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Secondary unit substations — below 1000 V

Contents

Powering Business Worldwide

General Description

Definition

A secondary unit substation is a close-coupled assembly consisting of enclosed primary high voltage equipment, three-phase power transformers, and enclosed secondary low voltage equipment. The following electrical ratings are typical:

- Primary voltage: 2.4–38 kV
- Transformer kVA: 300–3750
- Secondary voltage: 208, 240, 480 or 600 V (maximum)

A secondary unit substation is defined in the following standard:

- IEEE® C57.12.80

Advantages

As a result of locating power transformers and their close-coupled secondary switchboards as close as possible to the areas of load concentration, the secondary distribution cables or busways are kept to minimum lengths. This concept has obvious advantages such as:

- Reduced power losses
- Improved voltage regulation
- Improved service continuity
- Reduced exposure to low voltage faults
- Increased flexibility
- Minimum installation cost
- Efficient space usage

Additional advantages of Eaton's unit substations in this unified approach are:

- Single-source responsibility
- Complete electrical and mechanical control over coordination of the three close-coupled sections
- Availability of all switchboard and switchgear types gives broad application flexibility
- Modern design
- Composite assembly retains proven safety and integrity of each of its three major parts

Types of Distribution Systems

Simple Radial

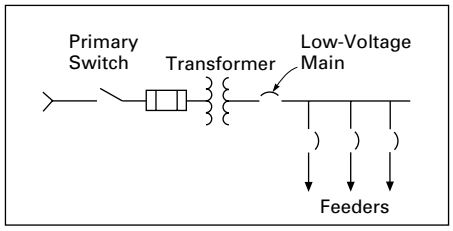


Figure 14.1-1. Simple Radial

- Simple and less costly
- Easy to coordinate
- No idle parts

Primary Selective

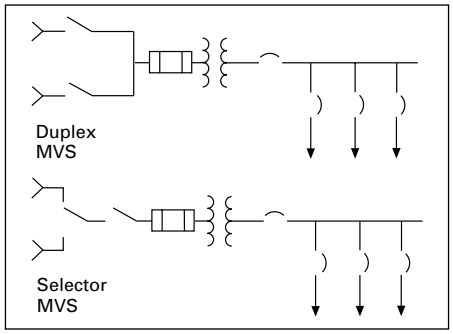


Figure 14.1-2. Primary Selective Radial

Similar to simple radial with added advantage of a second primary incoming cable circuit. By switching to a second circuit, duration of outage from cable failure is limited.

Secondary Selective

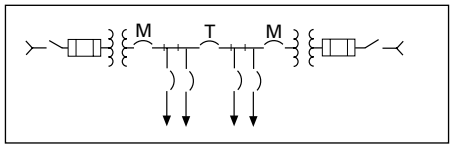


Figure 14.1-3. Secondary Selective

Normally operated as two electrically independent unit substations, with bus tie breaker (T) open, and with approximately half of the total load on each bus. In case of failure of either primary incoming circuit, only one bus is affected, and service can be promptly restored by opening main breaker (M) on the dead bus and closing tie breaker (T). This operation can be made automatic, with duration of outage on either bus limited to a few seconds.

Because the transformers are not paralleled, secondary fault currents and breaker applications are similar to those on radial unit substations. Service continuity and substation capacity can be further improved by substituting selector type primary switches as in B.

Loop Selective

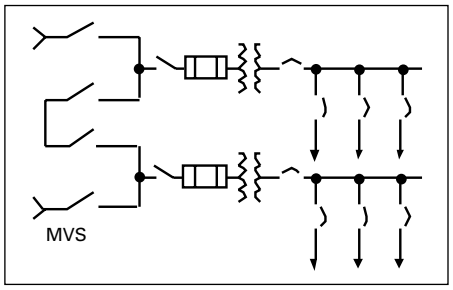


Figure 14.1-4. Loop Selective

This configuration is based upon a string of substations being fed from two sources. The power cables from the first source terminate at a "loop" switch in the substation primary switchgear assembly, down the switchgear bus to another "loop" switch in the same switchgear assembly, then back out to another "loop" switch in a different substation. The loop cabling system is continued through every unit substation until the cable connects to the second source. Typically, the path from one substation to another is broken by an open switch in one of the substations. The philosophy is if there is a failure somewhere, or it is desired to perform maintenance to cable or a switchgear assembly, it may be isolated by opening the appropriate switches in the loop, thus restoring service to the other substations.

Spot Network

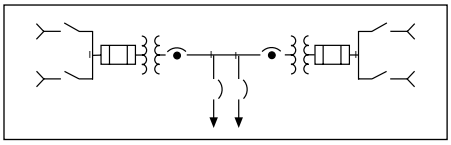


Figure 14.1-5. Spot Network

The transformers are parallel on the secondary sides through network protectors. In case of primary voltage failure, the associated protector automatically opens. The other protector remains closed, and there is no "dead time" on the bus, even momentarily. When primary voltage is restored, the protector automatically checks for synchronism and recloses.

Secondary voltage regulation is improved by paralleled transformers.

Secondary fault capability is increased by paralleled transformers and the feeder breakers must be selected accordingly. Primary switches are usually selector or duplex type so that transformers may be transferred to alternate live sources.

Liquid-Filled Substation Transformers

Application Description

Eaton's liquid-filled substation transformers are custom-designed power transformers suitable for both indoor and outdoor applications.

The transformers are of the sealed tank design and suitable for use in coordinated unit substation in most any type of application and environment. Typical applications of liquid-filled transformers are:

- Utility substations
- Pulp and paper mills
- Steel mills
- Chemical plants/refineries
- General industry
- Commercial buildings

Benefits

- Custom-design flexibility to meet special customer needs and applications such as retrofitting existing liquid-filled and dry transformers
- Computerized loss-evaluated designs for specific customer load and evaluation criteria

Standard Features

- High short-circuit strength
- IEEE short-time overload capability
- Impervious to the environment through sealed design
- Lowest first cost and cost of ownership to cast/dry designs
- Available as mineral oil-filled or with less-flammable liquids, such as silicone or Envirotemp FR3—an environmentally friendly fluid

Design and Technology

Liquid-filled transformers are custom designed and manufactured. Coils are of the rectangular design. Primary windings are comprised of wire conductors, either aluminum or copper. Secondary windings are either full height sheet conductors or wire conductor dependent on the voltage and kVA rating. The layer-to-layer insulation is coated with a diamond pattern of B-stage epoxy adhesive, which cures during processing to form a high-strength bond. This bond restrains the windings during operation and under short-circuit stresses.

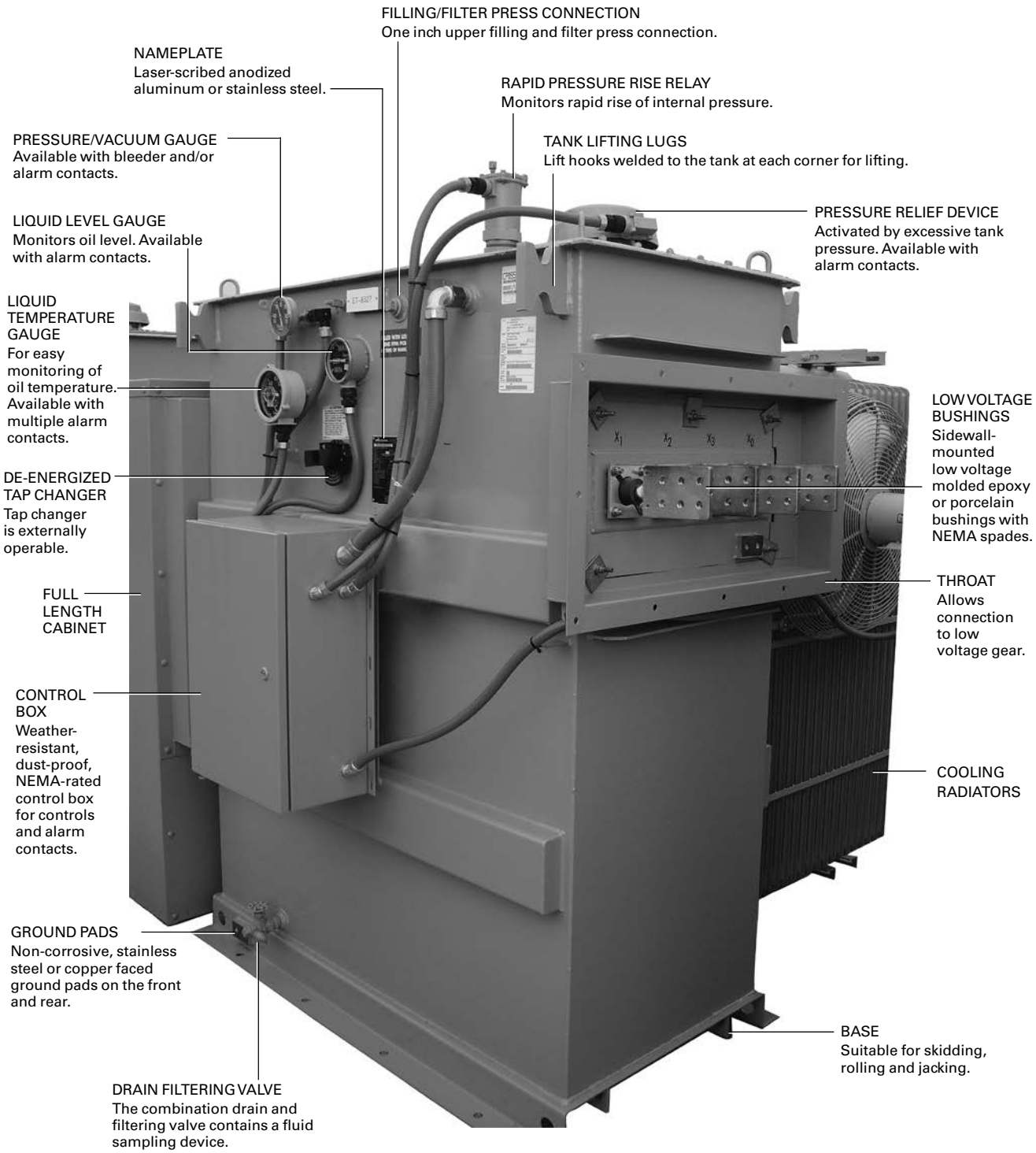
Liquid-filled transformers are suitable for use up to 65 °C average winding rise (75 °C average winding rise with Envirotemp FR3 fluid) over a maximum ambient temperature of 40 °C, not to exceed 30 °C average for any 24-hour period. The transformer may be specified as 55 °C rise, in which case the transformer has a self-cooled (OA) overload capability of 112% (55/65 °C rise) or 122% (55/75 °C rise) without loss of life.

Note: Envirotemp FR3 fluid-filled transformers are a potential cost, footprint and/or weight reducing option. This design is available due to the insulation life extending properties that Envirotemp FR3 provides. Insulation life of an Envirotemp FR3 fluid-filled transformer operating at a 75 °C average winding rise is expected to double the insulation life of a mineral oil-filled transformer operating at 65 °C average winding rise. This design is recognized in IEEE C57.154 and is available as a UL Listed transformer. Contact Eaton for more information.

Material used for cores is non-aging, cold rolled, high permeability, grain-oriented silicone steel or amorphous metal. Cores are rigidly braced to reduce sound levels and losses in the finished product.

The core and coil assembly is immersed in either mineral oil, silicone or environmentally friendly fluids and is contained in a sealed tank.

Flat, tubular or panel radiators may be mounted on the front and back of the tank. The liquid circulates through the tank and radiators by means of natural convection, and effectively cools the core and coil assembly.



Liquid-Filled Substation Transformer

Accessories

Standard accessories include:

- De-energized padlockable manual tap changer
- Liquid level gauge
- Dial type thermometer
- Drain valve
- Lifting lugs
- Jacking provisions
- Ground pad
- Diagrammatic nameplate
- Bolted handhole
- Provisions for rolling and skidding
- ANSI 61 paint finish
- Pressure relief valve or device
- Upper fill plug with filter press connection

Optional Features

- Rapid pressure rise relay with seal in relay
- Cover mounted high volume pressure relief device
- Upper filter press cap
- Dial winding temperature indicator
- Alarm contacts on gauges
- Control power transformer, single-phase 480–120/240 V
- 55 °C or 75 °C average winding rise
- Non-standard ambient temperature (30 °C average/24-hour 40 °C maximum is standard)
- Non-standard altitude (up to 3300 ft [1000 m] is standard)
- Non-standard BIL level
- Fan cooling package
- Lightning arresters
- Low loss design (loss evaluation)
- Special sound level
- Copper windings/bussing
- Containment pan with plug
- UL listed
- UL classification
- FM Global approved to meet NEC 450.23 listing restrictions
- Future fan provisions (on units 750–2500 kVA)
- Core ground strap
- Neutral grounding resistor
- Hazardous Location (Class I, Division 2, Groups B, C, and/or D)

Factory Tests

The following tests are standard:

- Induced potential
- Applied potential
- Insulation power factor test
- Resistance measurement
- Routine impulse test
- Ratio test
- Polarity and phase relationship test
- No load loss
- Exciting current at rated voltage
- Impedance and load loss
- Mechanical leak test

Special Tests

The following tests can be provided at additional cost:

- Temperature rise
- IEEE lightning impulse
- Sound level
- Corona (RIV-partial discharge)
- Insulation resistance
- Zero-phase sequence impedance

Fluid Tests

- Dissolved gas analysis (DGA)
- Dielectric strength

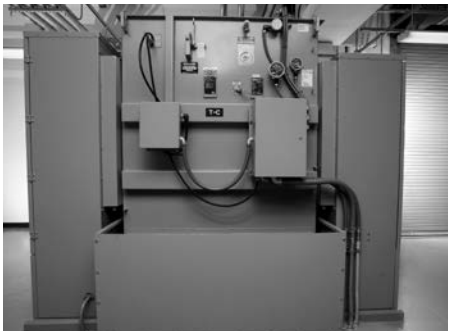
Note: Witnessing tests are available, but will incur a charge and shipment delay.

VFI Transformer

The VFI transformer combines a conventional liquid-filled distribution substation transformer with a vacuum fault interrupter (VFI) installed integral to the transformer. This combination provides both voltage transformation and primary transformer switching and overcurrent protection in a space-saving and money-saving package. The substation VFI transformer protects the transformer and can provide coordination with upstream protective devices. The three-phase VFI breaker has independent single-phase initiation, but is three-phase mechanically gang-tripped. A trip signal on any phase will open all three phases, eliminating single phasing of three-phase loads. The VFI breaker may also be used as a three-phase load-break switch. An optional visible break switch with blades visible via a sealed window may be installed in series with the VFI. This feature allows an operator to see if the switch blades are in an open or closed position before performing maintenance. VFI transformers may be utilized in a simple radial, primary selective radial, or loop selective system simply by adding a selector or loop feeding switch in series with the VFI and is integral to the transformer.

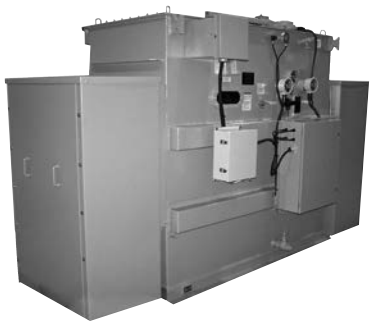
VFI may be controlled by:

- A tri-phase electronic controller, allowing tripping of all three phases upon sensing a fault condition
- Tri-Phase with Ground Trip Technology (TPG): Incorporates separate zero sequence circuit and settings for special applications where increased sensitivity and speed is required in detecting ground fault and phase loading imbalance conditions. Package includes standard Tri-Phase control features with an option for SCADA
- Relays: Eaton and Cooper Power series multi-function programmable relays may control the VFI



VFI Primary with Secondary Cable Connections and Containment Pan

VFI with Secondary Unit Substation



VFI End View with Secondary Cable Connections

Table 14.1-1. VFI Ratings

Description			Rating			
Nominal voltage, kV			15	15	25	35
Maximum design voltage, kV			15.5	15.5	27.0	38.0
BIL, kV			95	95	125	150
1-minute withstand voltage (60 Hz), kV			35	35	40	50
Momentary current, 10 cycles (sym.), kA			12.5	16.0	12.5	12.5
3-second withstand current (sym.), kA			12.5	16.0	12.5	12.5
Fault interrupter	Continuous current, (max), A		600	600	600	600
	Interrupting current (sym./asym.)		12.5/20.0	16/25.8	12.5/20.0	12.5/20.0
	Making current (sym.), kA		12.5	16.0	12.5	12.5
	Cable charging interrupting current, A		10.0	10.0	25.0	40.0
Load-break switch	Continuous current, (max), A		600	600	600	600
	Load switching, A		600	600	600	600
	3-shot make and latch (asym.), kA		20.0	25.8	20.0	20.0
Minimum full life fault interrupting duty cycle per IEEE Std C37.60™ standard (2 duty cycles)			Number of operations			
Percent of interrupting current rating		15–20%	88	88	88	88
		45–55%	112	112	112	112
		90–100%	32	32	32	32
Total			232	232	232	232

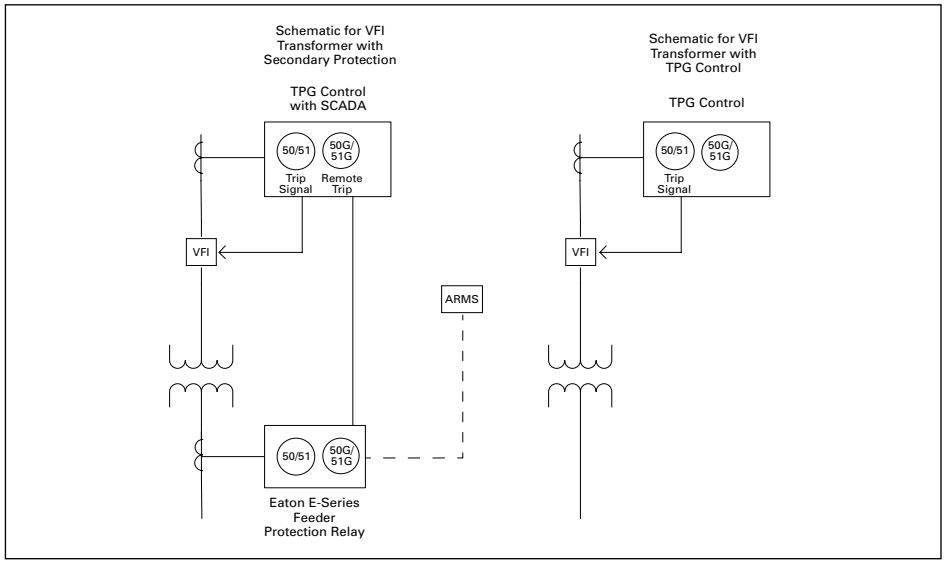


Figure 14.1-6. VFI Schematics with Arcflash Reduction Maintenance System™

PEAK Transformers

Product Description

Eaton's Cooper Power series PEAK™ transformers are uniquely designed to provide additional capability for managing increased loads and temporary overloads without accelerating loss of insulation system life when compared to mineral oil-filled transformer alternatives. Two options are currently available for PEAK transformers, both utilizing an advanced high-temperature insulation system comprised of thermally upgraded kraft paper, biodegradable Envirotemp™ FR3™ dielectric fluid, and an optimized core and coil design.

Application Description

- For applications where additional overload capacity is most important—to manage increased loads or peak demand–a 65/75 °C (Average Winding Rise) AWR or 55/75 °C AWR PEAK transformer is recommended
- For applications where a smaller footprint and a lighter transformer—capable of the same ratings as a physically larger 65 °C AWR rated unit—are desired, a 75 °C AWR PEAK transformer is recommended

Features, Benefits and Functions

Increased Overload Capacity

- Customers are now able to operate PEAK three-phase transformers 12% beyond full rated base load with a 65/75 °C AWR slash-rating. Customers are able to operate PEAK three-phase transformers 22% beyond full-rated base load with a 55/75 °C AWR slash rating. These options allow customers to more precisely size transformers based on periods of peak demand—without accelerated reduction of insulation life
- PEAK transformers can perform at higher kVA ratings than traditional mineral oil-filled units
- Aging equipment can be more easily replaced to add increased reliability to an existing system for long-term distribution planning

Increased Load Capacity

PEAK 65/75 °C AWR transformers are designed to accommodate heavier base loading for extended periods of time without accelerating loss of insulation system life. You can load PEAK three-phase transformers 12% beyond full rated base load while maintaining IEEE Std C57.91™- 2011 standard per unit life requirement. PEAK three-phase transformers can operate at 22% beyond full-rated base load with a 55/75 °C AWR slash rating.

Increased Reliability

Moisture and thermal stress are the enemy of transformer insulation system life. PEAK transformer's superior moisture and thermal stress managing capabilities allow for extended insulation system life, which contributes to better overall system reliability by reducing the frequency of outages due to transformer failures.

- 75 °C AWR designs offer transformer insulation system life extension of up to 4 times that of the IEEE 20.55 year life requirement
- 65/75 °C AWR designs offer transformer insulation system life extension of up to 8 times that of the IEEE 20.55 year life requirement, when operated at the base kVA rating
- Soybean oil-based fluid creates barrier against water at the surface of the insulation, helping to protect the kraft paper in the windings from thermal degradation, resulting in insulation extended life
- Filled with a soybean oil-based dielectric fluid–recognized by UL and FM Global as a less flammable fluid–providing significantly enhanced fire safety
- More than 15 years of field experience with no reported fires in Envirotemp FR3 fluid-filled transformers

Smaller, Lighter Transformers

When compared to traditional 65 °C AWR transformers of the same kVA rating, 75 °C AWR PEAK transformers have the ability to be smaller and lighter. These units will typically use less material and fewer gallons of dielectric fluid resulting in better value, as well as lower handling and operating costs.

- Easier to handle and install
- Lower crane/hoisting costs
- Simplifies retrofitting efforts
- Eliminates need to upgrade utility poles
- Accommodates doorway and elevator constraints
- Eliminates need for larger concrete pad

Product Scope

- 75 °C AWR (Average Winding Rise)
- 65/75 °C AWR
- 55/75 °C AWR, available three-phase only
- 5–167 kVA single-phase pole-mount transformers
- 5–167 kVA single-phase pad-mount transformers
- 45–12,000 kVA three-phase pad-mount transformers
- 500–6667 kVA single-phase substation transformers
- 300–12,000 kVA three-phase substation transformers

Transformer Standard

The IEEE Std C57.154-2012 standard, covering the design, testing, and applications of transformers operating at elevated temperatures, such as the PEAK transformer, was published October 30, 2012.

Table 14.1-2. PEAK Transformer Comparison

Description	Mineral Oil	PEAK 75 °C	PEAK 65/75 °C	PEAK 55/75 °C
Three-phase load capacity	IEEE Std C57.91-2011 standard	IEEE Std C57.91-2011 standard	+12% continuous (above base kVA rating)	+22% continuous (above base kVA rating)
Life extension	1x	3–4x	8x (when operating at base kVA rating)	8x (when operating at base kVA rating)
Enhanced fire safety	—	■	■	■
Environmentally preferred	—	■	■	■
First price	Lowest	Lower	Low	Low
Lifetime cost of ownership	Low	Lower	Lowest	Lower
Bioremediation cost	High	Moderate	Moderate	Moderate

Note: All values are design dependent.

Table 14.1-3. Three-Phase, Single Temperature kVA Ratings

Three-Phase kVA Self-Cooled and Forced-Air Cooled with 75 °C Temperature Rise		
75 °C Rise KNAN		**75 °C Rise KNAN/KNAF**
500 750 1000 1500 2000	+15%	— 863 1150 1725 2300
2500 3750 5000 7500 10,000	+25%	3125 4688 6250 9375 12,500
12,000	+33%	16,000

Table 14.1-4. Three-Phase, Dual or Triple Temperature kVA Ratings ①

Three-Phase kVA Self-Cooled and Forced-Air Cooled with PEAK Triple Rated 55 °C/75 °C Temperature Rise							
55 °C Rise KNAN		**65 °C Rise KNAN**		**75 °C Rise KNAN**	**55 °C Rise KNAN/KNAF**	**65 °C Rise KNAN/KNAF**	**75 °C Rise KNAN/KNAF**
500 750 1000	+12%	560 840 1120	+9%	610 916 1221	— 863 1150	— 966 1288	— 1053 1404
1500 2000 2500		1680 2240 2800		1831 2442 3052	1725 2300 3125	1932 2576 3500	2106 2808 3815
3750 5000 7500		4200 5600 8400		4578 6104 9156	4688 6250 9375	5250 7000 10,500	5123 7630 11,445
10,000 12,000		11,200 13,440		12,208 14,650	12,500 16,000	14,900 17,920	15,260 16,533

① If 65 °C Rise is the base rating, the 75 °C slash rating will increase the kVA capacity by 12%.

VPI/VPE Dry-Type Transformers

Application Description

Eaton's VPI and VPE transformers are custom-designed dry-type power transformers, which give environmental protection, for both indoor and outdoor applications. The transformers are explosion-resistant, fire-resistant, non-polluting to the environment, and ideally suitable for use in coordinated unit substations. Typical applications of VPI/VPE transformers are:

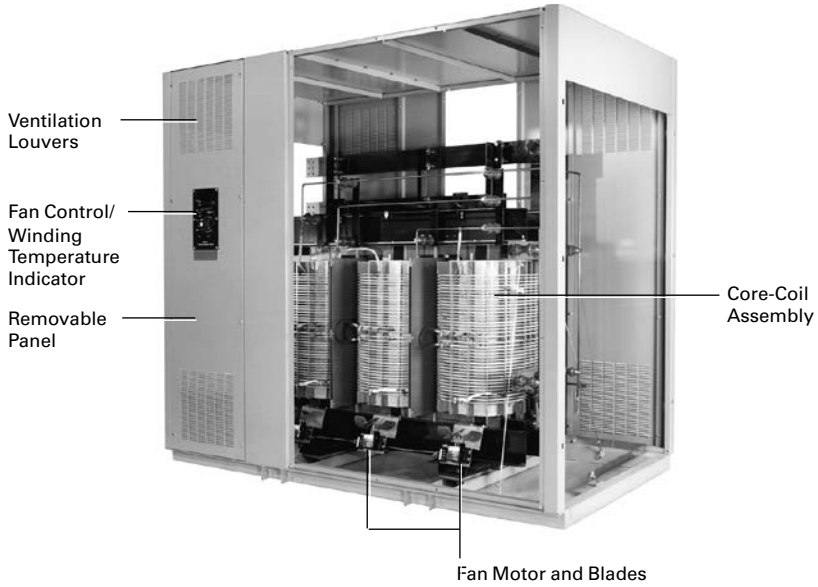
- Schools, hospitals, shopping centers
- High-rise buildings
- Industrial environments

Benefits

- Custom-design flexibility to meet special customer needs and applications
- Computerized loss-evaluated designs for specific customer load and evaluation criteria
- Environmental protection
- Low maintenance
- High short-circuit strength
- IEEE short-time overload capability
- Aluminum or copper windings
- Available in NEMA® 1, 2 and 3R enclosures
- Economical

Ratings

- 112.5–3750 kVA
- Primary voltages: 600 V – 35 kV
- Primary BIL: up to 150 kV
- Secondary voltages: 120 V – 15 kV
- Secondary BIL: up to 75 kV
- Temperature rise: 80/115/150 °C



Dry-Type Substation Transformer

Design and Technology

The dry-type transformers are custom designed and manufactured with coils insulated with a 220 °C, Class H, insulation system. Environmental protection is provided by vacuum pressure impregnation with polyester resin (VPI). Enhanced environmental protection is available through the use of silicone resin encapsulation (VPE). Both systems are superior to the conventional dry-type technology known as "Dip and Bake." Transformers with Class H insulation are suitable for use up to 150 °C average rise over a maximum ambient temperature of 40 °C, not to exceed 30 °C average for any 24-hour period. Other temperature rise options are 80 °C and 115 °C, which allow the transformer to be overloaded up to 150 °C rise.

Taps are provided on the central section of the HV coil face. Taps are accessed by removing enclosure panels, and taps are changed by moving the flexible bolted links from one connecting point to the other. To simplify these changes, the connection points are clearly identified.

Material used for cores is non-aging, cold rolled, high permeability, grain-oriented silicone steel. Cores are constructed with step lap mitered joints and are rigidly braced to reduce sound levels and losses in the finished product.

To reduce the transfer of noise to the case, the core is mounted on neoprene rubber vibration dampeners. The core is electrically grounded by means of a flexible ground braid.

The enclosure has removable panels for access to taps and for core and coil inspection. The complete case can be removed and knocked down to reduce size and weight for rigging into tight locations.

Accessories

Standard accessories include:

- Jacking pads
- Ground pad
- Diagrammatic nameplate
- Provisions for rolling
- Ventilation grilles
- Core ground strap
- Primary reconnectable taps
- Future fan provisions on units over 500 kVA
- ANSI 61 paint finish
- Step-lap mitered core
- NEMA 1 enclosure

Optional Features

- Copper windings/bussing (aluminum is standard)
- VPE silicone resin vacuum pressure impregnation and encapsulation
- Fan cooling package, complete with digital winding temperature
- 80 °C or 115 °C rise (150 °C rise is standard)
- Non-standard ambient temperature (30 °C average/24-hour 40 °C maximum is standard)
- Non-standard altitude (up to 3300 ft (1006 m) is standard)
- Non-standard BIL level
- NEMA 3R enclosure
- Aluminum or copper ground bus
- Lightning arresters
- Low loss design (loss evaluation)
- Special sound level
- Wye-wye connected windings
- UL label

Tests

The following tests are standard:

- Induced potential
- Applied potential
- Resistance measurement
- Ratio test
- Polarity and phase relationship test
- No load loss at rated voltage
- Exciting current at rated voltage
- Impedance and load loss
- Quality control impulse

Special Tests

The following tests can be provided at additional cost:

- Temperature rise
- ANSI impulse
- Sound level
- Witness

Cast Coil Transformers

Application Description

Eaton's cast coil transformers are premium, custom-designed, dry-type power transformers, which offer longer life, higher BIL levels, superior short-circuit strength and superior protection against high moisture, metallic dust-laden and harsh chemical environments. Cast coil transformers may be applied indoors as well as outdoors.

The transformers are explosion resistant, fire resistant, non-polluting to the environment and ideally suitable for use in coordinated unit substations. Typical applications of cast coil transformers are:

- Steel mills
- High-rise buildings/rooftop units
- Pulp and paper mills
- Cement mills and mining operations
- Chemical plants
- Water-side installations, sand and salt spray
- Onshore oil and gas

Benefits

- Practically maintenance free
- Highest possible short-circuit strength
- Custom-design flexibility to meet special customer needs and applications
- Computerized loss-evaluated designs for specific customer load and evaluation criteria
- Environmental immunity, unlimited storage
- IEEE short-time overload capability
- Aluminum or copper windings
- Available in NEMA 1, 2 and 3R enclosures
- Ultimate impulse withstand
- Moisture and chemical resistant

Ratings

- 112.5–3750 kVA
- Primary voltage: 2300 V – 46 kV
- Primary BIL: up to 250 kV
- Secondary voltages: 120 V – 15 kV
- Secondary BIL: up to 95 kV
- Temperature rise: 80/100/115 °C

Cast Coil Substation Transformer

Design and Technology

The cast coil transformers are custom-designed and manufactured with coils insulated with materials such as glass mat and aramid fiber. The thickness of the epoxy is carefully engineered to provide maximum strength and environmental protection and yet minimize the temperature differential through the core thickness in order to limit destructive stresses.

HV and LV coils are separately manufactured and mounted coaxially on the core legs with blocks to hold them firmly, yet permit expansion and contraction. HV windings are wound with one or more strands of rectangular wire, into disc or drum development, and placed into molds. They are dried and vacuum poured or cast, to eliminate moisture and voids in the sealing process. Low voltage windings are hermetically sealed in epoxy. Windings with operating voltage less than 600 V are cast using a pressure injection process. Winding with operating voltages greater than 600 V are processed using the same techniques employed for the high voltage windings. Although other low voltage techniques are available, this design offers the best long-term value in contaminated environments. Cast transformers use 185 °C class insulation and are typically specified for 80 °C average rise over a maximum ambient temperature of 40 °C, not to exceed 30 °C average for any 24-hour period. Other temperature rise options are 100 °C or 115 °C.

Taps are provided on the central section of the HV coil face. Taps are accessed by removing enclosure panels, and taps are changed by moving the flexible bolted links from one connecting point to the other. To simplify these changes, the connection points are clearly identified.

Material used for cores is non-aging, cold rolled, high permeability, grain-oriented silicone steel, cores are constructed with strap lap mitered joints and are rigidly braced to reduce sound levels and losses in the finished product.

To reduce the transfer of noise to the case, the core is mounted on neoprene rubber vibration dampeners. The core and associated core clamps and structural parts are electrically grounded to prevent an induced voltage buildup.

The enclosure has removable panels for access to taps, and for core and coil inspection. The complete case can be removed and knocked down to reduce size and weight for rigging into tight locations.

Accessories

Standard accessories include:

- Jacking pads
- Ground pad
- Diagrammatic nameplate
- Provisions for rolling
- Ventilation grilles
- Core ground strap
- Future fan provisions on units over 500 kVA
- Reconnectable primary taps
- ANSI 61 paint finish
- Step-lap mitered core
- NEMA 1 enclosure

Optional Features

- Copper windings
- Full cast secondary
- Fan cooling package, complete with digital winding temperature
- 100 °C or 115 °C rise (80 °C rise is standard)
- Non-standard ambient temperature (30 °C average/24-hour, 40 °C maximum is standard)
- Non-standard altitude (up to 3300 ft (1006 m) is standard)
- Non-standard BIL levels
- NEMA 3R enclosure
- Lightning arresters
- Low loss design (loss evaluation)
- Special sound level
- Wye-wye connected windings
- UL listing

Tests

The following tests are standard:

- Induced potential
- Applied potential
- Resistance measurement
- Ratio test
- Polarity and phase relationship test
- No load loss
- Exciting current at rated voltage
- Impedance and load loss
- Partial discharge test (for coils rated 1.2 kV and higher)
- Quality control impulse

Special Tests

The following tests can be provided at additional cost:

- Temperature rise
- ANSI impulse
- Sound level
- Witness

RESIBLOC® Epoxy Cast Resin Transformers

RESIBLOC Substation Transformer

Application Description

Eaton's RESIBLOC cast resin transformers are premium, custom-designed, dry-type power transformers that offer a robust solution for applications with high shock/vibration or ambient temperature extremes.

RESIBLOC cast resin transformer may be applied indoors as well as outdoors. The transformers are explosion-resistant, fire-resistant, non-polluting to the environment and ideally suitable for use in a coordinated unit substation. Typical applications of RESIBLOC cast resin transformers are:

- Heavy equipment
- Cranes
- Earth movers
- Cold climate applications
- Offshore oil and gas

Benefits

- Construction process yields superior mechanical strength that resists damage due to physical or thermal shock
- –60 °C cold startup temperature virtually eliminates warming processes after extended shutdowns
- Environmental immunity, unlimited storage
- Ultimate withstand to thermal and mechanical stresses
- ANSI short-time overload capability
- Copper windings
- Available in NEMA 1, 2, 3R enclosures
- Low losses and longest life for greatest economy of ownership

Ratings

- 112.5–3750 kVA
- Primary voltages: 2300 V – 34.5 kV
- Primary BIL: up to 150 kV
- Secondary voltages: 120 V – 15 kV
- Secondary BIL: up to 75 kV
- Temperature rise: 80 °C

Design and Technology

The RESIBLOC epoxy cast resin transformers are custom-designed and manufactured with coils insulated with epoxy and reinforced with glass fiber.

Low Voltage Windings

Transformer low voltage windings with an insulation class of 1.2 kV (600 V) and below, are wound using sheet conductors that allow free current distribution within the axial width of the coil and that eliminate the axial forces developed in other types of windings under short-circuit conditions. The impregnated insulation bonds the sheet conductors together to form a solid winding block for internal mechanical strength. During assembly, each low voltage winding is blocked radially against the core for additional short-circuit integrity.

High Voltage Windings

Transformer high voltage windings, insulation class 2.5 kV (2400 V) and above, are wound using the exclusive RESIBLOC cast resin construction, which is reinforced with a licensed glass roving technique. This fiber roving technique was originally developed for production of synthetic cylindrical components, such as containers, which are subject to high mechanical loads. The use of the glass fiber roving technique in the manufacture of RESIBLOC transformers provides mechanical, thermal and short-circuit strength that is unequaled. The high coils are coaxially mounted over the low voltage windings on the core legs.

Epoxy

The epoxy used in RESIBLOC is a bisphenol A-based resin that is halogen-free to ensure that no harmful decomposition products are formed in the event of a fire. In addition, epoxy is one of the best non-hygroscopic materials available for insulation, and is highly resistive to chemicals and harsh industrial environments.

Temperature Rise

RESIBLOC cast transformers use 155 °C class insulation and are typically specified for 80 °C average rise over a maximum ambient temperature of 40 °C, not to exceed 30 °C average for any 24-hour period.

Taps

Taps are provided on the central section of the HV coil face. Taps are accessed by removing enclosure panels, and taps are changed by moving the flexible bolted links from one connecting point to the other. To simplify these changes, the connection points are clearly identified.

Core

Material used for cores is non-aging, cold rolled, high permeability, grain-oriented silicone steel. Cores are constructed with strap lap mitered joints and are rigidly braced to reduce sound levels and losses in the finished product. To reduce the transfer of noise to the case, the core is mounted on neoprene rubber vibration dampeners. The core and associated core clamps and structural parts are electrically grounded to prevent an induced voltage buildup.

Enclosure

The enclosure has removable panels for access to taps and for core and coil inspection. The complete case can be removed and knocked down to reduce size and weight for rigging into tight locations.

Accessories

Standard accessories include:

- Jacking pads
- Ground pad
- Diagrammatic nameplate
- Provisions for rolling
- Ventilation grilles
- Core ground strap
- Future fan provisions on units over 500 kVA
- Reconnectable primary taps
- ANSI 61 paint finish
- Step-lap mitered core
- NEMA 1 enclosure

Optional Features

- Fan cooling package, complete with digital winding temperature
- Non-standard ambient temperature (30 °C average/24-hour 40 °C maximum is standard)
- Non-standard altitude (up to 3300 ft (1006 m) is standard)
- Non-standard BIL level
- NEMA 3R enclosure
- Lightning arresters
- Low loss design (loss evaluation)
- Special sound level
- Wye-wye connected windings

Tests

The following tests are standard:

- Induced potential
- Applied potential
- Resistance measurement
- Ratio test
- Polarity and phase relationship test.
- No load loss
- Exciting current at rated voltage
- Impedance and load loss
- Partial discharge test (for coils rated 1.2 kV and higher)
- Quality control impulse

Special Tests

The following tests can be provided at additional cost:

- Temperature rise
- ANSI impulse
- Sound level
- Witness

Secondary Unit Substation Plug-and-Play

General Description

For years, Eaton has provided standardized bus/cable coordination for unit substations, making it easier for installing contractors to put the substation components together in the field. Now, Eaton is introducing the next evolution of substation coordination—new substation plug-and-play wiring.

Traditionally, installing contractors have relied on point-to-point wiring diagrams of each piece of equipment (medium voltage switch, transformer and low voltage switchgear) to do the substation control interconnects wiring. The new plug-and-play feature includes dedicated pull-apart terminal blocks and pre-made harnesses designed to eliminate the headaches associated with wiring control and communications devices inside a substation.

Features and Benefits

Features

- Pre-made wiring harness inside the dry-type substation transformer, connecting the temperature controller, fans, low voltage switchgear and medium voltage switch components
- Pull-apart terminal blocks between the medium voltage switch, transformer and low voltage switchgear for error proof installation
- Basic feature set includes control power connections throughout the substation fed from the low voltage switchgear, as well as alarm/trip contacts from the transformer temperature controller
- Includes RS-485 communications wiring throughout the substation if required

Benefits

- Reduces substation installation time and complexity
- Reduces contractor-supplied external wiring, including conduit, special communications wiring and terminal blocks
- The interconnect points are pre-documented for easy reference
- Communications wiring to devices throughout the substation (including medium voltage switch and transformer temperature controller) are connected back to the Power Xpert Gateway in the low voltage switchgear, for one network termination point in the substation

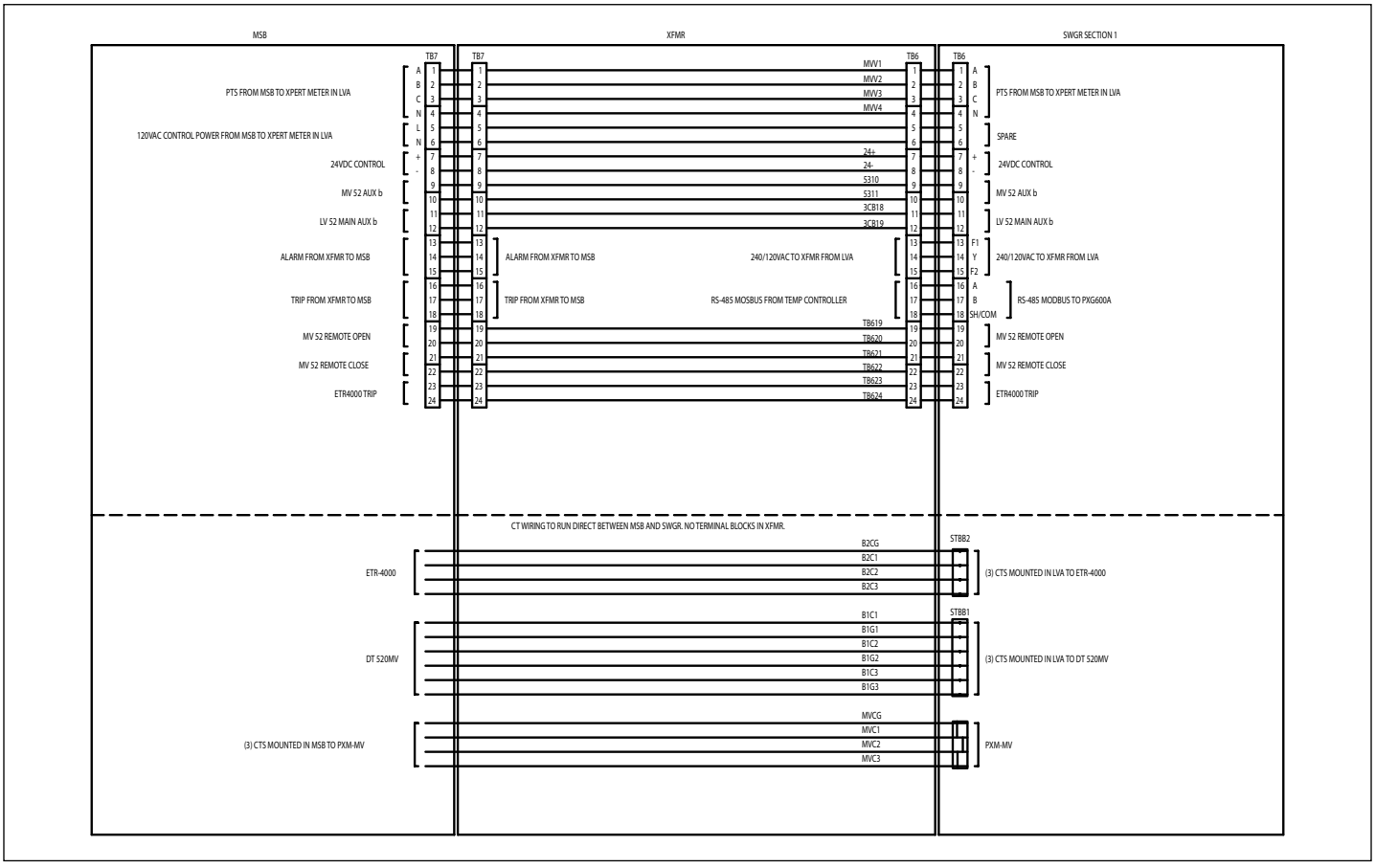
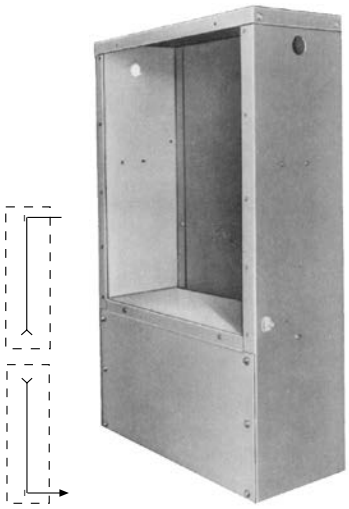


Figure 14.1-7. Plug-and-Play Diagram

Cable Terminal Compartment, Air Filled, No Disconnect



Air Terminal Compartment

Air terminal chamber is furnished when connecting cables only to the transformer, such as in the case when the primary circuit protection or disconnect switch is remotely located from the unit substation. The standard air terminal chamber is a floor-standing, metal-enclosure mechanically and electrically connected to the transformer primary, and includes the following equipment:

- Clamp-type terminals and bus-connectors, if required, for making the connection from the bushings to the customer-furnished incoming cables
- Undrilled entrance plate for top or bottom entry of customer cables
- Cutout and hardware for bolting to transformer Z-Bar flange
- Gasket for installation between terminal chamber and Z-Bar flange connection for outdoor designs only
- Removable end panel for access to chamber

Load Interrupter Switchgear, Type MVS, Unfused or Fused

Type MVS Fused Switch

Secondary unit substations requiring a primary disconnect are furnished with Eaton's Type MVS metal-enclosed load interrupter switchgear assemblies. Each assembly consists of one (or more) gang-operated MVS switch(es) with full air load break characteristics. With power fuses incorporated into the assembly, the MVS switchgear provides short circuit protection for the transformer as well. MVS switchgear is furnished as the standard high side disconnecting equipment for all secondary unit substations, both dry-types and liquid-filled types.

Ratings

See **Page 14.1-44** for standard ratings.

MVS Switchgear Features

- Quick-make, quick-break stored energy manual or optional electrically operated mechanism
- Removable operating handle conveniently and attractively stored
- DE-ION® arc interruption
- Positive position indication
- Standard insulated cable connections to transformer (voltage rating 15 kV maximum) for fused switches
- Available with current limiting fuses or expulsion fuses, or unfused
- Proven reliability
- UL® or CSA® listing is available as an option

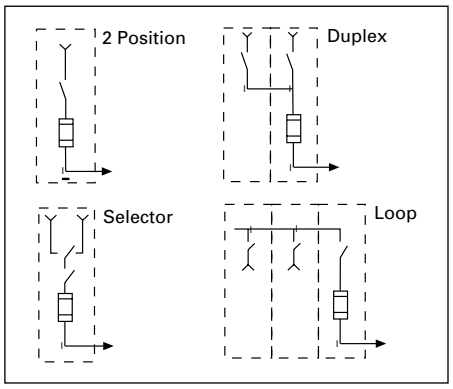


Figure 14.1-8. MVS Switch Arrangements

Switch Arrangements

In addition to the single, two-position switch for simple "ON-OFF" operation from a single primary feeder, other standard arrangements are available for use with primary selective power centers involving two primary alternate sources. These arrangements are shown above.

Metal-Enclosed Switchgear Assembly, Type MSB

MVS switchgear, when provided with a fixed-mounted medium voltage vacuum circuit breaker instead of fuses, is termed Type MSB metal-enclosed switchgear. Use of the medium voltage circuit breaker in conjunction with protective relaying provides a significantly higher level of protection for the transformer and low voltage switchboard/switchgear than that attainable with fuses. Typical protection relaying functions are:

- Overcurrent and ground fault protection
- Transformer differential
- Rate of rise relay on liquid-filled transformer

On single-ended substations, deleting the secondary main circuit breaker might be possible as the medium voltage circuit breaker and the protective relays would serve the same purpose. In some critical applications, it may still be necessary to apply overcurrent relaying on the secondary of the transformer to trip the medium voltage circuit breaker rather than relying solely on the primary overcurrent protection.

Triplex Indoor Power Center

Installation and removal of either dry-type or liquid-filled transformers can be difficult when encountering a size and weight constrained entry. An Eaton Triplex Indoor Power Center™ (IPC) offers a modular designed efficient liquid-filled transformer that may be installed even when access is limited by a freight elevator or doorway. A Triplex IPC is a three-phase transformer assembly consisting of three single-phase Envirotemp™ FR3™ fluid-filled transformers connected into one complete assembly built according to applicable D.O.E. (Department of Energy), ANSI/IEEE, UL, FM and NEMA standards and customer supplied specifications. The Triplex IPC shall be constructed in the field with single-phase transformers and partially assembled factory prepackaged modules. The core and coil construction uses the same proven methods as the conventional three-phase substation assemblies. Flawless fire safety of Triplex IPC is attributed to the use of Envirotemp™ FR3™ fluid, a less-flammable and bio-degradable dielectric fluid. Integrated switching and protection schemes are available with Triplex designs. Castors may be added to further facilitate transformer installation and to reduce the transmission of vibrations to the surrounding structures. Downtime may be reduced by stocking a spare single-phase transformer for emergency situations.

- Base ratings of 750–2500 kVA
- Three-phase, 50 or 60 Hz distribution substation transformers
- Primary voltage through 15 kV
- Secondary voltage through 600 V
- Envirotemp™ FR3™ fluid
- Temperature rise options: 55 °C, 55 °C to 65 °C, 65 °C, 55 °C to 75 °C, 75 °C
- FM™ approved
- UL® Listed/Classified
- Optional substation transformer accessories:
  - Air terminal chambers
  - Control boxes
  - Gauges (with or without contacts)
  - Rapid rise relays
  - Removable radiators
  - Containment pans
  - Removable castors
  - Infrared viewing windows
  - Air insulated bus for interconnections

Triplex Indoor Power Center

Magnum DS Low-Voltage Metal-Enclosed Switchgear

Magnum DS Switchgear with Power Circuit Breaker

Product Description

Eaton's Magnum DS switchgear has a 50-year history of power circuit breaker and switchgear development that has set industry standards for quality, reliability, maintainability and extended operating life. Magnum DS switchgear is an assembled metal enclosure that houses drawout power circuit breakers and typically includes control and metering devices. Low voltage switchgear is applied at 600 V and less.

Application Description

Switchgear is used for protection, control and monitoring of low voltage distribution systems in all types of industrial, commercial and utility environments requiring up to 600 V distribution between 1600 A and 10,000 A continuous loads, and between 42,000 A and 200,000 A interrupting current.

Product Offering

- Indoor NEMA 1
- Rear access
- Front access
- Arc resistant (2B)
- Integrated switchboard, MCC and ATS
- Unit substation transformer integration
- Outdoor NEMA 3R rear access
- Outdoor NEMA 3R front access

Pow-R-Line C Switchboards

Pow-R-Line C

Construction Details

- 6000 A main bus maximum
- Front and rear access—main section front and/or side accessible
- Feeder devices panel mounted
- Sections rear aligned, or front and rear aligned
- Not designed for mounting against a wall, self-supporting and requires code clearance at the rear

Main Devices—Individually Mounted

- Molded case circuit breaker, 400–2500 A, fixed or drawout
- Air power circuit breaker, Magnum DS, 800–6000 A, fixed or drawout
- Air power circuit breaker with current limiting fuses, DSL, 800–5000 A
- Bolted pressure switch, 800–5000 A, fixed
- Fusible switches, 400–1200 A, fixed

Feeder Devices—Group Mounted

- Molded-case circuit breaker, 15–1200 A
- Fusible switches, 30–1200 A

Feeder Devices—Individually Mounted

- Air power circuit breaker, Magnum DS, 800–5000 A
- Bolted pressure switches, 800–5000 A, fixed
- Molded-case circuit breaker, 1600–2500 A

TC-100 Transformer Temperature Controller for Dry-Type Transformers

TC-100

General Description

The TC-100 Transformer Temperature Controller monitors up to three ventilated dry-type transformer windings and one ambient temperature. The TC-100 operates relays by comparing the highest winding temperature to stored set point temperatures and displays four thermocouple inputs, as well as the stored maximum temperature and its associated winding. The unit provides fans, alarm and trip output relays. Up to two fans can be controlled via the TC-100. Each fan operating contact is fuse protected. A yellow LED indicates that fans are on. A fan exerciser turns the fans on automatically at periodic intervals to prevent fan motor seizing (on-time and interval is programmable).

Form C contacts are provided for notification of alarm conditions. A red LED illuminates to indicate that the alarm is actuated. An internal audible alarm also sounds when the unit goes into alarm condition. This audible buzzer can be silenced without canceling the alarm. The alarm and trip relays can be configured as a fail-safe relay (normally energized when the unit is powered up). For example, if the alarm relay was configured as a fail-safe; if supply control power to the TC-100 is interrupted, the alarm relay changes state for notification of this condition.

The alarm circuit is also used for notification of an open or a missing thermocouple. If a thermocouple were to open, the alarm relay operates and the corresponding channel will read "-" on the LED display. It is important to note that a failed thermocouple will not cause the device to trip the transformer offline.

Form C contacts are provided to trip the transformer offline if any of the winding temperatures exceed the trip setting. A red LED indicates that the trip relay has actuated.

A test function is provided to: test the digital display and all of the LEDs; simulate over-temperature conditions; and check the internal temperature of the monitor.

A 4–20 mA analog signal is provided for remote indication or for use with SCADA systems.

The TC-100 has built-in monitoring functions and logging functions to help you shed some light on the unknowns of the operation of your transformer. Temperature trending lets you understand the hour of the day that the transformer runs hotter, and modify its loading to extend the life of your transformer; logging information lets you restore the operation of your system faster, by letting you correlate tripping and alarming events to the overall conditions of your system; and fan wear information can be used to perform preventive maintenance to increase the uptime in your transformers.

Features and Benefits

Control

- Thermocouple inputs (E or K type thermocouples)
- Automatic correlation throughout entire temperature range to compensate for thermocouple non-linearity
- Programmable on and off set points
- Alarm relay for remote monitoring
- Trip relay for remote monitoring
- Two fan power relays
- Fan failure detection to start a backup fan or alarm
- Fan exerciser (cycle time and duration) to reduce fan wear
- Fans can be operated automatically or manually

Metering

- Average temperature (all three windings)
- Maximum instantaneous temperature (all three windings)
- Maximum temperature memory per winding
- Fans hours of operation
- Winding 1, Winding 2, Winding 3 and ambient temperature

Monitoring

- Trending
- Fan failure
- Fan wear
- Alarm log
- Trip log
- Test mode
- Detect failed sensors
- Self-diagnostics

Communications

- USB port in the front
- Modbus-RTU communications
- Programming and monitoring software (the unit can be completely programmed through the front of the unit)
- 4–20 mA output for integration with SCADA systems

Hardware

- One trip relay (Form C)
- One alarm relay (Form C)
- Two power fan relays (1 NO each)
- Two digital inputs
- 4–20 mA output for integration with SCADA systems
- Local Alarm 95 db
- Available in semi-flush or hinge panel-mounting versions

Indoor Composite Floor Plan—Liquid-Filled Transformer

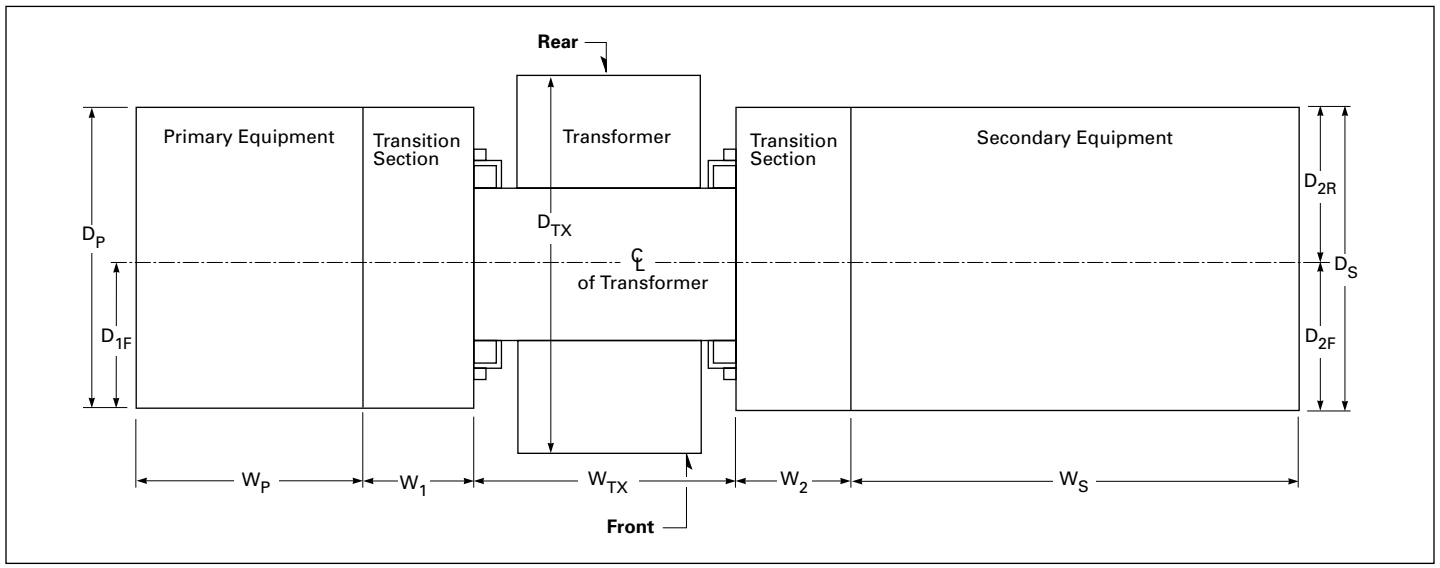


Figure 14.1-9. Liquid-Filled, Indoor—Top View

Table 14.1-5. Primary Equipment Dimension References

Primary Equipment	Dimensions	Reference Page(s)
Transformer	W_{TX}, D_{TX}	**Page 14.1-27**
MVS	W_P, D_P	**Page 14.1-26**
ME	W_P, D_P	**Page 14.1-26**
MC	W_P, D_P	②

Air Terminal Chamber (ATC) or Transition Section—Dimensions in Inches (mm)

Voltage kV	Primary Equipment	Three-Phase, Three-Wire or Three-Phase Four-Wire	
		W_1	D_{1F}
5 or 15	MVS	20.00 (508.0)	25.25 (641.3) ①
	ME	20.00 (508.0)	25.25 (641.3) ①
	MC	18.00 (457.2)	42.50 (1079.5)
27	MVS	30.00 (762.0)	③
	MC	36.00 (914.4)	③
38	MVS	30.00 (762.0)	③
	MC	42.00 (1066.8)	③

① For three-phase, four-wire, D_{1F} is 30.25.
② See Eaton.com/designguides.
③ Contact Eaton.

Legend:
MVC = Medium-Voltage Motor Control, Type AMPGARD
MVS = Medium-Voltage Metal-Enclosed Switches, Type MVS
ME = Medium-Voltage Metal-Enclosed Breakers, Type MEB, MEF, MSB
MC = Medium-Voltage Metal-Clad Breaker Assemblies, Type VacClad-W

Table 14.1-6. Secondary Equipment Dimension References—Dimensions in Inches (mm)

Secondary Equipment	W_2	D_{2F}	D_{2R}	For W_S, D_S Dimensions Tab-Page
Magnum DS and SB switchgear (rear access)	22.00 (558.8)	45.00 (1143.0)	—	④
Pow-R-Line C switchboard (front access)	20.00 (508.0)	—	24.00 (609.6)	④
Pow-R-Line C switchboard (rear access)	20.00 (508.0)	—	24.00 (609.6)	④
Pow-R-Line i switchboard (rear access)	20.00 (508.0)	—	24.00 (609.6)	④

④ See Eaton.com/designguides.

Outdoor Composite Floor Plan—Liquid-Filled Transformer

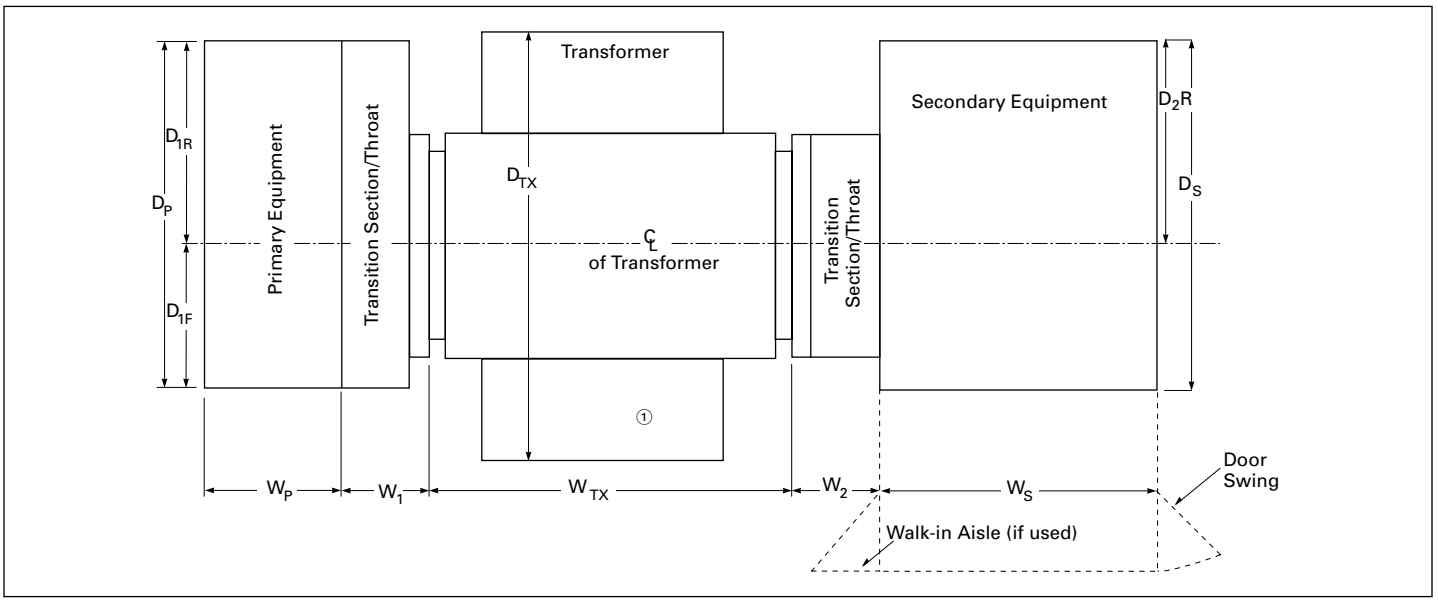


Figure 14.1-10. Liquid-Filled, Outdoor Enclosure—Top View

① Radiator position and number of radiators will vary based on design.

Table 14.1-7. Primary Equipment Dimension References

Primary Equipment	Dimensions	Reference Page(s)
Transformer	W_{TX}, D_{TX}	**Page 14.1-27**
MVS	W_P, D_P	**Page 14.1-26**
ME	W_P, D_P	**Page 14.1-26**
MC	W_P, D_P	②

Air Terminal Chamber (ATC) or Transition Section/Throat—Dimensions in Inches (mm)

Voltage kV	Primary Equipment	Three-Phase, Three-Wire or Three-Phase Four-Wire		
		W_1	D_{1F}	D_{1R}
5 or 15	MVS	20.00 (508.0)	25.25 (641.3) ③	—
	ME	20.00 (508.0)	25.25 (641.3) ③	—
	MC	16.00 (406.4)	—	16.50 (419.1) ④
27	MVS	35.00 (889.0)	—	—
	MC ⑤	—	—	—
38	MVS	35.00 (889.0)	—	—
	MC ⑤	—	—	—

② See Eaton.com/designguides.
③ For three-phase, four-wire, D_{1F} is 30.25 inches (768.4 mm).
④ For three-phase, four-wire, D_{1R} is 14.50 inches (368.3 mm).
⑤ Contact Eaton.

Table 14.1-8. Secondary Equipment Dimension References—Dimensions in Inches (mm)

Secondary Equipment	W_2	D_{2R}	For W_S, D_S Dimensions Tab-Page
Magnum DS and SB switchgear	38.50 (977.9)	27.00 (685.8)	⑥
Pow-R-Line C switchboard (front access)	25.00 (635.0)	20.00 (508.0)	⑥
Pow-R-Line C switchboard (rear access)	25.00 (635.0)	20.00 (508.0)	⑥
Pow-R-Line i switchboard (rear access)	25.00 (635.0)	25.00 (635.0)	⑥

⑥ See Eaton.com/designguides.

Legend:

MVC = Medium-Voltage Motor Control, Type AMPGARD
MVS = Medium-Voltage Metal-Enclosed Switches, Type MVS
ME = Medium-Voltage Metal-Enclosed Breakers, Type MEB, MSB
MC = Medium-Voltage Metal-Clad Breaker Assemblies, Type VacClad-W

Indoor Composite Floor Plan—Dry-Type Transformer

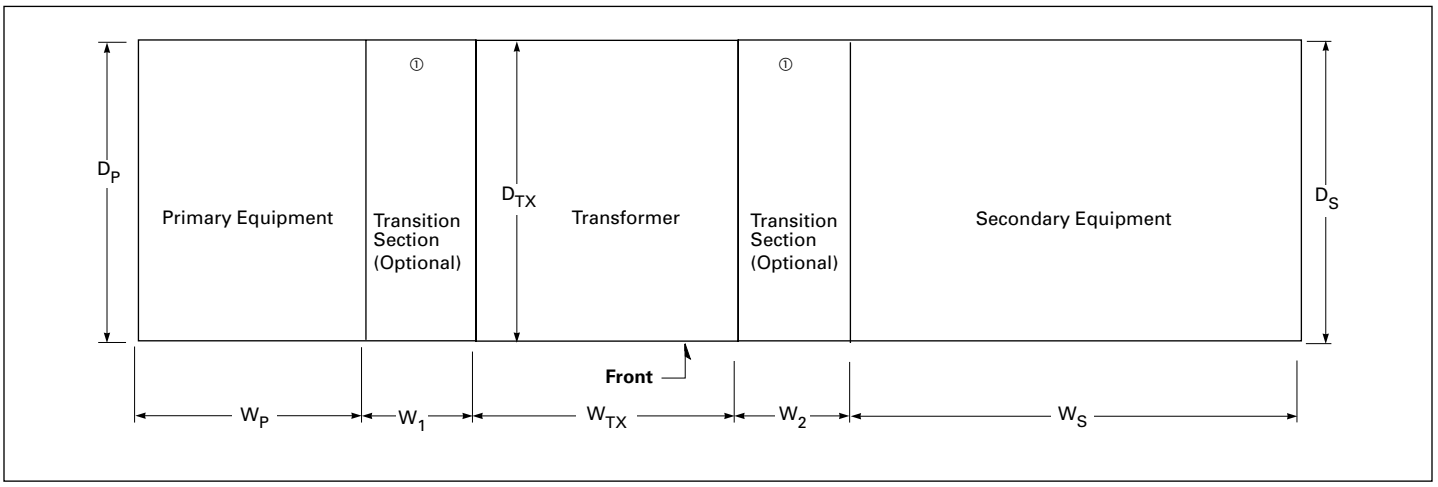


Figure 14.1-11. Ventilated Dry-Type, RESIBLOC and Cast Coil, Indoor—Top View

① Transition section may only be required for connection to existing transformers or rear alignment. Contact Eaton for details.

Table 14.1-9. Primary Equipment Dimension References

Primary Equipment	Dimensions	Reference Page(s)
Transformer	W_{TX}, D_{TX}	**Page 14.1-29** and **Page 14.1-30**
MVS	W_P, D_P	**Page 14.1-26**
ME	W_P, D_P	**Page 14.1-25**
MC	W_P, D_P	②

② See Eaton.com/designguides.

Legend:

MVC = Medium-Voltage Motor Control, Type AMPGARD
MVS = Medium-Voltage Metal-Enclosed Switches, Type MVS
ME = Medium-Voltage Metal-Enclosed Breakers, Type MEB, MSB
MC = Medium-Voltage Metal-Clad Breaker Assemblies, Type VacClad-W

Table 14.1-10. Secondary Equipment Dimension References—Dimensions in Inches (mm)

Secondary Equipment	For W_S, D_S Dimensions Tab-Page
Magnum DS and SB switchgear (front and rear access)	③
Pow-R-Line C switchboard (front access)	③
Pow-R-Line C switchboard (rear access)	③
Pow-R-Line *i* switchboard (rear access)	③

③ See Eaton.com/designguides.

Note: Dimensions for estimating purposes only.

Outdoor Composite Floor Plan—Dry-Type Transformer

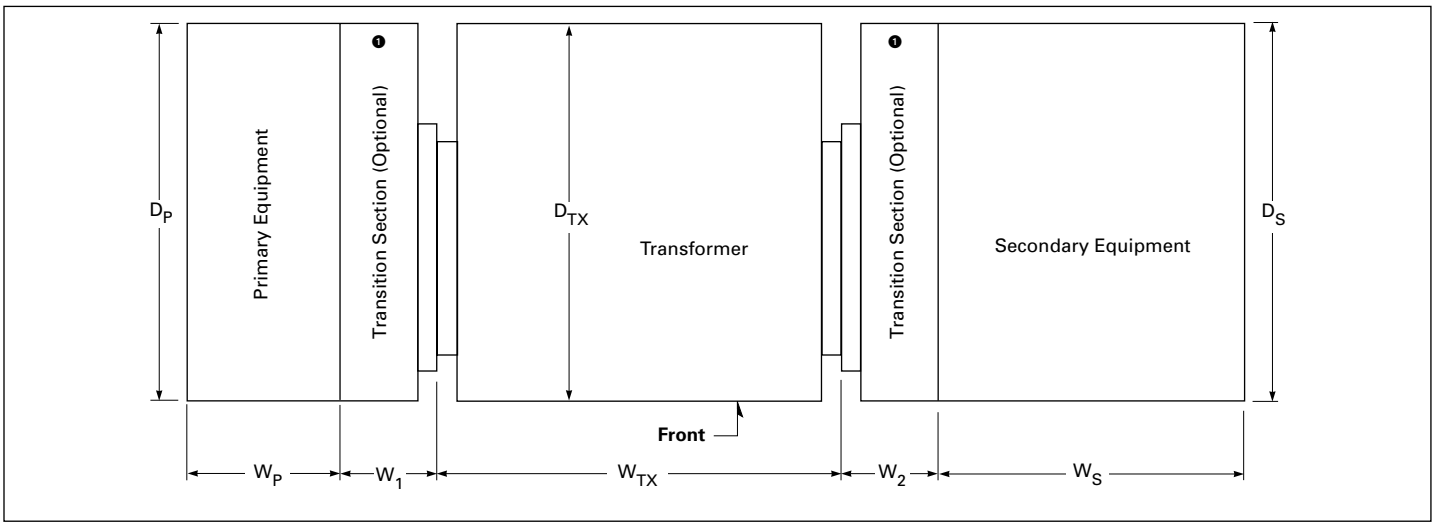


Figure 14.1-12. Ventilated Dry-Type, RESIBLOC and Cast Coil, Outdoor—Top View

① Transition section may only be required for connection to existing transformers or rear alignment. Contact Eaton for details.

Table 14.1-11. Primary Equipment Dimension References

Primary Equipment	Dimensions	Reference Page(s)
Transformer	W_{TX}, D_{TX}	**Page 14.1-29** and **Page 14.1-30**
MVS	W_P, D_P	**Page 14.1-26**
ME	W_P, D_P	**Page 14.1-26**
MC	W_P, D_P	②

Air Terminal Chamber (ATC) or Transition Section/Throat—Dimensions in Inches (mm)

Primary Equipment	W_1			
	5 kV	15 kV	27 kV	38 kV
MVS	5.00 (127.0)	5.00 (127.0)	③	③
ME	5.00 (127.0)	5.00 (127.0)	N/A	N/A
MC	16.00 (406.4)	16.00 (406.4)	③	③

② See Eaton.com/designguides.
③ Contact Eaton.

Table 14.1-12. Secondary Equipment Dimension References—Dimensions in Inches (mm)

Secondary Equipment	W_2	For W_S, D_S Dimensions Tab-Page
Magnum DS and SB switchgear	38.50 (977.9)	④
Pow-R-Line C switchboard (front access)	5.00 (127.0)	④
Pow-R-Line C switchboard (rear access)	5.00 (127.0)	④
Pow-R-Line i switchboard (rear access)	5.00 (127.0)	④

④ See Eaton.com/designguides.

Legend:

MVC = Medium-Voltage Motor Control, Type AMPGARD
MVS = Medium-Voltage Metal-Enclosed Switches, Type MVS
ME = Medium-Voltage Metal-Enclosed Breakers, Type MEB, MSB
MC = Medium-Voltage Metal-Clad Breaker Assemblies, Type VacClad-W

Substation with Air Terminal Chamber (ATC) Usage—Liquid-Filled Transformer

A substation using one or two air terminal chambers (ATCs) is different from a substation using close-coupling on both the primary and secondary sides. An ATC uses a cable connection on either the primary side, secondary side or both, and is placed between the transformer and the remotely mounted primary or secondary equipment.

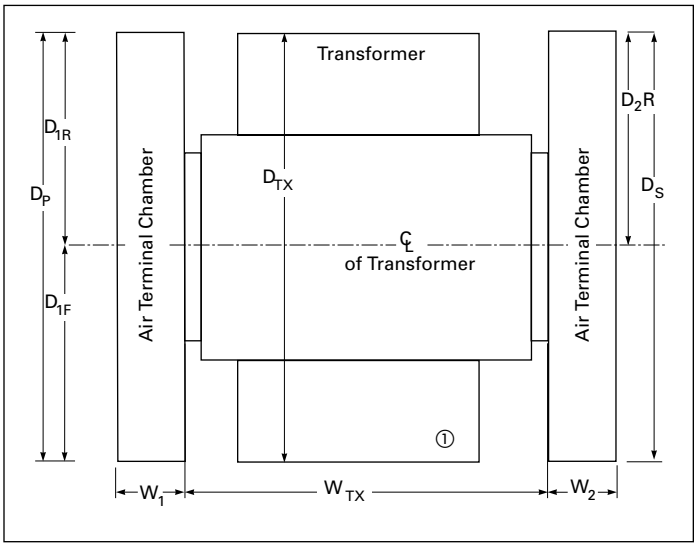


Figure 14.1-13. Liquid-Filled Indoor/Outdoor Using Air Terminal Chambers—Top View

① Radiator position and number of radiators will vary based on design.

Table 14.1-13. Primary ATC or Transition Section—Dimensions in Inches (mm)

Voltage	Three-Phase, Three-Wire or Three-Phase, Four-Wire	
kV	W_1	D_P
5 or 15	18.00 (457.2)	D_{TX}
27	24.00 (609.6)	D_{TX}
38	36.00 (914.4)	D_{TX}

Note: Minimum ATC widths by kVA are listed in the table above. The width of any ATC can be expanded to allow for the installation of additional conduits. When calculating the area of the conduit opening, allow for a 2.00-inch (50.8 mm) lip around the entire perimeter of the ATC.

Table 14.1-14. Secondary ATC or Transition Section—Dimensions in Inches (mm)

Voltage	W_2	D_S
V		
All	18.00 (457.2)	D_{TX}

Note: Minimum ATC widths by kVA are listed in the table above. The width of any ATC can be expanded to allow for the installation of additional conduits. When calculating the area of the conduit opening, allow for a 2.00-inch (50.8 mm) lip around the entire perimeter of the ATC.

Substation with Air Terminal Chamber (ATC) Usage—Dry-Type Transformer

A substation using one or two air terminal chambers (ATCs) is different from a substation using close-coupling on both the primary and secondary sides. An ATC using a cable connection on either the primary side, secondary side or both, and is placed between the transformer and the remotely mounted primary or secondary equipment.

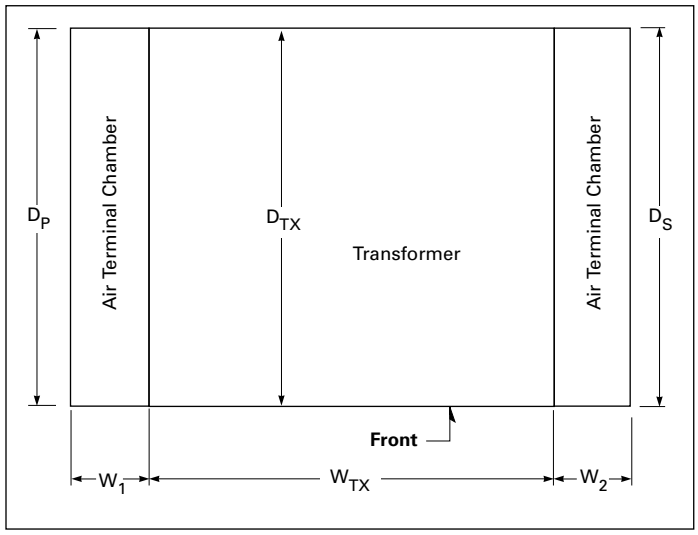


Figure 14.1-14. Dry-Type Indoor/Outdoor Using Air Terminal Chambers—Top View

Table 14.1-15. Primary ATC or Transition Section—Dimensions in Inches (mm)

Voltage	Three-Phase, Three-Wire or Three-Phase, Four-Wire	
kV	W_1	D_P
5 or 15	18.00 (457.2)	D_{TX}
27	24.00 (609.6)	D_{TX}
38	36.00 (914.4)	D_{TX}

Note: Minimum ATC widths by kVA are listed in the table above. The width of any ATC can be expanded to allow for the installation of additional conduits. When calculating the area of the conduit opening, allow for a 3.00-inch (76.2 mm) lip around the entire perimeter of the ATC.

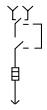
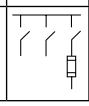
Table 14.1-16. Secondary ATC or Transition Section—Dimensions in Inches (mm)

Voltage	W_2	D_S
V		
All	18.00 (457.2)	D_{TX}

Note: Minimum ATC widths by kVA are listed in the table above. The width of any ATC can be expanded to allow for the installation of additional conduits. When calculating the area of the conduit opening, allow for a 3.00-inch (76.2 mm) lip around the entire perimeter of the ATC.

Primary Switching Equipment—Type MVS/MSB Switchgear

Table 14.1-17. Primary Switching Equipment—Type MVS Switchgear

Configuration of Switch(es)		Rated Maximum Voltage, kV	Fault Close kV Asym. Maximum	Dimensions in Inches (mm)						
				WP ①②	D_P		Height (Indoor)	Height (Outdoor Non-Walk-in)	W_C	C_C
					Three-Wire	Four-Wire				
Single switch		5 15 27 38	64 64 60 30	36.00 (914.4) 36.00 (914.4) 48.00 (1219.2) 48.00 (1219.2)	55.30 (1404.6) 55.30 (1404.6) 80.00 (2032.0) 80.00 (2032.0)	62.00 (1574.8) 62.00 (1574.8) 80.00 (2032.0) ③ 80.00 (2032.0) ③	90.40 (2296.2) 90.40 (2296.2) 127.00 (3225.8) ④ 127.00 (3225.8) ④	95.50 (2425.7) 95.50 (2425.7) 135.00 (3429.0) ⑤ 135.00 (3429.0) ⑤	10.00 (254.0) 10.00 (254.0) 16.00 (406.4) 16.00 (406.4)	8.00 (203.2) 8.00 (203.2) 8.00 (203.2) 8.00 (203.2)
Duplex (two) switches		5 15 27 38	64 64 60 30	72.00 (1828.8) 72.00 (1828.8) 96.00 (2438.4) 96.00 (2438.4)	62.00 (1574.8) 62.00 (1574.8) 100.00 (2540.0) 100.00 (2540.0)	62.00 (1574.8) 62.00 (1574.8) 100.00 (2540.0) 100.00 (2540.0)	90.40 (2296.2) 90.40 (2296.2) 127.00 (3225.8) ④ 127.00 (3225.8) ④	95.50 (2425.7) 95.50 (2425.7) 135.00 (3429.0) ⑤ 135.00 (3429.0) ⑤	10.00 (254.0) 10.00 (254.0) 16.00 (406.4) 16.00 (406.4)	8.00 (203.2) 8.00 (203.2) 8.00 (203.2) 8.00 (203.2)
Selector switch		5 15	64 64	36.00 (914.4) 36.00 (914.4)	62.00 (1574.8) 70.00 (1778.0) ⑥	62.00 (1574.8) 70.00 (1778.0) ⑥	90.40 (2296.2) 90.40 (2296.2)	95.50 (2425.7) 95.50 (2425.7)	10.00 (254.0) 10.00 (254.0)	20.00 (508.0) 20.00 (508.0)
Sectionalizing loop feed switches		5 15 27 38	64 64 60 30	108.00 (2743.2) 108.00 (2743.2) 144.00 (3657.6) 144.00 (3657.6)	55.30 (1404.6) 55.30 (1404.6) 80.00 (2032.0) ③ 80.00 (2032.0) ③	62.00 (1574.8) 62.00 (1574.8) 80.00 (2032.0) ③ 80.00 (2032.0) ③	90.40 (2296.2) 90.40 (2296.2) 127.00 (3225.8) ④ 127.00 (3225.8) ④	95.50 (2425.7) 95.50 (2425.7) 135.00 (3429.0) ⑤ 135.00 (3429.0) ⑤	10.00 (254.0) 10.00 (254.0) 16.00 (406.4) 16.00 (406.4)	8.00 (203.2) 8.00 (203.2) 8.00 (203.2) 8.00 (203.2)

① A transition section is required when any MVS switchgear assembly is connected to a liquid-filled transformer and when any MSB switchgear assembly is connected to any kind of transformer. When a 5 or 15 kV MVS switchgear assembly is connected to a dry-type or cast coil transformer, no transition section is required when installed indoors, but a 5.00-inch (127.0 mm) throat is required when installed outdoors.

② Where disconnect fuses are used, add 6.00 inches (152.4 mm) to section width, 5 and 15 kV only.

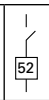
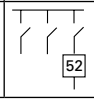
③ When height of 101.50 inches (2578.1 mm) is used with fuses identified in footnote ④, the depth increases to 100.00 inches (2540.0 mm).

④ Height is 101.50 inches (2578.1 mm) for 27 kV MVS switchgear without fuses or with Cooper type NX fuses, and 38 kV MVS switchgear without fuses or with GE type EJO-1 fuses.

⑤ Height is 110.00 inches (2794.0 mm) for 27 kV MVS switchgear without fuses or with Cooper type NX fuses, and 38 kV MVS switchgear without fuses or with GE type EJO-1 fuses.

⑥ Can be 62.00 inches (1574.8 mm) deep if incoming cable enters from below.

Table 14.1-18. Primary Switching Equipment—Type MSB Switchgear

Configuration of Switch(es) and Vacuum Breaker		Rated Maximum Voltage, kV	Fault Close kV Asym. Maximum	Dimensions in Inches (mm)					
				WP ⑦	D_P	Height (Indoor)	Height (Outdoor Non-Walk-in)	W_C	C_C
Single		5 15	64 64	42.00 (1066.8) 42.00 (1066.8)	70.00 (1778.0) 70.00 (1778.0)	90.40 (2296.2) 90.40 (2296.2)	95.50 (2425.7) 95.50 (2425.7)	10.00 (254.0) 10.00 (254.0)	8.00 (203.2) 8.00 (203.2)
Duplex		5 15	64 64	78.00 (1981.2) 78.00 (1981.2)	70.00 (1778.0) 70.00 (1778.0)	90.40 (2296.2) 90.40 (2296.2)	95.50 (2425.7) 95.50 (2425.7)	10.00 (254.0) 10.00 (254.0)	8.00 (203.2) 8.00 (203.2)
Sectionalizing loop feed switches		5 15	64 64	114.00 (2895.6) 114.00 (2895.6)	70.00 (1778.0) 70.00 (1778.0)	90.40 (2296.2) 90.40 (2296.2)	95.50 (2425.7) 95.50 (2425.7)	10.00 (254.0) 10.00 (254.0)	8.00 (203.2) 8.00 (203.2)

⑦ A transition section is required when any MVS switchgear assembly is connected to a liquid-filled transformer and when any MSB switchgear assembly is connected to any kind of transformer. When a 5 or 15 kV MVS switchgear assembly is connected to a dry-type or cast coil transformer, no transition section is required when installed indoors, but a 5.00-inch (127.0 mm) throat is required when installed outdoors.

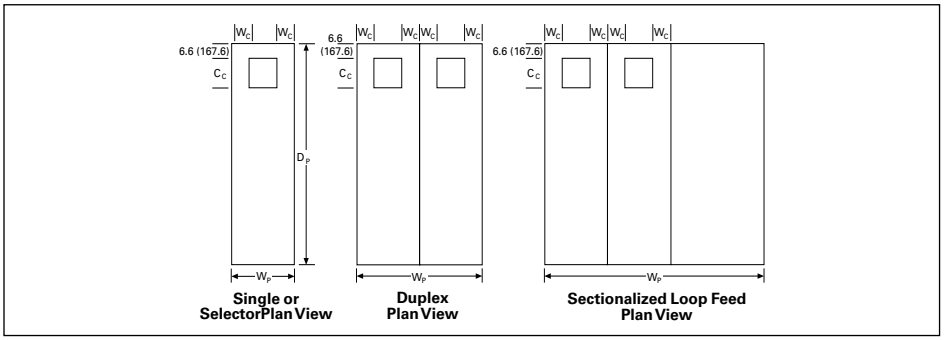


Figure 14.1-15. Primary Equipment Floor Plan

Table 14.1-19. Approximate Weights in Lb (kg)

Description	Indoor	Outdoor
5 or 15 kV Class		
MSB section	1600 (726)	1900 (863)
MVS section (non-fused)	1500 (681)	1800 (817)
Fuses (3) add	200 (91)	200 (91)
Transition section	300 (136)	—
Outdoor throat	—	1200 (544)
25.8 or 38 kV Class		
MVS section (non-fused)	2000 (908)	2400 (1090)
Fuses (3) add	300 (136)	300 (136)
Transition section	1100 (499)	—
Outdoor throat	—	1200 (544)

Dimensions for estimating purposes only.

Liquid-Filled Transformers

Table 14.1-20. Oil-Filled Standard Design, 60 Hz, HV Delta, LV at 600 V Class (30 kV BIL) Indoor or Outdoor Application

kVA	HV, kV	HV BIL, kV	Dimensions in Inches (mm)			Weight Lb (kg)	Liquid Gallons (Liters)
			H_{TX}	W_{TX}	D_{TX}		
Oil-Filled 55°, 65° and 75 °C Rise							
300	5 or 15	60 or 95	74.05 (1880.9)	65.50 (1663.7)	53.50 (1358.9)	4800 (2177)	330 (1249)
500	5 or 15	60 or 95	74.05 (1880.9)	67.50 (1714.5)	57.50 (1460.5)	5800 (2631)	330 (1249)
750	5 or 15 25 or 35	60 or 95 125 or 150	74.05 (1880.9) 74.05 (1880.9)	71.50 (1816.1) 78.00 (1981.2)	59.50 (1511.3) 66.50 (1689.1)	6800 (3084) 8500 (3856)	370 (1401) 460 (1741)
1000	5 or 15 25 or 35	60 or 95 125 or 150	82.05 (2084.1) 82.05 (2084.1)	75.50 (1917.7) 82.00 (2082.8)	59.50 (1511.3) 66.50 (1689.1)	8400 (3810) 9400 (4264)	440 (1666) 480 (1817)
1500	5 or 15 25 or 35	60 or 95 125 or 150	82.05 (2084.1) 82.05 (2084.1)	79.10 (2009.1) 91.60 (2326.6)	84.70 (2151.4) 91.70 (2329.2)	10,800 (4899) 12500 (5670)	480 (1817) 600 (2271)
2000	5 or 15 25 or 35	60 or 95 125 or 150	82.05 (2084.1) 82.05 (2084.1)	81.10 (2060.0) 93.60 (2377.4)	94.10 (2390.1) 97.10 (2466.3)	13,000 (5897) 15,000 (6804)	500 (1893) 620 (2347)
2500	5 or 15 25 or 35	60 or 95 125 or 150	82.05 (2084.1) 82.05 (2084.1)	89.10 (2263.1) 103.60 (2631.4)	94.10 (2390.1) 98.10 (2491.7)	15,500 (7031) 18,800 (8528)	560 (2120) 730 (2763)
3000	25 or 35	125 or 150	92.25 (2343.2)	89.60 (2275.8)	119.90 (3045.5)	19,000 (8618)	750 (2839)
3750	25 or 35	125 or 150	106.50 (2705.1)	97.60 (2479.0)	119.90 (3045.5)	23,000 (10,433)	980 (3710)
5000	5 or 15	60 or 95	85.00 (2159.0)	98.00 (2489.2)	105.00 (2667.0)	25,000 (11,340)	960 (3634)

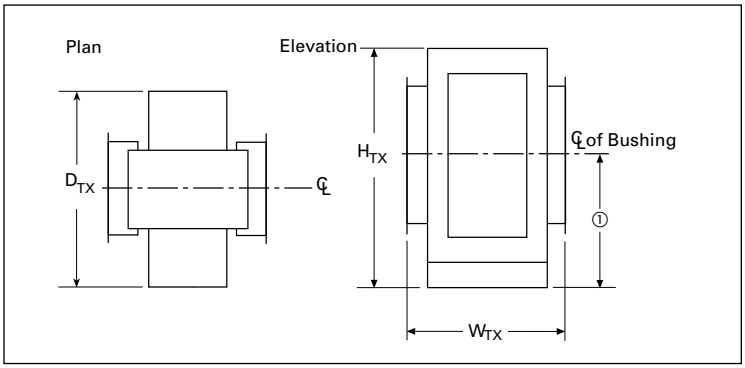


Figure 14.1-16. Liquid-Filled, Indoor and Outdoor

① = 55.00 inches (1397.0 mm) for all ratings through 15 kV primary, 600 V secondary.

Dimensions for estimating purposes only.

Environmentally Friendly Fluid-Filled Units

Table 14.1-21. Liquid-Filled Standard Design, 60 Hz, HV Delta, LV at 600 V Class (30 kV BIL) Indoor or Outdoor Application

kVA	HV, kV	HV BIL, kV	Dimensions in Inches (mm)			Weight Lb (kg)	Liquid Gallons (Liters)
			H_{TX}	W_{TX}	D_{TX}		
Oil-Filled 55°, 65° and 75 °C Rise							
300	5 or 15	60 or 95	74.05 (1880.9)	65.50 (1663.7)	53.50 (1358.9)	4800 (2177)	330 (1249)
500	5 or 15	60 or 95	74.05 (1880.9)	67.50 (1714.5)	57.50 (1460.5)	5800 (2631)	330 (1249)
750	5 or 15 25 or 35	60 or 95 125 or 150	74.05 (1880.9) 74.05 (1880.9)	71.50 (1816.1) 78.00 (1981.2)	59.50 (1511.3) 66.50 (1689.1)	6800 (3084) 8500 (3856)	370 (1401) 460 (1741)
1000	5 or 15 25 or 35	60 or 95 125 or 150	82.05 (2084.1) 82.05 (2084.1)	75.50 (1917.7) 82.00 (2082.8)	59.50 (1511.3) 66.50 (1689.1)	8400 (3810) 9400 (4264)	440 (1666) 480 (1817)
1500	5 or 15 25 or 35	60 or 95 125 or 150	82.05 (2084.1) 82.05 (2084.1)	79.10 (2009.1) 91.60 (2326.6)	84.70 (2151.4) 91.70 (2329.2)	10,800 (4899) 12500 (5670)	480 (1817) 600 (2271)
2000	5 or 15 25 or 35	60 or 95 125 or 150	82.05 (2084.1) 82.05 (2084.1)	81.10 (2060.0) 93.60 (2377.4)	94.10 (2390.1) 97.10 (2466.3)	13,000 (5897) 15,000 (6804)	500 (1893) 620 (2347)
2500	5 or 15 25 or 35	60 or 95 125 or 150	82.05 (2084.1) 82.05 (2084.1)	89.10 (2263.1) 103.60 (2631.4)	94.10 (2390.1) 98.10 (2491.7)	15,500 (7031) 18,800 (8528)	560 (2120) 730 (2763)
3000	25 or 35	125 or 150	92.25 (2343.2)	89.60 (2275.8)	119.90 (3045.5)	19,000 (8618)	750 (2839)
3750	25 or 35	125 or 150	106.50 (2705.1)	97.60 (2479.0)	119.90 (3045.5)	23,000 (10,433)	980 (3710)
5000	5 or 15	60 or 95	85.00 (2159.0)	98.00 (2489.2)	105.00 (2667.0)	25,000 (11,340)	960 (3634)

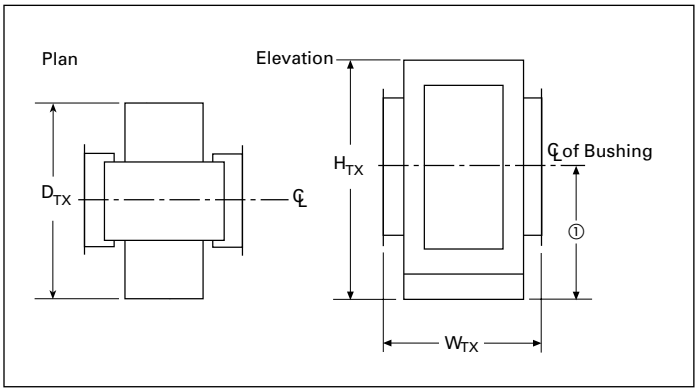


Figure 14.1-17. Liquid-Filled, Indoor and Outdoor

① = 55.00 inches (1397.0 mm) for all ratings through 15 kV primary, 600 V secondary.

Table 14.1-22. Non-DOE (Top End /Worst Case) Transformer Efficiencies Three-Phase Liquid-Filled Transformers

Three-Phase kVA	Approximate Losses (watts)
300	5145
500	7560
750	10,500
1000	13,283
1500	18,060
2000	22,838
2500	27,405

Dimensions for estimating purposes only.

VPI and VPE Ventilated Dry-Type—Standard Unit Substation

Table 14.1-23. Aluminum Windings, Standard Design, Delta-Wye, 60 Hz, Indoor, 600 V LV Class at 10 kV BIL, Indoor ①

kVA	HV, kV	HV BIL, kV ②	Dimensions in Inches (mm) H_{TX}	W_{TX}	D_{TX}	Weight Lb (kg)
150 °C Rise						
300	5	60	90.00 (2286.0)	78.00 (1981.2)	60.00 (1524.0)	3840 (1745)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	4320 (1964)
	27	125	102.00 (2590.8)	90.00 (2286.0)	66.00 (1676.4)	4800 (2182)
	38	150	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	5400 (2455)
500	5	60	90.00 (2286.0)	78.00 (1981.2)	60.00 (1524.0)	5280 (2400)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	5520 (2509)
	27	125	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	6000 (2727)
	38	150	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	6600 (3000)
750	5	60	90.00 (2286.0)	78.00 (1981.2)	60.00 (1524.0)	6600 (3000)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	7440 (3382)
	27	125	102.00 (2590.8)	108.00 (2743.2)	66.00 (1676.4)	7800 (3545)
	38	150	102.00 (2590.8)	108.00 (2743.2)	72.00 (1828.8)	8400 (3818)
1000	5	60	90.00 (2286.0)	84.00 (2133.6)	66.00 (1676.4)	7560 (3436)
	15	95	90.00 (2286.0)	84.00 (2133.6)	66.00 (1676.4)	8880 (4036)
	27	125	112.00 (2844.8)	114.00 (2895.6)	66.00 (1676.4)	9000 (4091)
	38	150	112.00 (2844.8)	114.00 (2895.6)	72.00 (1828.8)	9600 (4364)
1500	5	60	90.00 (2286.0)	90.00 (2286.0)	66.00 (1676.4)	9840 (4473)
	15	95	96.00 (2286.0)	90.00 (2286.0)	66.00 (1676.4)	11,160 (5073)
	27	125	112.00 (2844.8)	120.00 (3048.0)	66.00 (1676.4)	12,000 (5455)
	38	150	120.00 (3048.0)	120.00 (3048.0)	72.00 (1828.8)	12,600 (5727)
2000	5	60	90.00 (2286.0)	90.00 (2286.0)	66.00 (1676.4)	11,280 (5127)
	15	95	96.00 (2438.4)	96.00 (2438.4)	66.00 (1676.4)	12,600 (5727)
	27	125	120.00 (3048.0)	126.00 (3200.4)	72.00 (1828.8)	14,400 (6545)
	38	150	120.00 (3048.0)	126.00 (3200.4)	78.00 (1981.2)	15,000 (6818)
2500	5	60	102.00 (2590.8)	90.00 (2286.0)	66.00 (1676.4)	14,040 (6382)
	15	95	108.00 (2743.2)	96.00 (2438.4)	66.00 (1676.4)	15,600 (7091)
	27	125	120.00 (3048.0)	132.00 (3352.8)	78.00 (1981.2)	17,400 (7909)
	38	150	120.00 (3048.0)	132.00 (3352.8)	78.00 (1981.2)	18,000 (8182)
3000	5	60	102.00 (2590.8)	96.00 (2438.4)	66.00 (1676.4)	18,000 (8182)
	15	95	108.00 (2743.2)	102.00 (2590.8)	66.00 (1676.4)	19,200 (8727)
	27	125	120.00 (3048.0)	138.00 (3505.2)	78.00 (1981.2)	21,600 (9818)
	38	150	120.00 (3048.0)	144.00 (3657.6)	78.00 (1981.2)	22,800 (10,364)
3750	5	60	102.00 (2590.8)	108.00 (2743.2)	66.00 (1676.4)	19,200 (8727)
	15	95	112.00 (2844.8)	114.00 (2895.6)	66.00 (1676.4)	20,400 (9273)
	27	125	120.00 (3048.0)	144.00 (3657.6)	78.00 (1981.2)	22,800 (10,364)
	38	150	120.00 (3048.0)	150.00 (3810.0)	78.00 (1981.2)	25,200 (11,455)

kVA	HV, kV	HV BIL, kV ②	Dimensions in Inches (mm) ① H_{TX}	W_{TX}	D_{TX}	Weight Lb (kg)
80 ° or 115 °C Rise						
300	5	60	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	4800 (2182)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	6000 (2727)
	27	125	102.00 (2590.8)	96.00 (2438.4)	66.00 (1676.4)	7200 (3273)
	38	150	102.00 (2590.8)	108.00 (2743.2)	66.00 (1676.4)	7800 (3545)
500	5	60	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	6240 (2836)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	6960 (3164)
	27	125	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	8400 (3818)
	38	150	102.00 (2590.8)	108.00 (2743.2)	66.00 (1676.4)	9000 (4091)
750	5	60	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	7440 (3382)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	8400 (3818)
	27	125	102.00 (2590.8)	114.00 (2895.6)	72.00 (1828.8)	9600 (4364)
	38	150	102.00 (2590.8)	114.00 (2895.6)	78.00 (1981.2)	10,200 (4636)
1000	5	60	90.00 (2286.0)	84.00 (2133.6)	66.00 (1676.4)	9360 (4255)
	15	95	90.00 (2286.0)	90.00 (2286.0)	66.00 (1676.4)	10,500 (4773)
	27	125	112.00 (2844.8)	120.00 (3048.0)	72.00 (1828.8)	11,400 (5182)
	38	150	112.00 (2844.8)	120.00 (3048.0)	72.00 (1828.8)	12,000 (5455)
1500	5	60	90.00 (2286.0)	90.00 (2286.0)	66.00 (1676.4)	11,400 (5182)
	15	95	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	12,600 (5727)
	27	125	112.00 (2844.8)	120.00 (3048.0)	72.00 (1828.8)	13,200 (6000)
	38	150	112.00 (2844.8)	120.00 (3048.0)	72.00 (1828.8)	13,800 (6273)
2000	5	60	96.00 (2438.4)	96.00 (2438.4)	66.00 (1676.4)	14,400 (6545)
	15	95	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	15,600 (7091)
	27	125	120.00 (3048.0)	126.00 (3200.4)	72.00 (1828.8)	15,840 (7200)
	38	150	120.00 (3048.0)	126.00 (3200.4)	72.00 (1828.8)	16,200 (7364)
2500	5	60	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	18,000 (8182)
	15	95	108.00 (2743.2)	108.00 (2743.2)	66.00 (1676.4)	18,960 (8618)
	27	125	130.00 (3302.0)	132.00 (3352.8)	78.00 (1981.2)	19,200 (8727)
	38	150	130.00 (3302.0)	138.00 (3505.2)	78.00 (1981.2)	19,800 (9000)
3000	5	60	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	20,400 (9273)
	15	95	108.00 (2743.2)	114.00 (2895.6)	66.00 (1676.4)	21,600 (9818)
	27	125	130.00 (3302.0)	138.00 (3505.2)	78.00 (1981.2)	24,000 (10,909)
	38	150	140.00 (3556.0)	144.00 (3657.6)	78.00 (1981.2)	26,400 (12,000)
3750	5	60	102.00 (2590.8)	114.00 (2895.6)	66.00 (1676.4)	21,600 (9818)
	15	95	112.00 (2844.8)	120.00 (3048.0)	66.00 (1676.4)	22,800 (10,364)
	27	125	130.00 (3302.0)	150.00 (3810.0)	78.00 (1981.2)	26,400 (12,000)
	38	150	140.00 (3556.0)	150.00 (3810.0)	78.00 (1981.2)	28,800 (13,091)

① Dimensions based on MVS primary coordination and Magnum DS secondary coordination. For outdoor base construction, add 12.00 inches (304.8 mm) to height and 6.00 inches (152.4 mm) to width and depth. Roof overhangs 8.50 inches (215.9 mm) front and rear.

② 30 kV BIL is standard for 5 kV class; 60 kV BIL is available as an option. 60 kV BIL is standard for 15 kV class; 95 kV BIL is available as an option.

Note: Smaller dimensions/weights may be available, refer to Eaton. Add 6.00 inches to depth dimension for seismic rating <1.25 SDS. Add 12.00 inches to depth dimension for seismic rating M1.25 SDS.

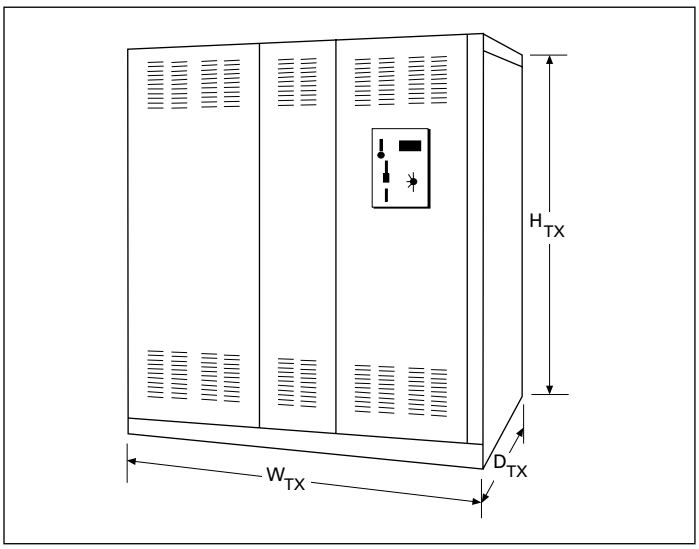


Figure 14.1-18. Indoor Ventilated Enclosure (NEMA 1 Construction)

Table 14.1-24. High Voltage 15 kV and Below. Low Voltage 600 V and Below. Copper Conductor Windings. Losses in Watts. Three-Phase Dry-Type Unit Substation Transformers ③

VPI, 15 kV Primary 150 °C Temp. Rise				
kVA	**No Load (Watts)**	**Load Loss at 100% Load and 170 °C Ref. Temp. (Watts)**	**Total Losses at 100% Load and 170 °C (Watts)**	**46–95 kV BIL Total Losses at 50% Load and 75 °C Ref. Temp. per DOE (Watts)**
300 ④	950	3450	4400	1806
500 ④	1300	5650	6950	2551
750 ④	1600	8600	10,200	3329
1000 ④	1850	10,700	12,550	4032
1500 ④	2700	11,850	14,550	5287
2000 ④	2950	16,900	19,850	6441
2500 ④	4500	14,500	19,000	7419
3000	6200	26,100	32,300	N/A
3750	7100	33,400	40,500	N/A

③ Losses offered are typical only, not guaranteed.

④ Units must typically meet the new DOE efficiency guideline levels with noted losses complying with such.

Dimensions for estimating purposes only.

Cast Coil and Resibloc Dry-Type—Standard Unit Substation

Table 14.1-25. Standard Windings, Standard Design, Delta-Wye, 60 Hz, Indoor, 600 V LV Class at 10 kV BIL, Indoor ①

kVA	HV, kV	HV BIL, kV ②	Dimensions in Inches (mm) H_{TX}	W_{TX}	D_{TX}	Weight Lb (kg)
80 °C Rise						
300	5	60	90.00 (2286.0)	78.00 (1981.2)	60.00 (1524.0)	4600 (2091)
	15	95	90.00 (2286.0)	78.00 (1981.2)	60.00 (1524.0)	5060 (2300)
500	5	60	90.00 (2286.0)	78.00 (1981.2)	60.00 (1524.0)	6785 (3084)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	8165 (3711)
	27	125	90.00 (2286.0)	100.02 (2590.8)	66.00 (1676.4)	8625 (3920)
750	5	60	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	8510 (3868)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	9085 (4130)
	27	125	102.00 (2590.8)	108.00 (2743.2)	66.00 (1676.4)	9660 (4391)
1000	5	60	90.00 (2286.0)	90.00 (2286.0)	66.00 (1676.4)	10,005 (4548)
	15	95	90.00 (2286.0)	90.00 (2286.0)	66.00 (1676.4)	10,120 (4600)
	27	125	102.00 (2590.8)	108.00 (2743.2)	66.00 (1676.4)	10,350 (4705)
	38	150	102.00 (2590.8)	114.00 (2895.6)	72.00 (1828.8)	12,995 (5907)
1500	5	60	90.00 (2286.0)	96.00 (2438.4)	66.00 (1676.4)	12,650 (5750)
	15	95	102.00 (2590.8)	96.00 (2438.4)	66.00 (1676.4)	13,110 (5959)
	27	125	112.00 (2844.8)	120.00 (3048.0)	66.00 (1676.4)	13,455 (6116)
	38	150	112.00 (2844.8)	126.00 (3200.4)	72.00 (1828.8)	14,950 (6795)
2000	5	60	96.00 (2438.4)	96.00 (2438.4)	66.00 (1676.4)	15,640 (7109)
	15	95	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	16,100 (7318)
	27	125	112.00 (2844.8)	126.00 (3200.4)	72.00 (1828.8)	16,100 (7318)
	38	150	120.00 (3048.0)	132.00 (3352.8)	78.00 (1981.2)	20,700 (9409)
2500	5	60	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	19,435 (8834)
	15	95	112.00 (2844.8)	108.00 (2743.2)	66.00 (1676.4)	19,090 (8677)
	27	125	112.00 (2844.8)	138.00 (3505.2)	72.00 (1828.8)	18,400 (8364)
	38	150	120.00 (3048.0)	144.00 (3657.6)	78.00 (1981.2)	24,380 (11,082)
3000	5	60	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	22,500 (10,215)
	15	95	112.00 (2844.8)	108.00 (2743.2)	66.00 (1676.4)	23,500 (10,669)
	27	125	120.00 (3048.0)	144.00 (3657.6)	78.00 (1981.2)	24,000 (10,896)
	38	150	124.00 (3149.6)	150.00 (3810.0)	84.00 (2133.6)	24,000 (10,896)
3750	5	60	102.00 (2590.8)	126.00 (3200.4)	66.00 (1676.4)	24,000 (10,896)
	15	95	120.00 (3048.0)	126.00 (3200.4)	72.00 (1828.8)	25,000 (11,350)
	27	125	120.00 (3048.0)	144.00 (3657.6)	78.00 (1981.2)	26,000 (11,804)
	38	150	124.00 (3149.6)	150.00 (3810.0)	84.00 (2133.6)	27,000 (12,258)

kVA	HV, kV	HV BIL, kV ②	Dimensions in Inches (mm) ① H_{TX}	W_{TX}	D_{TX}	Weight Lb (kg)
100 °C Rise or 115 °C Rise						
300	5	60	90.00 (2286.0)	78.00 (1981.2)	60.00 (1524.0)	4485 (2039)
	15	95	90.00 (2286.0)	78.00 (1981.2)	60.00 (1524.0)	4830 (2195)
500	5	60	90.00 (2286.0)	78.00 (1981.2)	60.00 (1524.0)	6900 (3136)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	7130 (3241)
	27	125	90.00 (2286.0)	102.00 (2590.8)	66.00 (1676.4)	9000 (4082)
750	5	60	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	8625 (3920)
	15	95	90.00 (2286.0)	84.00 (2133.6)	60.00 (1524.0)	9085 (4130)
	27	125	96.00 (2438.4)	108.00 (2743.2)	66.00 (1676.4)	10,100 (4581)
1000	5	60	90.00 (2286.0)	90.00 (2286.0)	66.00 (1676.4)	9660 (4391)
	15	95	90.00 (2286.0)	90.00 (2286.0)	66.00 (1676.4)	9775 (4443)
	27	125	102.00 (2590.8)	108.00 (2743.2)	66.00 (1676.4)	13,000 (5897)
	38	150	102.00 (2590.8)	114.00 (2895.6)	72.00 (1828.8)	14,900 (6759)
1500	5	60	90.00 (2286.0)	96.00 (2438.4)	66.00 (1676.4)	11,730 (5332)
	15	95	102.00 (2590.8)	96.00 (2438.4)	66.00 (1676.4)	12,420 (5645)
	27	125	112.00 (2844.8)	118.00 (2997.2)	72.00 (1828.8)	15,400 (6985)
	38	150	112.00 (2844.8)	120.00 (3048.0)	72.00 (1828.8)	16,500 (7484)
2000	5	60	96.00 (2438.4)	96.00 (2438.4)	66.00 (1676.4)	14,260 (6482)
	15	95	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	14,950 (6795)
	27	125	114.00 (2895.6)	126.00 (3200.4)	78.00 (1981.2)	17,900 (8119)
	38	150	118.00 (2997.2)	132.00 (3352.8)	78.00 (1981.2)	19,100 (8664)
2500	5	60	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	17,480 (7945)
	15	95	112.00 (2844.8)	108.00 (2743.2)	66.00 (1676.4)	16,905 (7684)
	27	125	114.00 (2895.6)	132.00 (3352.8)	72.00 (1828.8)	18,400 (8346)
	38	150	120.00 (3048.0)	138.00 (3505.2)	78.00 (1981.2)	21,200 (9616)
3000	5	60	102.00 (2590.8)	102.00 (2590.8)	66.00 (1676.4)	20,000 (9080)
	15	95	112.00 (2844.8)	108.00 (2743.2)	66.00 (1676.4)	21,000 (9534)
	27	125	120.00 (3048.0)	138.00 (3505.2)	78.00 (1981.2)	21,400 (9707)
	38	150	120.00 (3048.0)	144.00 (3657.6)	78.00 (1981.2)	22,800 (10,342)
3750	5	60	102.00 (2590.8)	126.00 (3200.4)	66.00 (1676.4)	23,000 (10,442)
	15	95	120.00 (3048.0)	126.00 (3200.4)	72.00 (1828.8)	26,000 (11,804)
	27	125	120.00 (3048.0)	144.00 (3657.6)	78.00 (1981.2)	28,700 (13,018)
	38	150	124.00 (3149.6)	150.00 (3810.0)	84.00 (2133.6)	31,700 (14,379)

① Dimensions based on MVS primary coordination and Magnum DS secondary coordination. For outdoor base construction, add 12.00 inches (304.8 mm) to height and 6.00 inches (152.4 mm) to width and depth. Roof overhangs 8.50 inches (215.9 mm) front and rear.

② 30 kV BIL is standard for 5 kV class; 60 kV BIL is available as an option. 60 kV BIL is standard for 15 kV class; 95 kV BIL is available as an option.

Note: Smaller dimensions/weights may be available, refer to Eaton. Add 6.00 inches to depth dimension for seismic rating <1.25 SDS. Add 12.00 inches to depth dimension for seismic rating M1.25 SDS.

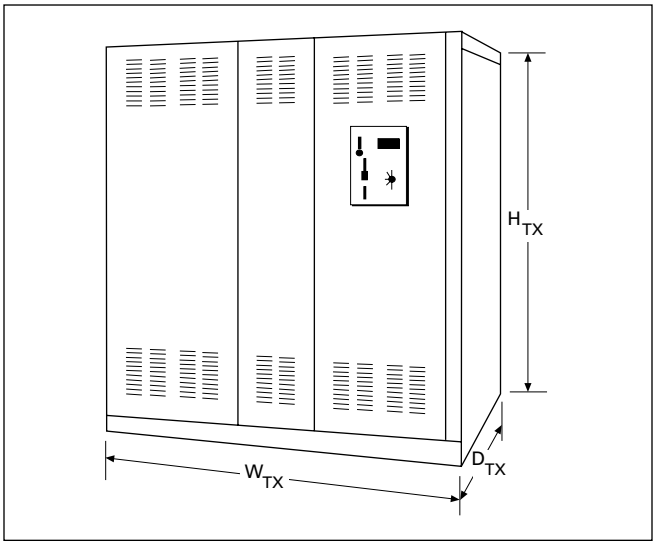


Figure 14.1-19. Indoor Ventilated Enclosure (NEMA 1 Construction)

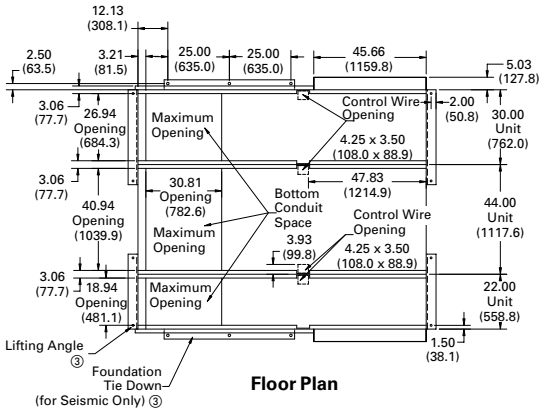
Table 14.1-26. High Voltage 15 kV and Below. Low Voltage 600 V and Below. Copper Conductor Windings. Losses in Watts. Three-Phase Dry-Type Unit Substation Transformers. ③

Cast, 15 kV Primary 115 °C Temp. Rise				
kVA	**No Load (Watts)**	**Load Loss at 100% Load and 135 °C Ref. Temp. (Watts)**	**Total Losses at 100% Load and 135 °C (Watts)**	**46–95 kV BIL Total Losses at 50% Load and 75 °C Ref. Temp. per DOE (Watts)**
300 ④	950	3400	4350	1806
500 ④	1350	4450	5800	2551
750 ④	2050	4700	6750	3329
1000 ④	2350	7200	9550	4032
1500 ④	2900	12,200	15,100	5287
2000 ④	3150	13,200	16,350	6441
2500 ④	4350	16,150	20,500	7419
3000	7200	20,000	27,200	N/A
3750	8600	21,000	29,600	N/A
5000	13,500	30,000	43,500	N/A
7500	20,000	35,000	55,000	N/A
10,000	22,500	45,000	67,500	N/A

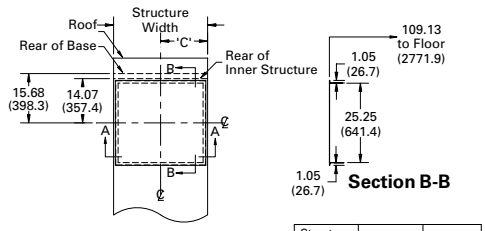
③ Losses offered are typical only, not guaranteed.

④ Units must typically meet the new DOE efficiency guideline levels with noted losses complying with such.

Dimensions for estimating purposes only.

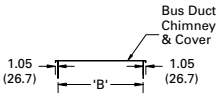


Floor Plan



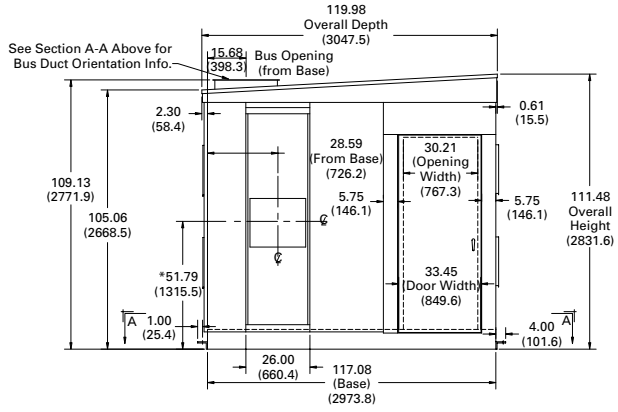
Top View A

Section B-B

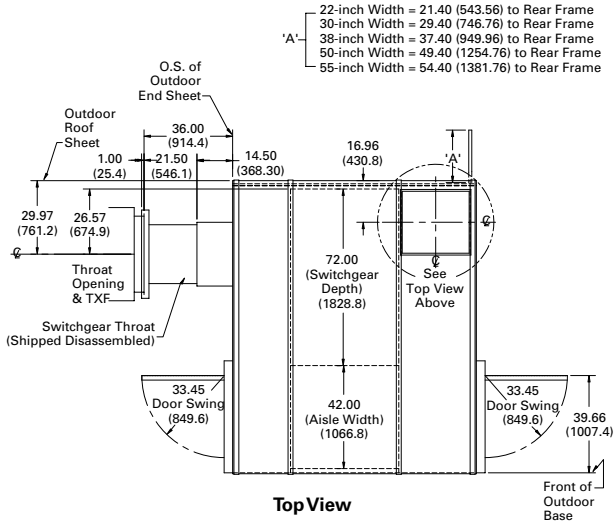


Section A-A

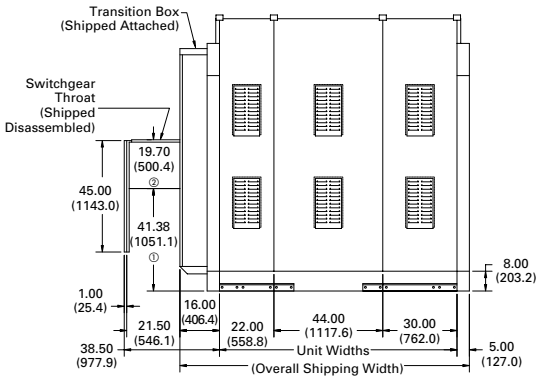
Structure Width	'B'	'C'
22.00 (558.8)	16.99 (431.6)	11.00 (279.4)
30.00 (762.0)	24.99 (634.8)	15.00 (381.0)
38.00 (965.2)	32.99 (838.0)	19.00 (482.6)
44.00 (1117.6)	38.99 (990.4)	22.00 (558.8)
50.00 (1270.0)	44.99 (1142.8)	25.00 (635.0)



Side View



Top View



Front View

Weights of Outdoor Structures (without breakers)

Structure	Weight-Lb (kg)
End trims (one set per lineup)	1500 (681)
22-inch (558.8 mm) wide breaker structure	2600 (1180)
30-inch (762.0 mm) wide breaker structure	2700 (1226)
44-inch (1117.6 mm) wide breaker structure	5200 (2361)
22-inch (558.8 mm) wide auxiliary structure	2300 (1044)
22-inch (558.8 mm) wide transition structure	2500 (1135)
38-inch (965.2 mm) wide utility structure	2700 (1226)
50-inch (1270.0 mm) wide utility structure	3200 (1453)
Transformer throat	150 (68)

9255C25

Figure 14.1-20. Outdoor Walk-in Enclosure Magnum DS Switchgear and Magnum SB Switchboards—Dimensions in Inches (mm)

① 46.63 inches (1184.4 mm) = 55.00-inch (1397.0 mm) throat (44.00-inch [1117.6 mm] wide transition box).
52.63 inches (1336.8 mm) = 61.00-inch (1549.4 mm) throat (44.00-inch [1117.6 mm] wide transition box).

② 18.70 inches (475.0 mm) = 44.00-inch [1117.6 mm] wide transition box.

③ 0.50-inch (12.7 mm) hardware recommended in all tie down locations.

Enclosures—Pow-R-Line C

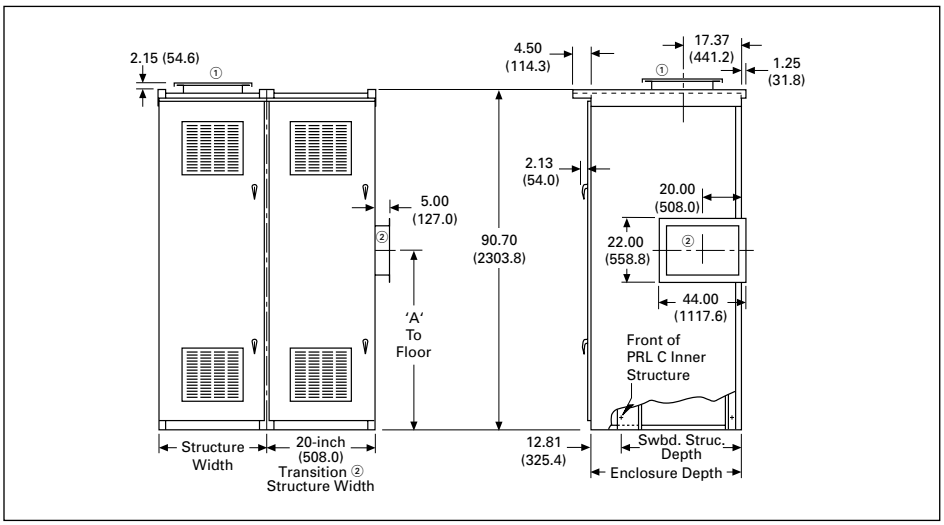


Figure 14.1-21. Front or Rear Access—Non-Walk-in with Flat Roof—Dimensions in Inches (mm)

Table 14.1-27. Enclosure—Dimensions in Inches (mm)

Switchboard Indoor Structure Depth	Non-Walk-in Enclosure Depth
48.00 (1219.2)	61.00 (1549.4)
Dimension "A"	
0–2500 kVA transformer	55.00 (1397.0)
2501–5000 kVA transformer	61.00 (1549.4)

① Standard busway entry/exit location, 36.00-inch (914.4 mm) deep minimum.

② 20.00-inch (508.0 mm) wide structure always required when throat connecting to other equipment. Standard transformer throat connection, 48.00-inch (1219.2 mm) deep structure only.

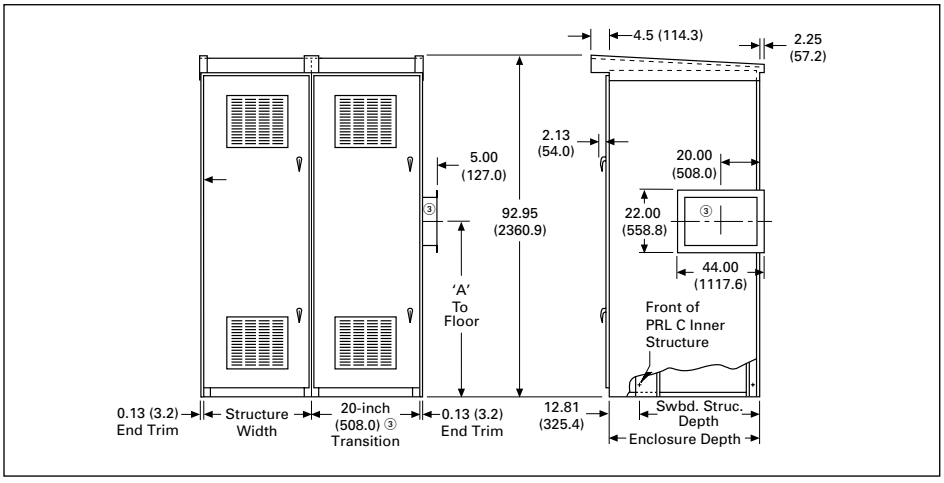


Figure 14.1-22. Front Access—Non-Walk-in with Sloped Roof—Dimensions in Inches (mm)

Table 14.1-28. Enclosure—Dimensions in Inches (mm)

Switchboard Indoor Structure Depth	Non-Walk-in Enclosure Depth
48.00 (1219.2) 54.00 (1371.6) 66.00 (1676.4)	61.00 (1549.4) 67.00 (1701.8) 79.00 (2006.6)
Dimension "A"	
0–2500 kVA transformer	55.00 (1397.0)
2501–5000 kVA transformer	61.00 (1549.4)

③ 20.00-inch (508.0 mm) wide structure always required when throat connecting to other equipment. Standard transformer throat connection, 48.00-inch (1219.2 mm) deep structure minimum.

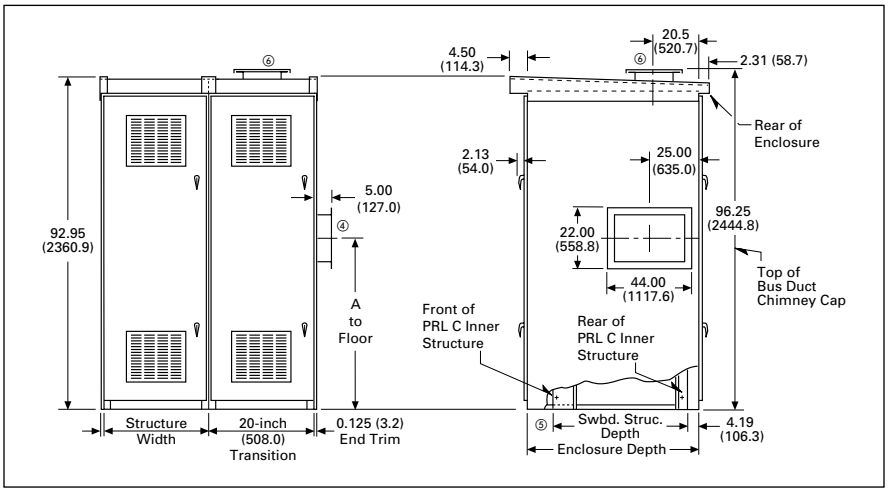


Figure 14.1-23. Rear Access—Non-Walk-in with Sloped Roof—Dimensions in Inches (mm)

Dimensions for estimating purposes only.

Table 14.1-29. Enclosure—Dimensions in Inches (mm)

Switchboard Indoor Structure Depth	Non-Walk-in Enclosure Depth
48.00 (1219.2) 54.00 (1371.6) 66.00 (1676.4)	65.00 (1651.0) 71.00 (1803.4) 83.00 (2108.2)
Dimension "A"	
0–2500 kVA transformer	55.00 (1397.0)
2501–5000 kVA transformer	61.00 (1549.4)

④ Standard transformer throat connection, 48.00 inches (1219.2 mm) deep only. 20.00-inch (508.0 mm) wide structure always required when throat connecting to other equipment.

⑤ Non-walk-in dimension—12.81 inches (325.4 mm).

⑥ Standard busway entry/exit location.

Transformer Product Selector

Table 14.1-30. Transformer Product Selector

Transformer		Maximum Voltage		Available kVA	Types	Application Considerations	Standards and Certifications
		Primary	Secondary				
Unit Substation Transformer—Dry-Type							
	**Secondary Unit Substation** (provides secondary system voltage)	34.5 kV	600 V	112.5 kVA–3750 kVA	**VPI**—An economical choice—suitable for most commercial applications. Technology characterized by design flexibility and overload safety factor. Vacuum pressure impregnation with polyester resin. **Cast Coil**—Lowest maintenance for most commercial and industrial applications. By hermetically sealing the windings in epoxy, higher levels of performance and environmental robustness are achieved in high moisture, dust laden, and chemical contaminated environments. **RESIBLOC®**—For applications with high shock and vibration or cold climates, RESIBLOC delivers a differentiated solution. Coils are insulated with epoxy and reinforced with glass-fiber rovings.	Transformer is part of a close-coupled assembly that includes both primary and secondary equipment. Explosion-resistant, fire-resistant and nonpolluting to the environment. Neither containment nor fire suppression required for indoor installations.	IEEE C57.12.01/ C57.12.91 UL® available Seismic Zone 4 certification
Unit Substation Transformer—Liquid-Filled							
	**Secondary Unit Substation** (provides secondary system voltage)	34.5 kV	600 V	300 kVA–3750 kVA	**Mineral Oil**—Typical outdoor installation. **Silicone**—Applied where flammability is a concern. **Envirotemp™ FR3™**—Specified where flammability, clean-up and life extension are a concern.	Transformer is part of a close-coupled assembly that may include both primary and secondary equipment. High short-circuit strength. Sealed tank design is impervious to the environment. Smaller footprint, greater efficiency, nonpolluting to the environment when filled with Envirotemp™ FR3™	Complies with IEEE C57.12.00 and C57.12.90, CSA®–88 UL, FM available Seismic Zone 4 certification

Cooling Classes of Transformers

The cooling classes of transformers have changed, and are explained in **Table 14.1-31.** The IEEE® transformer cooling designations were changed to become consistent with the IEC standards (IEC 60076-2: 1998). The new classifications are described in IEEE C57.12.00 for liquid-filled transformers. IEEE C57.12.01-2015 describes dry-type transformers.

The new cooling designations have four-letter descriptions that describe the type of oil, how the oil is internally circulated, what is used to cool the oil, and how the oil is externally cooled.

For example: ONAN

Table 14.1-31. IEEE Transformer Cooling Classes

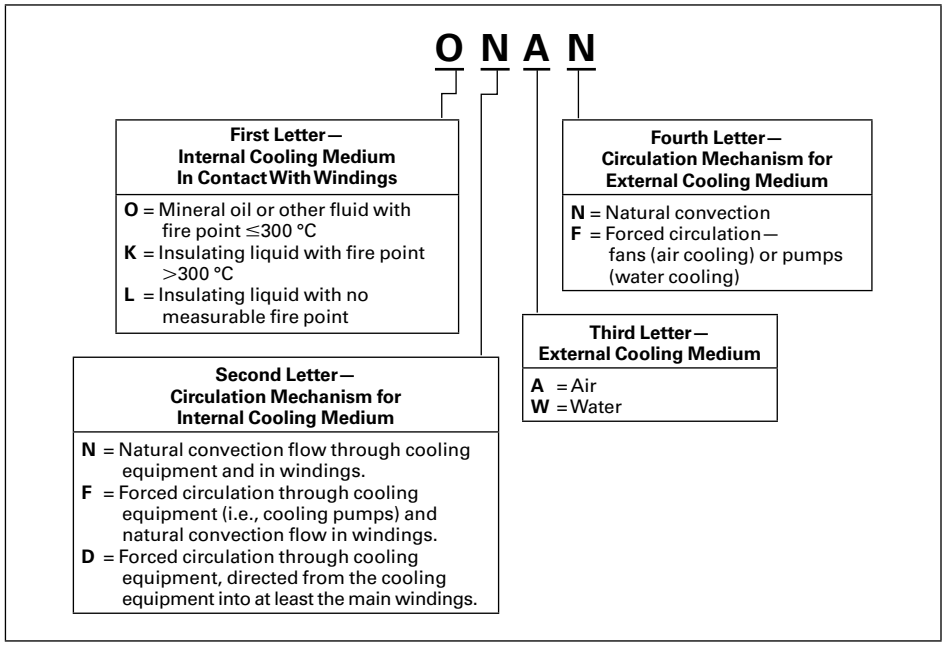


Table 14.1-32. Cooling Classes Comparisons, Past/Present Designations

Designations	
Previous	**Present**
OA FA OA/FA/FA	ONAN ONAF ONAN/ONAF/ONAF
OA/FA/FOA OA/FOA OA/FOA/FOA	ONAN/ONAF/OFAF ONAN/ODAF ONAN/ODAF/ODAF
FOA FOW FOA FOW	OFAF OFWF ODAF ODWF

Table 14.1-33. Dry-Type Transformer Cooling Classes

Description	Class	IEC Equivalent
Ventilated self-cooled	AA	AN
Ventilated forced-air-cooled	AFA	AF
Ventilated self-cooled/forced-air-cooled	AA/FA	AN/AF
Non-ventilated self-cooled	ANV	—
Sealed self-cooled	GA	—

Note: In the IEC symbols, "N" indicates natural.

Transformer Fluids Comparison

Table 14.1-34. Fluid Advantages and Disadvantages

Advantages	Disadvantages
Mineral Oil	
■ Low transformer cost ■ Good dielectric performance ■ Low maintenance cost ■ Good heat dissipation ■ Good cold climate performance ■ Preventative maintenance—DGA historical data available	■ Higher installation cost ■ Potential vaults required for indoor installations per NEC® low fire point—160 °C ■ <30% Biodegradability
Silicone Fluid	
■ Low heat release ■ Reduced smoke ■ Low flame ■ Self extinguishing ■ Good dielectric performance ■ Low toxicity ■ Moderate viscosity ■ High stability	■ Non-biodegradable ■ Not suitable for use with internal Bay-O-Net fuses ■ Transformer cost ■ Disposal cost ■ Viton gaskets required ■ Retrofil applications ■ High transformer cost ■ High moisture absorption
Environmentally Friendly Fluids	
■ High fire point—360 °C ■ High flash point—330 °C ■ Compatible with mineral oil ■ Excellent retrofil fluid (compatible with oil up to a 10% mixture) ■ Excellent dielectric performance ■ 99% biodegradable ■ Renewable resource ■ Greater tolerance to moisture ■ Excellent switching medium ■ Excellent cold weather performance ■ Significant extension of transformer insulation life	■ Transformer cost (lower than silicone fluid) ■ Pour point (–15 °C to –25 °C) transformer energized with full load with top oil temperature at –50 °C with no dielectric problems—no crystals formed at –68 °C
Air	
■ Non-flammable ■ No fluid analysis necessary ■ Zero environmental impact	■ Transformer cost (oil is better dielectric than air)

Table 14.1-35. Fluid Properties Comparison

Property	Mineral Oil	Silicone Fluid	Environmentally Friendly Fluids
Specific gravity Flash point °C Fire point °C	0.91 145 160	0.96 300 330	0.91 330 360
Viscosity (cSt.) 100 °C 40 °C 0 °C	3 12 76	16 38 90	10 45 300
Pour point °C Dielectric strength, kV Dissipation factor (%) 25 °C	–40 30 0.05	–55 4.3 0.01	–15–25 49 0.025–0.05
Permittivity Resistivity Oxidation inhibitor Biodegradability	2.2 10^{13} Optional <30%	2.7 10^{14} No 0%	3.1 10^{13} Required 99%

NEC Requirement Guidelines for the Installation of Transformers

NEC (NFPA) Recognition

These guidelines focus on the requirements of Article 450 of the National Electrical Code® (NEC®). Articles 450.21 and 22 describe the installation of dry-type transformers; Article 450.23 describes the installation of less-flammable liquid insulated transformers; and Articles 450.26 and 27 describe the installation of mineral-insulated transformers. Typical applications of fire concern include installations indoor, on rooftops, near buildings, bush and forest fire prone areas, and in pedestrian traffic areas.

NEC Requirements

Mineral-Oil Insulated Transformers

Per NEC 450.27 for mineral oil insulated transformers installed outdoors, in cases where the transformer installation presents a fire hazard, one or more of the following safeguards shall be applied according to the degree of hazard involved:

1. Space separation
2. Fire-resistant barriers
3. Automatic fire suppression systems
4. Enclosures that confine the oil of a ruptured transformer tank

Per NEC 450.26, mineral oil insulated transformers installed indoors shall be installed in a 3-hour rated vault per Article 450, Part III.

Mineral oil insulated transformers are most commonly installed outdoors.

Dry-Type Transformers

Information regarding installation of dry-type transformers indoors is referenced from NEC 450.21. According to NEC Article 450.21, dry-type transformers that are completely enclosed, excluding ventilating openings, may be installed indoors without further requirements. The only consideration is allowing 6.00 inches minimum clearance on the front and rear to ensure proper ventilation.

Open ventilated dry transformers must either have space separation of 6 feet horizontally or 12 feet vertically from combustible material, have a fire resistant heat insulating barrier between the transformer and combustible material or be installed in a transformer room of fire resistant construction. Dry-type transformers rated over 35,000 volts shall be installed in a vault complying with Part III of Article 450.

Per Article 450.22, dry-type transformers installed outdoors shall have a weatherproof enclosure. Dry-type transformers are most commonly installed indoors.

Less-Flammable Liquid Insulated Transformers

Less-flammable liquids, also known as high fire point liquids, are transformer dielectric coolants that have a minimum fire point of 300 °C. Commonly used less-flammable fluids include dimethysiloxane, and ester-based fluids. Two Nationally Recognized Testing Laboratories (NRTL); Underwriters Laboratories (UL®) and FM Global (FM) currently list less-flammable liquids. They also list less-flammable liquid-filled transformers.

Less-flammable liquid-filled transformers were formally recognized by the NEC for indoor installation in 1978. In 1990, the NEC integrated specific less-flammable transformer requirements for outdoor installations in Article 450.23, in effect recognizing less-flammable transformers as inherently safer than conventional oil-filled transformers. Less-flammable transformers, long recognized as an additional safeguard for indoor installations, are becoming increasingly recognized for outdoor applications as well. Less-flammable liquid insulated transformers are commonly installed either indoors or outdoors.

The requirements and options for the different types of indoor and outdoor installations of less-flammable liquid-insulated transformers per NEC 450.23 are outlined in **Table 14.1-36**. These guidelines also summarize the UL Classification and FM Approval installation requirements for less-flammable fluids referred to as “listing” requirements in NEC 450.23.

Outdoor installations may be made simpler by utilizing a less-flammable fluid in lieu of mineral oil per NEC 450.23 part B. Less-flammable liquid-filled transformers shall be permitted to be installed outdoors, attached to, adjacent to, or on the roof of buildings, where the building is a type I or II (non-combustible) construction and the installation shall comply with all restrictions provided for in the listing of the liquid. Installations unable to comply with these requirements shall comply with Article 450.27.

Indoor installations using less-flammable liquid-insulated transformers must comply with NEC Article 450.23 part A, which defines the requirements for three types of indoor transformer installations as detailed in **Table 14.1-36**.

- Type I or II (non-combustible) building with no combustible materials stored in area
- Combustible building or combustibles stored in area
- Rating greater than 35 kV

The installation of less-flammable liquid insulated transformers indoors without a vault in a Type I or II non-combustible building where no combustible materials are stored requires that:

- A liquid confinement area be provided
- The transformer be filled with a listed less-flammable insulating liquid with a minimum 300 °C fire point
- The installation complies with the listing requirements (either UL or FM) of the liquid in the transformer

Liquid containment can be offered as a transformer accessory for indoor installations by the transformer manufacturer. If the installation cannot comply with the liquid listing requirements, it must either be provided with an automatic fire extinguishing system and liquid containment or the transformer must be installed complying with NEC 450.26.

NEC Article 450.28, modification of transformers, requires that when modifications are made to transformers in existing installations that change the transformer type, the transformers must be marked to show the type of insulating liquid installed and the installations must comply with current requirements of the NEC. Examples of changes include replacing a complete transformer (retrofitting) or replacement of the liquid only (retrofilling). Askarel (PCB) and conventional mineral oil-filled transformers are frequently retrofitted or retrofilled using less-flammable liquids. NEC 110.34 sets minimum clear work space dimensions around transformers.

Table 14.1-36. NEC Article 450 Requirements

Installation Type	NEC Requirements
Indoor Installations	
Transformer rated m35 kV, installed in a non-combustible building with no combustible materials stored in area.	■ Less-flammable fluid filled with liquid confinement, and equipped and installed per either of the following listing requirements ①: – Underwriters Laboratories Classification – FM Global ■ Less-flammable fluid filled with liquid confinement and auto extinguishment ■ Vault per NEC 450, Part III ① ■ Dry-type transformer
Transformer rated m35 kV, installed in a combustible building or in a building with combustible materials stored in area.	■ Less-flammable fluid filled with liquid confinement and auto extinguishment ① ■ Vault per NEC 450, Part III ① ■ Dry-type transformer in accordance with NEC 450.21 (B)
Transformer rated L35 kV	■ Vault per NEC 450, Part III ①
Outdoor Installations	
Non-combustible building ② and no combustible materials stored in area.	■ Less-flammable fluid filled per either of the following listing requirements ③: – Underwriters Laboratories Classification – FM Global ■ Dry-type transformer in accordance with NEC 450.21 (B)
Combustible building ② or combustible materials stored in area.	■ In accordance with NEC Article 450.27, oil insulated transformers installed outdoors, i.e., space separation, fire barriers or water spray systems ■ Dry-type transformer in accordance with NEC Article 450.22

① Optional—no additional safeguards are required if one or more Exceptions 1-6 of Article 450.26, oil-insulated transformers installed indoors apply.
② Refer to NFPA 220-1999 for definition of non-combustible Type I and II building construction.
③ Fine print note, Article 450.23, (B) (1) states: "Installations adjacent to combustible material, fire escapes, or door and window openings may require additional safeguards such as those listed in Article 450.27."

Underwriters Laboratories Requirements

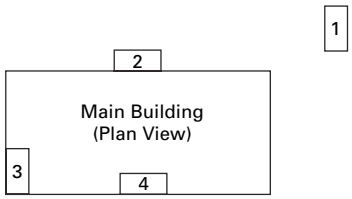
The UL Classification of less-flammable liquids per the NEC Article 450.23 for three-phase 45–10,000 kVA transformers requires transformer fluid that will be UL Classified complying with the following transformer requirements:

- Transformers be equipped with tanks capable of withstanding 12 psig minimum without rupture
- Transformers be equipped with pressure relief devices with minimum pressure relief capacity per the UL Classification marking

Note: Refer to **Table 14.1-38**.

- Transformer primaries be protected with overcurrent protection options per the UL Classification marking

Transformers will be supplied with appropriate pressure withstand and pressure relief when UL Classification is specified. Overcurrent protection may be supplied integral to the transformer or via switchgear feeding the transformer.



1: Detached building
2: Outside room with direct access from outside only
3, 4: Inside room with direct access from outside only
See **Table 14.1-37** for construction features.

Figure 14.1-24. FM Global Recommended Construction for Transformer Buildings and Rooms

Table 14.1-37. Construction Features

Transformer Type	Fluid Type	Fluid Volume in Largest Transformer	Room or Building Fire Rating	Fire Protection for Transformer Liquids
Dry or gas insulated ①	N/A	N/A	Noncombustible	None ②
FM approved or equivalent ③	FM approved liquids	Any ④	Noncombustible	None ②
Non-approved transformer	FM approved liquids	Any ④	1-hour fire-rated	None ②
			Noncombustible	Per Section 2.2.3 ⑤
	Non-approved liquids	Less than 100 gal (380 L) ④	1-hour fire-rated	None ②
		More than 100 gal (380 L) ④	3-hour fire-rated with subdivisions if multiple transformers ⑥	None ②
			3-hour fire-rated with multiple transformers and no subdivision	Per Section 2.2.3 ⑤
			1-hour fire-rated with single transformer	Per Section 2.2.3 ⑤

① No mineral oil-filled bushings, tap changers or other mineral oil-filled accessories.
② Refer to FM Global DS 5-4 Section 2.2.3.4 for protection of other combustibles other than transformer liquids.
③ FM Global DS 5-4 Section 3.3 describes FM Approved and equivalent transformers (also described on 17.0-7).
④ Provide liquid spill containment in accordance with DS 5-4 Section 2.2.1.5.
⑤ Automatic sprinklers, foam water sprinklers or water mist. Also provide emergency drainage for sprinkle discharge per DS 5-4 Section 2.2.1.6.
⑥ Subdivide room or building with 3-hour rated construction for each transformer if multiple transformers are present.

FM Approved Transformer

Less-flammable liquid-filled transformers rated 5–10,000 kVA must be equipped with specific design and protection features to be FM approved or equivalent. Key characteristics of this protection system are fire properties of the liquid, the ability to mechanically withstand pressure generated by a low-level electrical fault and the ability of electrical protection to clear a fault before tank rupture. According to FM approval Standard 3990, the key protection features are as listed below. Refer to the FM standard for complete requirements:

- The transformer tank rupture strength shall be a minimum of 15 psi for rectangular and 20 psi for cylindrical tanks. All transformer tanks shall be designed to withstand a pressure of 7 psi without permanent distortion. The transformer tank shall be provided with a pressure relief device to vent internal over-pressures. The device must be capable of venting a minimum specified flow rate, based on the kVA as noted in **Table 14.1-38** Section 2.3.3 of the FM approval Standard 3990. Proper pressure venting coordinated with proper tank pressure withstand rating has proven highly effective in preventing tank rupture from overpressure due to internal fault currents below the trip rating of primary circuit current limiting fuses
- The transformer is filled with an FM Approved less-flammable fluid to reduce the probability of ignition to the liquid. Less-flammable fluids, also known as high fire point or fire-resistant liquids, are dielectric coolants that have a minimum fire point of 300 °C (572 °F) per the ASTM D92 Cleveland Open Cup test method

Note: For a listing of FM-approved less-flammable fluids, refer to Factory Mutual Research Approval Guide P7825.

- The primary circuit shall have overcurrent protection that limits the let-through current (I^2t) to a specified maximum value as listed in **Table 14.1-39** and in Section 2.3.5 of the FM approval Standard 3990. Current-limiting fusing and its functional equivalents are designed to interrupt a high current internal fault before the tank withstand pressure level is reached. If protection is designed to vent gas during operation, such as with expulsion fuses, this protection shall be located outside the transformer tank. Certain exceptions apply and permit expulsion fusing to be mounted in the tank if in series and properly coordinated with current limiting fusing
- The transformer shall have an additional nameplate with the FM approval mark with the following data: tank pressure rating, fuse part number, pressure relief device part number, and requirements particular to the type of installation Transformer manufacturers instructed to design and build transformers per the UL Classification Mark (refer to UL Classification Mark in 17.0-5) the utilized less-flammable fluid should be designed accordingly. If primary overcurrent protection is specified as integral to the transformer, transformer manufacturers should also comply. Otherwise, meeting FM Approval requirements will be the responsibility of the user
- For grounded wye secondary windings of 150 V or more and rated at 1000 or more nominal amperes, a notification tag shall be provided by the manufacturer, secured to the low voltage neutral bushing, advising that the transformer installation requires ground fault relay protection prior to energization (if not installed at time of manufacturing)
- Indoor units greater than 500 kVA and outdoor units greater than 2500 kVA shall be equipped with alarm contacts on the pressure relief device. Transformer above 2500 kVA in all locations shall be equipped with a rapid rise relay
- Three-phase pad-mounted and substation transformers shall be equipped with an oil level gauge. Additionally, all transformers rated 750 kVA or higher shall be equipped with a liquid temperature indicator and pressure-vacuum gauge
- Transformers shall be capable of maintaining rated basic lightning impulse insulation level (BIL) at a minimum tilt of 1.5° from vertical

Transformers will be supplied with appropriate pressure withstand, pressure relief and other devices noted above when FM Approval is specified. The required overcurrent protection may be supplied integral to the transformer or via switchgear feeding the transformer as noted above depending how it is specified by the user.

Additional FM Global Requirements Applying to All Indoor Transformers

Indoor installation requirements, according to FM loss prevention data (LPD) 5-4, consist of requirements for all transformer types and likely would apply to those who are FM insured or those choosing FM Approval as their means to comply with the listing restrictions of NEC 450.23 for less-flammable insulated transformers.

If transformers cannot be located outdoors, provide a detached dedicated building or room with location and construction safeguards as noted in **Table 14.1-1** and **Figure 14.1-9**.

Arrange transformer rooms for direct access only from outdoors or install transformer(s) in a detached building of the following construction:

- Dry-type, gas-insulated and FM approved or equivalent less-flammable liquid insulated transformers:
  - ❑ Liquid containment
  - ❑ Noncombustible building construction
- Non-FM Approved transformers with FM Approved transformer fluids:
  - ❑ Liquid containment
  - ❑ 1-hour fire-rated construction if no fire protection is provided, or
  - ❑ Noncombustible construction if fire protection (automatic sprinklers, FM Approved foam-water sprinklers, or FM Approved water mist) is also provided
- Transformers with no more than 100 gal (380 L) of non-approved fluids: 1-hour fire-rated construction
- Transformers with greater than 100 gal (380 L) of non-approved fluids:
  - ❑ 3-hour fire-rated construction.
  - ❑ If multiple transformers are present, also provide one of the following:
    - – 3-hour fire-rated subdivisions for each transformer
    - – Automatic sprinklers, FM approved foam-water
    - – FM approved water mist protection per Section 2.2.3

(Non-approved fluids generally applies to mineral oil.)

Table 14.1-38. FM and UL Pressure Relief Device Required Ratings

kVA Rating		Flow Rate SCFM at 15PSI (103 kPa)
Three-Phase	**Single-Phase**	
112.5 150 300	37.5 50 100	35 50 100
1000 2000 10,000	333 667 3333	350 700 5000

Note: For kVA ratings not listed, use next highest rating in table.

Table 14.1-39. FM and UL Maximum I^2t Let-Through Required Ratings

kVA Rating		Current Limiting Fusing	Other Protection
Three-Phase	**Single-Phase**		
45 75	15 25	500,000 500,000	700,000 800,000
112.5 150 225	37.5 50 75	550,000 600,000 650,000	900,000 1,000,000 1,200,000
300 500 750	100 167 250	750,000 900,000 1,100,000	1,400,000 1,900,000 2,200,000
1000 1500 2000	333 500 667	1,250,000 1,500,000 1,750,000	3,400,000 4,500,000 6,000,000
2500 3000 3750	833 1000 1250	2,000,000 2,250,000 2,500,000	7,500,000 9,000,000 11,000,000
5000 7500 10,000	1667 2500 3333	3,000,000 3,000,000 3,000,000	14,000,000 14,000,000 14,000,000

Note: For kVA ratings not listed, use next lowest rating in table.

DOE 2016 Requirements

This information details the minimum efficiencies required of distribution transformers rated 2500 kVA and below, as defined by the Department of Energy (DOE) Federal Regulation for Distribution Transformers.

This federal regulation requires all transformers rated 2500 kVA and below with a primary voltage of 35,000 V and below, and a low voltage of 600 V and below to meet the efficiency levels as stated below. This regulation affects all transformers in scope manufactured as of January 1, 2016. This regulation affects all applicable transformers installed in the U.S., regardless of domestic or foreign manufacturing.

Note: There are transformers exempt from DOE efficiency requirements. Contact Eaton with any questions.

Table 14.1-40. DOE 2016 Transformer Efficiencies Three-Phase Liquid-Filled Transformers

Three-Phase kVA	Efficiency at 50% Load	No-Load (Watts)	Load Loss at 100% (Watts)	Total Losses at 100% (Watts)	Total Losses at 50% Load (Watts)
300	99.27	730.8	2372.4	3103.2	1323.6
500	99.35	1083.6	3518.4	4602.0	1963.2
750	99.40	1500.0	4868.4	6368.4	2716.8
1000	99.43	1898.4	6163.2	8061.6	3439.2
1500	99.48	2596.8	8430.0	11,026.8	4704.0
2000	99.51	3261.6	10,588.8	13,850.4	5908.8
2500	99.53	3909.6	12,693.6	16,603.2	7083.6

Table 14.1-41. High-Voltage 15 kV and Below. Low Voltage 600 V and Below. Copper Conductor Windings. Losses in Watts. Three-Phase Dry-Type Unit Substation Transformers ①

VPI, 15 kV Primary 150 °C Temp. Rise				
kVA	**No Load (Watts)**	**Load Loss at 100% Load and 170 °C Ref. Temp. (Watts)**	**Total Losses at 100% Load and 170 °C (Watts)**	**46–95 kV BIL Total Losses at 50% Load and 75 °C Ref. Temp. per DOE (Watts)**
300 ②	950	3450	4400	1806
500 ②	1300	5650	6950	2551
750 ②	1600	8600	10,200	3329
1000 ②	1850	10,700	12,550	4032
1500 ②	2700	11,850	14,550	5287
2000 ②	2950	16,900	19,850	6441
2500 ②	4500	14,500	19,000	7419
3000	6200	26,100	32,300	N/A
3750	7100	33,400	40,500	N/A
5000	13,000	40,000	53,000	N/A
7500	18,500	45,000	63,500	N/A
10,000	23,500	55,000	78,500	N/A

① Losses offered are typical only, not guaranteed.
② Units must typically meet the new DOE efficiency guideline levels with noted losses complying with such.

Table 14.1-42. High-Voltage 15 kV and Below. Low Voltage 600 V and Below. Copper Conductor Windings. Losses in Watts. Three-Phase Dry-Type Unit Substation Transformers ③

Cast, 15 kV Primary 115 °C Temp. Rise				
kVA	**No Load (Watts)**	**Load Loss at 100% Load and 135 °C Ref. Temp. (Watts)**	**Total Losses at 100% Load and 135 °C (Watts)**	**46–95 kV BIL Total Losses at 50% Load and 75 °C Ref. Temp. per DOE (Watts)**
300 ④	950	3400	4350	1806
500 ④	1350	4450	5800	2551
750 ④	2050	4700	6750	3329
1000 ④	2350	7200	9550	4032
1500 ④	2900	12,200	15,100	5287
2000 ④	3150	13,200	16,350	6441
2500 ④	4350	16,150	20,500	7419
3000	7200	20,000	27,200	N/A
3750	8600	21,000	29,600	N/A
5000	13,500	30,000	43,500	N/A
7500	20,000	35,000	55,000	N/A
10,000	22,500	45,000	67,500	N/A

③ Losses offered are typical only, not guaranteed.
④ Units must typically meet the new DOE efficiency guideline levels with noted losses complying with such.

Table 14.1-43. Suggested Minimum Ratings (kV) for Metal Oxide Surge Arresters Located in Metal-Enclosed Switchgear

System Grounding	Nominal System Line-to-Line Voltage (kV)											
	2.4	4.16	4.8	7.2	12.0	12.47	13.2	13.8	14.4	22.9	24.9	34.5
Solidly grounded system	3	6	6	6	12	12	12	12	12	12	24	30
Low resistance grounded system	3	6	6	6	12	12	12	12	12	21	24	30
High resistance or ungrounded system	6	6	9	12	18	18	21	21	24	36	39	54

Note: Arrester rating is based on a 55°C maximum ambient temperature in the enclosure.

Table 14.1-44. Transformer Primary Fuse Applications

Rated Maximum System Voltage, kV	Fuse Type	Type Nomenclature	Amperes Symmetrical Interrupting Rating
2.75	Current limiting	CLE (striker pin type) CLE-750 CXN	63,000 40,000 50,000
	Expulsion	RBA200 RBA400/RBA800	19,000 37,500
5.5	Current limiting	CLE (striker pin type) CLE-750 CXN	63,000 40,000 50,000
	Expulsion	RBA200 RBA400/RBA800	19,000 37,500
8.3	Current limiting	CLE (striker pin type) CXN	63,000 50,000
	Expulsion	RBA200 RBA400/RBA800	19,000 37,500
14.4	Expulsion	HRBA400/HRBA800	34,800
15.5	Current limiting	CLE (striker pin type) CXN	63,000 50,000
	Expulsion	RBA200 RBA400/RBA800	14,400 29,400
25.8	Expulsion	RBA200 RBA400/RBA800	10,500 21,000
38	Expulsion	RBA200 RBA400/RBA800	6,900 16,800

To find the suggested minimum fuse size for transformer:

1. Calculate the transformer's base full load current rating by dividing the transformer base kVA by the nominal transformer voltage, then dividing this result by 1.732.
2. Multiply the result of Step 1 by 1.4 to determine the theoretical minimum recommended fuse continuous current rating.
3. Find the closest available fuse continuous current rating that is equal to or greater than this value.This is the suggested minimum recommended fuse size for the transformer's base kVA rating.

If the transformer has a fan rating, perform two calculations: 1.) self-cooled (as above), and 2.) fan-cooled, however in the later calculation, use the fan full load amperes and use a 1.2 multiplier instead of 1.4, as directed above. Select the fuse rating for each of the applications by selecting a fuse value equal to or greater than the calculated ampere values.

Usually, fan-cooled transformers require a higher rated primary fuse, and the higher rated fuse from the calculations should be selected. However, it is possible that the fuse selection process yields the same fuse rating for self-cooled and fan-cooled units; when that occurs, higher rated fuses are not required for fan-cooled units.

These application guidelines are subject to modification when specific factors such as transformer characteristics, other protective devices, coordination requirements and load variations may indicate a different ratio of fuse ampere rating to transformer full load current rating.

Caution: Primary fuses must not be relied upon for clearing secondary ground faults.

Table 14.1-45. Suggested Current Limiting Fuse Current Ratings for Self-Cooled 2.4–15.5 kV Transformer Applications (Check Compliance of Fuses to FM Requirements if Installation Must Comply with FM)

System Nominal kV	2.4		4.16		4.8		7.2		12.0		13.2		13.8		14.4		Percent Impedance (% Z)
Fuses Max. kV	2.75		5.5		5.5		8.3		15.5		15.5		15.5		15.5		
Transformer kVA Rating Self-Cooled	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	
112.5	27.1	40E	15.6	25E	13.5	20E	9.0	15E	5.4	10E	4.9	10E	4.7	10E	4.5	10E	2.25
150	36.1	50E	20.8	30E	18.0	25E	12.0	20E	7.2	10E	6.6	10E	6.3	10E	6.0	10E	3.0
225	54.1	80E	31.2	50E	27.1	50E	18.0	25E	10.8	15E	9.8	15E	9.4	15E	9.0	15E	3.0
300	72.2	100E	41.6	80E	36.1	65E	24.1	40E	14.4	20E	13.1	20E	12.6	20E	12.0	20E	5.0
500	120.3	175E	69.4	125E	60.1	100E	40.1	65E	24.1	40E	21.9	30E	20.9	30E	20.0	30E	5.0
750	180.4	250E	104.1	150E	90.2	150E	60.1	100E	36.1	65E	32.8	65E	31.4	65E	30.1	65E	5.75
1000	240.6	350E	138.8	200E	120.3	175E	80.2	125E	48.1	80E	43.7	80E	41.8	80E	40.1	80E	5.75
1500	360.8	600E ①	208.2	300E	180.4	250E	120.3	175E	72.2	100E	65.6	100E	62.8	100E	60.1	100E	5.75
2000	481.1	750E ①	277.6	400E	240.6	350E	160.4	250E	96.2	150E	87.5	125E	83.7	125E	80.2	125E	5.75
2500	601.4	1100E ①	347.0	600E	300.7	400E	200.5	300E	120.3	175E	109.3	150E	104.6	150E	100.2	150E	5.75

① Fuse ratings represent the smallest fuse possible that will withstand transformer inrush (12 x FLA for 0.1 second and 25 x FLA for 0.01 second) and be able to handle temporary overloads (133% of FLA).

Table 14.1-46. Suggested Minimum RBA Expulsion Fuse Current Ratings for Self-Cooled 2.4–15.5 kV Power Transformer Applications ②

System Nominal kV	2.4		4.16		4.8		7.2		12.0		13.2		13.8		14.4		Percent Impedance (% Z)
Fuses Max. kV	8.3		8.3		8.3		8.3		15.5		15.5		15.5		15.5		
Transformer kVA Rating Self-Cooled	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	
Three-Phase Transformers																	
112.5	27	40E	16	25E	14	20E	9	15E	5	10E	5	7E	5	7E	5	7E	2.25
150	36	50E	21	30E	18	25E	12	20E	7	10E	7	10E	6	10E	6	10E	3.0
225	54	80E	31	50E	27	40E	18	25E	11	15E	10	15E	9	15E	9	15E	3.0
300	72	100E	42	65E	36	50E	24	40E	14	20E	13	20E	13	20E	12	20E	5.0
500	120	200E	69	100E	60	100E	40	65E	24	40E	22	30E	21	30E	20	30E	5.0
750	180	250E	104	150E	90	125E	60	100E	36	50E	33	50E	31	50E	30	50E	5.75
1000	241	400E	139	200E	120	200E	80	125E	48	80E	44	65E	42	65E	40	65E	5.75
1500	361	540E ③	208	300E	180	250E	120	200E	72	100E	66	100E	63	100E	60	65E	5.75
2000	481	720E ④	278	400E	241	400E	160	250E	96	150E	87	125E	84	125E	80	125E	5.75
2500	601	—	347	540E ③	301	450E ⑤	200	300E	120	200E	109	150E	105	150E	100	150E	5.75
3750	—	—	—	—	—	—	—	—	180	250E	164	250E	157	250E	150	250E	—

② Fuse ratings represent the smallest fuse possible that will withstand transformer inrush (12XFLA for 0.1 second and 25XFLA for .01 second) and be able to handle temporary overloads (133% of FLA).
③ Two 300 E-Ampere fuse refills used in parallel with 10% derating factor.
④ Two 400 E-Ampere fuse refills used in parallel with 10% derating factor.
⑤ Two 250 E-Ampere fuse refills used in parallel with 10% derating factor.

Table 14.1-47. Suggested Minimum RBA Expulsion Fuse Current Ratings for Self-Cooled 25.8–38.0 kV Power Transformer Applications

System Nominal kV	22.9		23.9		24.9		34.5	
Fuses Maximum kV	25.8		25.8		25.8		38.0	
Transformer kVA Rating Self-Cooled	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E	Full Load Current Amps	Fuse Rating Amps E
Three-Phase Transformers								
750	19	30E	18	25E	17	25E	13	20E
1000	25	40E	24	40E	23	40E	17	25E
1500	38	65E	36	50E	34	50E	25	40E
2000	50	80E	48	80E	46	65E	33	50E
2500	63	100E	60	100E	58	80E	42	65E
3750	95	150E	91	150E	87	125E	63	100E

Table 14.1-48. Type MVS Primary Switch, Standard Ratings

Rated Maximum Voltage, kV	Impulse Withstand, kV (BIL)	Rated Current Continuous and Load Break, Amperes	Rated Fault-Close and Momentary Current, kA Asym.
5	60	600	40
5	60	600	64
5	60	1200	40
5	60	1200	64
15	95	600	40
15	95	1200	40
15	95	600	64
15	95	1200	64
27	125	600	40
27	125	600	64
38	150	600	40

Table 14.1-49. Available Vacuum Breaker Ratings, MSB Switchgear

Rated Control Voltage	Spring Charge Motor ①		Close or Trip Amperes	Voltage Range	
	Run Amperes	Time Seconds		Close	Trip
48 Vdc	4.0	5	5.2	38–56	28–56
125 Vdc	3.0	5	3.6	100–140	70–140
250 Vdc	2.0	5	1.8	200–280	140–180
120 Vac	3.0	5	3.6	104–127	104–127
240 Vac	2.0	5	1.8	208–254	208–254

① Inrush current is four times running amperes.

Transformer Technical Data

Transformer Standards

Dimensions and weights as listed in the tables are based on the following:

- Standard base kVA ratings:
  300–500–750–1000–1500–2000–2500–3000–3750
- Three-phase, 60 Hz, two windings
- Standard temperature rise (see tables) above ambient air temperature of 40 °C (104 °F) maximum and 30 °C (86 °F) average in any 24-hour period
- Maximum altitude of 3300 ft (1006 m) above sea level for full rating
  - VPI altitude derating is 0.3% per 100 m on the AA rating and 0.5% per 100 m on the FA rating
  - Liquid-filled transformer derating is 0.4% per 100 m above 1000 m
- Standard high voltages:
  2400–4160–4800–6900–7200–12000–12470–13200–13800–20800–22900–34500, delta connected only
- Standard high voltage taps:
  Two approximately 2-1/2% full capacity above and two below rated voltage
- Standard low voltages (no taps):
  208Y/120 (2000 kVA maximum)
  240 delta (2000 kVA maximum)
  480 delta (all ratings)
  480Y/277 (all ratings)

Note: 600Y and 600 delta also available.

- Aluminum winding conductors
- No series-parallel or delta-wye terminal boards
- Standard accessories and losses
- Standard surface preparation, finish processes, materials and colors
- Standard tests in accordance with IEEE standard test code (see below)
- HV and LV basic impulse levels (BIL), impedance and sound levels in line with the following tables

IEEE Standard Tests

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

Table 14.1-50. Liquid-Filled Transformer Continuous kVA for Different Base Temperature Rise Ratings

Temperature Rise, °C, Base Rating, OA	Transformer Base, kVA	Continuous kVA Multiplier		
		65 °C OA	55 °C FA	65 °C FA
55	Below 2500 2500 and larger	1.120 1.120	1.150 1.250	1.290 1.400
65	Below 2500 2500 and larger	1.000 1.000	N/A N/A	1.150 1.250

Table 14.1-51. Dry-Type (Conventional VPE and VPI) Transformer Continuous kVA for Different Base Temperature Rise Ratings

Temperature Rise, °C, Base Rating, AA	Continuous kVA Multiplier					
	80 °C AA	115 °C AA	150 °C AA	80 °C FA	115 °C FA	150 °C FA
80 115 150	1.000 N/A N/A	1.150 1.00 N/A	1.330 1.150 1.00	1.330 N/A N/A	1.500 1.330 N/A	1.800 1.500 1.330

Table 14.1-52. Dry-Type Cast Coil, Dura-Cast, and RESIBLOC Transformer Continuous kVA for Different Base Temperature Rise Ratings

Temperature Rise, °C, Base Rating, AA	Type	Continuous kVA Multiplier					
		80 °C AA	100 °C AA	115 °C AA	80 °C FA	100 °C FA	115 °C FA
80 100 115	Cast Coil or Dura-Cast	1.000 N/A N/A	1.120 1.000 N/A	1.170 1.050 1.000	1.330 N/A N/A	1.450 1.330 N/A	1.500 1.380 1.330
80	RESIBLOC	1.000	N/A	N/A	1.330	N/A	N/A

Table 14.1-53. Three-Phase, Single Temperature kVA Ratings

Three-Phase kVA Self-Cooled and Forced-Air Cooled with 75 °C Temperature Rise		
75 °C Rise KNAN		75 °C Rise KNAN/KNAF
500 750 1000 1500 2000	+15%	— 863 1150 1725 2300
2500 3750 5000 7500 10,000	+25%	3125 4688 6250 9375 12,500
12,000	+33%	16,000

Table 14.1-54. Three-Phase, Dual or Triple Temperature kVA Ratings ①

Three-Phase kVA Self-Cooled and Forced-Air Cooled with PEAK Triple Rated 55 °C/75 °C Temperature Rise							
55 °C Rise KNAN		65 °C Rise KNAN		75 °C Rise KNAN	55 °C Rise KNAN/KNAF	65 °C Rise KNAN/KNAF	75 °C Rise KNAN/KNAF
500 750 1000	+12%	560 840 1120	+9%	610 916 1221	— 863 1150	— 966 1288	— 1053 1404
1500 2000 2500		1680 2240 2800		1831 2442 3052	1725 2300 3125	1932 2576 3500	2106 2808 3815
3750 5000 7500		4200 5600 8400		4578 6104 9156	4688 6250 9375	5250 7000 10,500	5123 7630 11,445
10,000 12,000		11,200 13,440		12,208 14,650	12,500 16,000	14,900 17,920	15,260 16,533

① If 65 °C Rise is the base rating, the 75 °C slash rating will increase the kVA capacity by 12%.

Table 14.1-55. Secondary Short-Circuit Capacity of Typical Power Transformers

Transformer Rating Three-Phase kVA and Impedance %	Maximum Short-Circuit kVA Available from Primary System	208V, Three-Phase				240V, Three-Phase				480V, Three-Phase				600V, Three-Phase			
		Rated Load Continuous Current, Amps	Short-Circuit Current rms (Symmetrical Amperes)			Rated Load Continuous Current, Amps	Short-Circuit Current rms (Symmetrical Amperes)			Rated Load Continuous Current, Amps	Short-Circuit Current rms (Symmetrical Amperes)			Rated Load Continuous Current, Amps	Short-Circuit Current rms (Symmetrical Amperes)		
			Transformer Alone ①	50% Motor Load ②	Combined		Transformer Alone ①	100% Motor Load ②	Combined		Transformer Alone ①	100% Motor Load ②	Combined		Transformer Alone ①	100% Motor Load ②	Combined
300 5%	50,000 100,000 150,000 250,000 500,000 Unlimited	834	14,900 15,700 16,000 16,300 16,500 16,700	1700	16,600 17,400 17,700 18,000 18,200 18,400	722	12,90 13,60 13,90 14,10 14,300 14,400	2900	15,800 16,500 16,800 17,000 17,200 17,300	361	6,400 6,800 6,900 7,000 7,100 7,200	1400	7,800 8,200 8,300 8,400 8,500 8,600	289	5,200 5,500 5,600 5,600 5,700 5,800	1200	6,400 6,700 6,800 6,800 6,900 7,000
500 5%	50,000 100,000 150,000 250,000 500,000 Unlimited	1388	21,300 25,200 26,000 26,700 27,200 27,800	2800	25,900 28,000 28,800 29,500 30,000 30,600	1203	20,000 21,900 22,500 23,100 23,600 24,100	4800	24,800 26,700 27,300 27,900 28,400 28,900	601	10,000 10,900 11,300 11,600 11,800 12,000	2400	12,400 13,300 13,700 14,000 14,200 14,400	481	8,000 8,700 9,000 9,300 9,400 9,600	1900	9,900 10,600 10,900 11,200 11,300 11,500
750 5.75%	50,000 100,000 150,000 250,000 500,000 Unlimited	2080	28,700 32,000 33,300 34,400 35,200 36,200	4200	32,900 36,200 37,500 38,600 39,400 40,400	1804	24,900 27,800 28,900 29,800 30,600 31,400	7200	32,100 35,000 36,100 37,000 37,800 38,600	902	12,400 13,900 14,400 14,900 15,300 15,700	3600	16,000 17,500 18,000 18,500 18,900 19,300	722	10,000 11,100 11,600 11,900 12,200 12,600	2900	12,900 14,000 14,500 14,800 15,100 15,500
1000 5.75%	50,000 100,000 150,000 250,000 500,000 Unlimited	2776	35,900 41,200 43,300 45,200 46,700 48,300	5600	41,500 46,800 48,900 50,800 52,300 53,900	2406	31,000 35,600 37,500 39,100 40,400 41,800	6900	40,600 45,200 47,100 48,700 50,000 51,400	1203	15,500 17,800 18,700 19,600 20,200 20,900	4800	20,300 22,600 23,500 24,400 25,000 25,700	962	12,400 14,300 15,000 15,600 16,200 16,700	3900	16,300 18,200 18,900 19,500 20,100 20,600
1500 5.75%	50,000 100,000 150,000 250,000 500,000 Unlimited	4164	47,600 57,500 61,800 65,600 68,800 72,500	8300	55,900 65,800 70,100 73,900 77,100 80,800	3609	41,200 49,800 53,500 56,800 59,600 62,800	14,400	55,600 64,200 57,900 71,200 74,000 77,200	1804	20,600 24,900 26,700 28,400 29,800 31,400	7200	27,800 32,100 33,900 35,600 37,000 38,600	1444	16,500 20,000 21,400 22,700 23,900 25,100	5800	22,300 25,800 27,200 28,500 29,700 30,900
2000 5.75%	50,000 100,000 150,000 250,000 500,000 Unlimited	—	— — — — — —	—	— — — — — —	—	— — — — — —	—	— — — — — —	2406	24,700 31,000 34,000 36,700 39,100 41,800	9600	34,300 40,600 43,600 46,300 48,700 51,400	1924	19,700 24,800 27,200 29,400 31,300 33,500	7800	27,500 32,600 35,000 37,200 39,100 41,300
2500 5.75%	50,000 100,000 150,000 250,000 500,000 Unlimited	—	— — — — — —	—	— — — — — —	—	— — — — — —	—	— — — — — —	3008	28,000 36,500 40,500 44,600 48,100 52,300	12,000	40,000 48,500 52,500 56,600 60,100 64,300	2405	22,400 29,200 32,400 35,600 38,500 41,800	9600	32,000 38,800 42,000 45,200 48,100 51,400
3000 5.75%	50,000 100,000 150,000 250,000 500,000 Unlimited	—	— — — — — —	—	— — — — — —	—	— — — — — —	—	— — — — — —	3609	30,700 41,200 46,600 51,900 56,800 62,800	14,000	44,700 55,200 60,600 65,900 70,800 76,800	2886	24,600 33,000 37,300 41,500 45,500 50,200	11,500	36,100 44,500 48,800 53,000 57,000 61,700
3750 5.75%	50,000 100,000 150,000 250,000 500,000 Unlimited	—	— — — — — —	—	— — — — — —	—	— — — — — —	—	— — — — — —	4511	34,000 47,500 54,700 62,200 69,400 78,500	18,000	52,000 65,500 72,700 80,200 87,400 96,500	3608	27,200 38,000 43,700 49,800 55,500 62,800	14,400	41,600 52,400 58,100 64,200 69,900 77,200

① Short-circuit capacity values shown correspond to kVA and impedances shown in this table. For impedances other than these, short-circuit currents are inversely proportional to impedance.

② The motor's short-circuit current contributions are computed on the basis of motor characteristics that will give four times normal current. For 208 V, 50% motor load is assumed while for other voltages 100% motor load is assumed. For other percentages, the motor short-circuit current will be in direct proportion.

Table 14.1-56. IEEE Standard Insulation Levels—kV BIL

High-Voltage Rating	Transformer					
	Liquid-Filled		Ventilated Dry		Cast Coil	
	HV	LV ①	HV	LV ①	HV	LV ①
2400 4160 4800	45 60 60	30 30 30	20 30 30	10 10 10	20 30 30	10 10 10
6900 7200 12,000	75 75 95	30 30 30	45 45 60	10 10 10	45 45 60	10 10 10
12,470 13,200 13,800	95 95 95	30 30 30	60 60 60	10 10 10	60 60 60	10 10 10
22,900 34,400	125 150	30 30	110 150	10 10	110 150	10 10

① 600 V maximum.
Note: Increased BIL option is available.

Table 14.1-57. Standard Guaranteed Sound Levels—Decibels

Maximum Base kVA (Self-Cooled)	Liquid-Filled Transformer		Ventilated Dry and Cast Coil Transformer	
	OA	FA	AA	FA
300 500 750	55 56 58	— 67 67	55 60 64	67 67 67
1000 1500 2000	58 60 61	67 67 67	64 65 66	67 68 69
2500 3000 3750	62 63 64	67 67 67	68 68 70	71 71 73

Table 14.1-58. Impedances (±7-1/2% Tolerance) ②

kVA	Liquid-Filled Transformer	Ventilated Dry and Cast Coil Transformer
300 500 750	5.0% 5.0% 5.75%	5.75% 5.75% 5.75%
1000 1500 2000	5.75% 5.75% 5.75%	5.75% 5.75% 5.75%
2500 3000 3750	5.75% 5.75% 5.75%	5.75% 5.75% 5.75%

② Optional impedance values are available up to 8.0%. Contact Eaton for more information.

Table 14.1-59. De-Rating Factors for Elevated Altitudes

Altitude (FT)	kVA Correction		BIL Correction
	VPI (AA)	Forced Air (FA)	
3300 4000 5000	1.00 0.994 0.985	1.00 0.989 0.974	1.00 0.98 0.95
6000 7000 8000	0.975 0.966 0.957	0.959 0.944 0.929	0.92 0.89 0.86
9000 10,000 11,000	0.948 0.939 0.930	0.914 0.898 0.883	0.83 0.80 0.77
12,000 13,000 14,000 15,000	0.921 0.912 0.903 0.894	0.868 0.853 0.838 0.823	0.75 0.70 0.70 0.67

Note: 3.28 ft = 1 meter

Table 14.1-60. Transformer kVA Ratings, Three-Phase

In addition to their self-cooled (AA or OA) kVA ratings, Eaton's standard secondary unit substation transformers of liquid-filled and ventilated dry-types are designed for continuous operation at the following supplementary self-cooled and fan-cooled (FA) kVA ratings:

Liquid-Filled

65 °C Rise		55/65 °C Rise			
OA	FA	OA 55 °C	OA 65 °C	FA 55 °C	FA 65 °C
300 500 750	N/A N/A 862	300 500 750	336 560 840	N/A N/A 862	N/A N/A 966
1000 1500 2000	1150 1725 2300	1000 1500 2000	1120 1680 2240	1150 1725 2300	1288 1932 2576
2500 3000 3750	3125 3750 4690	2500 3000 3750	2800 3360 4200	3125 3750 4690	3500 4200 5250

Ventilated Dry-Type

150 °C Rise		115/150 °C Rise		
AA	FA	AA 115 °C	AA 150 °C	FA 150 °C
300 500 750	400 667 1000	300 500 750	345 575 863	450 750 1125
1000 1500 2000	1333 2000 2667	1000 1500 2000	1150 1725 2300	1500 2250 3000
2500	3333	2500	2875	3750

80/115 °C Rise			80/150 °C Rise		
AA 80 °C	AA 115 °C	FA 115 °C	AA 80 °C	AA 150 °C	FA 150 °C
300 500 750	345 575 863	450 750 1125	300 500 750	399 665 997	540 900 1350
1000 1500 2000	1150 1725 2300	1500 2250 3000	1000 1500 2000	1330 1995 2660	1800 2700 3600
2500 3000 3750	2875 3450 4313	3750 4500 5625	2500 3000 3750	3325 3990 4987	4500 5400 6750

Cast Coil

80/115 °C Rise		
AA 80 °C	AA 115 °C	FA 115 °C
300 500 750	351 585 877	450 750 1125
1000 1500 2000	1170 1755 2340	1500 2250 3000
2500 3000 3750	2925 3510 4387	3750 4500 5625

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