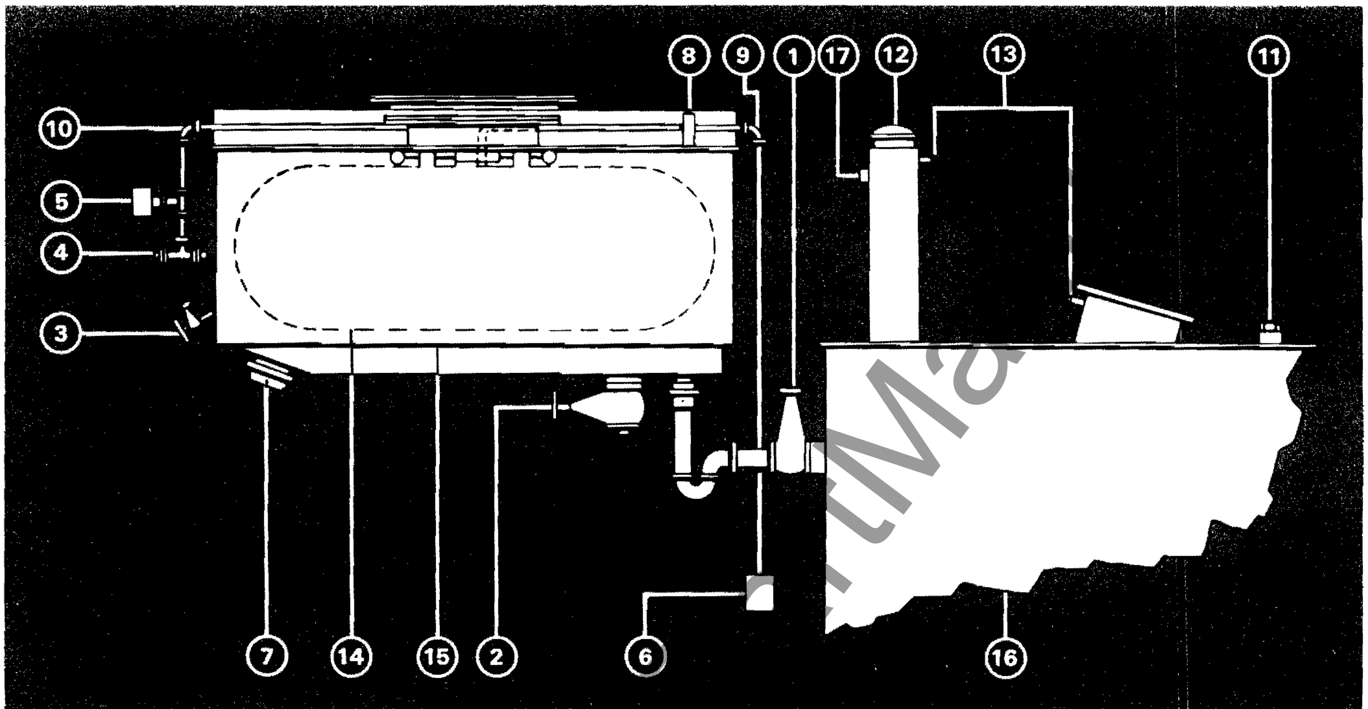
Inertaire® Enquipment — Type RBE
Westinghouse Inertaire equipment assures long insulation life and negligible oil deterioration by maintaining a cushion of dry nitrogen above the oil of the transformer. The nitrogen is supplied from a steel cylinder and is automatically fed into the transformer through a reducing valve whenever the internal pressure in the tank falls below ½ pound per square inch.

A relief valve incorporated into the controls conserves nitrogen in the gas space by permitting it to escape into the atmosphere only when the pressure in the transformer reaches a predetermined value.

A valve connected to the gas space provides a means of sampling the gas for oxygen content. A compound pressure gauge indicates internal tank pressure or vacuum.

All equipment except the nitrogen cylinder is enclosed in a weatherproof cabinet with padlocking provisions.

COPS



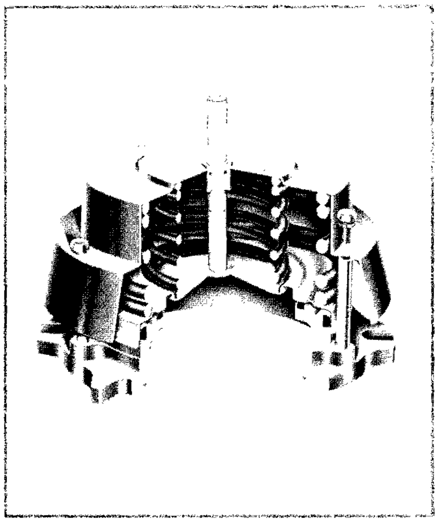
Constant Oil Pressure Oil Preservation System (COPS)

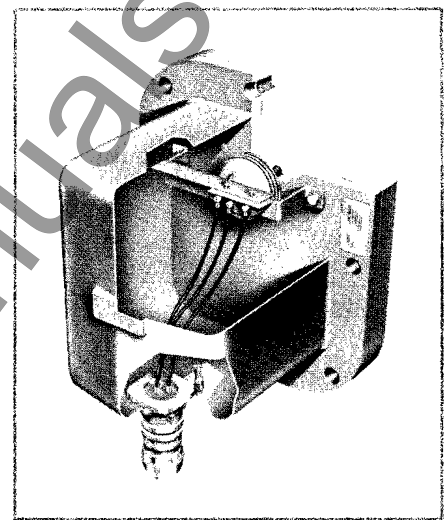
The Westinghouse Constant Oil Pressure System (COPS) of oil preservation maintains a constant pressure on the surface of the oil in the transformer. The tank and the oil are sealed from the atmosphere preventing exposure of the oil to oxygen and moisture.

The oil expansion in the transformer, caused by thermal cycling, is absorbed into a steel reservoir mounted above the main tank. Contact between the oil and the atmosphere is prohibited by a flexible Nitrile air cell in the expansion reservoir. The air cell is vented to the atmosphere through a dehydrating breather and inflates or deflates as the oil volume in the transformer changes. Connection between the main tank and the reservoir is made through a globe valve, thus permitting isolation of the main tank.

1. Globe Shut Off Valve
2. Drain and Fill Valve
3. Pressure-Vacuum Gauge
4. Pressure-Vacuum Bleeder
5. Vacuum Switch
6. Dehydrating Breather
7. Liquid Level Gauge
8. 3 Inch Vacuum Plug
9. Breather Line From Air Cell to Dehydrating Breather
10. Line Connecting Pressure-Vacuum Switch to Reservoir
11. 3 Inch Fill Plug On Transformer
12. Mechanical Relief Device
13. Vent Plugs
14. Air Cell
15. Reservoir
16. Transformer Tank
17. 3 Inch Vacuum Plug

Accessories





Automatic Resetting Relief Device

The Automatic Resetting Relief Device used on Westinghouse transformers is designed to relieve dangerous pressure which may build up within the transformer tank. When a predetermined pressure is exceeded, the reaction lifts the diaphragm of the relief device and vents the transformer tank.

The design features a dome-shape diaphragm, compression springs, gaskets and a protective cover. A lightweight plastic semaphore is used to indicate an operation of the relay. An alarm switch with contacts is available for remote signal of an operation. The compression springs reset the diaphragm on the gaskets following an operation thus preventing the entry of foreign material into the transformer tank.

Combustible Limit Relay CLR-2

The Combustible Limit Relay automatically tests the combustibility of the gas in a power transformer. The relay is specifically designed for application on transformers equipped with Inertaire Oil Preservation System, and will actuate an alarm circuit if the combustible gas content over the surface of the oil reaches a predetermined level.

Many types of incipient faults produce combustible gasses as breakdown products of oil or organic insulating materials in a transformer. Periodic testing of the nitrogen atmosphere over the oil will reveal the presence of combustible gasses and serve as a warning of impending problems.

The relay contains an electrical timer and a solenoid valve, which controls the flow of the sample to an aspirator. The aspirator blends air with the sample to insure oxidation of any combustible gas that may be present. The blend of air and gas sample are passed into a gas reaction chamber where any combustibles are ignited by a heated filament. The filament is connected as one leg of a bridge circuit and the additional heat from the combustion of the gas sample raises the temperature of the filament, changes the resistance and unbalances the bridge circuit. The meter indication in the bridge circuit is proportional to the degree of unbalance and the percentage of combustibles in the sample.

A recorder is available for application in the relay circuit to provide a record of periodic sampling. The relay and the recorder are optional accessories and can be purchased with the transformer or added in the field to installed transformers.

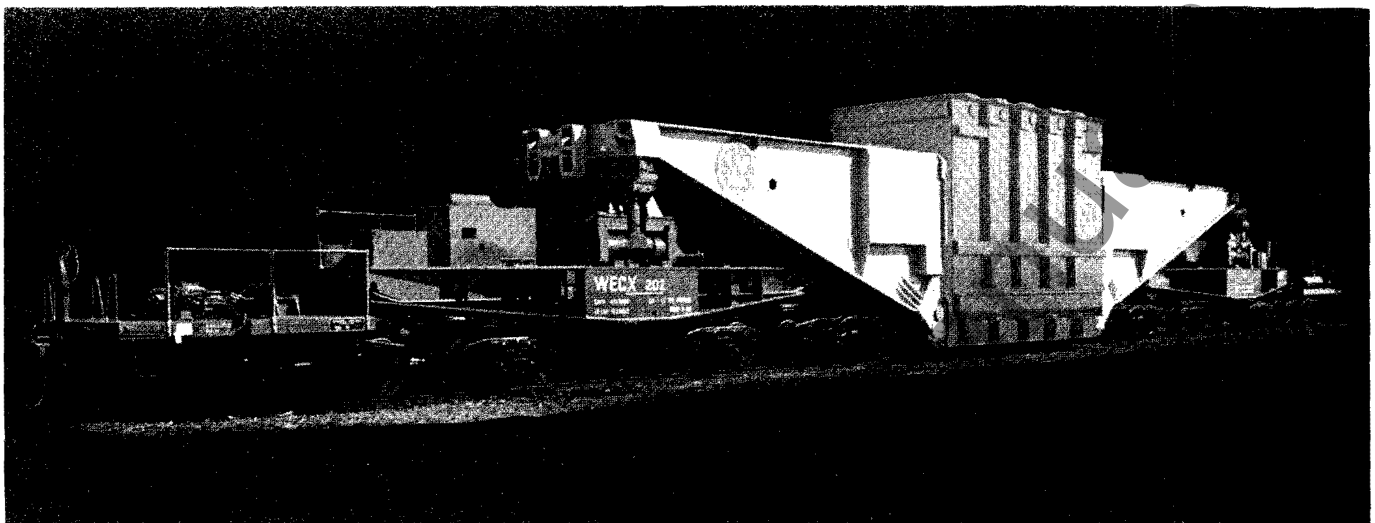
Sudden Pressure Relay

The Westinghouse Sudden Pressure Relay is designed to respond to sudden increases in internal gas pressure in a power transformer. Normally, such pressure increases are caused by an internal arc and the associated circuitry of the relay can be arranged to initiate alarm and trip circuits to deenergize the transformer. Damage to the transformer can be minimized in this way.

The relay consists of a pressure sensing bellows, an alarm switch, and a pressure equalizing orifice all enclosed in a sealed case. The relay is specifically designed for application with the Inertaire Oil Preservation System. It is mounted at the top of the transformer, at the gas space.

A seal-in relay, reset switch and other associated circuitry are mounted on a panel in the transformer control cabinet A Voltrap® surge suppressor is connected across the trip contacts at the seal-in relay to prevent extraneous induced voltages in the alarm circuits from causing false operations. The relay is not affected by external mechanical shock or vibration.

Shipment



Westinghouse large power transformers are designed for shipment on the exclusive Schnabel railroad car.

Benefits of the Schnabel Car

- $5,000 to $10,000 savings in unloading expense:

  Reduces unloading time by 40 to 60%
  Eliminates the need for heavy mobile lifting equipment

- $20,000 to $30,000 additional savings by eliminating tank sectionalization and internal disassembly for shipment.
- Minimizes the exposure of critical insulation structures to the atmosphere thereby enhancing transformer reliability.

The transformer, loaded on the superstructure, is actually part of the car and rides within 6 inches of the top of the rail. By comparison the bed of a depressed center rail car is a minimum of 28 inches high, thus the effective shipping clearance height of a transformer is reduced 22 inches with Schnabel shipments.

This reduction in shipping clearance height eliminates the necessity of sectionalizing the tank for shipment and greatly reduces field assembly time. Since the tank need only be opened for installing and connecting the bushings, the atmospheric exposure is minimized and the transformer's reliability is enhanced.

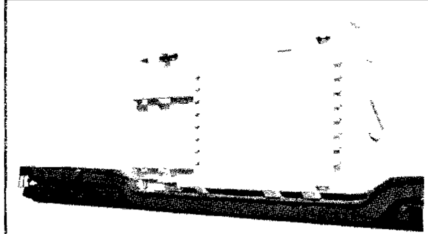
The pivot centers on the loaded Schnabel car are the same as a standard railroad box car, therefore it can negotiate standard railroad curves and does not require special routing.

The cars are equipped with a power driven hydraulic system and their own jacking system, facilitating direct unloading of the transformer without using heavy mobile lifting equipment. After the transformer is skidded to the pad the two halves of the empty car are coupled together for return to the factory. The unloading operation and moving the transformer onto its own foundation pad from an adjacent rail siding can be completed in an 8-hour working shift with a minimum of labor.

Westinghouse has three cars available (500,000 pound, 750,000 pound and 1,000,000 pound capacities) for maximum flexibility in scheduling transformer shipments.

Single Phase Transformer Shipment
Westinghouse single phase large power transformers are frequently shipped on their sides because of shipping clearance limitations. Single phase designs are used primarily on EHV applications where the tank dimensions are high and narrow. Shipment of the transformer on its side eliminates the necessity of sectionalizing the tank and disassembling internal parts of the transformer.

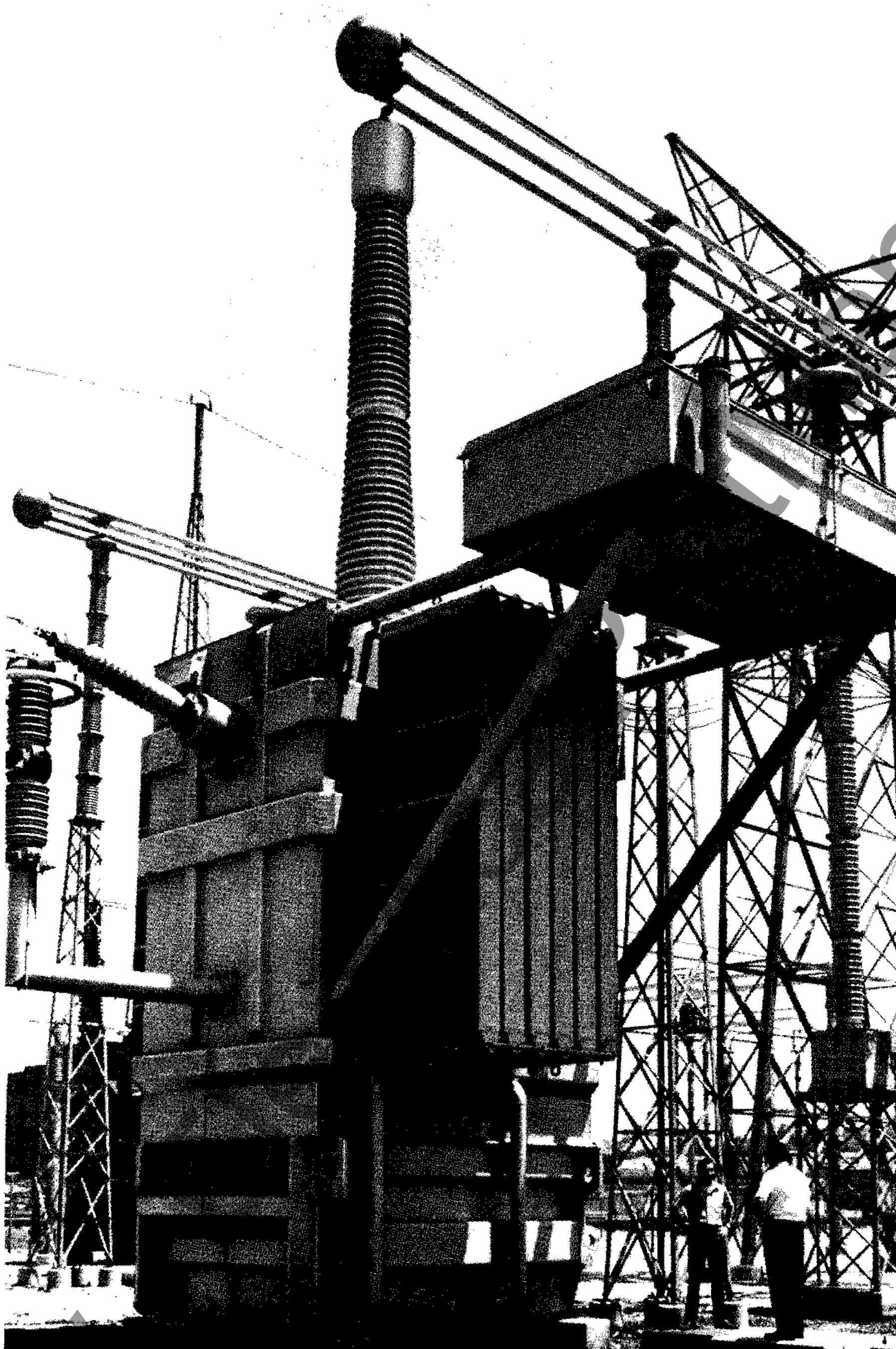
The construction of shell form, form fit transformers is ideal for this method of shipment because the core and coils are a strong unit assembly, securely clamped and supported by internal structures of the tank.



Single Phase Shipment

Uprighting the transformer at the installation site can be done by several methods — the most common being with a mobile crane. A specifically designed transformer rocker device is available which reduces the necessary lifting capability to approximately ten per cent of the shipping weight of the transformer.

Large Power Transformers



1100 KV Single Phase Transformer Installed at Waltz Mill Underground Transmission Test Facility

Westinghouse Developments for Power Transformers

1886 George Westinghouse granted first American transformer patent.

1906 Silicon Steel.

1907 Condenser bushings.

1921 220,000 volt power transformer with no load tap changer.

Load tap changers.

Surge generator for power transformer testing.

Sealedaire oil protection for power transformers.

Commercial impulse testing.

Forced oil cooling (railway); Hipersil steel; vacuum filling of transformers.

Solder seal bushings.

Type "O" oil filled condenser bushings.

Form fit tank.

500 kv Tidd transmission line transformers (experimental).

Coastal finish paint.

220,000 kva power transformer.

345,000 volt power transformer.

400,000 kva power transformer.

World's largest sound testing laboratory; power transformer designed by computer.

Schnabel railroad car.

Insuldur insulation system.

Resistance type tap changer for high voltage applications.

750 kv Apple Grove transmission line transformer (experimental); first transformer shipped from Muncie plant; 750,000 lb. capacity Schnabel car.

Contract signed for 500 kv commercial system; 600,000 kva transformer shipped.

Order received for 725,000 kva, 345 kv three phase transformer.

First 500 kv transformer for commercial use shipped; new improved Insuldur.

First 735 kv transformer for commercial use shipped.

Order received for 1,000,000 kva transformer.

950 Mva 3 phase transformer shipped; first 765 kv transformer and reactor for commercial operation shipped.

First 1100 kv transformer (experimental) shipped; 1,000,000 lb. capacity Schnabel car.

1,000,000 kva transformer shipped

Second 1100 kv transformer (experimental) shipped.

Order received for 1,300,000 kva, 345 kv three phase transformer.

Large Power Transformers

Westinghouse Power Transformer Plant Muncie, Indiana

This modern manufacturing facility was designed and constructed specifically for manufacturing large power transformers. Proven manufacturing concepts are combined with innovative processing techniques to produce a reliable transformer in a minimum cycle time. Sophisticated test equipment and procedures are utilized to prove the reliability of the transformer prior to shipment.

The plant is staffed with highly trained, experienced personnel. Complete Engineering and Development facilities are included as an integral part of the operation and are fully supported by the extensive Westinghouse Corporate Research Department.

Westinghouse Electric Corporation
Power Transformer Division, Muncie, Indiana 47305
Printed in USA