

Transformers – Dry & Liquid Filled

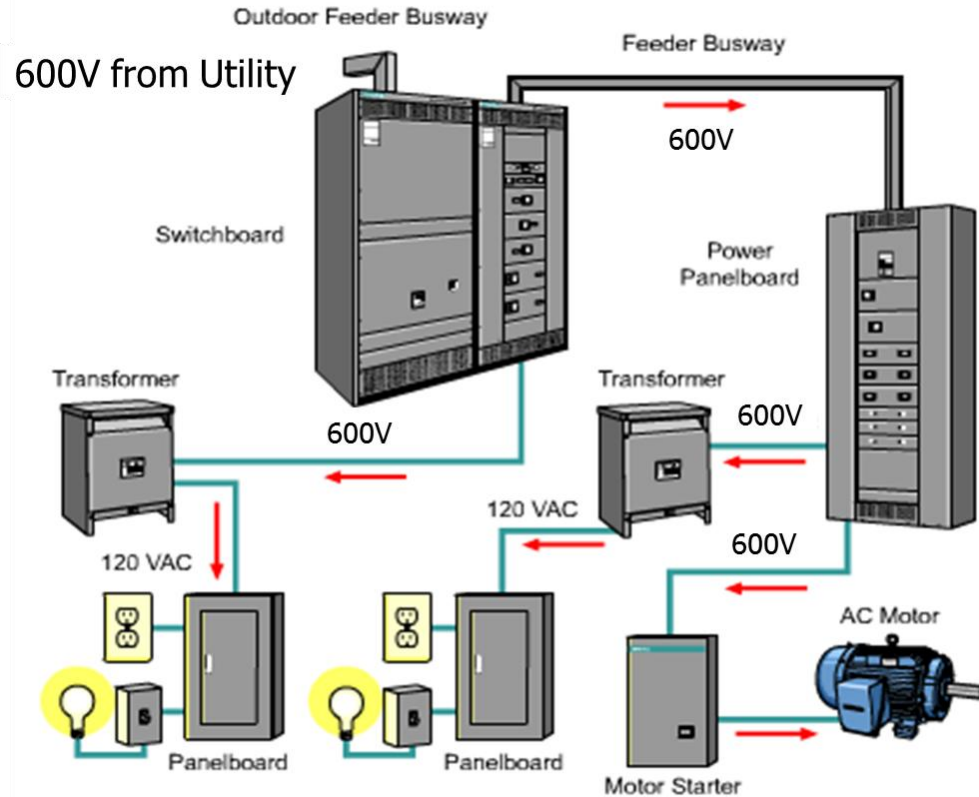
Milad Tannous E.I.T.

Applications Engineering

Spectrum Power Systems Inc.



Why Transformers



STI

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Cambridge
ON, N3H 4R7

Tel: 519-653-1847

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General Purpose Transformers

K-Rated Transformers

Harmonic Mitigation Transformers

UPS System's Transformers

Auto & Drive Isolation Transformers

Power Transformers

Building Better Transformers

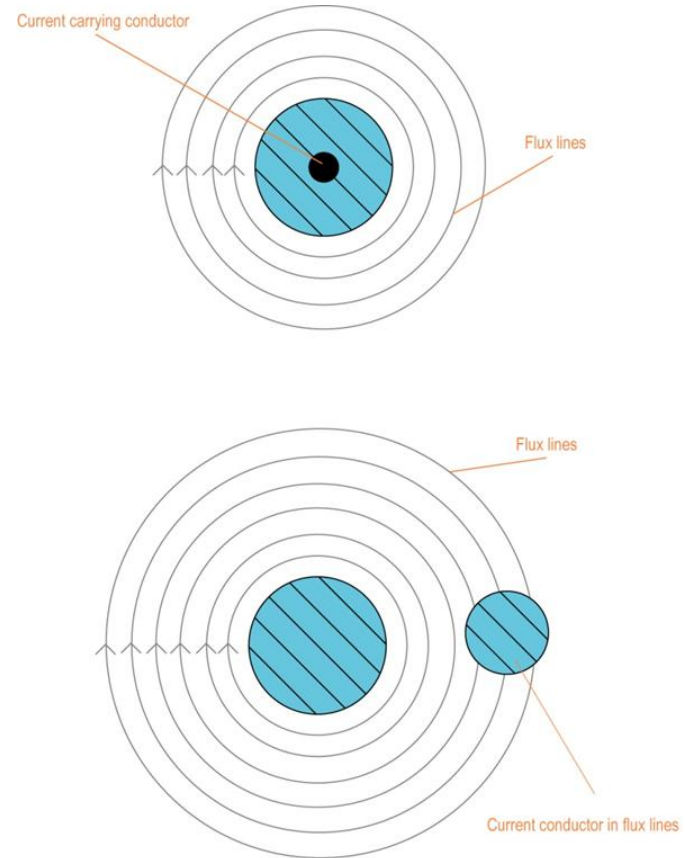
Product Scope

- Low Voltage
 - ▣ Any kVA any type
- Medium Voltage
 - ▣ Up to 27.6 kV
 - ▣ Up to 3000 kVA
 - With fans 4000 kVA



Transformer Basics

A transformer consists of a pair of windings primary and secondary, linked by a magnetic circuit or core.



Transformer Basics

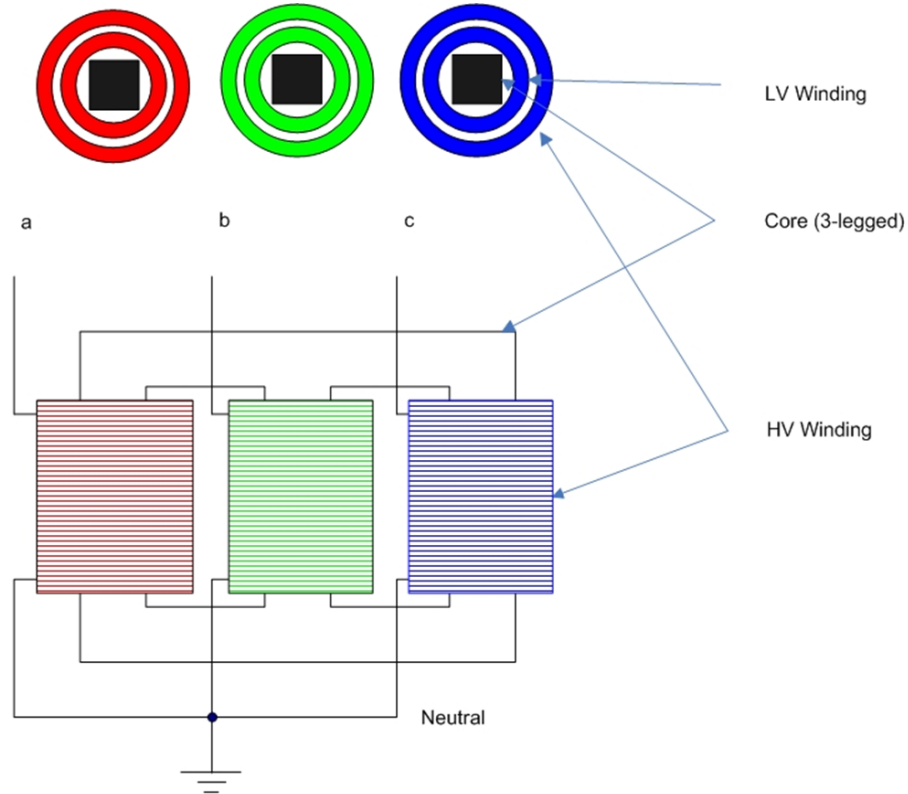
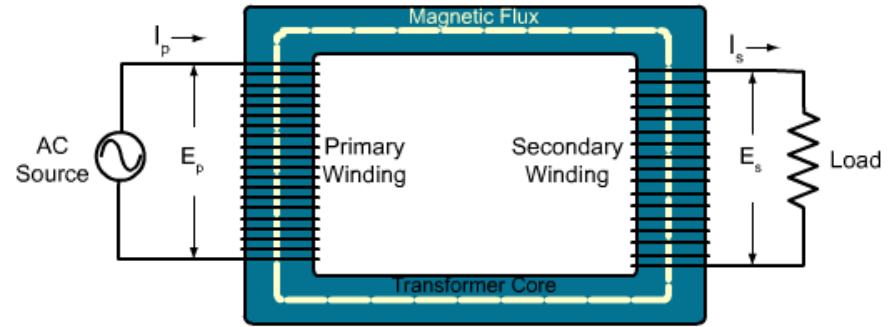


Fig – B: Three Phase Transformer with Top View

Transformer Basics

A transformer consists of a pair of windings primary and secondary, linked by a magnetic circuit or core.



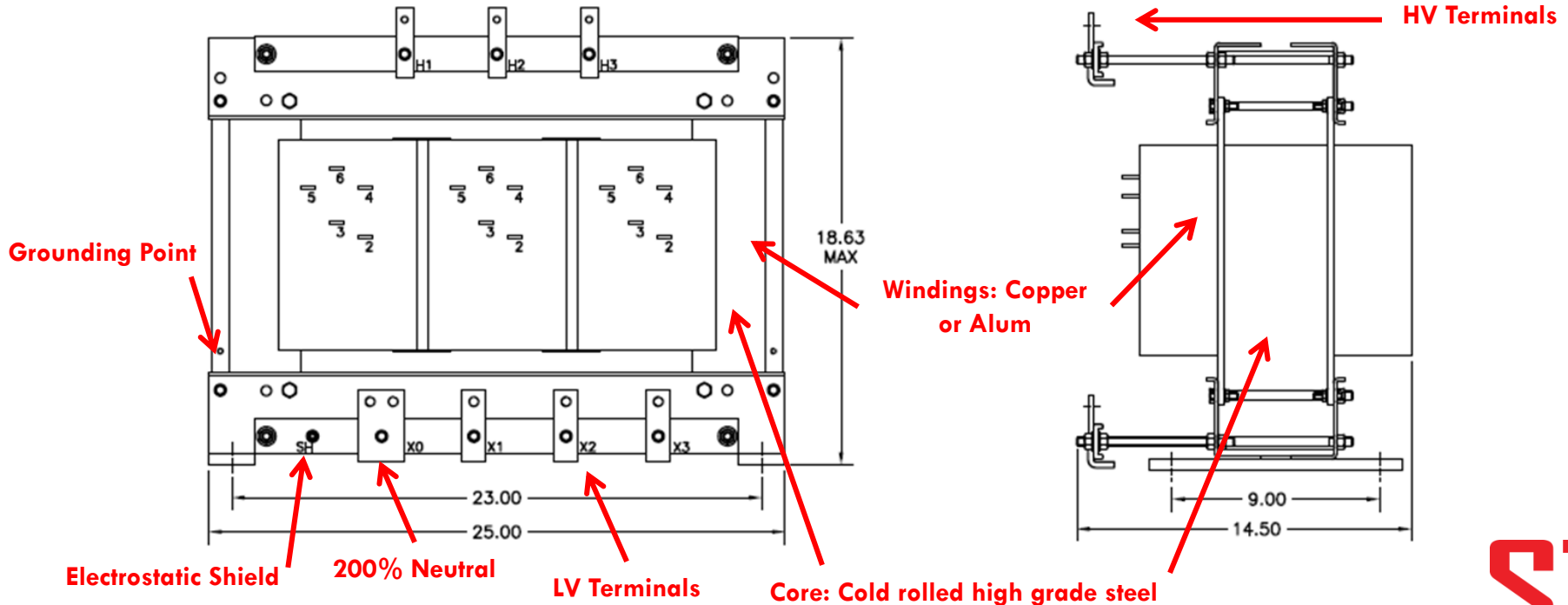
E_p = Primary Voltage
 I_p = Primary Current

E_s = Secondary Voltage
 I_s = Secondary Current

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

Transformer Basics

- A transformer consists of a pair of windings primary and secondary, linked by a magnetic circuit or core.



Transformer Basics

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Core: Cold rolled high grade steel

**Windings: Copper or Alum.
Windings can be
rectangular or round.**

Core and Coil Assemblies – Multi Legged Cores

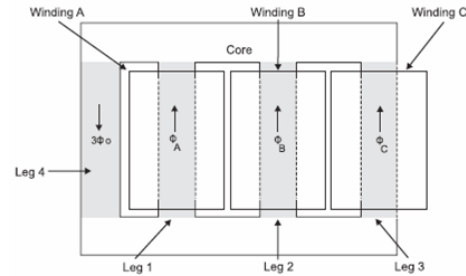
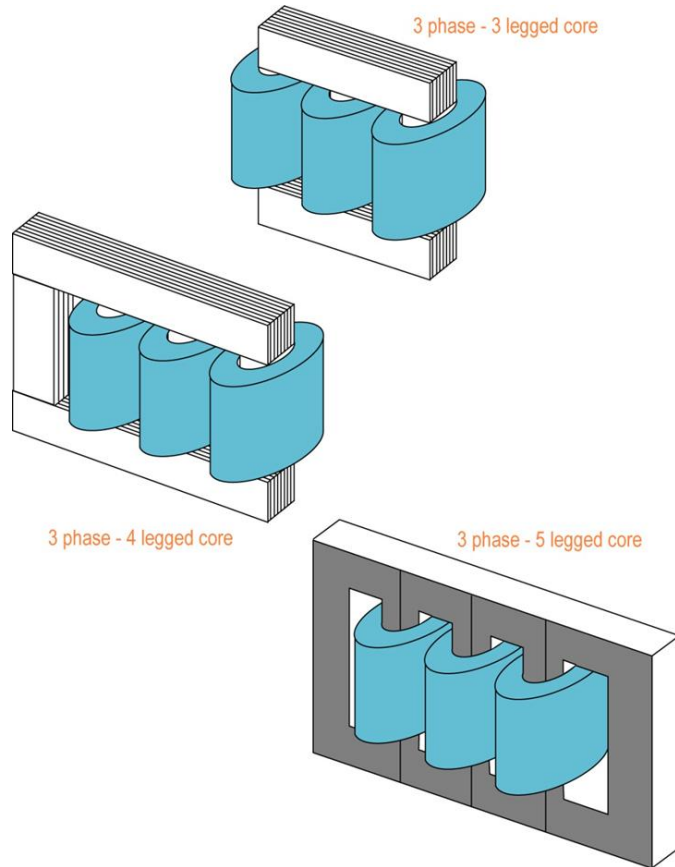
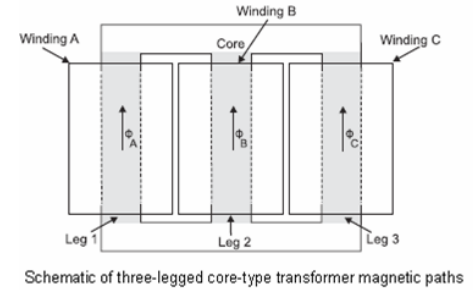


Fig. 8 Schematic of four-legged core-type transformer magnetic paths



Schematic of three-legged core-type transformer magnetic paths

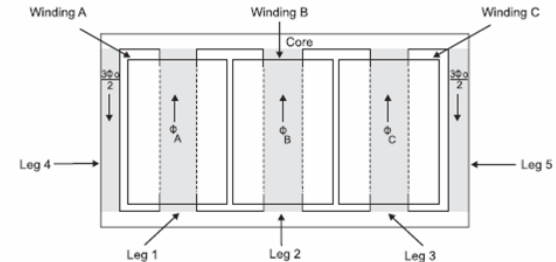


Fig. 10 Schematic of five-legged core-type transformer magnetic paths

How long does a transformer last?

- 10 – 20 years
- 20 – 25 years
- 25 – 30 years
- 30 – 40 years
- 40 – 50 years
- 50 years plus

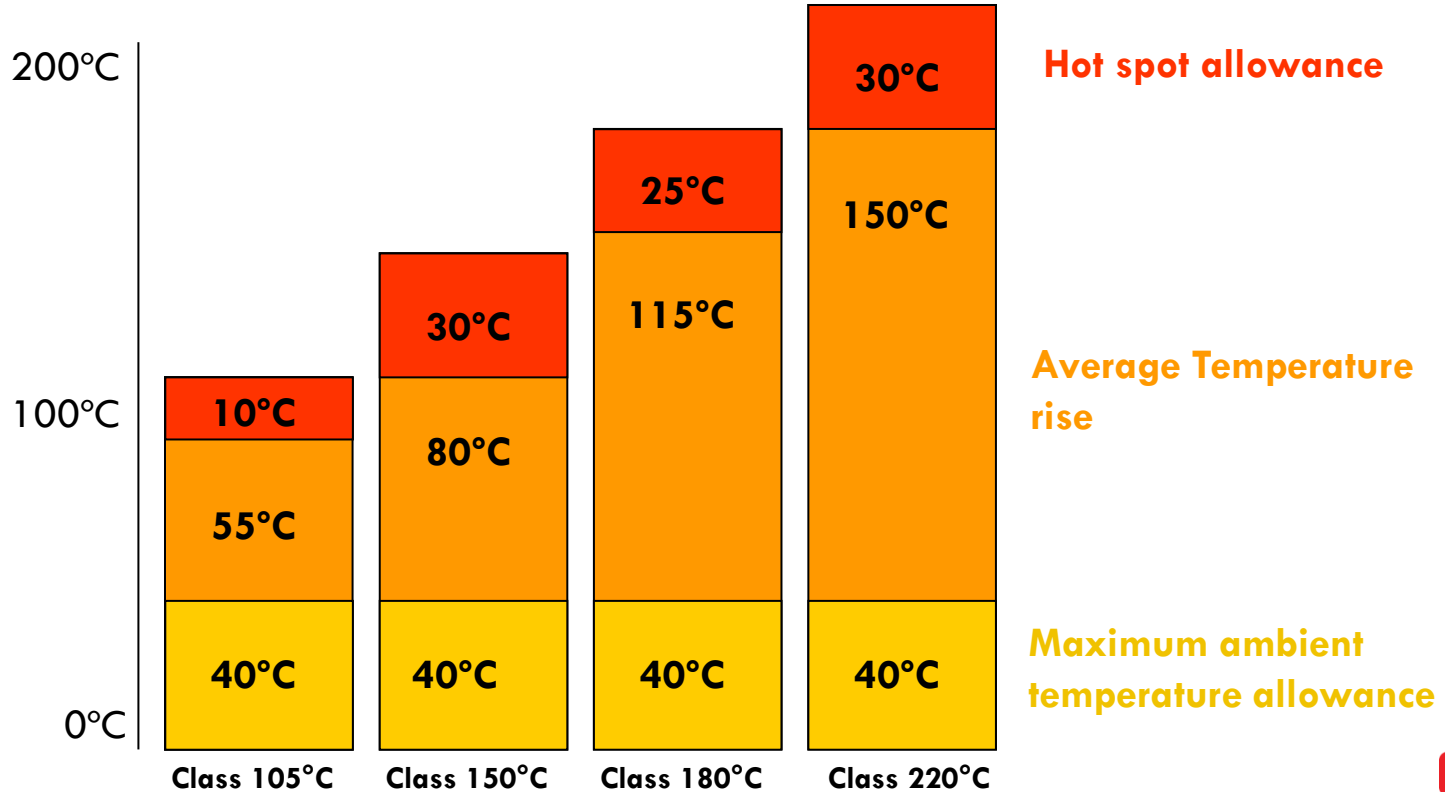
Why does a transformer fail?

- Over voltage
- Over current

Insulation



Insulation Class and Temp Rise



Temperature Rise

- Standard temp rise is 150 Deg. C.
- 115 and 80 Deg. C. rise units are available. These units will also have a continuous overload capacity of 15% for 115 Deg. C rise units and 30% for 80 Deg. C. rise units when operate at 150 Deg. C. rise.
- Since the insulation system is rated 220 Deg. C., this overload operation will not reduce the normal life expectancy of the transformers.
- Since operating in an overload condition results in higher temperatures and higher losses, the efficiency will decrease under these conditions.

Transformer Standards

Design, manufacture and test the dry type transformers in accordance with good industry practices and in accordance with the following standards:

- CSA C9
- CSA C22.2 No. 47
- CSA C802.00
- NEMA TP1

Transformer Impedance

- Transformation between primary and secondary is not perfect
- Not all of the flux produced by the secondary windings links the secondary
- The transformer is said to possess leakage reactance
- The combination of resistance and reactance is expressed in practical terms as impedance
- Normal method of expressing transformer impedance is as a % voltage drop in the transformer at full load current.

Percent Impedance Voltage Drop

- Inherent resistance and reactance in a transformer
- The transformer impedance assists in determining transformer contribution to the available fault current at the secondary terminations of the transformer.
- Important for over-current coordination and selecting secondary over-current protection.

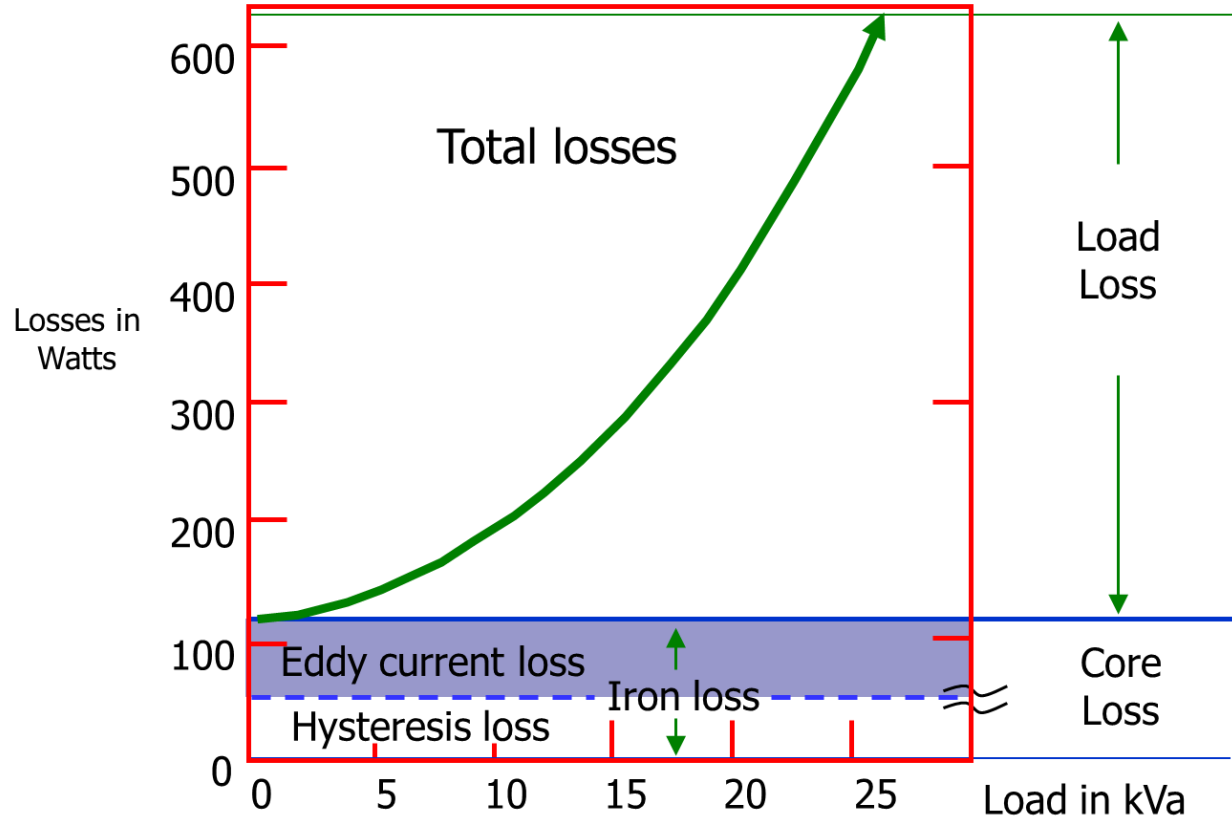
Fault Current

- ❑ Calculating Maximum Available Fault Current on Transformer Secondary
- ❑ Full Load Current (I) \div %IZ
- ❑ Example
 - ❑ 3 \emptyset Transformer Secondary Current:
 - ❑ $I = 500 \text{ kVA} \div .480 \text{ kV} \div 1.73 = 602\text{A}$
 - ❑ $I_Z = 4.0\%$
- ❑ Maximum available fault current
 $= 602 \text{ Amps} \div .04 = 15,050 \text{ Amps}$

Regulation

- When a transformer is energized with no load, the secondary voltage will be exactly the primary voltage divided by the turns ratio (N_P/N_S).
- When the transformer is loaded, the secondary voltage will be diminished by an amount determined by the impedance and the power factor of the load. This change in voltage is called regulation and is defined as the rise in voltage when the load is removed.
- % regulation can be specified to be a certain number at a certain power factor, usually 1.0 or 0.8 and is always a positive number.

Transformer Losses



Efficiency

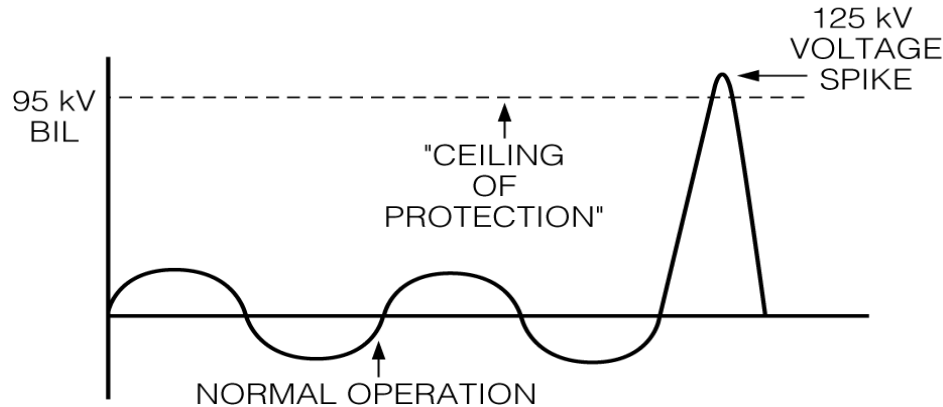
- As with any other energy conversion device, the efficiency of a transformer is the ratio of energy delivered to the load divided by the total energy drawn from the source.
- Transformer efficiency in Canada is mandated by CSA Standard 802

CSA vs. DOE Efficiencies

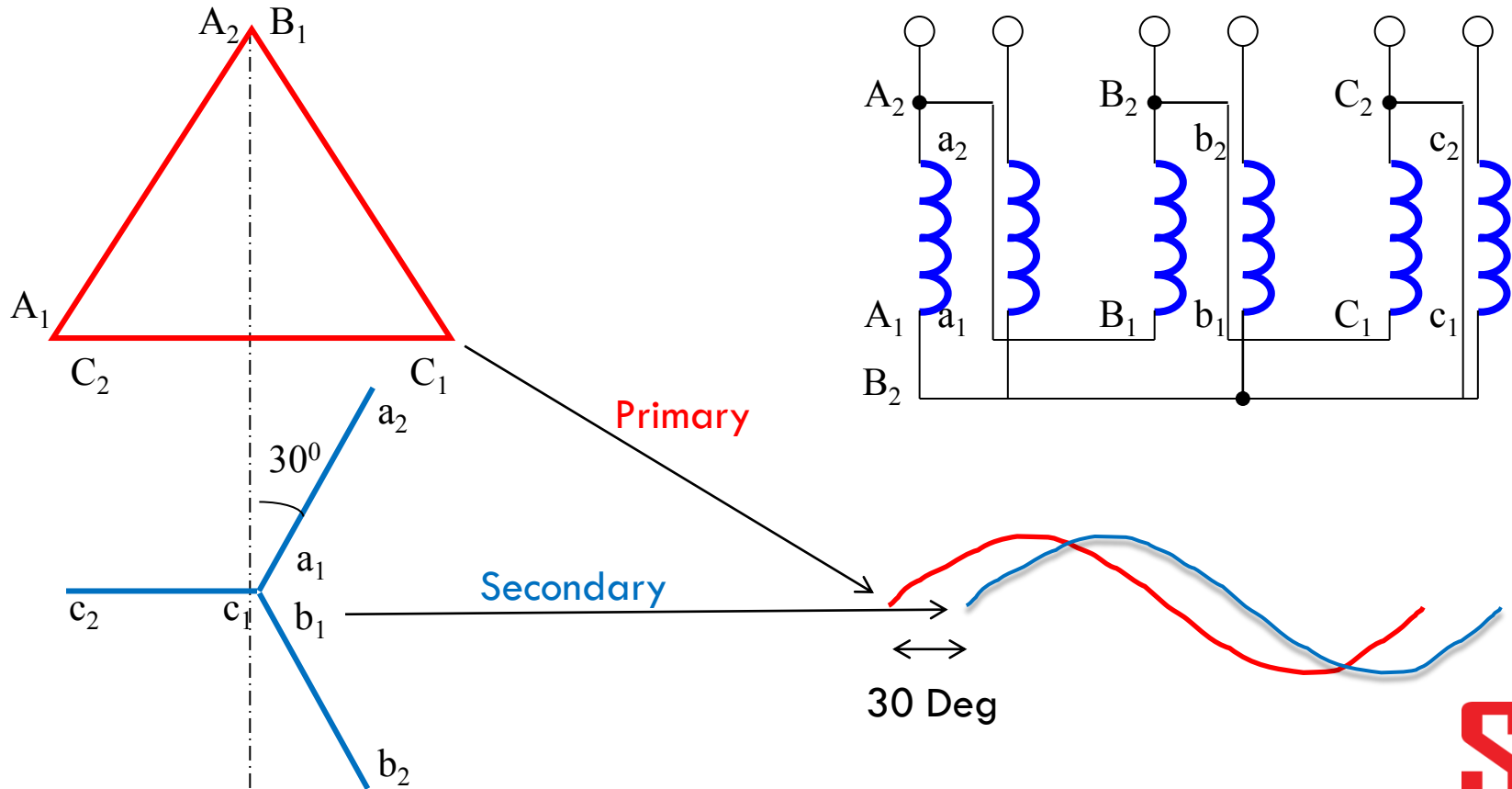
kVA	DOE 10 CFR Part 431	CSA C802.1-00
15	98.36	97.89
30	98.62	98.20
45	98.76	98.41
75	98.91	98.63
112.5	99.01	
150	99.08	98.84
225	99.17	98.94
300	99.23	98.94
500	99.25	99.05
750	99.32	99.15
1000	99.36	99.15
1500	99.42	99.37
2000	99.46	99.37
2500	99.49	99.37

BIL – Surge Withstand Rating

- Electrical distribution systems are subject to lightning surges.
- The Basic Impulse Level (BIL) of the transformer measures its ability to withstand these surges.

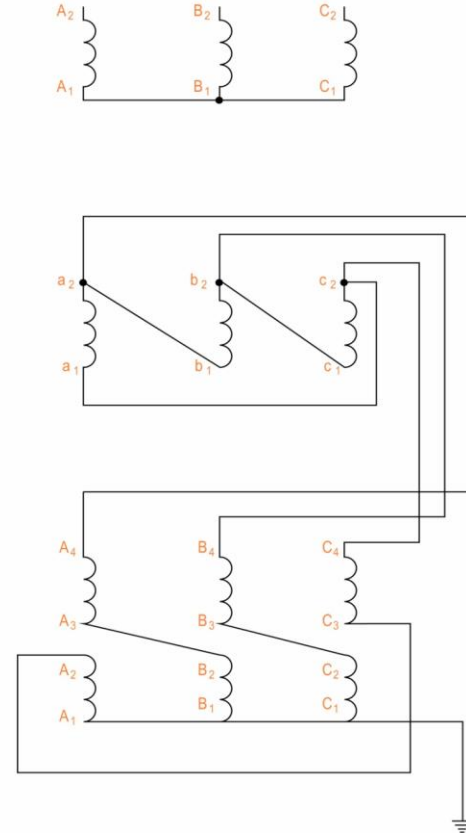


Delta Wye Connected Transformers



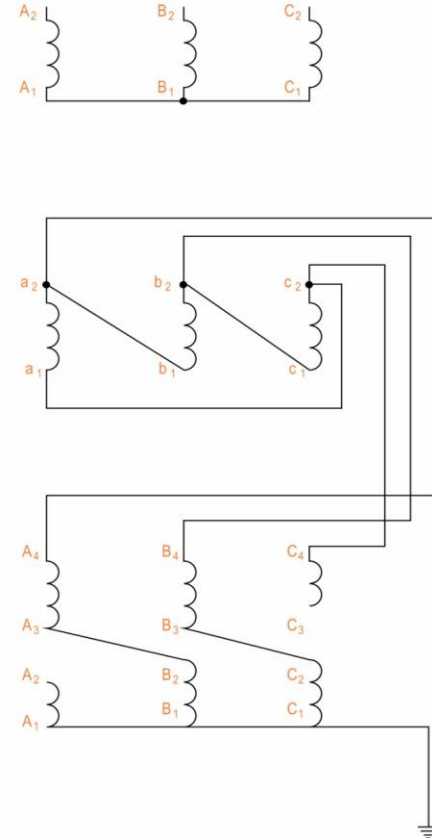
0 Degrees Transformer Connections

Phasor Symbols	Marking of line terminals and phasor diagram of induced voltages		Winding Connections
	H.V. Winding	L.V. Winding	
YyO			
DdO			
DzO			
ZdO			

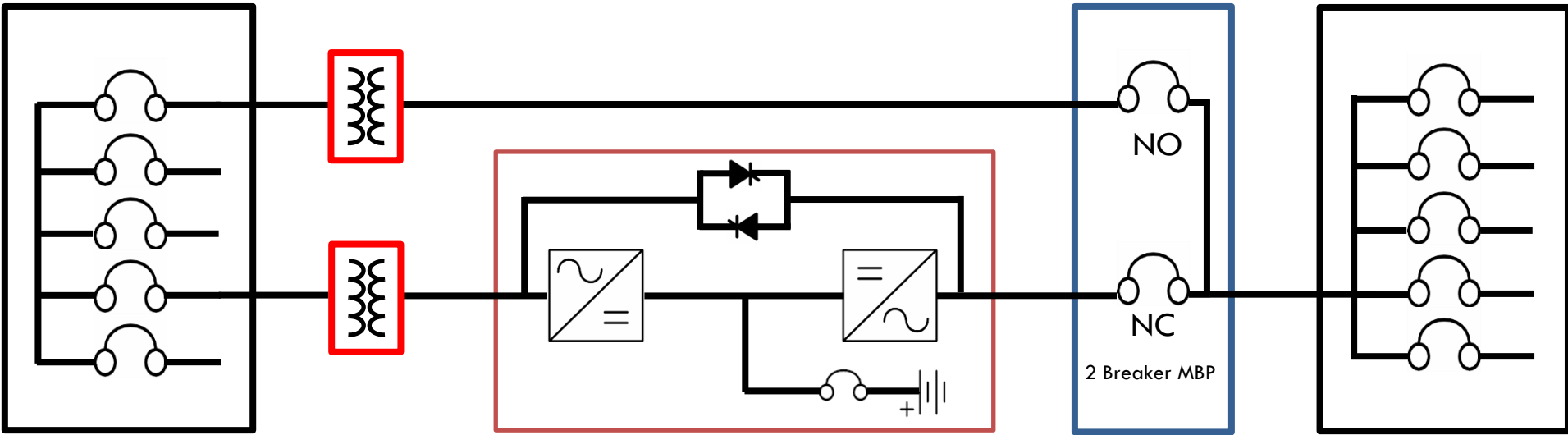


30 Degrees Transformer Connections

Phasor Symbols	Marking of line terminals and phasor diagram of induced voltages		Winding Connections
	H.V. Winding	L.V. Winding	
Dy1			
Yd1			
Yz1			
Zy1			

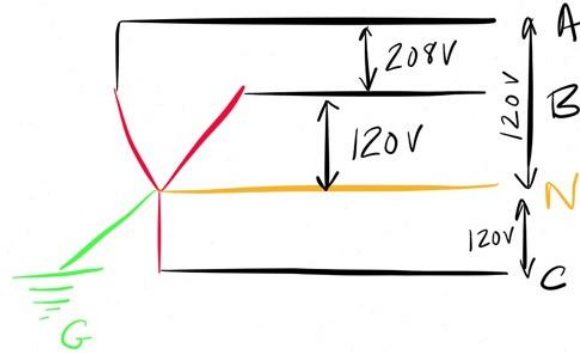
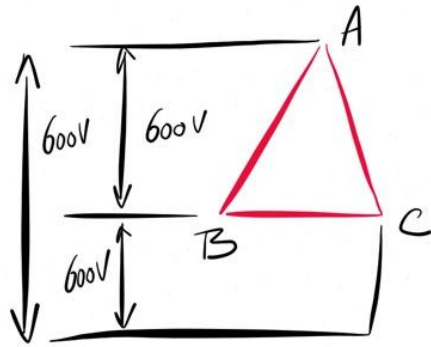


Phase Shift Issues



Connections

DELTA WYE



600V — 120/208V
DELTA — WYE

Taps

- Transformers also provide the option of compensating for regulation
- Regulation which is system introduced or introduced by the transformer itself



Braze-on Taps



Weld-on Taps



Loop-out Taps

Taps

If transformer voltage is 600V to 120/208V

- FCAN

- ▣ 615V

- ▣ 630V

- FCBN

- ▣ 585V

- ▣ 570V

Inrush Current

- When a transformer is taken off-line, there will be a certain amount of residual flux that can remain in the core due to the properties of the magnetic core material.
- The residual flux can be as much as 50 to 90% of the maximum operating flux, depending on the type of core steel.
- When voltage is reapplied to the transformer, the flux introduced by this source voltage will build upon that which already exists in the core.
- In order to maintain this level of flux in the core, which can be well into the saturation range of the core steel, the transformer can draw current well in excess of the transformer's rated full load current.

Tests

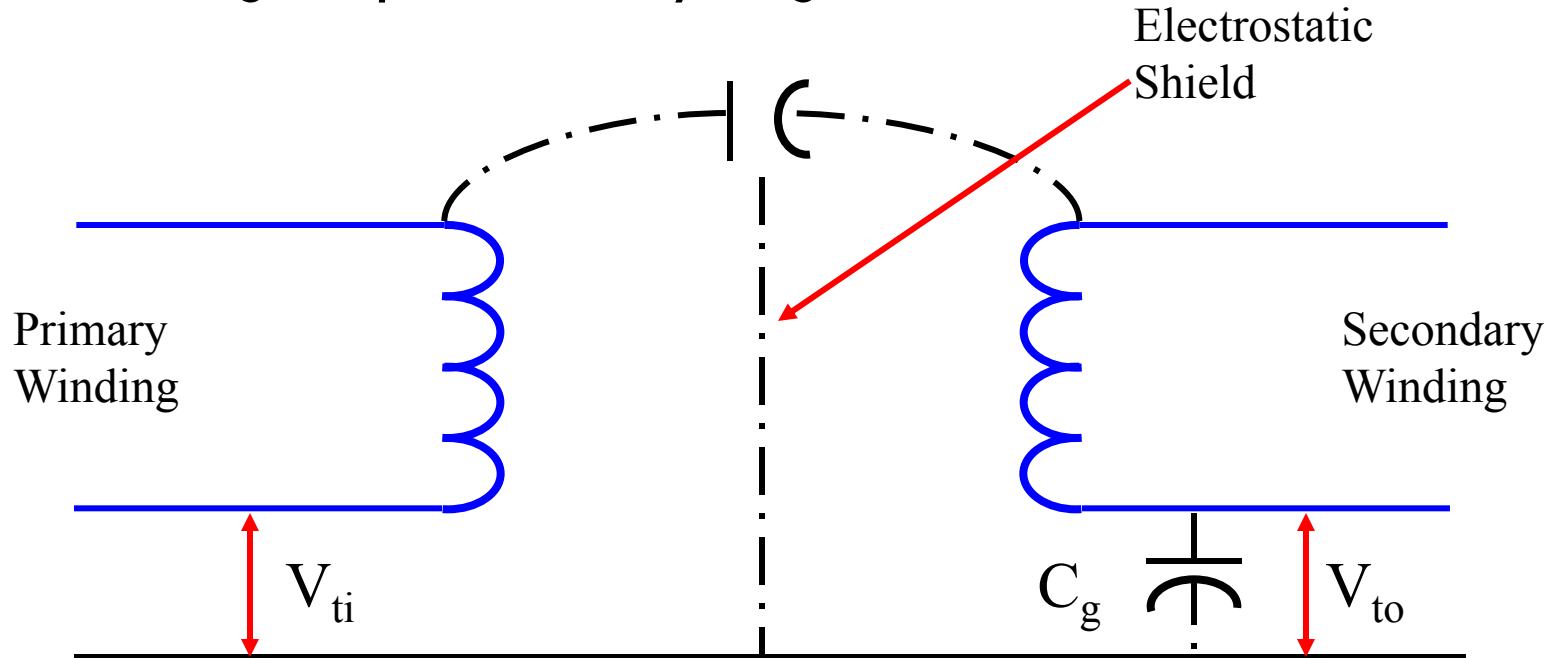
- Basic Impulse Level test
- Partial discharge test
- Heat run test
- Sound level test
- Ratio test

Winding Material

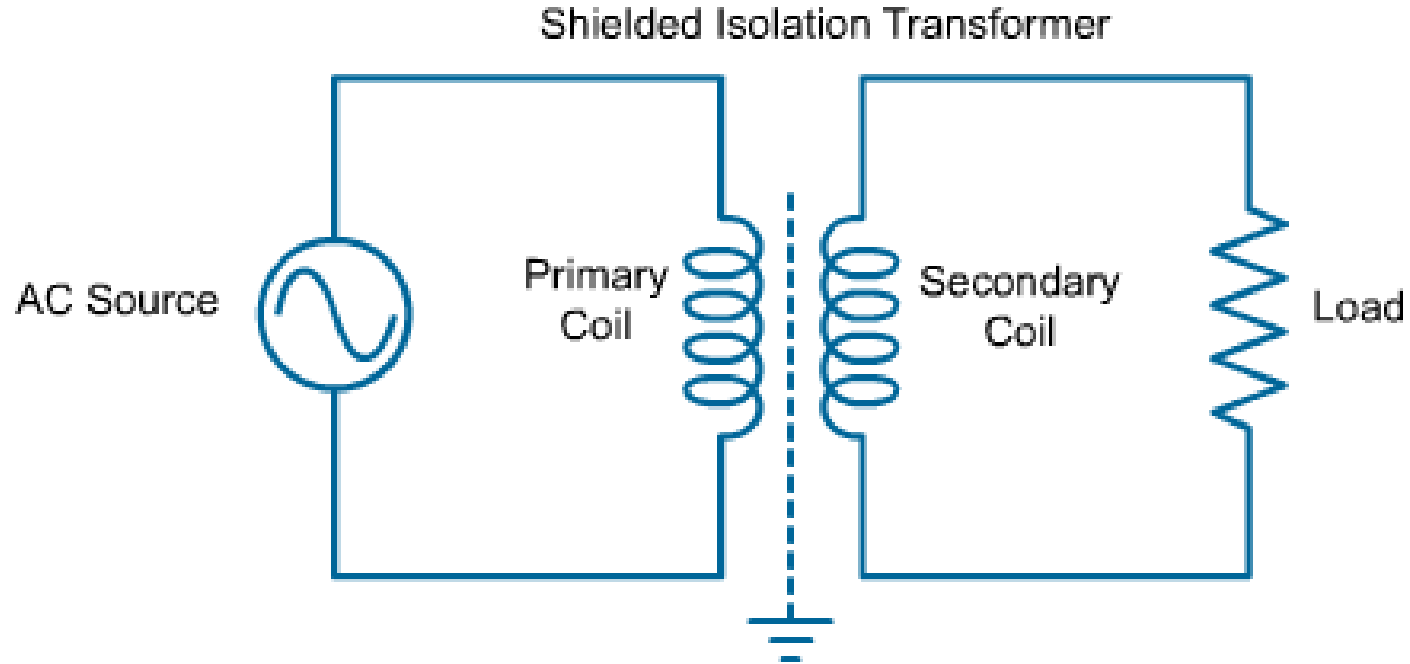
- ❑ Copper or aluminum
- ❑ Depends on application and individual preference
- ❑ Copper has higher electrical conductivity and cost
- ❑ Copper units are smaller
- ❑ Both oxidize over time

Shielded Isolation Transformers

- Dry type transformers can be manufactured with its windings separated by a grounded metal-foil shield.



Shielded Isolation Transformer





Transformer Sound

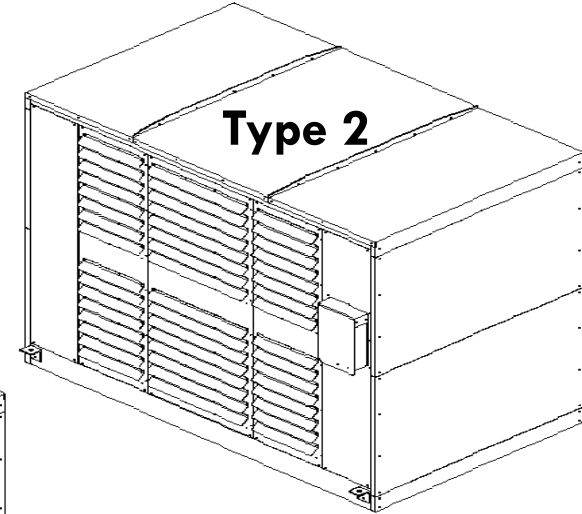
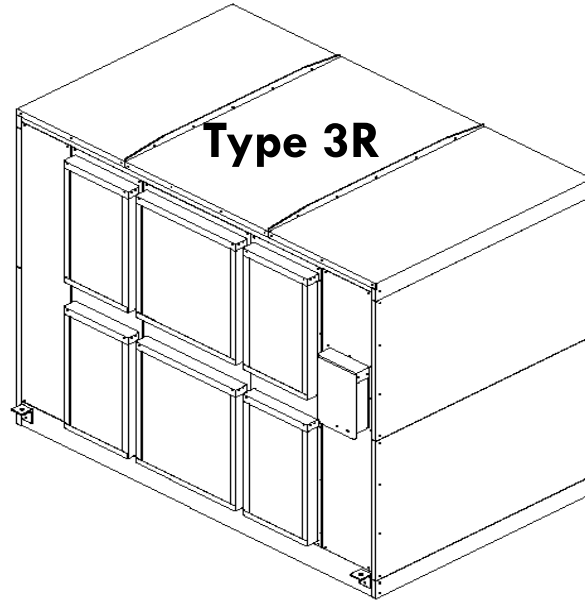
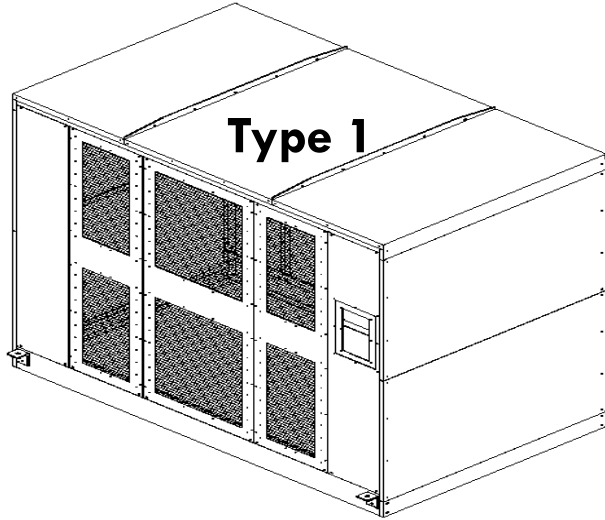
- The "hum" is due to the alternating flux in the core
- Transformer "hum", is commonly referred to as "noise"
- Noise is an inherent characteristic of the core and cannot be completely eliminated.
- Quality core steel will minimize audible sound levels.

Transformer Sound Level Standards	
Transformer kVA	Average dB
0-9	40
10-50	45
51-150	50
151-300	55
301-500	60
501-700	62
701-1000	64

Enclosures Types

	NEMA	 UL LISTED	 CSA
Enclosure Rating	National Electrical Manufacturers Association (NEMA Standard 250) and Electrical and Electronic Mfg. Association of Canada (EEMAC)	Underwriters Laboratories Inc.(UL 50 and UL 508)	Canadian Standards Association (Standard C22.2 No. 94)
Type 1	Enclosures are intended for indoor use primarily to provide a degree of protection against contact with the enclosed equipment or locations where unusual service conditions do not exist.	Indoor use primarily to provide protection against contact with the enclosed equipment and against a limited amount of falling dirt.	General purpose enclosure. Protects against accidental contact with live parts.
Type 2	Enclosures are intended for indoor use primarily to provide a degree of protection against limited amounts of falling water and dirt.	Indoor use to provide a degree of protection against limited amounts of falling water and dirt.	Indoor use to provide a degree of protection against dripping and light splashing of non-corrosive liquids and falling dirt.
Type 3	Enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain, and sleet; undamaged by the formation of ice on the enclosure.	Outdoor use to provide a degree of protection against windblown dust and windblown rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain, snow, and windblown dust; undamaged by the external formation of ice on the enclosure.
Type 3R	Enclosures are intended for outdoor use primarily to provide a degree of protection against falling rain and sleet; undamaged by the formation of ice on the enclosure.	Outdoor use to provide a degree of protection against falling rain; undamaged by the formation of ice on the enclosure.	Indoor or outdoor use; provides a degree of protection against rain, snow, and windblown dust; undamaged by the external formation of ice on the enclosure.

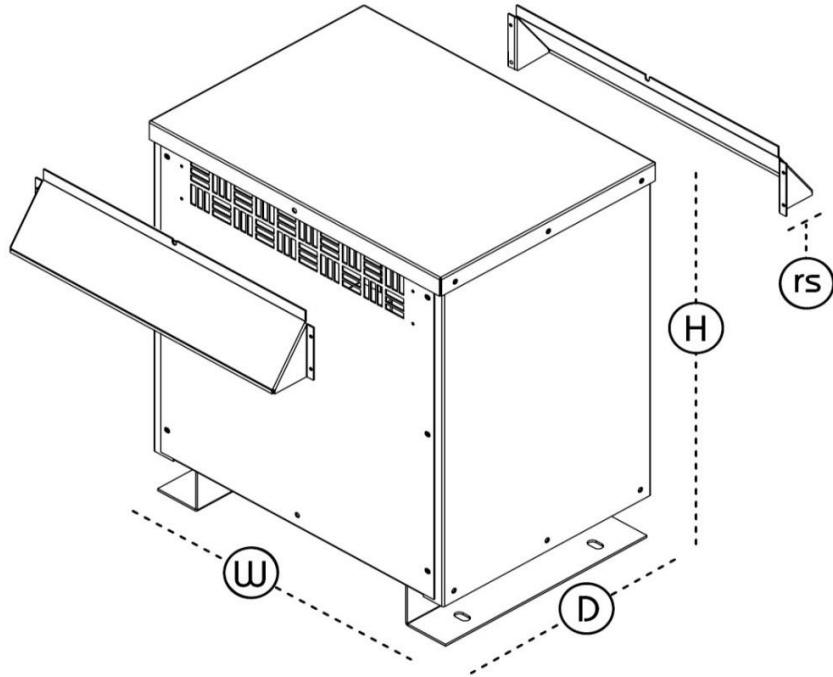
Enclosures



STI Enclosure Dimensions

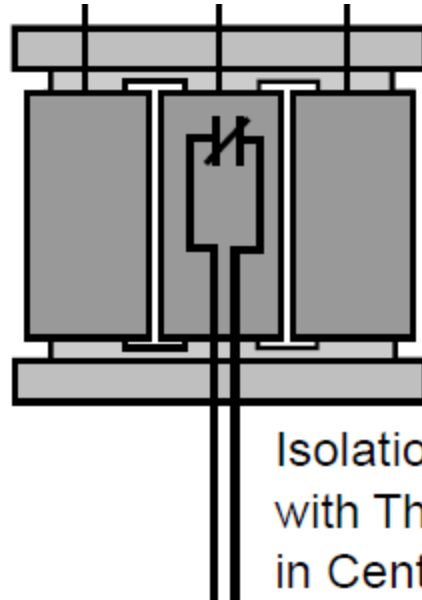
Enclosure Specifications

All dimensions in inches



KVA	15-30	45-75	112-150	225-300	450-500	600-1000
H	26	32	42	49	62	76
W	22	26	30	36	52	66
D	18	20	24	27	36	38
D+rs	23	25	31	37	42	44

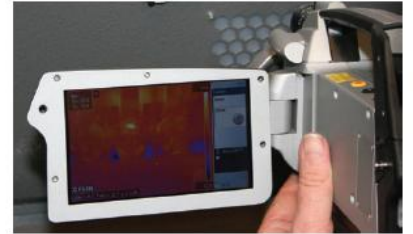
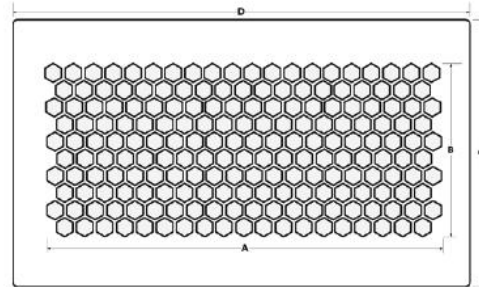
Thermal Sensors – Single or 1 per coil



Isolation Transformer
with Thermal Sensor Switch
in Center Coil

Switch Type	Normally closed (normally open also available)
Temperature Setting	180°C non-adjustable (other temperatures also available)

IR Window

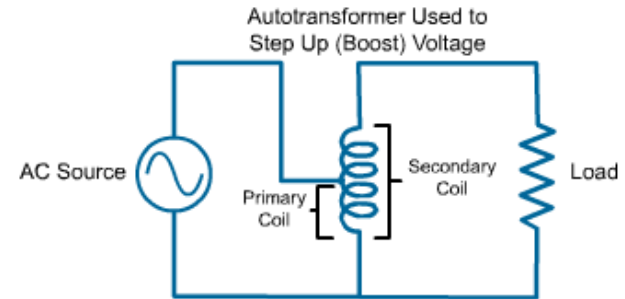
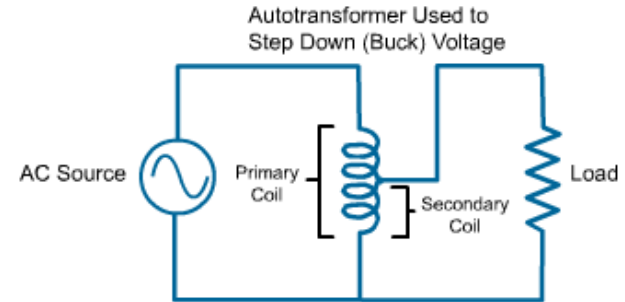


Epoxy Vacuum Impregnation

- Increased mechanical strengths
- Enhanced performance in heavily contaminated environments
- Comparable with cast coil performance
- Reduced noise
- Improved winding insulation
- No air pockets

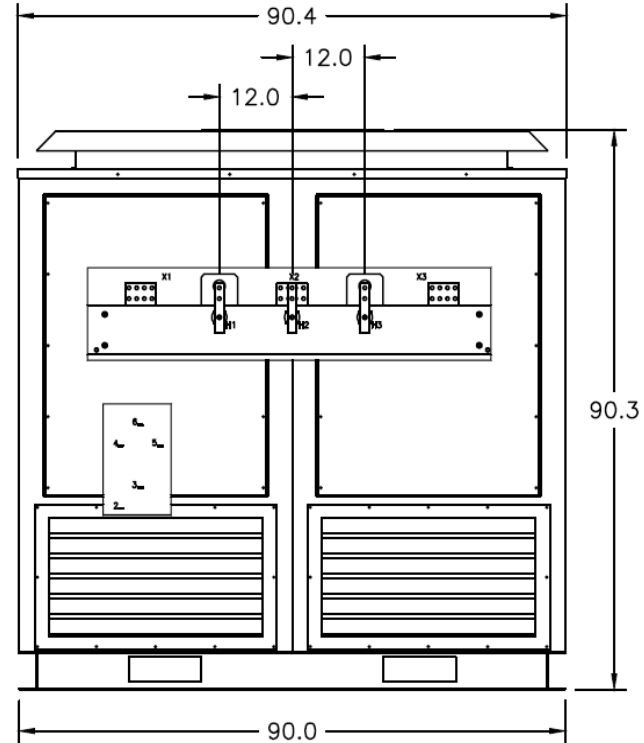
Auto Transformers

- ❑ Designed for linear loads
- ❑ Common primary and secondary winding
- ❑ Light and compact
- ❑ More cost effective
- ❑ 600-480V, 10 to 1,000 kVA
- ❑ 3 windings, 3-phase

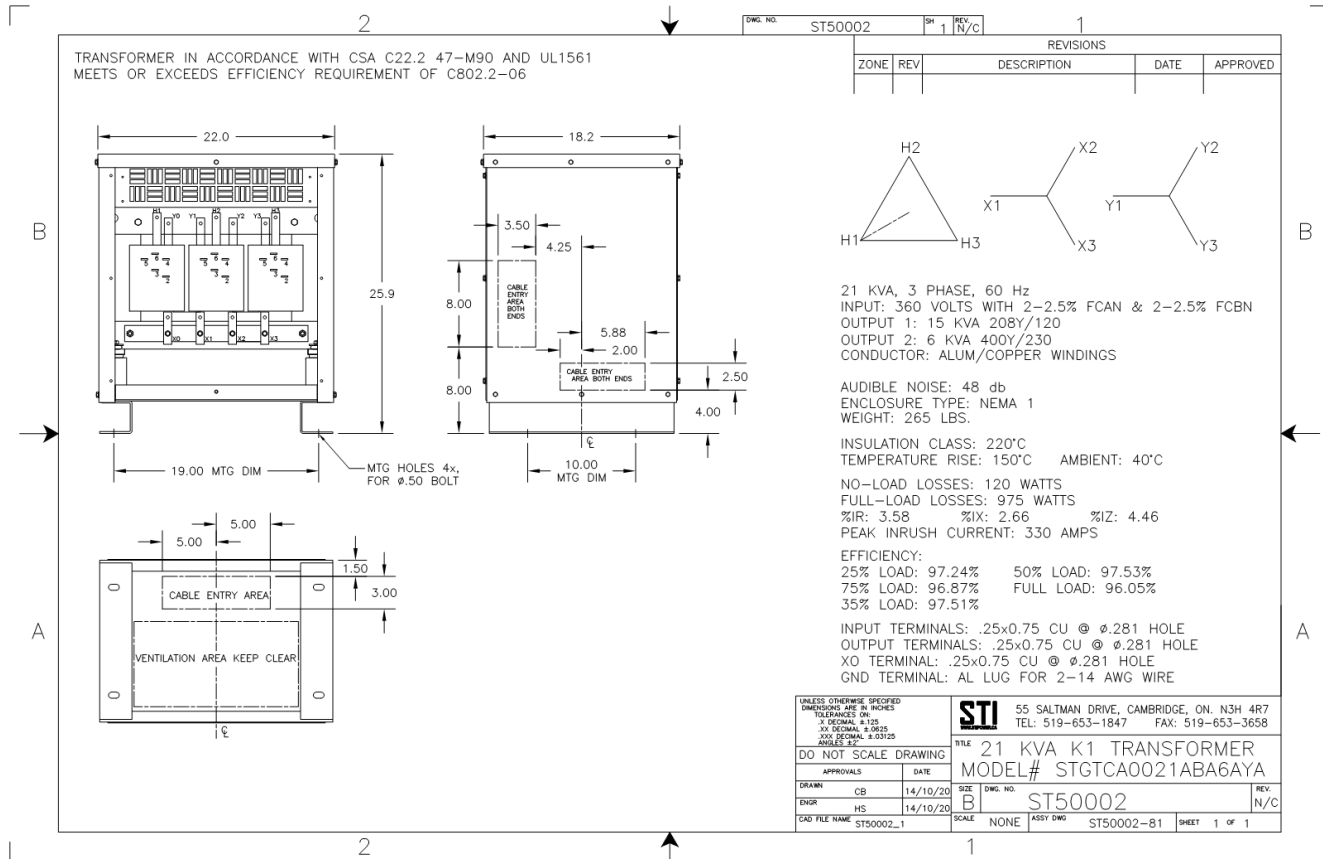


Power Transformers

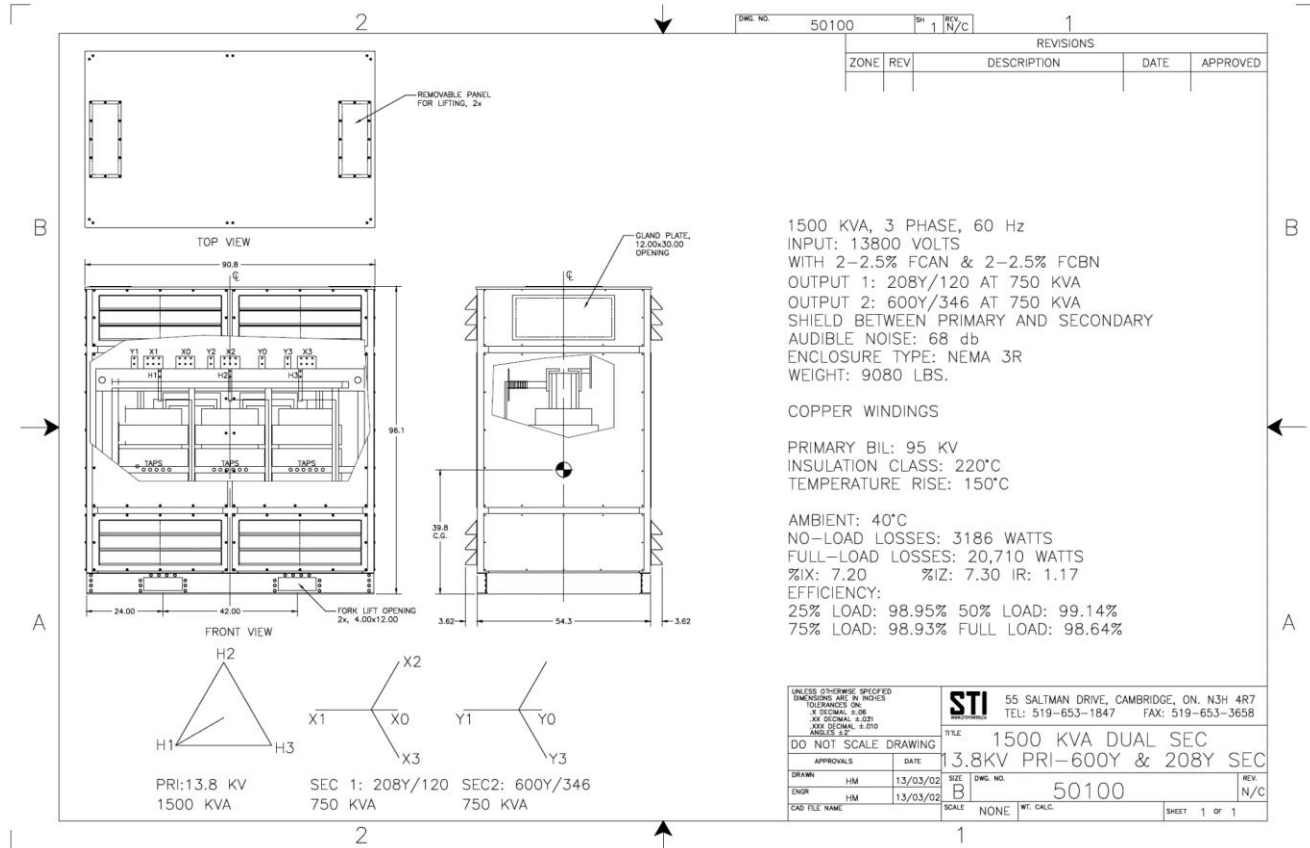
- 150 kVA onwards
- 5 kV to 27.6 kV,
- Provision for close coupling to either new or existing switchgear equipment



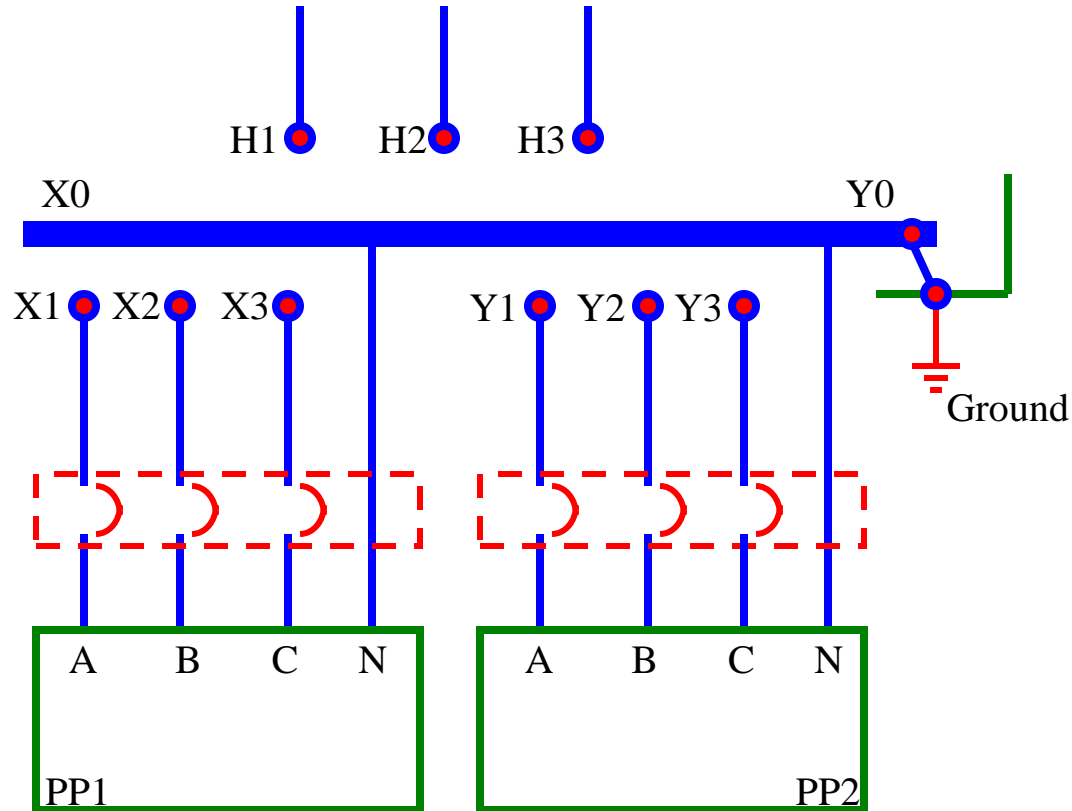
Dual Output Transformer - LV



Dual Output Transformer - MV



Dual Output Transformer



Dry Type Cooling

- ANN – Air Natural Convection Cooled
 - ▣ kVA is name plates rated kVA, single rating only
- ANF – Forced Air Cooled



**COOPER** Power Systems

Eaton's Cooper Power Systems

Transformers



- Single-Phase Poles
- Single & Three-Phase Pads
- Substations

- Upstream – Onshore and offshore exploration & production
- Midstream – Booster Stations
- Downstream – Gas Processing, Refining and Petrochemical Plants.

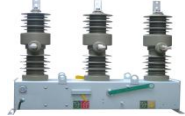
Voltage Regulators



- Voltage Regulators
- Auto Boosters
- Variable Power Regulators

- Upstream – Onshore oil & gas field power distribution & Oil Sands EOR
- Midstream – Pipeline & storage distribution.
- Downstream – Refining, Gas Processing in lieu of LTC's

Switchgear



- Overhead switchgear
- Pad-mount switchgear

- Upstream – Onshore Oil & Gas production distribution systems.
- Midstream – Tank Storage & Distribution
- Downstream – Process power management

Capacitors



- HV capacitor Unit
- Capacitor banks
- Filter banks

- Upstream – Onshore production power factor correction
- Midstream - VFD harmonic's mitigation
- Downstream – Power factor correction

Arresters, Fuses, Switches & Connectors



- Fuses/Surge Arrestors
- Cable connectors
- Transformer Components
- Service parts

- All three vertical segments – Upstream, Midstream & Downstream.

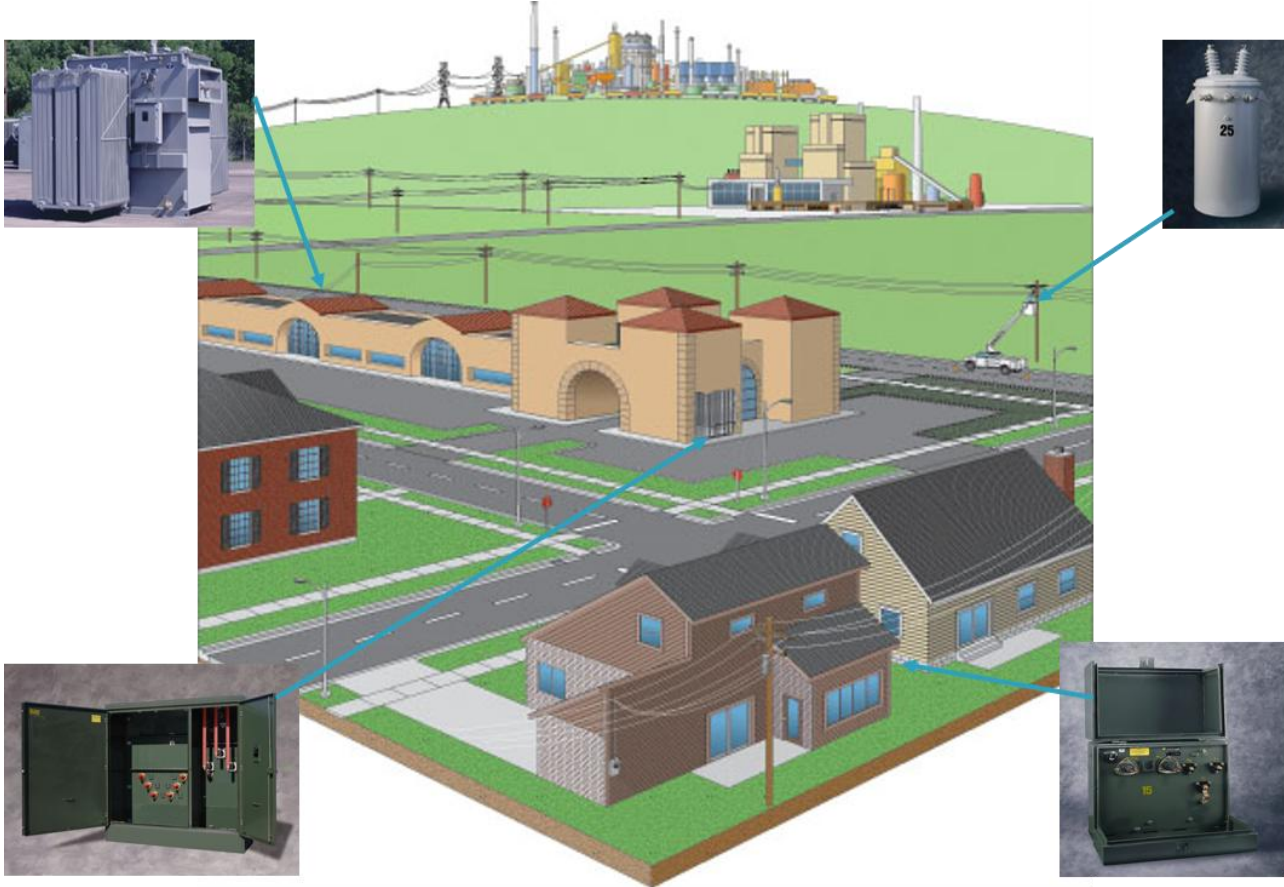
Energy Automation Systems



- AMR
- Demand response
- Distribution automation

- Product development & design to be defined for O&G specific requirements. Remote monitoring , management & control.

Transformer Products

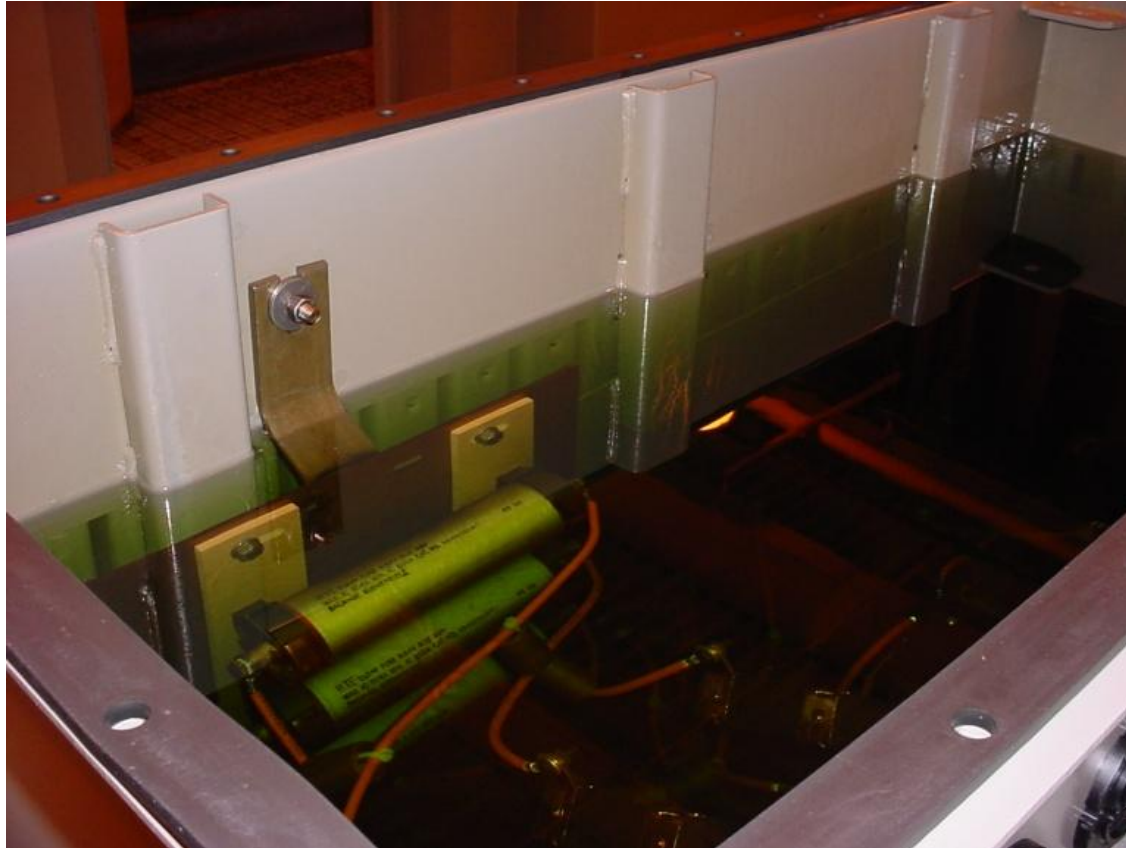


3Ø Transformer product scope

- Pad-mounted and Substation transformers
- kVA range:
 - 45-12,000
 - Envirotemp™ FR3™ Filled
- Primary Voltage
 - 2400 to 46,000 volts
 - Up to 250 kV BIL
- Secondary Voltage
 - 120 to 24,940 volts
 - 125 kV BIL



Liquid Power Transformers



Pad-mounted vs. Substation

- ❑ No Fencing
- ❑ Smaller Footprint
- ❑ Less Space Needed
- ❑ Underground Feed
- ❑ No Overhead Lines



Liquid-Filled Transformer Four Letter Cooling Classes

1

Medium

Internal

2

Mechanism

3

Medium

External

4

Mechanism

Liquid-Filled Transformer Four Letter Cooling Classes

		Letter	Description
Internal	First Letter (Cooling medium)	O	Liquid with flash point less than or equal to 300°C
		K	Liquid with flash point greater than 300°C
		L	Liquid with no measurable flash point
	Second Letter (Cooling mechanism)	N	Natural convection through cooling equipment and windings
		F	Forced circulation through cooling equipment, natural convection in windings
		D	Forced circulation through cooling equipment, directed flow in man windings
External	Third letter (Cooling medium)	A	Air
		W	Water
	Fourth letter (Cooling medium)	N	Natural convection
		F	Forced circulation

Forced Air



Forced Air



Envirotran Plus

Envirotran *PLUS* kVA Ratings

55°C Rise ONAN/KNAN	65°C Rise ONAN/KNAN	75°C Rise KNAN		55°C Rise ONAF/KNAF	65°C Rise ONAF/KNAF	75°C Rise KNAF
500	560	610		575	644	702
750	840	916		863	966	1053
1000	1120	1221		1150	1288	1404
1500	1680	1831		1725	1932	2106
2000	2240	2442		2300	2576	2808
2500	2800	3052		3125	3500	3815
3750	4200	4578		4688	5250	5722
5000	5600	6104		6250	7000	7630
7500	8400	9156		9375	10500	11445
10000	11200	12208		12500	14000	15260

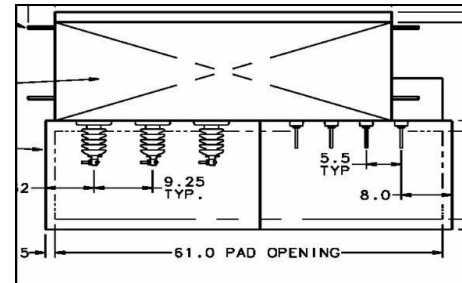
High Voltage Connections

- Dead Front means no exposed connections



Live Front

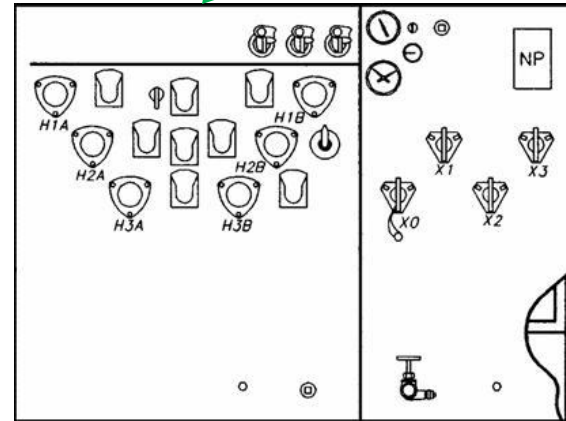
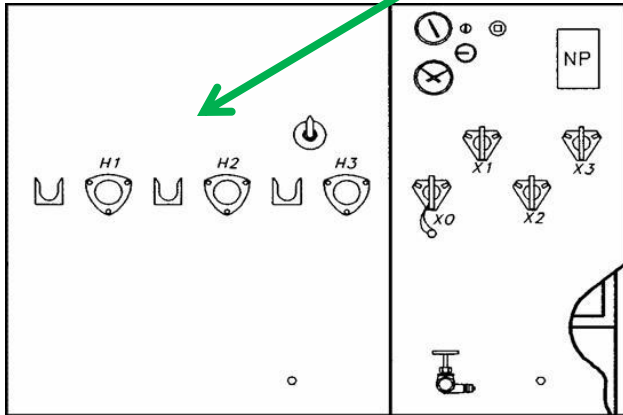
- Live Front means exposed connections



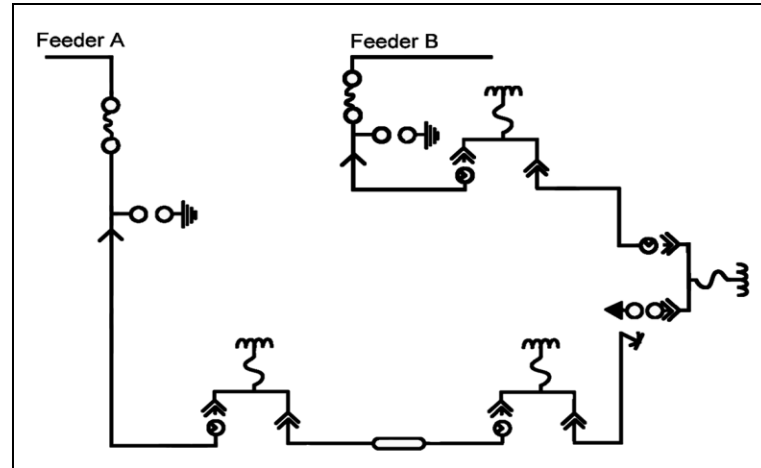
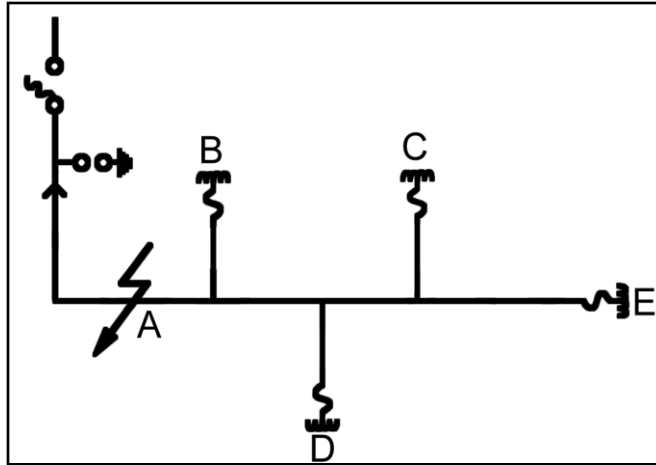
Live Front vs. Dead Front



Transformer Bushing Layout Radial Feed vs. Loop Feed



System Configurations Radial Feed vs. Loop Feed



Transformer Construction

- **Winding Material**
 - Aluminum or Copper
- **No-Load Taps**
 - +/- 2-2 1/2% (Standard) on High Voltage
 - - 4 - 2 1/2% (optional)
 - Other Tap positions available
- **Fluid**
 - Envirotemp FR3 Fluid
 - Mineral Oil
 - Other (Luminol or Voltesso are possible)

Envirotemp FR3 the First Truly Green Dielectric Fluid

- ❑ May be Used Indoors and Outdoors
- ❑ 100% Food Grade Ingredients
- ❑ Rapid Biodegradation Rate
- ❑ Renewable Resource Based
- ❑ Non-Toxic (zero trout fingerling mortality)
- ❑ Does Not Contain Petroleum, Silicones, nor Halogens*



* PCB's, SF6, CFC, PERC, etc.

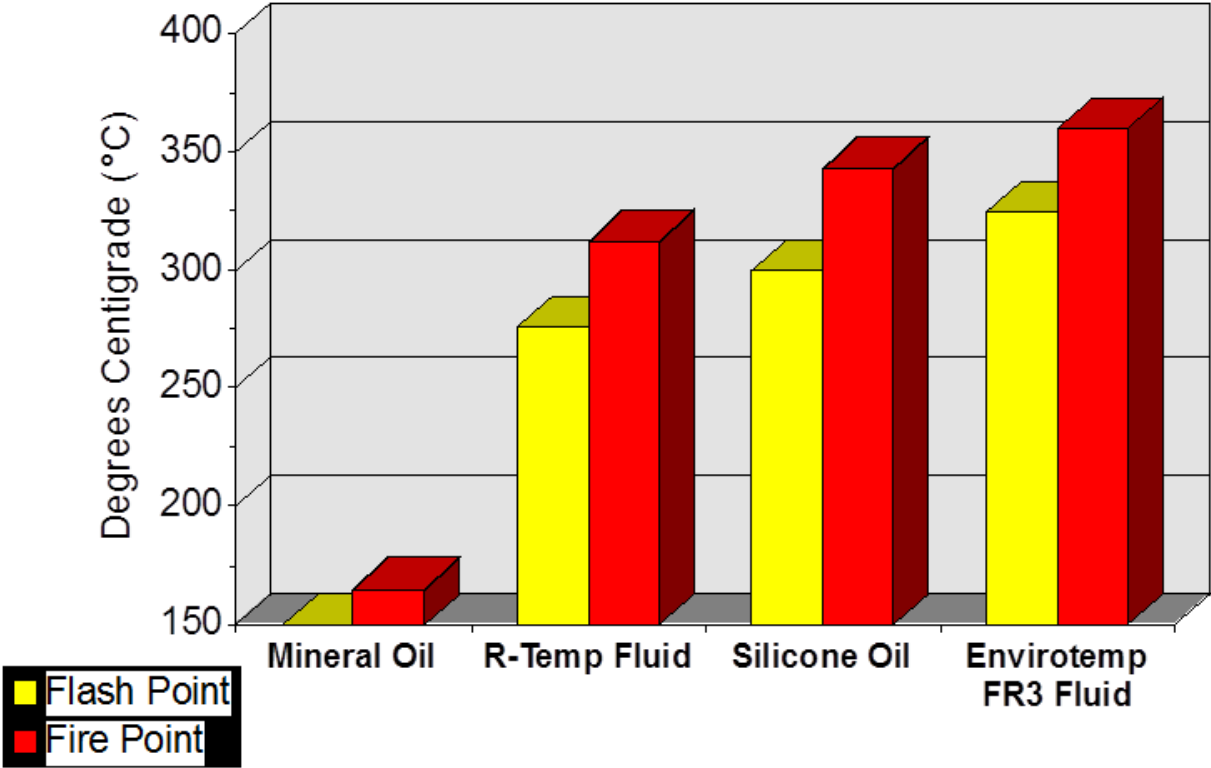
Why Envirotemp™ FR3™ is better

- Higher moisture content in insulation during manufacturing process
- Natural ester based fluid - higher affinity for and tolerance of moisture
 - 25 C saturation levels
 - Mineral oil: 70 ppm
 - Envirotemp™ FR3™: 1000 ppm
- Insulation moisture migrates to Envirotemp™ FR3™ when transformer is loaded in the field
- Maintains dielectric strength similarly to mineral oil in terms of relative saturation meaning higher dielectric strength throughout the life of the transformer

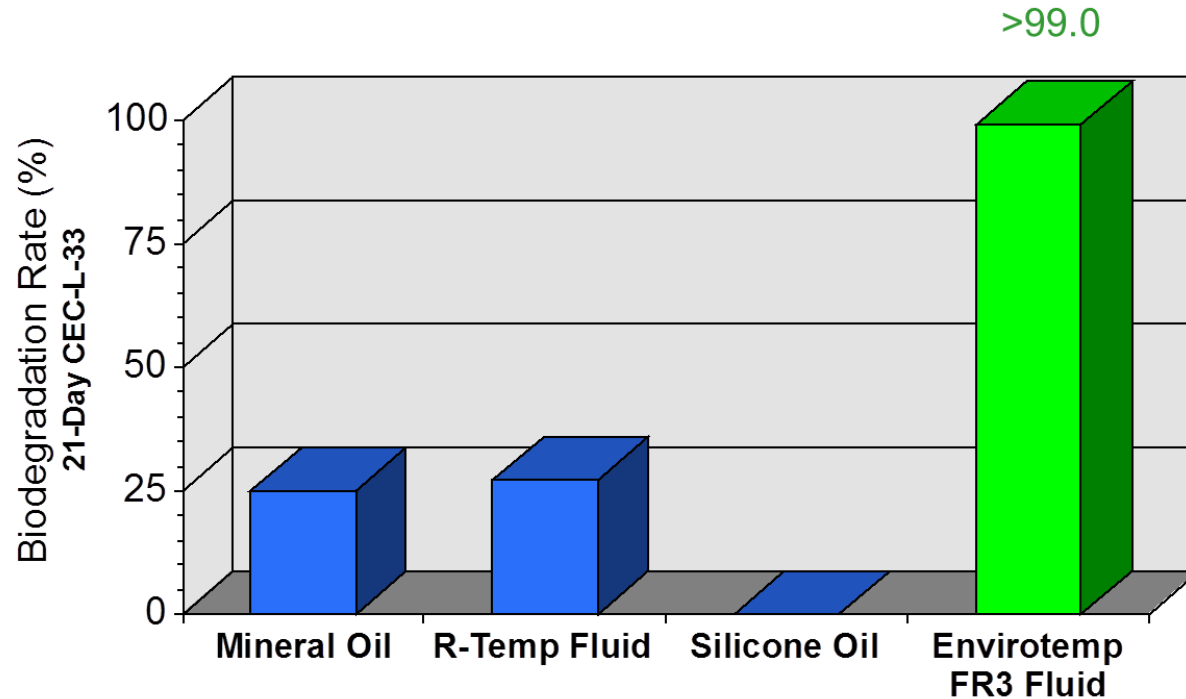
Why Envirotemp™ FR3™ is better

- FR3™ fluid extends insulation life by a factor of as much as 5-8 times because it has the unique ability to draw out retained moisture and absorb water driven off by aging paper.
- It also helps prevent paper molecules from severing when exposed to heat. These properties can result in an increase of overload ability and/or longer transformer insulation life, resulting in both lower life cycle costs and delayed asset replacement.”

FIRE SAFETY – Flash & Fire Point of Dielectric Fluids



ENVIRONMENTAL IMPACT Biodegradation Rate of Dielectric Fluids



FR3 spill degrades in 21 days

ENVIRONMENTAL IMPACT - Biodegradation Rate of Dielectric Fluids

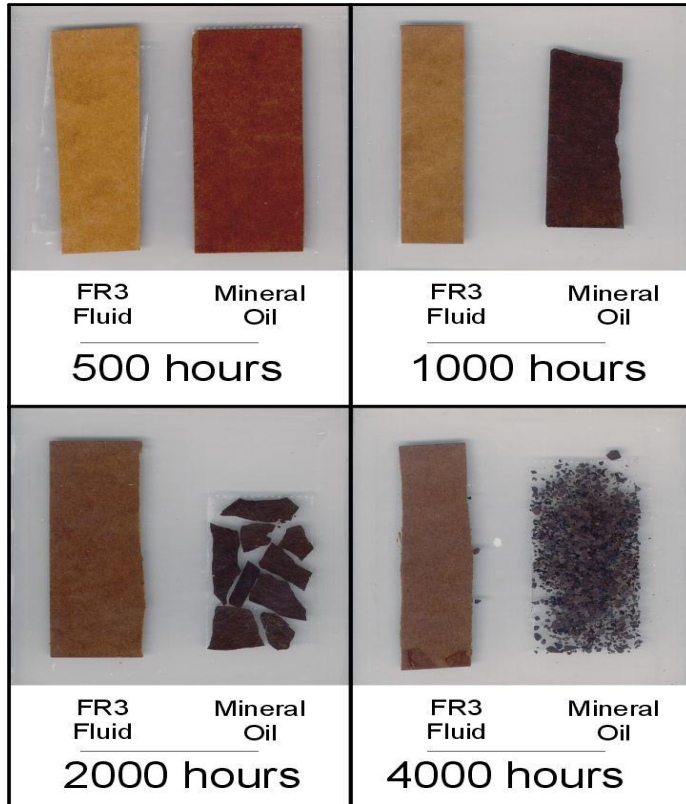
- Biodegradation - "Transformation of a substance into new compounds through biochemical reactions or the actions of microorganisms such as bacteria." - U.S. Geological Survey, 2007
- "A process by which microbial organisms transform or alter (through metabolic or enzymatic action) the structure of chemicals introduced into the environment." - U.S. Environmental Protection Agency, 2009

This may be characterized for purpose of hazard assessment as:

- 1. Primary. Alteration of the chemical structure of a substance resulting in loss of a specific property of that substance.
- 2. Environmentally acceptable. Biodegradation to such an extent as to remove undesirable properties of the compound. This often corresponds to primary biodegradation but it depends on the circumstances under which the products are discharged into the environment.
- 3. Ultimate. Complete breakdown of a compound to either fully oxidized or reduced simple molecules (such as carbon dioxide/methane, nitrate/ammonium, and water).

FR3 biodegradation rate and completeness meets the U.S. Environmental Protection Agency (EPA) criteria for "Ultimate Biodegradability" classification."

FR3 Relative Accelerated Aging Study



Transformer Aging Study

- 500 hours = 10 yrs
- 1000 hours = 20 yrs
- 2000 hours = 40 yrs
- 4000 hours = 80 yrs

Liquid Indoors

- ❑ Liquid-filled can be Listed and Labeled as meeting the NEC by a Nationally Recognized Testing Laboratory (NRTL).
- ❑ FM Approved; or UL Classified with FR-3 Fluid; Less Flammable Fluids
- ❑ Complies with Indoor Installation requirements
- ❑ No Fire Suppression Systems Req'd
- ❑ Pad-mounted and Substation transformers



Indoor installations

- ❑ NEC® allows for indoor installation of liquid-filled transformers with few constraints:
- ❑ Less-Flammable Liquid-Filled Transformers - NEC 450-23
- ❑ May be installed in Type I or Type II non-combustible buildings with these restrictions:
- ❑ No combustible materials stored around transformer
- ❑ Fluid confinement (Cooper can provide with transformer as an option)
- ❑ Installation to comply with all fluid listing restrictions.



Examples of fluid containment



Dual Voltage Switch

- Allows for Two Primary Voltages
 - ▣ Facilities with two voltages on system
 - ▣ Future system upgrade
- Maximum Voltage Ratio - 3.3:1
- Coils are placed in series or parallel depending on voltage requirements
- Example: 4160V x 13,200V



Overcurrent protection

□ Expulsion & Back-up Current-Limiting Fusing

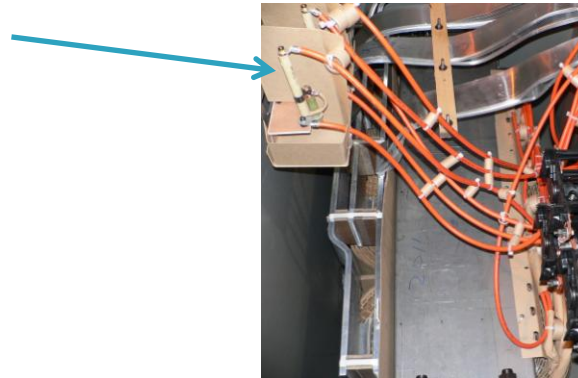
Fusing – Expulsion (Bay-O-Net Mounted) & Partial Range Current-Limiting



Overcurrent Protection

- ❑ Expulsion Fuse in Series With Partial Range Back-up Current-Limiting Fuse
 - ▣ Internal cartridge mounted
 - ▣ For higher ratings than Bay-O-Net mounting is rated

Expulsion Fuse



Overcurrent protection

- What if
- Transformer rating exceeds what may be internally fused
- Resettable device preferred
- No single phasing
- More sophistication needed/wanted

VFI Transformer

- ❑ Vacuum Fault Interrupter (VFI) Installed Integral to the Transformer
- ❑ Switchgear-type over-current protection for large pad-mounted or substation transformers
- ❑ Control box in HV Termination compartment (pad-mounted)



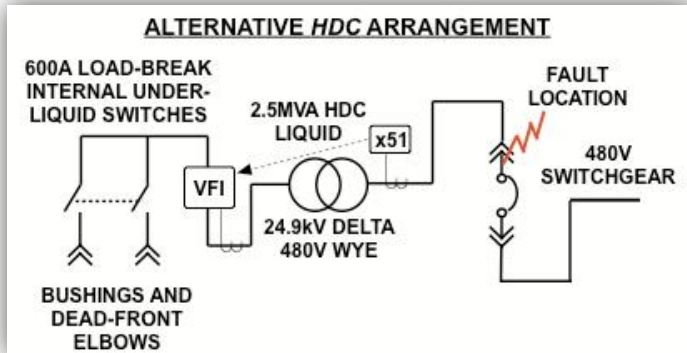
VFI transformer

- 3Ø Primary over-current protection and switching (Vacuum Fault Interrupter) installed integral to transformer.
- Resettable medium voltage breaker with electronic control
- Over 100 minimum trip settings

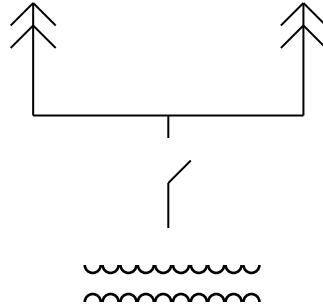


VFI transformer

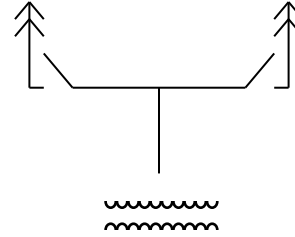
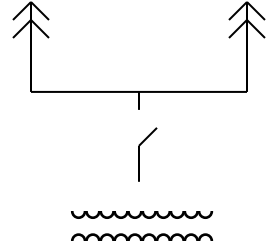
- ❑ Up to 35 kV rating
- ❑ 600 or 900 A continuous rating
- ❑ 12 kA & 16 kA interrupting rating*
- ❑ Optional secondary relay
- ❑ Used to trip VFI on secondary fault
- ❑ Helps mitigate secondary arc flash hazards



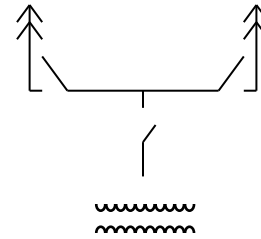
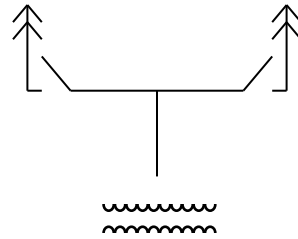
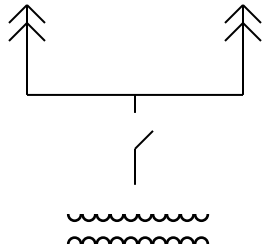
On/Off Load-Break Switch(s)



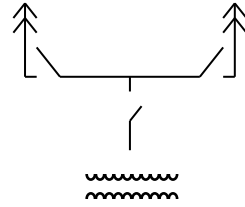
On/Off Load-Break Switch(s) (two)



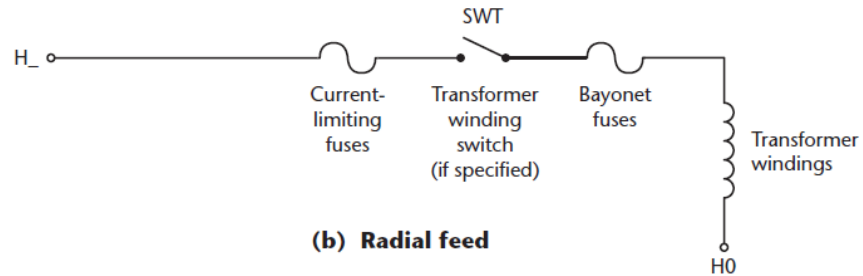
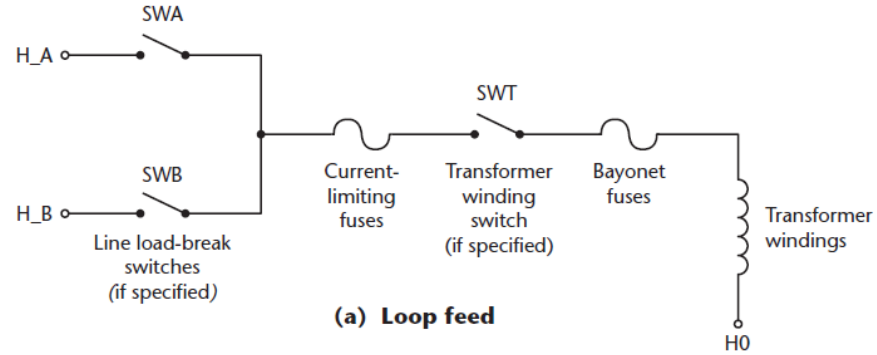
On/Off Load-Break Switch(s) (three)



On/Off Load-Break Switch(s) (three)

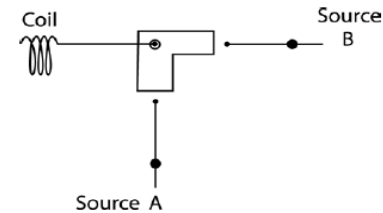
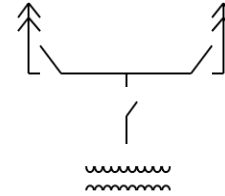


Load-break Switching



4-Position sectionalizing switches

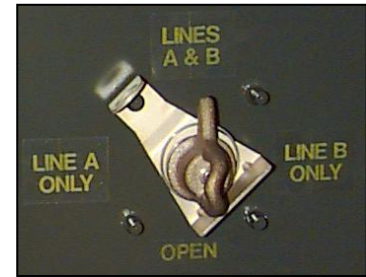
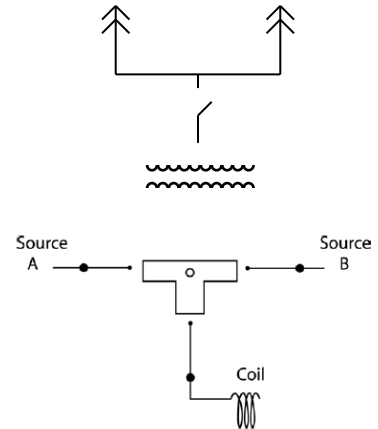
- V-Blade Switch
- Description of Positions
 - ▣ Feed from A & B
 - ▣ Feed from A only
 - ▣ Feed from B only
 - ▣ Open — the loop is open and the transformer is de-energized



4-Position sectionalizing switches

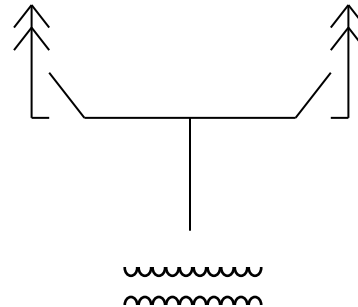
T-Blade Switch

- Description of Positions
 - ▣ Feed from A & B
 - ▣ Feed from A only
 - ▣ Feed from B only Open — the loop is closed and the transformer is de-energized



Features and accessories - 3-Position Selector Switch

- ❑ Applications with Two Separate Sources Which May Not Be Tied Together
- ❑ Allows selection of “A” source or “B” source or Open
- ❑ Open means transformer is off or de-energized
- ❑ Both Sources Cannot Simultaneously Feed the Transformer
- ❑ No Interlocks Required



Other optional accessories

- Gauges
 - Liquid level
 - Temperature
 - Pressure vacuum
 - Alarm contacts
- LV breaker provisions
- Watt-hour Meter
- 304L stainless steel
 - Full
 - Partial
- Others
 - Winding temperature indicator
 - Rapid rise relay



Addressing arc flash



Addressing arc flash



Addressing arc flash

- Essential monitoring equipment accessible outside termination compartments
- Drain Valve & Sampler
- Gauges
- Load-break switches



Addressing arc flash

- ❑ Externally operable visible break switching
- ❑ Reduce unnecessary arc flash exposure
- ❑ Improved visibility and safety compared to standard load-break switch mounting
- ❑ Ability to ground transformer windings with on/off/ground option
- ❑ Reduce maintenance costs
- ❑ Maintains tamper resistance



Externally operated visible load-break switch



Visible break window

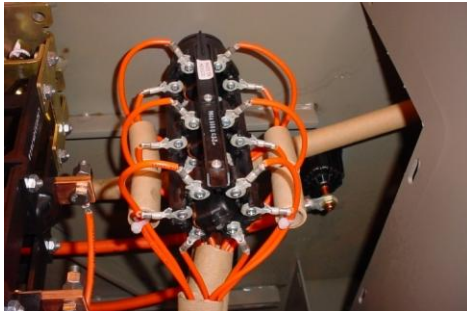


Gauges

Load-break
switch handle

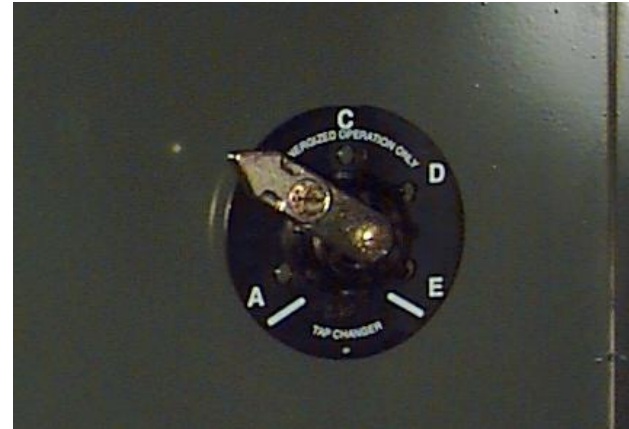
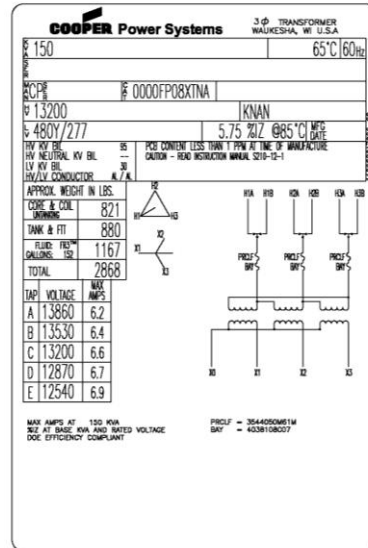
Taps

- Change the quantity of high-voltage windings to match incoming primary voltage
- Goal is obtain correct secondary voltage
- $\pm 2 - 2.5 \%$ (split taps) are most common



Taps

- Tap Voltage Values Appear on the Transformer Nameplate



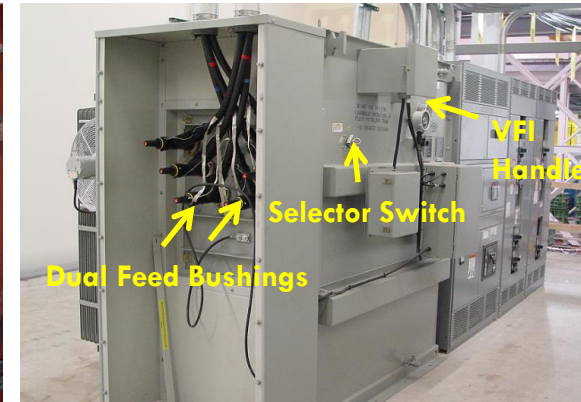
Over-Voltage Protection

- Surge arresters
- Classes defined by:
 - ▣ Voltage rating
 - ▣ Protective characteristics
 - ▣ Pressure Relief



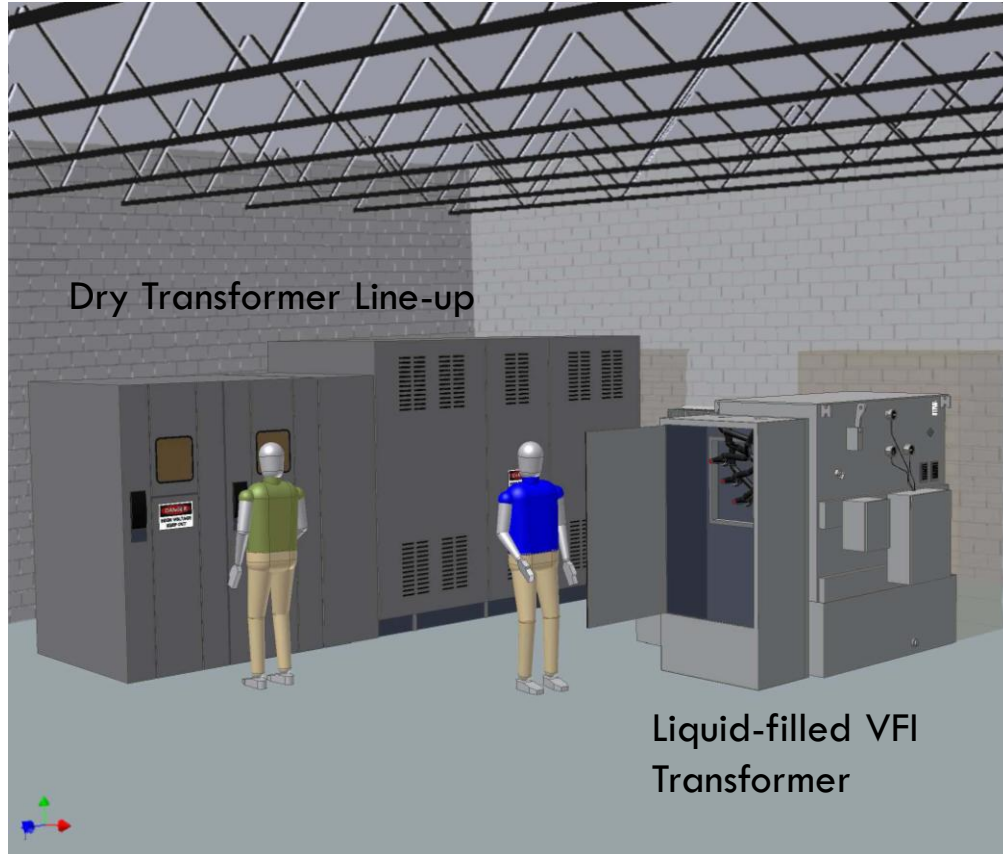
Dry vs. Liquid

- ❑ Fire Safety
- ❑ Losses & Efficiency
- ❑ First Cost
- ❑ Overload Capacity
- ❑ Sound Levels
- ❑ Temperature Rise
- ❑ Contamination
- ❑ Diagnostics (DGA)
- ❑ Extended Life
- ❑ Protection
- ❑ Floor Space Required



Liquid / Dry Transformer Comparison

Each line-up performs the same function



Double-ended unit substation



**FR3 Filled
Transformer**

**MV Circuit
Breaker**

Canadian Electrical Code

- 26-242 – Outdoor transformer installations
- Pad-mounted transformers
- Min. 3m to combustible surface or material on a building
- Min. 6m to windows, doors, or ventilation inlets or outlets
- Except if:
 - ▣ Internal current-limiting fuses & pressure relief
 - ▣ 3m on access side(s) and 1m on other sides

Standard Substation Accessories

- De-energized tap changer
- One inch combination drain and filtering valve/sampling device
- Pressure test connect
- One inch upper filling and filter press connection
- Pressure relief valve
- Provision for lifting and jacking
- Ground pads
- Non-corrosive nameplate
- Liquid level gauge
- Temperature gauge
- Pressure/vacuum gauge

Optional Accessories

- Pressure relief device (std above 2500 kVA)
- Rapid Rise relay (seal-in panel optional)
- Winding temperature indicator and relay
- Contacts for temperature, liquid level, and pressure/vacuum gauges
- Pressure/vacuum bleeder (std above 2500 kVA)
- Surge arresters
- Throats/flanges/ ATC (primary and/or secondary connections)
 - ▣ Can accommodate equipment by others i.e. LV switchgear

Optional Accessories (continued)

- ❑ Air terminal chambers (primary and/or secondary connections with sidewall mounted bushings)
- ❑ Detachable bolt-on radiators with valves
- ❑ Fan control package
- ❑ Nitrogen blanket, 2 - 3 p.s.i., including purge valves
- ❑ Nitrogen preservation system includes: bottle, regulator, and appropriate high and low pressure contacts

Questions

