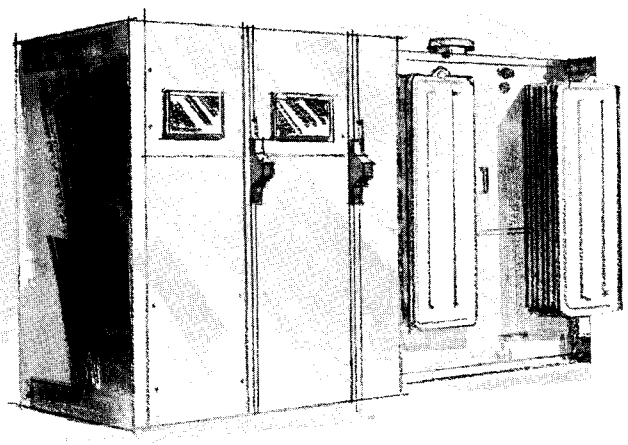
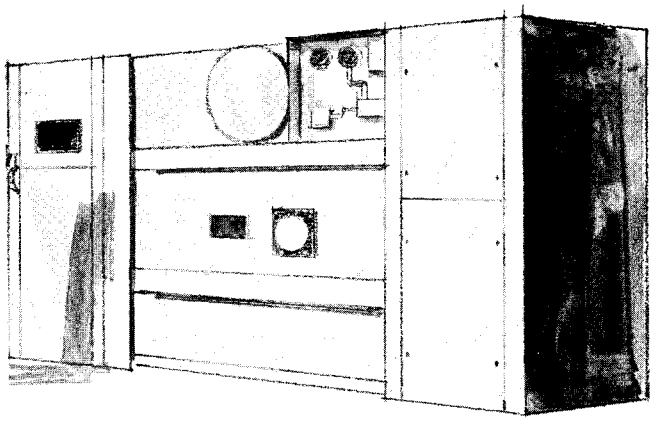
# SECONDARY UNIT SUBSTATION TRANSFORMERS

**RATINGS 112½ THRU 2500 kVA**
**Primary—5 and 15 kV Class  Secondary—208Y/120, 240, 480Y/277 and 480 Volts**
**TYPES: OIL OR ASKAREL-IMMERSED, VENTILATED OR SEALED-DRY**



Askarel Type



Sealed-Dry Type

This Section describes the primary section and transformers normally associated with unit substations. They can be used as free standing units with the addition of a secondary air terminal chamber suitable for cable connection to associated equipment; or directly connected by close coupling or throat to other associated low-voltage equipment.

## AVAILABLE COMPONENTS

### PRIMARY SECTION—Incoming

Air Interrupter Switch (Fused or Unfused)
Air Interrupter Selector Switch (Fused or Unfused)
Air Terminal Chamber
Liquid Interrupter or Disconnect Switch
Oil Cutouts (Fused or Unfused)

### SECONDARY SECTION—Outgoing

Air Terminal Chamber

Other low-voltage sections are available to form complete secondary unit substations:
Motor Control Centers—Section 6.10
Low-Voltage Stationary Switchboards—Section 7.1
Low-Voltage Drawout Switchgear—Section 7.2

### TRANSFORMER SECTION

**Oil-Immersed**—Basically for outdoor applications. Operates at 65° C rise. Features light weight and smaller size plus an improved radiator design for more efficient cooling.

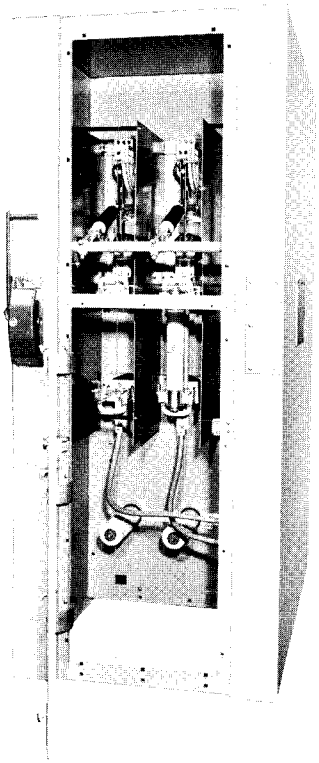
**Askarel-Immersed**—Mainly for indoor applications, but often used outdoor near building walls or on roofs. Same basic features as oil-immersed type.

**Ventilated-Dry Type**—Utilizes a superior moisture resistant insulation system designed to operate at 150° C rise. Features small size, light weight and low sound levels.

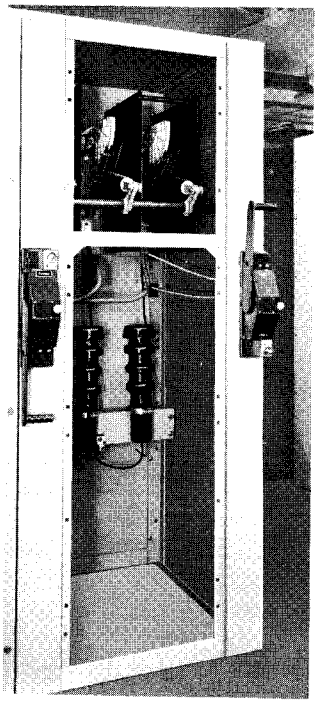
**Sealed-Dry Type** using fluorocarbon ($C_2F_6$) gas as a coolant and dielectric medium. High dielectric and low viscosity to improve heat transfer.

# INCOMING LINE SECTION

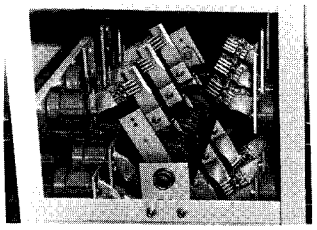
## PRIMARY DEVICES



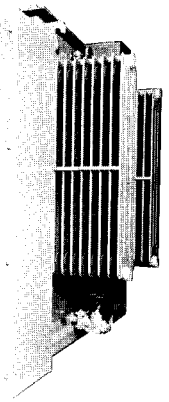
1. Air Interrupter Switch



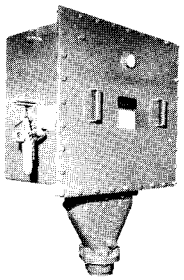
Air Interrupter Selector Switch



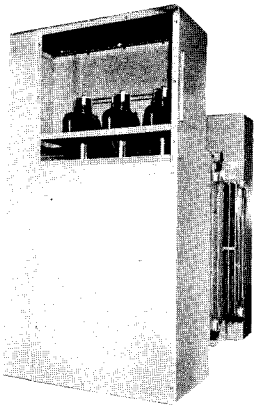
Cutaway of 3-Pole Selector Switch



2. Air Terminal Chamber



3. Liquid Interrupter or Disconnect Switch



4. Oil Cutout

### 1. AIR INTERRUPTER SWITCHES— FUSED OR UNFUSED

**The I-T-E type HPL-C air interrupter switch** is a 3-pole, 2-position device which utilizes a snap-action blade in combination with an arc chute for safe closing and interruption. Visual indication thru the optional safety glass front window and on the handle mechanism shows the blade position.

**Selector Switch** consists of a rear mounted 3-pole, 2-position selector device in series and interlocked with the interrupter switch. An interlock prevents switching of lines while under load. It has a front mounted handle mechanism which visually indicates Line 1 or Line 2.

**Duplex switches** are available, consisting of two key-interlocked switches located side by side.

Fused switches are interlocked to prevent opening of the fuse door while the switch is in the closed position, I-T-E type CL-13 current-limiting fuses are used.

The switches are available with or without lightning arresters, can be equipped with cable lugs or potheads and can be entered from top or bottom. (Lightning arresters are recommended for use with ventilated-dry type transformers).

### 2. AIR TERMINAL CHAMBERS

Full height floor-mounted air terminal chambers equipped with cable lugs or potheads are directly connected to the transformer. Top or bottom entrance and indoor or outdoor construction are available.

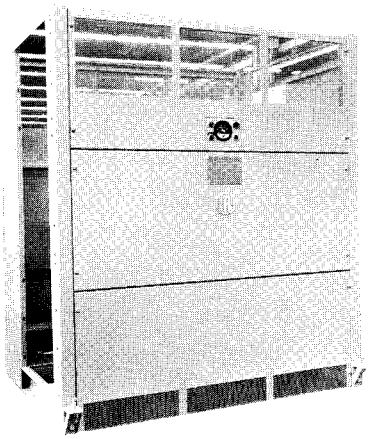
### 3. LIQUID INTERRUPTER OR DISCONNECT SWITCH

These devices can be provided on liquid-immersed transformers only. They are three-pole, two- or three-position units. The switch enclosure is welded or bolted to the transformer tank. The liquid in the switch is always the same type as used in the transformer to prevent any possible interchange of liquids. When oil filled, they are interrupter switches that can interrupt load currents up to 400 amperes. When askarel filled, they have no interrupting capacity but can be used as a disconnect switch to break magnetizing currents up to 10 amperes five times, after which the askarel must be changed. Potheads are always provided. Liquid is shipped in separate container to avoid draining the switch to make cable connections.

### 4. OIL CUTOUTS—FUSED OR UNFUSED

Oil cutouts are supplied mounted in a terminal chamber and have provisions for terminating one 3-phase feeder cable. They are available in 200 and 300 ampere ratings at 5 kV and 100 and 200 amperes at 15 kV. As a fused switch they may be used within rating limits of 500 kVA at 2400 volts, 750 kVA at 4160 volts and 1000 kVA at 15 kV they can also be used unfused as disconnects up to 750 kVA at 2400 volts, 1000 kVA at 4160 volts and 2000 kVA at 15 kV. Values are based on applying fuses at twice the full-load current rating of the transformer. Available for indoor or outdoor installation.

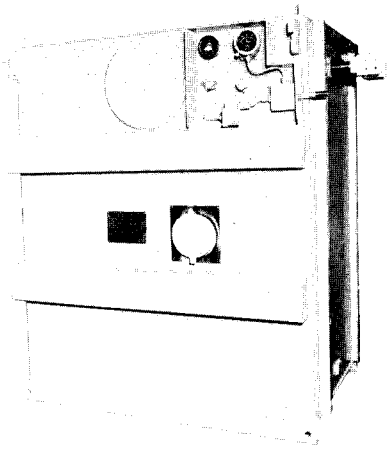
# TRANSFORMER SECTION



Ventilated-Dry

## VENTILATED-DRY

- Moisture-resistant insulating materials
- Low sound levels
- Reduced size and weight
- Increased impulse and dielectric level



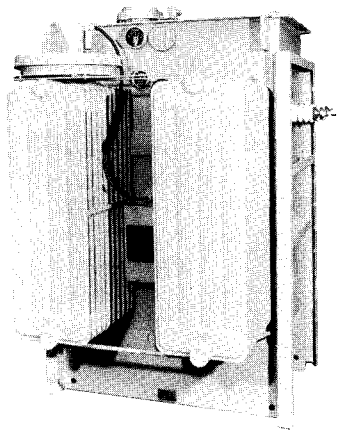
Sealed-Dry

## SEALED-DRY

- Fluorocarbon gas
- Higher dielectric
- Higher impulse levels
- Faster heat transfer
- Lighter weight
- More compact

## TABLE 1
## STANDARD TRANSFORMER RATINGS

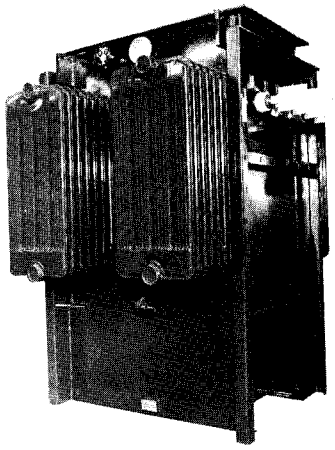
| Type | Primary Voltage Delta | kVA 3-Phase Self Cooled | kVA 3-Phase Forced Air Cooled | Secondary Voltage 208Y/120 240 Delta | Secondary Voltage 480Y/277 480 Delta |
|---|---|---|---|---|---|
| Liquid-Immersed Oil Askarel 65° C Rise | 2400 | 112½ | — | X | X |
| | 4160 | 150 | — | X | X |
| | 4800 | 225 | — | X | X |
| | 6900 | 300 | — | X | X |
| | 7200 | 500 | — | X | X |
| | 12000 | 750 | 862 | X | X |
| | 12470 | 1000 | 1150 | X | X |
| | 13200 | 1500 | 1725 | | X |
| | 13800 | 2000 | 2300 | | X |
| | | 2500 | 3125 | | X |
| | 2400 | 112½ | — | X | X |
| | 4160 | 150 | — | X | X |
| | 4800 | 225 | — | X | X |
| | | 300 | — | X | X |
| Vent.-Dry 150° C Rise | 2400 | | | | |
| | 4160 | 500 | — | X | X |
| | 4800 | 750 | 1000 | X | X |
| | 6900 | 1000 | 1333 | X | X |
| | 7200 | 1500 | 2000 | | X |
| | 12000 | 2000 | 2666 | | X |
| | 12470 | 2500 | 3333 | | X |
| | 13200 | | | | |
| | 13800 | | | | |
| Sealed-Dry Fluoro-carbon Gas ($C_2F_6$) Filled 150° C Rise | 2400 | | | | |
| | 4160 | 300 | | X | X |
| | 4800 | 500 | | X | X |
| | 6900 | 750 | | X | X |
| | 7200 | 1000 | | X | X |
| | 12000 | 1500 | | | X |
| | 12470 | 2000 | | | X |
| | 13200 | 2500 | | | X |
| | 13800 | | | | |



Askarel-Immersed, Indoor

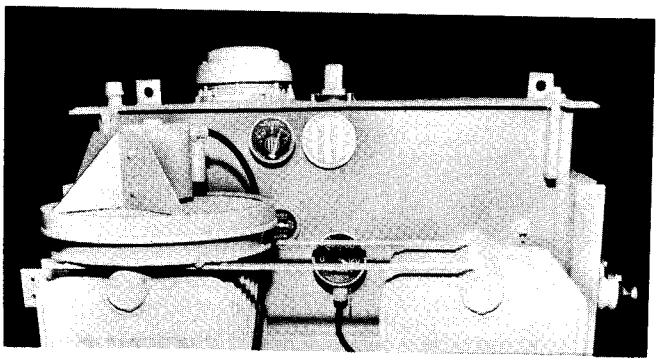
## LIQUID-IMMERSED

- Lighter weight
- Less floor space
- Constant bushing height
- Proven radiator design
- Proven insulation system



Oil-Immersed, Outdoor

# STANDARD ACCESSORIES ON UNIT SUBSTATION TRANSFORMERS



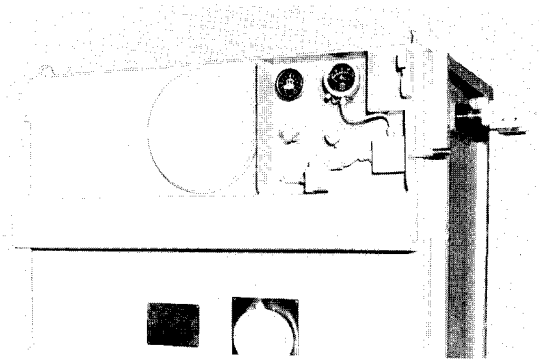
Liquid-Immersed Type

### Liquid-Immersed Transformers

Magnetic liquid level gauge
Thermometer in closed well with maximum indicating hand
Pressure-vacuum gauge
Pressure relief device (askarel only)
Combination drain valve, lower filter connection and sampling valve
Upper filter connection
Sampling device at top liquid level (askarel only)
Skid base with jacking and towing provisions
Transformer lifting hooks
Cover lifting eyes
Ground pad located in front of transformer
No load, externally operated tap changer
1-inch vent plug in cover
Hand-hole in cover
Diagrammatic nameplate
Sealed tank with welded cover

### Ventilated-Dry Transformers

Skid base with provision for jacking or towing
Flexible links for changing taps
Ground pad
Lifting eyes on upper core clamp
Diagrammatic nameplate



Sealed-Dry Type

### Sealed-Dry Transformers

Pressure test and filling valve
High-low pressure alarm device with contacts
Pressure-vacuum gauge
No load externally operated tap changer
Ground pad on LV side
Skid base with provision for jacking and towing
Transformer lifting hooks
Cover lifting eye
Hermetically sealed bushings
Diagrammatic nameplate
Pressure relief valve

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### Fan Provisions:

All liquid-filled and ventilated-dry transformers, 750 kVA and above have provision for the future addition of cooling fans.
This provision for forced air cooling will include:

1. Capacity in all current carrying parts, including bushings for the forced cooled rating.
2. Provision for mounting in the field, the balance of the equipment required.
3. Provision for the future automatic control of the fans as follows:
   a. Liquid filled units—provision for incorporating the thermometer relay for control of the future fans from top liquid temperature.
   b. Ventilated dry units—provision only for mounting winding temperature relay for control of future fans from winding temperature.

### Optional Accessories Are Available as Follows:

Winding temperature equipment
Gas absorbers for askarel-filled transformers
Tap changer interlocks for liquid and sealed-dry transformers.
Alarm contacts on thermometer, liquid level gauges and pressure relief device.
Sudden pressure relay on liquid-filled transformers

### STANDARD ELECTRICAL TESTS

Winding resistance test
Ratio test
Polarity and phase-relation test
No load loss test
Exciting current test
Impedance and load loss test
Applied potential test
Induced potential test

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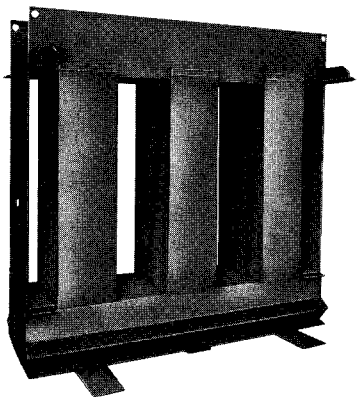
# TRANSFORMER SECTION

## DETAILS OF CONSTRUCTION—LIQUID AND DRY TYPES



Core Assembly—Liquid-Immersed Type

### CORE CONSTRUCTION

The core of each transformer is made of non-aging, high permeability, grain-oriented, cold-rolled, silicon steel specifically processed for consistently low losses.

The thin-gauge laminations are sheared with special high quality shear blades in such a manner that the flux path will be aligned with the axis of highest permeability in the steel. Each lamination is flat and free from burrs and is inorganically insulated on both surfaces to minimize eddy-current loss.

Laminations are hand stacked on a specially designed table which ensures flatness and prevents the introduction of bending stresses while the finished core is being set in an upright position. Careful positioning of each lamination produces close fitting lap and butt joints to further minimize core loss and noise.

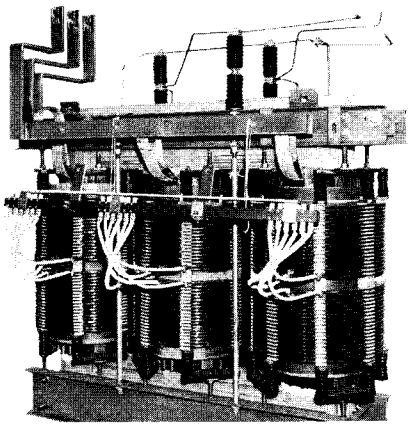
Core legs are assemblies of laminations with cross sections designed to accommodate the coils with the optimum combination of high space factor and coolant flow.

The upper and lower core yokes are rigidly clamped by welded assemblies of steel members consistent with bracing and supporting requirements. Core clamps are chemically cleaned to remove any dirt or impurities from the forming and welding operations. Core clamps on ventilated-dry transformers are steel grit blasted to remove mill scale and slag. This assures that only clean, bright metal will be in contact with the cooling liquid. Then the core assembly is painted to insure against oxidation. Core clamps and all structural parts are insulated to prevent local circulating currents and are solidly bonded to ground and to the core to prevent development of potential in any part.

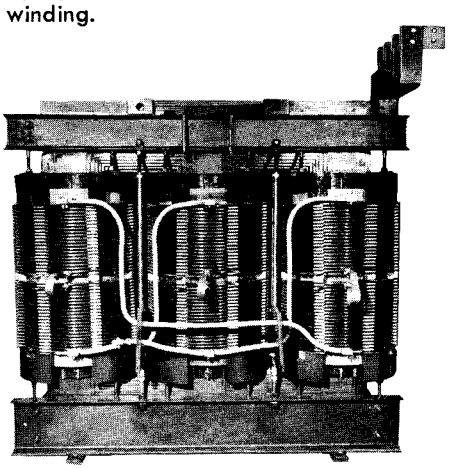
### COIL CONSTRUCTION

I-T-E regards the coils as the most important part of the transformer. No fixed rules are followed for their construction. They may be barrel helical, disk or sheet wound depending on rating, current and voltage. Regardless of the construction used, the following requirements must be met:

1. STRESSES: Primary and secondary coils must be vertically balanced to eliminate interaction of forces caused by short-circuit stresses. I-T-E coils are, therefore, wound with the secondary coil nearest the core and supported by a strong insulating cylinder. The primary coil is then wound on top of the secondary coil. A suitable insulating full-length barrier is provided between the two coils, consisting of spacers and sheet insulation built up to the proper thickness. The coil wire is wound tightly and uniformly thru a tension device to insure maximum strength.
2. COOLING: The coils must be equipped with cooling channels in order to dissipate the heat generated in the coils. This is accomplished by insertion of spacer sticks or other suitable duct spacing material, depending on design.
3. CURRENT CARRYING ABILITY: The current density in the individual conductors of the coil must not be greater than permitted by the proper cooling of the coil. Secondary coils are sometimes made of sheet conductor properly insulated to maintain maximum efficiency and cooling.
4. TAPS: Tap leads or terminals are secured to the winding at their proper location, without breaking the continuity of the winding.



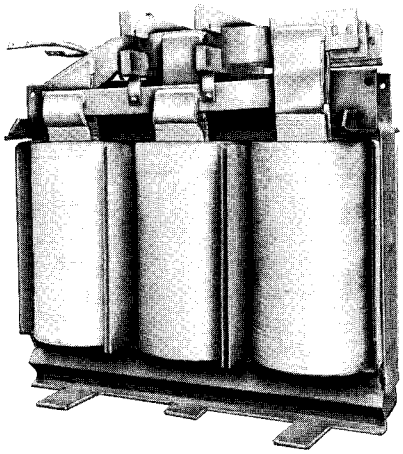
Core and Coils—Sealed-Dry Type



Core and Coils—Ventilated-Dry Type

# TRANSFORMER SECTION

## LIQUID-IMMERSED TYPE



Core and Coils—Liquid-Immersed Type

### INSULATING MATERIAL

All insulating materials used have been thoroughly tested and proven with respect to their electrical and mechanical characteristics and are stable at operating temperatures and compatible with the cooling medium.

In liquid-filled transformers, the insulation system is thermally upgraded. It is chemically modified to resist the effects of high temperature. The improved insulation enables the new, compact transformers to maintain full load-carrying ability at their higher operating temperature without affecting life expectancy.

Thermally-upgraded pressboard insulation is used for coil spacers, both longitudinal and radial, as well as ends. It is also used between layers and between high and low-voltage coils. The porosity of the insulating materials permits the insulating liquid to penetrate the insulating materials giving it a high dielectric strength.

The figure below compares the absolute value of toughness, measured in inch-pounds, of thermally-upgraded insulation and untreated electrical-grade kraft.

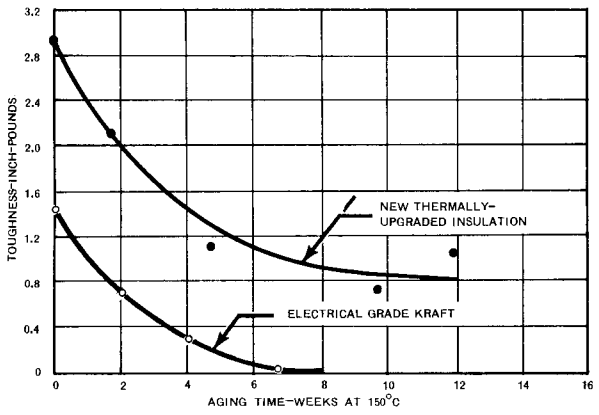


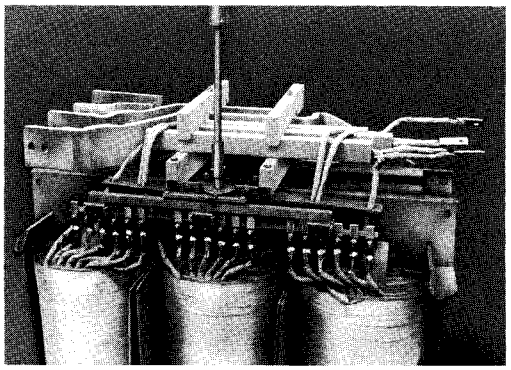

Figure 1—Comparison of absolute values for toughness of new thermally-upgraded insulation vs electrical-grade kraft

As shown by the curve, the initial toughness of the new insulation after drying and oil impregnating is 97% higher than that of electrical-grade kraft, and a substantial improvement in toughness is maintained during aging at 150°C.

### TRANSFORMER SUPERSTRUCTURE

The superstructure consists of the secondary bus bars with their associated connections to the secondary coil leads, the tap changer and the supporting channels for the primary leads. Secondary bus bars are held in alignment by pressboard spacers. Non-magnetic through-bolts in an insulating tube bind the spacers securely together. The primary leads are supported in pressboard channels.

The complete superstructure is pre-assembled and installed on the transformer.



Tap Changer—Liquid-Immersed Type

### TAP CHANGER

The tap changer is the in-line type, consisting of an insulated bar on which are mounted three-sets of six stationary contacts. Bridging two stationary contacts of each set are two self-aligning spring-loaded movable contacts. The movable contacts are driven by a common insulated bar by means of a gear and rack thru an externally-operated tap-changer handle.

### DRYING OF CORE AND COIL

An important step in the manufacturing process of liquid filled transformers is the drying of the coil and core assembly prior to tanking. The coil and core is heated in an oven to 105° C.

During the drying, the insulating materials give up moisture and therefore shrink in dimensions. While the core and coil are still hot, the core and coil clamping fixture is tightened and the core is welded solidly together.

The core and coil assembly is then vacuum impregnated in an insulation liquid, to remove remaining moisture and entrapped air. It is then lowered into its tank and the connection between coil and core and tank are then made. The braces to the tank are secured and the tank is filled with liquid while the transformer is still warm. The cover is welded in place and the transformer is ready for tests.

# TRANSFORMER SECTION

## TANK

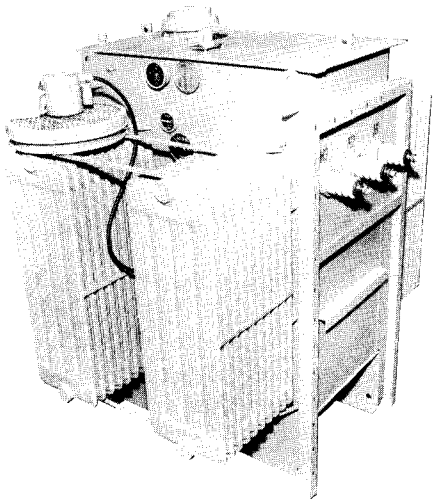
The transformer tank is fabricated of heavy gauge steel plates. A minimum number of plates are used to reduce the number of welded seams.

The tank base is fabricated of formed steel to receive and transmit the core and coil weight to the mounting pad or foundation and provides for skidding or rolling in any direction. Facilities for jacking are at the ends of the base.

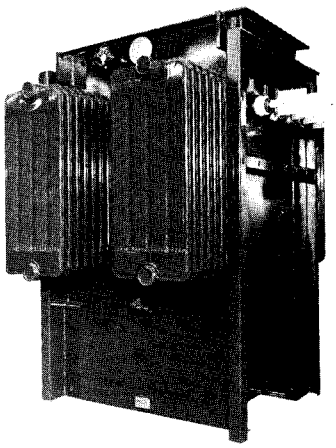
Formed structural members are welded to the side walls so that the complete tank will be sufficiently reinforced to withstand a test of 7.5 lbs. pressure or 7.5 lbs. vacuum. This will prevent tank distortion during operation or pressure testing. The top of the tank is further strengthened by a flange which is used as a welding ring for securing the tank cover. An asbestos-type gasket is provided between the reinforced cover and the top flange and is compressed during the welding operation to prevent weld spatter from entering the tank. Lifting hooks are provided at the corners of the tank to permit the finished transformer, complete with liquid, to be handled by a crane.

Adequate radiation surface is provided by plate type radiators to assure that the temperature rise of the cooling liquid will not exceed the specified limit when the transformer is continuously operated at rated full load. The combination of the plate principle and special design features assures maximum cooling surface in compact form.

The entire tank is chemically cleaned before painting to remove any oil, dirt or other impurities from the forming and welding operation. Each tank is painted with a rust inhibiter prime coat and two finish coats in accordance with ANSI standards. The use of hermetically-sealed glass bushings welded to the tank assures reliable leak-free service.



Askarel-Immersed Type—Indoor



Oil-Immersed Type—Outdoor

# TRANSFORMER SECTION

## DRY TYPE

### INSULATING MATERIAL

All insulating materials used have been thoroughly tested and proven with respect to their electrical and mechanical characteristics and are stable at operating temperatures and compatible with the cooling medium. In dry-type 150° C transformers, the wire is film insulated. Spacers and packout are suitable class H materials, and with disc coil construction the key spacers are ceramic. Layer insulation is glass and mica cloth. These insulation materials will withstand the high operating temperature permitted in this type of transformer.

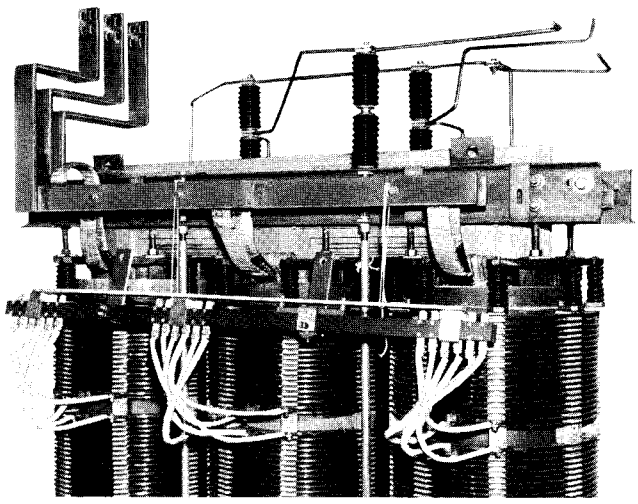
### IMPREGNATION OF COILS

All coils are first dried in spring-loaded compression fixtures in temperature controlled ovens to relieve stresses and assure proper dimensions. They are next impregnated with silicone varnish under vacuum. The vacuum helps avoid tiny air pockets where corona might start, or where moisture and dirt might penetrate the coils and coil insulation. It gives the highest dielectric strength possible. Finally they are returned to the ovens to give the varnish a thorough curing.

## SEALED-DRY TYPE

### BUS ASSEMBLY

A superstructure, mounted on the transformer upper core clamp, contains all of the secondary and primary bus and associated insulators and connections to the high and low-voltage coil leads. Both high and low-voltage bus ends are then clamped or bolted to the transformer bushings.



Tap changer and Internal Bus Assembly

### TAP CHANGER

The tap changer is the in-line type similar in construction to that used on liquid-immersed transformers. It is operated thru an externally-operated mechanism which prevents the loss of pressure.

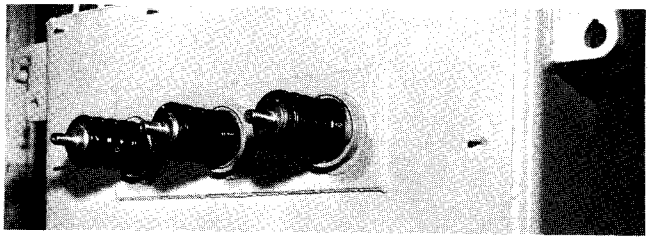
### $C_2 F_6$ FLUOROCARBON GAS

The fluorocarbon gas has a dielectric strength of approximately 2.8, compared with air as a base of 1.0. This higher dielectric strength results in higher basic impulse levels than nitrogen-filled or ventilated-dry type units.

As a heat-transfer medium, the higher molecular weight and lower viscosity of fluorocarbon make it more efficient than nitrogen. This results in faster heat transfer from the transformer core and coils to the tank walls and permits a lighter, more compact design.

### TANK

The tank on the sealed-dry transformer is similar in construction to the liquid-immersed type. It, however, is designed to withstand 15 lbs. pressure or vacuum. Other features include: protected instrumentation, external stiffeners and hermetically-sealed glass bushings.

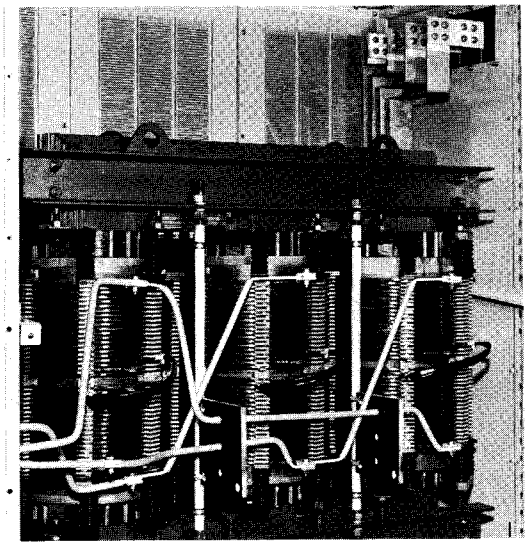


Glass bushings

## VENTILATED-DRY TYPE

### BUS ASSEMBLY

The low-voltage bus is mounted to the upper core clamp of the transformer. The primary connections from the high-voltage compartment are made directly to the coil terminals. Tap connections are changed manually.



Ventilated-Dry Bus Assembly