Distribution Transformer Handbook

FIFTH EDITION

Additional Publications

Alexander Publications offers a variety of books, manuals, and online learning services for electric utilities. For details, visit www.alexander-publications.com.

Comments

If you have comments on this handbook, or suggestions how we might make it more valuable for you or your company, please call or write:

Alexander Publications
1048 Irvine Avenue, #484
Newport Beach, California 92660

Telephone: 1-800-992-3031 or (949)642-0101
Web site: www.alexanderpublications.com
Email: info@alexanderpublications.com

Fifth edition
Third printing: January 2017
Each printing incorporates minor improvements.

Foreword

I am pleased to introduce the Fifth Edition of our handy reference on distribution transformers for lineworkers. As in the previous editions, this practical handbook provides quick access to essential information for immediate use, whether in the field or in the shop.

We have tried to select the most commonly required information, then present it in an easy-to-read format, to make this guide a useful and reliable reference document.

Richard Alexander

Acknowledgements

This handbook is a supplement to other excellent resources on transformers currently available.

Among the materials consulted while preparing this book are: ANSI 05.1 *Specifications and Dimensions for Wood Poles*, ANSI C57.12.70 *Terminal Markings and Connections for Distribution and Power Transformers*, ANSI C57.105 *Guide to Three-Phase Transformer Connections, Distribution Transformer Manual* by General Electric, Transformers for Linemen and *RUS++* by Alexander Publications, and *Transformer Connections* by General Electric.

Product literature and application advice were provided by ABB Power T&D Company Inc., Alec Wolowidnyk, Arkansas Electric Cooperatives, BC Hydro, Cooper Power Systems, David Wagner, ERMCO, General Electric, Howard Industries, Jim Canavan, John Bullock, Mark Anders, Northeast Utilities, Northeastern JATC, Northwest Lineman College, Puget Sound Energy, Solomon Corporation, Southern California Edison, and Tommy Edwards.

We gratefully acknowledge the assistance from each of these sources.

Warnings

Energized transformers and live distribution lines present the risk of electrical shock. All work on this equipment should be performed only by qualified specialists. The connection diagrams, tables, and other data in this handbook are intended to be aids for field personnel. This material does not replace the extensive training necessary to safely work with transformers in service.

This handbook describes work practices which are accepted by most utilities, but some may not apply to you. Always follow your company's established safety procedures and work practices.

Notice

Table of Contents

CHAPTER 1

TRANSFORMER CONCEPTS

Introduction to Distribution Transformers

Distribution transformers convert the high voltages that economically distribute power, into the lower voltages required by customers.

Distribution transformers are installed overhead on poles, at grade level on pads, and totally underground in vaults. For years, the most widely used transformer has been the single-phase, overhead version, installed either to deliver single-phase service or in a bank of transformers to deliver three-phase service. Padmount transformers are becoming more popular because the higher cost of underground distribution is being offset by increased interest in aesthetics, safety, and system reliability.

Primary (high side) distribution voltage is from 2400 volts to 34,400 volts. Connections to the transformer primary windings are at the top of overhead and underground transformers, and the left panel of padmount transformers.

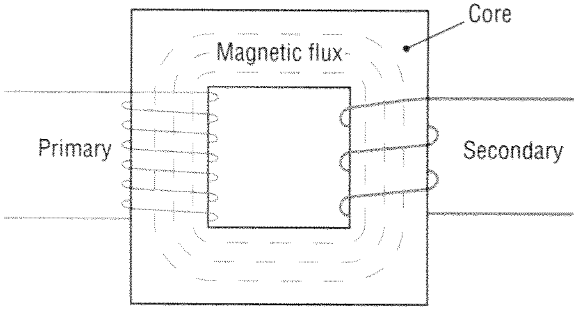
Secondary (low side) service voltages are typically 120 volts, 208 volts, 240 volts, 277 volts, 347 volts, 480 volts, and 600 volts. Connections to the transformer secondary windings are at the side of overhead and underground transformers, and the right panel of padmount transformers.

The Transformer

A transformer consists of a laminated iron core, around which two or more coils of conductors are wound.

When an AC voltage is applied to one coil, current flowing in that coil magnetizes the core – first in one direction, then in the opposite direction. This oscillating magnetic field intersects the second coil, inducing a voltage in it.

The voltage across the secondary terminals causes current to flow through its coil and through any load connected across the secondary terminals. The secondary voltage is determined by the primary voltage and the effective ratio of the number of turns in the primary coil to the number of turns in the secondary coil. The secondary current is the secondary voltage, divided by the load impedance.



Core – The part of the transformer in which the magnetic field oscillates. It is built from thin laminated sheets, each coated with a thin layer of insulation, and cut to form the shape around which the coils are wound. Laminations are used instead of solid cores to reduce core losses.

The ease with which a material can be magnetized is known as its permeability. Iron or a special type of steel is used for transformer cores because these materials have high permeability.

Coil – A coil, also called a winding, consists of insulated conductors, wound around the core. The type of insulation depends on the voltage across the coil. Power transformers at generating stations step up voltages to efficiently transmit electrical power. Distribution transformers step down voltages for convenient use by customers. At distribution transformers, the higher voltage (input) coil is the primary, the lower voltage (output) coil is the secondary. The primary coil has many turns of small wire. The secondary coil has fewer turns and its conductors are large wire or strips with rectangular cross-sections.

Turns ratio – The number of turns on the primary coil, divided by the number of turns on the secondary coil.

Effective turns ratio – The relationship between the input and output voltage. Also called: voltage ratio.

Bushing – Porcelain bushings bring the high and low voltage leads from the coils out through the tank, to external connections.

Tank – The enclosure for the core, coils, and transformer oil. The outer surface of the tank dissipates heat generated in the core and coils.

Note: A transformer does not work on DC. DC produces a magnetic flux that flows constantly in one direction, only. Transformation requires a changing magnetic flux.

Motors, Generators, and Transformers

- Motors convert electric power, to magnetic flux, to mechanical power.
- Generators convert mechanical power, to magnetic flux, to electric power.
- Transformers convert electric power, to magnetic flux, to electric power in a new form. Unlike motors and generators, transformers are nearly 100% efficient, operate continuously with no maintenance, and have no moving parts. In a transformer, the only "moving part" is the oscillating magnetic flux in the core.

Formulas

V_P	Primary voltage
V_S	Secondary voltage
I_P	Primary current
I_S	Secondary current
N_P	Number of turns in the primary winding
N_S	Number of turns in the secondary winding

Voltage times current in the primary = voltage times current in the secondary:

$$V_P \times I_P = V_S \times I_S$$

or: kVA in = kVA out

This formula is approximate. In practice, small losses in the transformer make kVA out slightly less than kVA in.

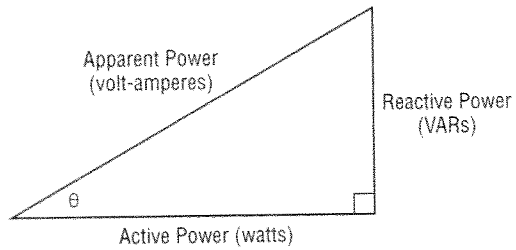
Voltages are proportional to the turns ratio:

$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

Currents are inversely proportional to the turns ratio:

$$\frac{I_P}{I_S} = \frac{N_S}{N_P}$$

Power Triangle



Apparent power is the power generated by the utility. Transformers are rated by their ability to deliver apparent power.

Watthour meters measure active power, which is what most customers are billed for.

Reactive power is consumed in alternatively building and collapsing magnetic fields in transformers and motor windings – and electrostatic fields in capacitors.

The ratio of active power to apparent power is the power factor of the circuit. Adding capacitors to distribution lines makes the angle between these vectors smaller, bringing the power factor closer to 1. This reduces the total power (kVA) the utility must generate.

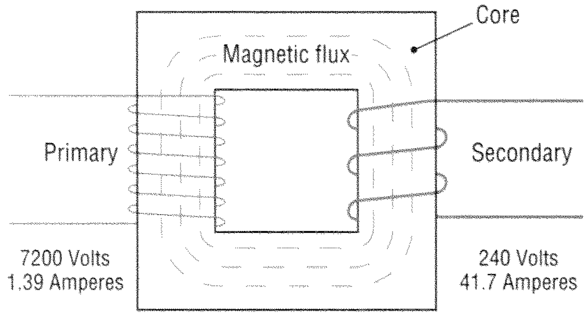
Abbreviations

k	kilo. A prefix indicating one thousand.
VA	volt-ampere. A unit of apparent power.
VAR	volt-ampere reactive. A unit of reactive power.
W	watt. A unit of active power.

Transformer Rating

Transformers are rated by the amount of apparent power (kVA) they can deliver.

The example shown here is for a 10 kVA transformer operating at full load.



$$\text{Primary: } \frac{7200 \times 1.39}{1000} = 10 \text{ kVA}$$

$$\text{Secondary: } \frac{240 \times 41.7}{1000} = 10 \text{ kVA}$$

Rated kVA is the full-load capacity for either the primary or the secondary – they are the same.

For example, a 10 kVA transformer could accept any of these primary inputs, and deliver any of these secondary outputs.

Primary Inputs	Secondary Outputs
7200V × 1.39A = 10 kVA	480V × 20.0A = 10 kVA
4169V × 2.40A = 10 kVA	277V × 36.1A = 10 kVA
2400V × 4.16A = 10 kVA	240V × 42.7A = 10 kVA
	120V × 83.3A = 10 kVA

Transformers are manufactured in the ratings listed here.

Overhead		
Single-Phase	(kVA)	5, 10, 15, 25, 37.5, 50, 75, 100, 167, 250, 333, 500
Three-Phase	(kVA)	15, 30, 45, 75, 112.5, 150, 225, 300, 500
Padmounted		
Single-Phase	(kVA)	25, 37.5, 50, 75, 100, 167
Three-Phase	(kVA)	75, 112.5, 150, 225, 300, 500, 750, 1000, 1500, 2000, 2500

Transformer Losses

The two main causes of losses in a transformer are iron losses and copper losses.

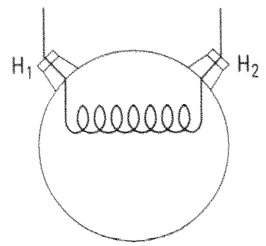
Iron losses are caused by magnetic hysteresis – the opposition by atoms in the core to being aligned first in one direction and then in the other, by the AC field. Iron losses are also caused by small circles of current that flow, like eddy currents in a pool of water, within the core laminations. Iron losses are called no-load losses because they occur regardless of the loading on the transformer.

Copper losses, also called I^2R losses, are produced by the resistance in the transformer windings and the currents flowing through them.

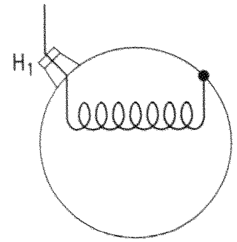
Total losses within a transformer are typically a small percentage of its kVA rating.

Transformer Bushing Designations

H designates a primary, or high-side bushing. When facing the front of the transformer, H1 is always the bushing at the left. If the transformer has a second primary bushing, it is H2. Single-bushing transformers connect the other end of the winding to the transformer tank, as a ground. These transformers can be used only in grounded-wye systems.



Two primary bushings

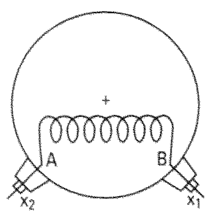


One primary bushing

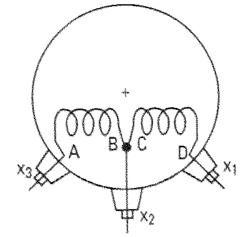
X designates a secondary, or low-side bushing. On additive polarity transformers, secondary bushings are numbered right-to-left. Example: X3, X2, X1. On subtractive polarity transformers, secondary bushings are numbered left-to-right. Example: X1, X2, X3. See also Polarity on pages 10-13.

A transformer secondary can have one winding (coil) and two bushings, or two windings (most common) of equal size, with three or four bushings. Inside the transformer, the ends of the left winding are designated A and B. The ends of the right winding are designated C and D.

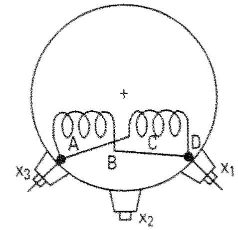
Two bushings, one secondary winding.



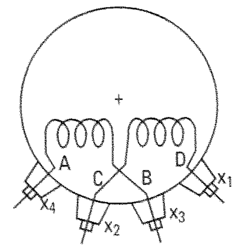
Three bushings, two secondary windings connected in series. This is how three-bushing transformers are supplied by the factory. This configuration can provide 240 volts between X1 and X3, and two 120-volt services: X1 to X2, and X2 to X3.



Three bushings, two secondary windings connected in parallel. The previous connection has two 120-volt services. This connection has only one 120-volt service (half as many) but can deliver twice as much current. Both connections deliver the same kVA. Here, the secondary coils are connected to X1 and X3, and X2 is abandoned. Some utilities connect the secondary coils to X1 and X2, and abandon X3. To make the change from a series to a parallel connection, remove the lid from the transformer (de-energized) and reposition the secondary connections. Be careful to not contaminate the oil or drop tools or nuts or any other foreign matter inside the transformer tank.



Four-bushing transformers allow external access to all ends of the secondary windings. This eliminates the need to go inside the transformer to reconfigure the connections. Notice, the ends of the windings in the middle cross making the designations of the internal windings at the external bushings, left to right, A-C-B-D. "Alley Cat, Bad Dog." The bushing designations X2 and X3 are crossed, as shown here. Transformers larger than 100 kVA have four bushings.



Transformer Taps

Some transformers have taps on their primary windings so lineworkers can adjust the voltages delivered to customers. Typically, five settings are available. By changing the taps, voltages are changed in 2-1/2% steps.

A common application for tap-changing occurs near the end of a long distribution line where the primary voltage is low, and service voltages delivered to customers are below acceptable limits. Changing the taps on the transformer raises the secondary voltages.

Taps are installed on the high-side (primary) winding. The tap-changing handle is usually located inside the transformer above the oil, and accessed by removing the lid. In some cases, the operating handle is on the outside of the tank. The actual tap-changing contacts are below the oil level. ***Caution:*** Operate tap changers only when the transformer is de-energized.

Polarity

Transformer polarity refers to the instantaneous relationship between the AC voltage at the primary, and the voltage at the secondary. There are two possibilities: the voltages are either in-phase, or 180° out-of-phase – it depends on whether the primary and secondary windings are wound in the same direction, or in opposite directions.

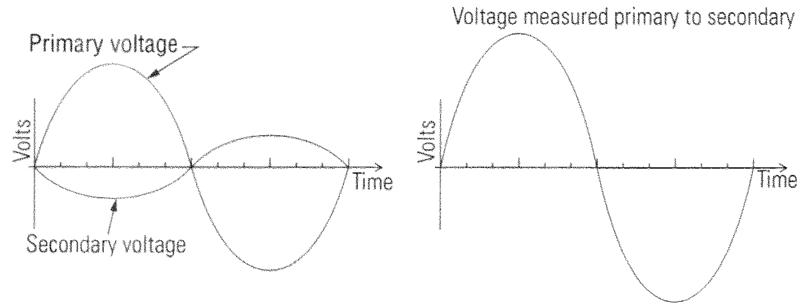
These rules apply to all overhead transformers:

- What comes in on H1 is in phase with what goes out of X1.
- H1 is the top left bushing.
- On additive transformers, X1 is diagonally opposite H1.
- On subtractive transformers, X1 is vertically below H1.

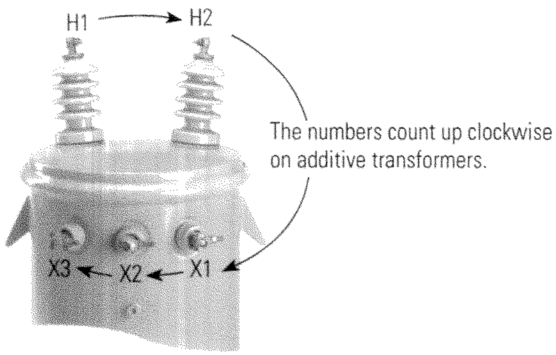
Polarity is unimportant when a transformer is installed alone, but is extremely important when transformers are installed in parallel, or as a bank. If one transformer in a bank has a different polarity, the connections to either the primary or the secondary bushings of that transformer must be reversed.

Additive Polarity Transformers

The graph below at the left shows primary and secondary voltages for an additive transformer, with measurements taken left-to-right. The voltages are 180° out-of-phase. The graph below at the right shows the voltage difference between the two graphs. This voltage is more than the primary voltage. This is what the voltmeter reads in the polarity test on page 13. This is an additive transformer.

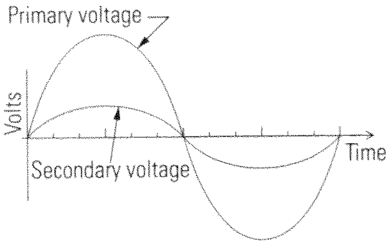


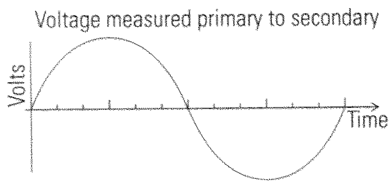
On additive transformers, the secondary bushings are numbered right-to-left, like this: X3, X2, X1. To remember how bushings on additive transformers are numbered, if you count around the bushings clockwise, the bushing numbers count up, similar to addition: H1, H2, X1, X2, X3.



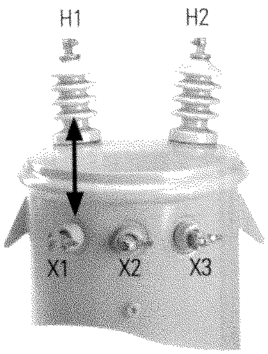
Subtractive Polarity Transformers

The graph below at the left shows primary and secondary voltages for a subtractive transformer, with measurements taken left-to-right. Both voltages are in-phase. The graph below at the right shows the voltage difference between the two graphs. This voltage is less than the primary voltage. This is what the voltmeter reads in the polarity test on page 13. This is a subtractive transformer.





On subtractive transformers, the secondary bushings are numbered left-to-right, like this: X1, X2, X3. To remember how subtractive bushings are numbered, memorize "Same side subtractive." The X1 bushing is on the same side as the H1 bushing on subtractive transformers.

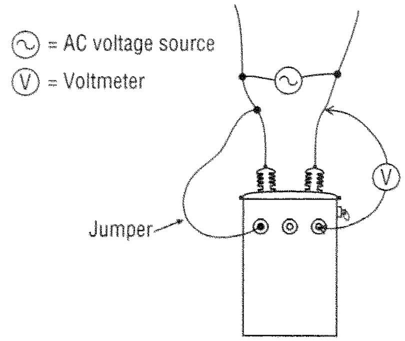


X1 is on the same side as H1.

Polarity Test

Polarity is listed on the transformer nameplate. If in doubt, this test will determine the polarity of a transformer:

1. Connect two adjacent terminals of the high and low voltage windings.
2. Apply a moderate (120 volts) voltage across the high voltage terminals. Do not apply the 120 volts to the secondary terminals. This will induce a lethal voltage across the primary terminals.
3. Measure the voltage across the other high and low voltage terminals.



4. The polarity is additive if the measured voltage is higher than the applied voltage. The polarity is subtractive if the measured voltage is lower than the applied voltage.

Transformer Voltage Designations

Slash Means Both

A slash (/) is used to define voltages that can be applied to the primary windings of a transformer, or voltages available at the transformer's secondary windings. For example, for a primary:

- 7,200/12,460 GrdY
- 14,400/24,940Y
- 4,160/7,200 GroundedY

The first number (7,200, 14,400, 4,160) is the voltage that can be applied across the primary coil of the transformer. If the transformer is installed on a wye system, this first number is the phase-to-neutral primary voltage. The second number is the voltage you will then get phase-to-phase. (In a wye system, the voltage phase-to-phase is 1.73 times the voltage phase-to-wye center-point.) If the transformer is installed on a delta system, the first number is the phase-to-phase primary voltage; the second voltage is not applicable to a delta installation.

Another example of a slash: 120/240. This slash designates a transformer secondary that delivers both 120 volts and 240 volts. Instead of a slash, sometimes a comma is used: 120, 240 volts.

X Means Either, Not Both

X is used to separate two optional input voltages for a dual-primary-voltage transformer. For example: 72 X 144. This transformer can operate with a primary input of either 7,200 volts or 14,400 volts. Using a switch, the lineman can change the transformer to accept one or the other primary voltage. This type transformer is usually installed when a system upgrade is planned but not implemented. When the new higher system voltage is implemented, rather than replacing the transformer, the switch on the transformer is moved to operate with the higher voltage.

Dash Separates Primary - Secondary

A dash (-) is used to separate voltages from primary and secondary windings. The number before the dash is the primary voltage. The number after the dash is the secondary voltage(s) available. For example: 7,200 - 277 and 14,400/24,940GrdY - 120/240.

One Voltage for One Coil

If a transformer is specified as just one voltage, that is the voltage you can apply on a wye system from one phase to the wye center-point, or on a delta system from phase to phase. For example:

- 4,800 V
- 12,000 V
- 12 kV

Backfeed

Backfeed is a condition in which a transformer is energized from a source other than the distribution feeder. For example, backfeed occurs when electricity flows from a customer's solar panels back into the power company's distribution system. Backfeed can also occur between transformers connected in parallel, and between transformers in certain three-phase banks.

Undetected backfeed can be dangerous to lineworkers and equipment. Even though the transformer has been de-energized at the primary cutout, it is still energized. When working on transformers, consider all possible energizing sources. Always follow your company's established procedures and safe work practices.

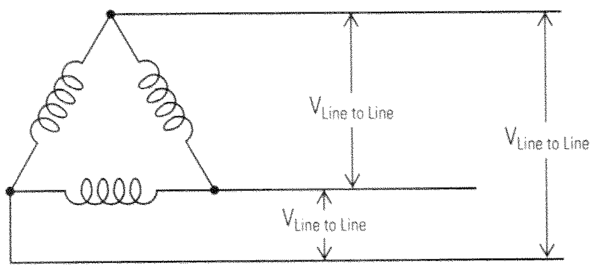
To protect workers from backfeed, some utilities follow this practice:

- Measure the voltages at secondary bushings. All readings should be zero. Then, remove and isolate the secondary conductors at the job site to provide a local, visual confirmation of protection.

Wye, Delta Configurations

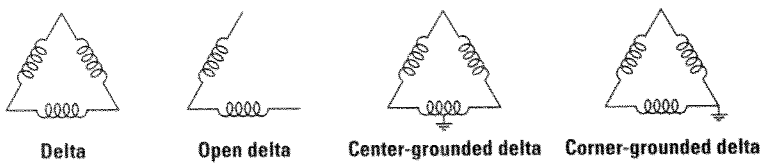
Three transformer windings can be configured as a delta or a wye, to deliver three-phase services.

Delta



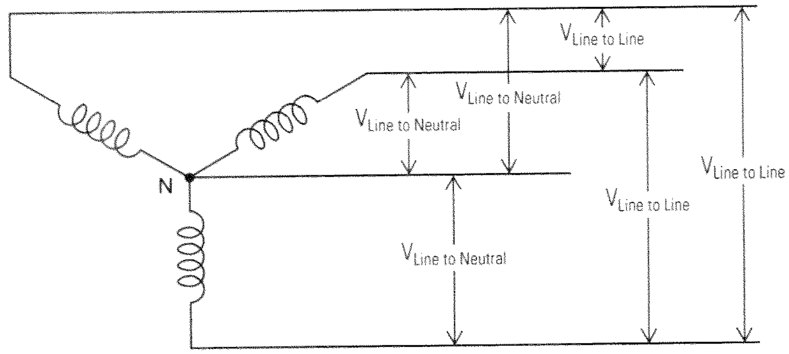
Line-to-line voltage is the same as the voltage across a transformer winding. Line current is 1.73 times the current in a transformer winding.

Delta configurations:

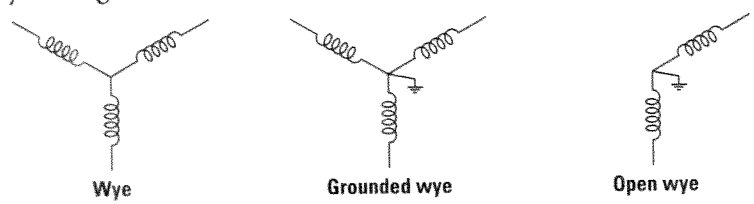


Wye

Line-to-line voltage is 1.73 times line-to-neutral voltage (the voltage across a transformer winding). Line current is the same as the current in a transformer winding.



Wye configurations:



Transformer Protection

The main enemies of transformers are heat, and high current or voltage.

Heat Protection

Transformers can deliver considerably more current than their nameplate indicates, for a short while. The heat-rise from an 80-100% overload can usually be tolerated for an hour or more, before it becomes dangerous.

For cooling, distribution transformers are oil-filled. The oil carries heat away from the core and coils, to the tank wall which dissipates the heat to the surrounding air. Oil around the core and coils heats and rises to the top of the tank, then flows away from the center to the walls of the tank. At the tank walls, the oil cools and sinks to the bottom, and the cycle repeats. To circulate easily, transformer oil has a low viscosity (resistance to flow).

Oil in older transformers may contain PCBs, a chemical whose use is now banned. Use caution when handling this substance.

Heat rise in the tank is accompanied by a rise in pressure in the air space above the oil. Pressure relief valves automatically discharge this pressure to the atmosphere, and pop out to provide a visual indication that they were activated.

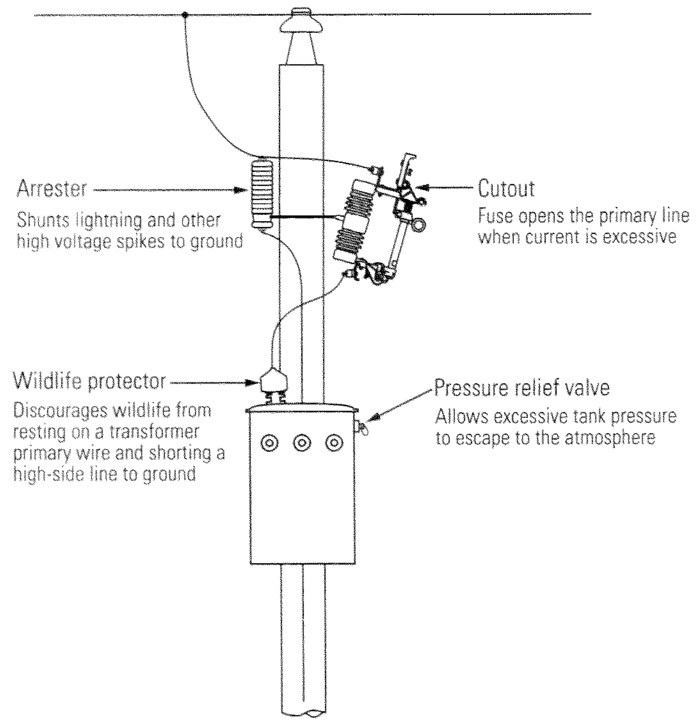
Current Protection

Fused cutouts protect transformers from excessive currents and short circuits. Cutouts are installed between the primary line and the transformer. The fuse in the cutout must be carefully sized to blow only when abnormal conditions occur.

Voltage Protection

Arresters protect transformers from high voltage spikes, such as lightning. If lightning strikes a power pole or line, it seeks the easiest path to ground, which could be through a transformer.

Arresters create a safe, low-resistance path for lightning to get to ground, that bypasses the transformer. Lightning strikes can exceed one million volts, so the connections at the arrester must be tight, and the ground wire properly sized for surge currents that accompany these high voltages.



Transformer protective devices.

Fusing Overhead Transformers

Transformer Rating (kVA)	System Voltage 2,400 V Fuse	7,200 V Fuse	14,400 V Fuse	19,920 V Fuse
3	2H	1H	1H	—
5	3H	1H	1H	—
7.5	5H	2H	1H	—
10	6T	2H	1H	1H
15	10T	3H	2H	—
25	15T	6T	3H	2H
37.5	25T	6T	3H	—
50	25T	10T	5H	3H
75	40T	15T	6T	5H
100	65T	25T	10T	6T
150	100T	25T	15T	—
167	100T	40T	15T	10T
200	100T	40T	15T	—
250	—	40T	25T	15T

Select the fuse below the system voltage and across from the transformer rating. To determine the 100% rated current for a transformer, divide the kVA rating on the nameplate by the system primary voltage. Most utilities size fuses at 150% to 250% of the rated current for the transformer being protected.

When fusing a single-phase transformer in a three-phase bank, fuse each transformer according to its individual rating.

H-series fuses are for small transformers. T-series fuses are for large transformers. The number in each fuse-type is related to how much current the fuse will conduct before blowing. Fuses are designed to not operate during temporary current surges from motors starting, lighting, or similar causes.

Fuses at distribution transformers are coordinated with the several other protective devices in the system. To minimize the number of customers affected by a problem, distribution transformer fuses are usually sized to blow before upstream protective devices operate.

The transformer fuses listed in this table are typical for grounded wye systems, and might not apply to you. Always follow your company's fusing practices.

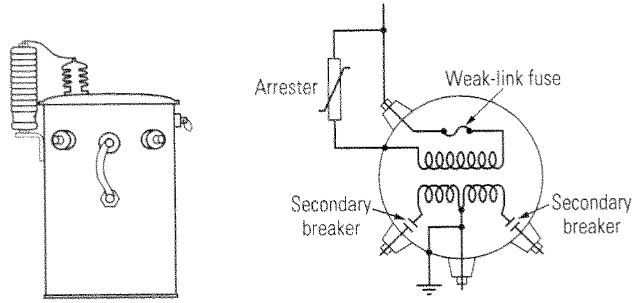
Completely Self-Protected Transformers

The conventional transformer requires externally mounted protection, such as a fuse cutout and arrester. The Completely Self-Protected (CSP) transformer has this protection built-in:

- An arrester mounted externally on the tank
- A high-voltage fuse in series with the primary bushing, for protection in the event of an internal failure in the transformer
- Low-voltage circuit breaker(s) on the secondary side which open if there is a secondary fault. The breaker(s) trip before the primary fuse blows.
- An overload signal lamp near the operating handles of the circuit breaker, to indicate overload or trip.

Conflicts can arise between protective devices when a CSP is installed on the same circuit as other protective devices.

CSP transformers should not be used in three-phase four-wire delta banks serving combined three-phase power and single-phase lighting loads.



Completely self-protected transformer.

Ferroresonance

Ferroresonance is a special condition which creates a high voltage between the transformer primary winding and ground. This voltage is often more than five times the normal voltage, and sometimes as much as 15 times normal voltage. This high voltage can damage the transformer, the primary cable insulation, and other equipment. When ferroresonance is present, the transformer usually makes a rattling, rumbling, or whining noise which is considerably different from the normal transformer hum.

Ferroresonance occurs rarely, and only under these conditions:

- Three-phase systems.
- The primary system is ungrounded, the transformer is grounded.
- The primary cable feed is long, producing a relatively high capacitance.
- The bank has no load, or is lightly loaded (less than 5%).

Underground installations are more susceptible to ferroresonance than overhead installations because underground cables have higher capacitances to ground.

In any AC circuit, when the inductive reactance is equal to the capacitive reactance, a resonant circuit, or "ringing" occurs. Ferroresonance can occur in a distribution system when the inductive reactance of one winding of a three-phase transformer is approximately equal to the phase-to-ground capacitive reactance distributed along the primary cable to that winding. A high voltage appears between the transformer winding and ground, not the usual phase-to-ground voltage. If a transient voltage also occurs at the same time, the voltage between the transformer winding and ground will go even higher.

To decrease the possibility of ferroresonance, design engineers:

- Keep cable lengths from the switching point to the transformer well within design limits.
- Convert three-phase closed delta banks to wye-wye connections.
- Use a triplex core cable to the transformer.

To decrease the possibility of ferroresonance, field personnel:

- Perform switching operations only at three-phase gang-operated switches.
- Perform single-phase switching only when the primary cable length is less than maximum design limits.
- Load the transformer bank to greater than 5-10% of the nameplate rating.
- Add a resistive load to lower the peak voltage that occurs during ferroresonance.
- On floating-wye closed-delta banks, temporarily ground the floating wye point during switching operations.

Why Do Transformers Hum?

When a transformer core is magnetized and demagnetized, its core laminations expand and contract. These physical changes to the laminations happen twice during each 60 hertz cycle, on the positive and negative sides of the flux cycle, causing the laminations to vibrate at 120 hertz. The vibrations are conveyed by the cooling oil to the tank wall, where they escape into the air as sound waves.

Transformer hum also occurs at higher harmonics of 120 hertz, but these tones are less audible.

Angular Displacement

Angular displacement refers to the angle, in degrees, between the phase of the primary voltage and the phase of the secondary voltage.

Delta-delta and wye-wye configurations have either a 0° or 180° angular displacement. If the secondary phases a, b, and c are in-phase with the primary phases A, B, and C, the angular displacement is 0°. If the voltages are 180° out-of-phase, the angular displacement is 180°.

Delta-wye and wye-delta configurations have either a 30° or a 210° angular displacement. The 30° or 210° displacement is inherent in all delta-wye and wye-delta configurations.

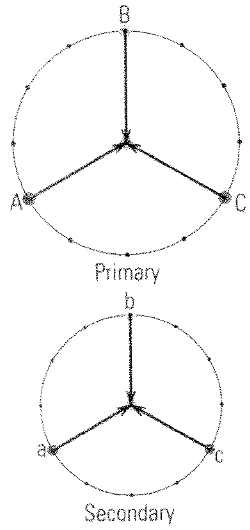
The vector diagrams on the next page show four banks, each with the same wye primary. The secondary connections produce different displacements.

A is a wye-wye with 0° displacement. The secondary vectors point in the same direction as the primary vectors.

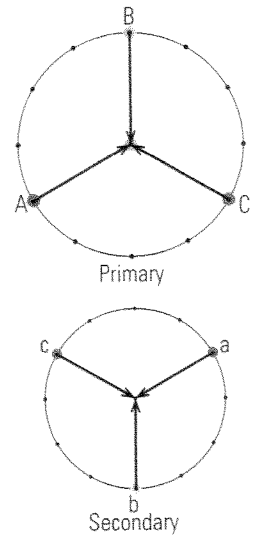
B is a wye-wye with 180° displacement. The secondary vectors point in the opposite direction as the primary vectors.

C is a wye-delta with 30° displacement. A new vector drawn from the tip of A to the tip of B points approximately north-northeast. A vector drawn from a to b points northeast. The angular difference between these vectors is 30°.

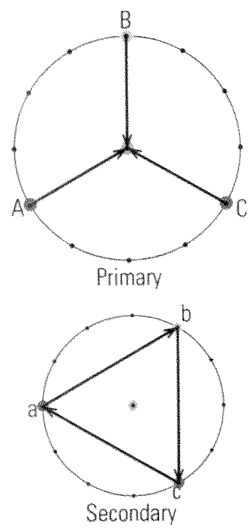
D is a wye-delta with 210° displacement. A new vector drawn from the tip of A to the tip of B points approximately north-northeast. A vector drawn from a to b points south-southwest. The angular difference between these vectors is 210°.



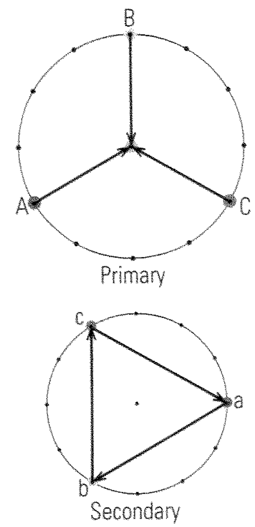
A. 0° displacement



B. 180° displacement



C. 30° displacement



D. 210° displacement

Paralleling Transformers

When paralleling transformers, always consult your company's established safety procedures and work practices.

Single-Phase Paralleling

To increase the capacity of a single-phase service, a second single-phase transformer may be connected in parallel. Transformers of either additive or subtractive polarity may be paralleled, provided the primary phase sources are the same and the H and X terminals are correspondingly connected. This assures that the secondary voltages are in-phase.

When single-phase transformers are paralleled, the transformers must meet these conditions:

- Voltage ratings are identical.
- Tap settings are identical.
- Percent impedances are very nearly the same.

Three-Phase Paralleling

Occasionally, three-phase transformer banks are paralleled.

This additional condition must be met:

- The voltages on the secondary terminals must be in-phase.

One way to determine if the angular displacements match, is to take voltage readings between corresponding pairs of bushings. For details on paralleling three-phase transformers, see pages 74-77.

A wye-wye bank can be paralleled with another wye-wye bank. A delta-delta bank can be paralleled with another delta-delta bank. These banks can have the same angular displacement.

A wye-wye bank can not be paralleled with a wye-delta bank, and a delta-delta bank can not be paralleled with a delta-wye bank. These transformers can not be wired to have the same angular displacement.

Vector Diagrams

Vector diagrams provide a visual picture of the magnitude (in volts) and phase of every primary and secondary voltage at a bank. Two vector diagrams are required: one for the primary and one for the secondary.

After drawing the two vector diagrams, make a physical wiring connection in the field at the transformer bank at every point where a vector touches a circle or another vector.

A vector is a line with a head and a tail. The length of the line represents a a certain number of volts, relative to the other voltages in the same diagram.

The head and tail show how the voltage measurement is taken, from tail to head, from the low-number bushing to the high-number bushing. The direction a vector points shows its phase, relative to all primary and secondary voltages.

Dots are used to represent the conductors. Each dot is the cross-section of a conductor going into the page. In this book, dots are small circles, colored to indicate the phase of the conductor.

The primary voltage vector diagram gives this information:

- The length of each vector represents the voltage between two primary bushings, measured from Hl to H2.
- The direction each vector points shows its phase angle, relative to all primary and secondary voltages.

The secondary voltage vector diagram gives this information:

- The length of each vector represents the voltage between two secondary bushings, measured from Xl to the highest-numbered secondary bushing.
- The direction each vector points shows its phase angle, relative to all primary and secondary voltages.

Four Rules for Labeling Vector Diagrams

Rule 1: Left to right.
Assign numbers and letters left to right – just like the way we read a book. Label phase conductors, left to right. Label transformers on a pole, left to right. Everything is left to right.

Rule 2: Clockwise.
Assign labels to delta or wye diagrams, clockwise – the same direction the hands of a clock move. Add arrowheads to delta vectors, pointing clockwise. Add arrowheads to wye vectors pointing to the center of the diagram. These are voltage vectors, but imagine current flowing to ground.

Rule 3: A B C.
Place letters in alphabetic order. Label conductors on poles and crossarms in alphabetic order. Electricity is generated in three phases: A B C. This sequence repeats over and over: ABCABCABCA...

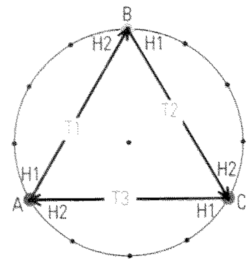
Rule 4: 1 2 3.
Place numbers in vector drawings in numeric sequence: 1 2 3. Rule 3 and Rule 4 work together. For example, phase A goes with transformer 1. Phase B goes with transformer 2. Phase C goes with transformer 3.

Five Steps for Drawing Vector Diagrams

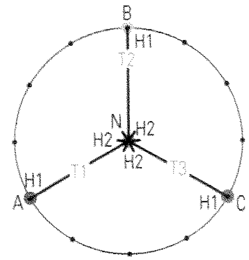
Step	Action
1	Determine if the circuit is wye or delta.
2	Draw a wye (or a delta) on the vector diagram circle.
3	Show direction – clockwise for delta, to ground for wye.
4	Label the transformers T1, T2, T3. Show the polarity on each transformer (+ or –).
5	Label the bushings.

Drawing Primary Vector Diagrams

Following the five steps, draw the primary vector diagrams. Label the drawings using the five rules. There are only two possible primary vector diagrams – a delta and a wye.



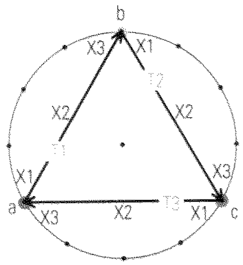
Delta



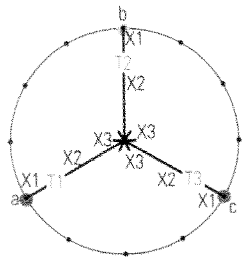
Wye

Drawing Secondary Vector Diagrams

Step	Action
1	To determine if the secondary is a delta or wye circuit, find out what voltage(s) the customer needs. Then, from the transformer nameplate, read the low-voltage (LV) rating. If all the voltages the customer needs are on the nameplate, the secondary is a delta circuit. Same = Delta. If all the voltages the customer needs are not on the nameplate, the secondary is a wye circuit. Different = Wye.
2	If the bank is connected delta-delta, draw a delta on the secondary vector diagram circle. Add labels.
	If the bank is connected wye-wye, draw a wye on the secondary vector diagram circle. Add labels.



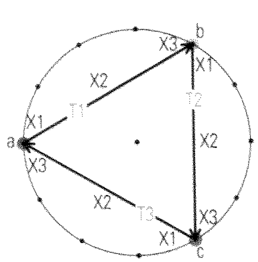
Secondary vector diagram for a delta-delta bank



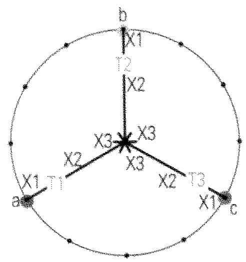
Secondary vector diagram for a wye-wye bank

If the bank is connected delta-wye, draw the secondary wye with the vectors rotated 30 degrees (1 "hour") backward. This makes these vectors parallel with the primary vectors. Complete the diagram, including labels.

If the bank is connected wye-delta, draw the secondary delta ortated 30 degrees (1 "hour") forward. This makes these vectors parallel with the primary vectors. Complete the diagram, including labels.



Secondary vector diagram for a delta-wye bank



Secondary vector diagram for a wye-delta bank

CHAPTER

2

TRANSFORMER CONNECTIONS

Notes to the Connection Diagrams

The diagrams in this chapter illustrate a variety of popular configurations. Many others are possible. If other configurations are used by your utility, you might sketch them for reference on one of the blank diagrams on pages 59 and 60.

These diagrams do not show connections to ground. Most utilities ground the neutral conductors and transformer tanks. But not all utilities do that. Always follow all your company's established grounding practices.

The connection diagrams show transformers with two primary bushings. One-bushing transformers can be used if the installation is a grounded-wye primary and the transformer tanks are grounded to complete the primary circuit through the transformer.

Transformer Banks Convert "Fruit" to "Smoothies"

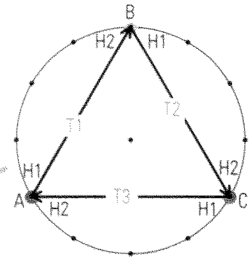
Imagine this: At a three-transformer bank, on the primary side, the first transformer H1 is connected to A (Apples). The second transformer H1 is connected to B (Bananas). The third transformer H1 is connected to C (Carrots). What goes into H1 must come out of X1. Apples go into H1 and come out as applesauce on X1. Bananas go into H1 and come out as banana mush on X1. Carrots go into H1 and come out as carrot juice on X1. What goes into the blender is the same as what comes out – just a little smaller.

It's always the same. Big or small. Additive or subtractive. Delta or wye. What goes into H1 comes out on X1. The transformer's job is to take large voltage (fruit) and convert it to small voltage (smoothies).

Delta - Delta

4,160 to 240 Volts

0° phase displacement



Primary Voltage Vectors

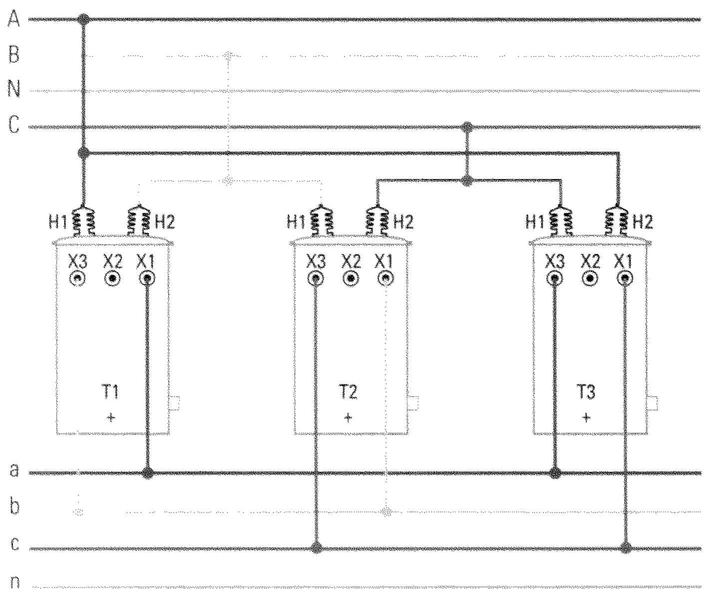
Transformer Nameplate Data

Polarity: Additive

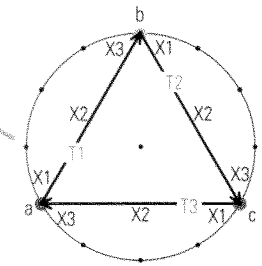
Primary volts: 4,160/7,200Y

Secondary volts: 120/240

Measured line-to-line primary voltage: 4160 volts.



Secondary coils are in series.



Secondary Voltage Vectors

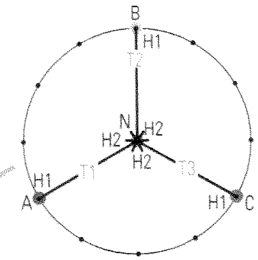
Customer Needs

240 volts: a to b, b to c, c to a

Wye - Wye

12,460 to 120, 208 Volts

0° phase displacement



Primary Voltage Vectors

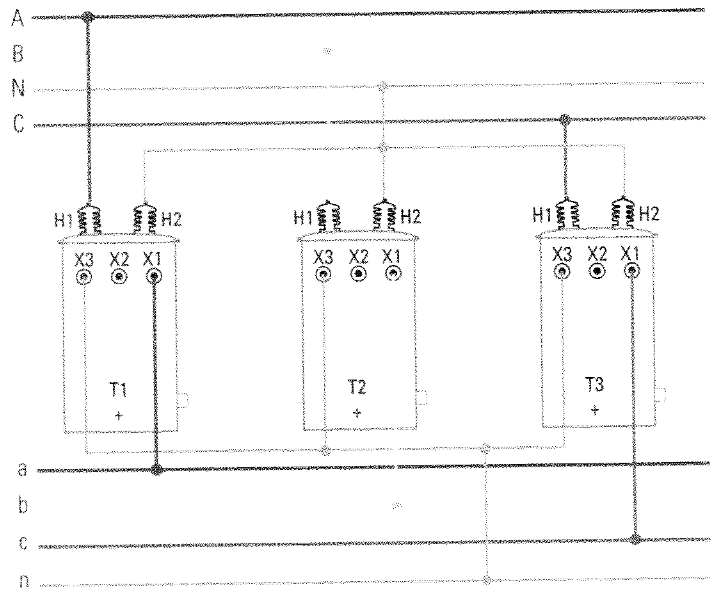
Transformer Nameplate Data

Polarity: Additive

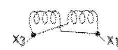
Primary volts: 7,200/12,460Y

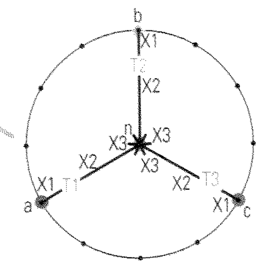
Secondary volts: 120/240

Measured line-to-line primary voltage: 12,460 volts.



Secondary coils are in parallel.





Secondary Voltage Vectors

Customer Needs

120 volts: a to n, b to n, c to n

208 volts: a to b, b to c, c to a

Delta - Wye

7,200 to 120, 208 Volts

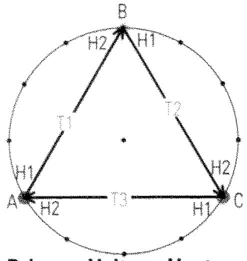
30° phase displacement

Transformer Nameplate Data

Polarity: Additive

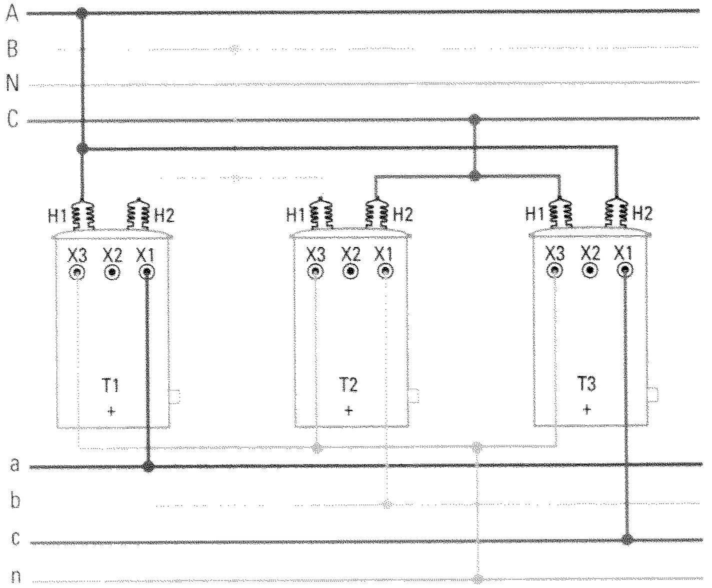
Primary volts: 7,200/12,460Y

Secondary volts: 120/240

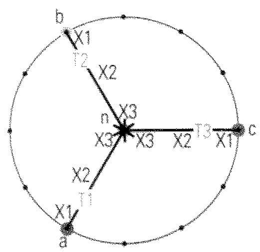


Primary Voltage Vectors

Measured line-to-line primary voltage: 7,200 volts.



Secondary coils are in parallel.



Secondary Voltage Vectors

Customer Needs

120 volts: a to n, b to n, c to n

208 volts: a to b, b to c, c to a

Wye -Delta

12,000 to 240 Volts

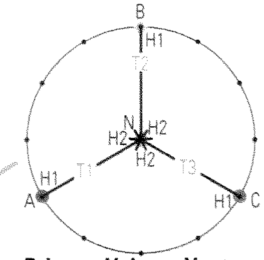
30° phase displacement

Transformer Nameplate Data

Polarity: Subtractive

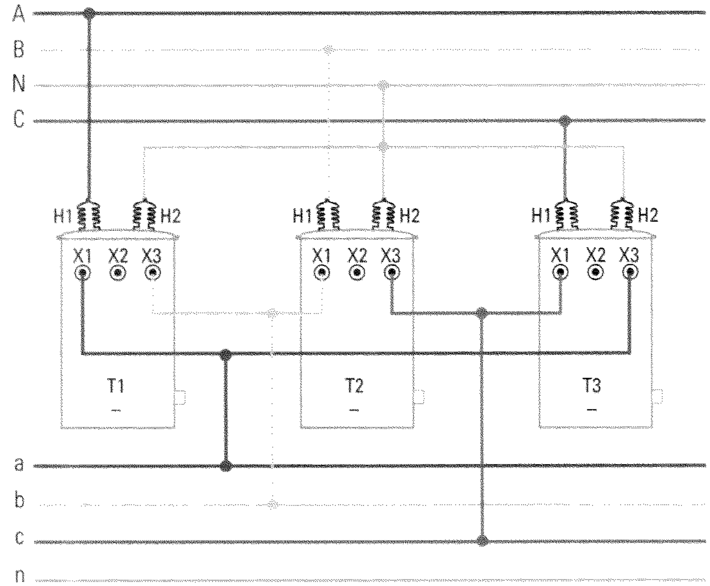
Primary volts: 6,900/12,000Y

Secondary volts: 120/240

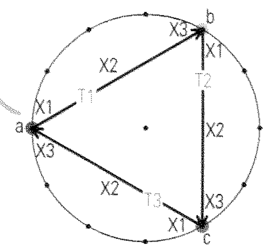


Primary Voltage Vectors

Measured line-to-line primary voltage: 12,000 volts.



Secondary coils are in series.



Secondary Voltage Vectors

Customer Needs

240 volts: a to b, b to c, c to a

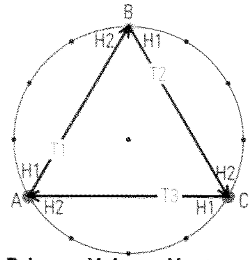
Delta -Delta

4,800 to 120, 240 Volts

0° phase displacement

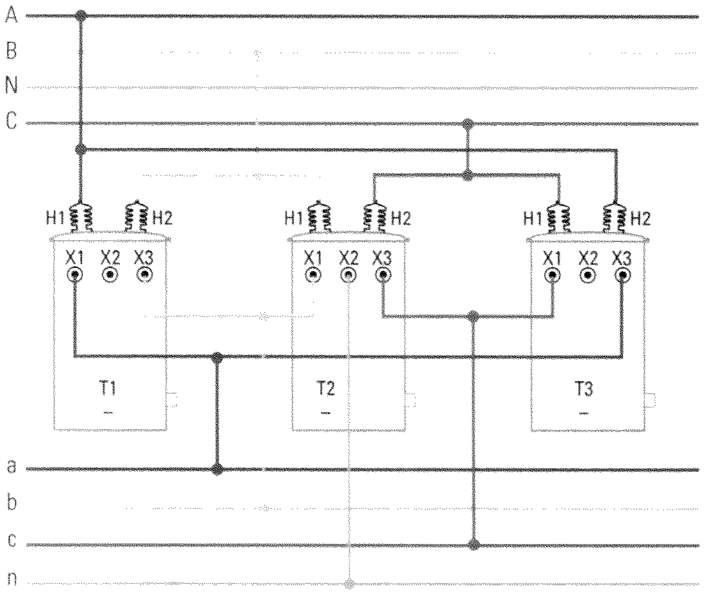
Transformer Nameplate Data

Polarity: Subtractive
Primary volts: 4,800
Secondary volts: 120/240

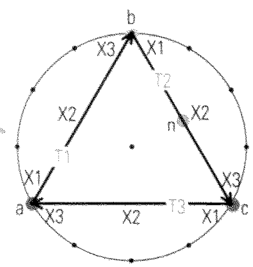


Primary Voltage Vectors

Measured line-to-line primary voltage: 4,800 volts.



Secondary coils are in series.



Customer Needs

240 volts: a to b, b to c, c to a
120 volts: b to n, c to n

Secondary Voltage Vectors

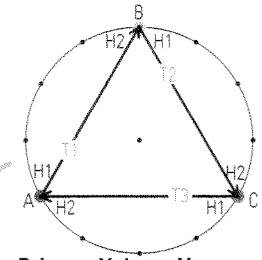
Delta -Delta

6,900 to 120, 240 Volts

0° phase displacement

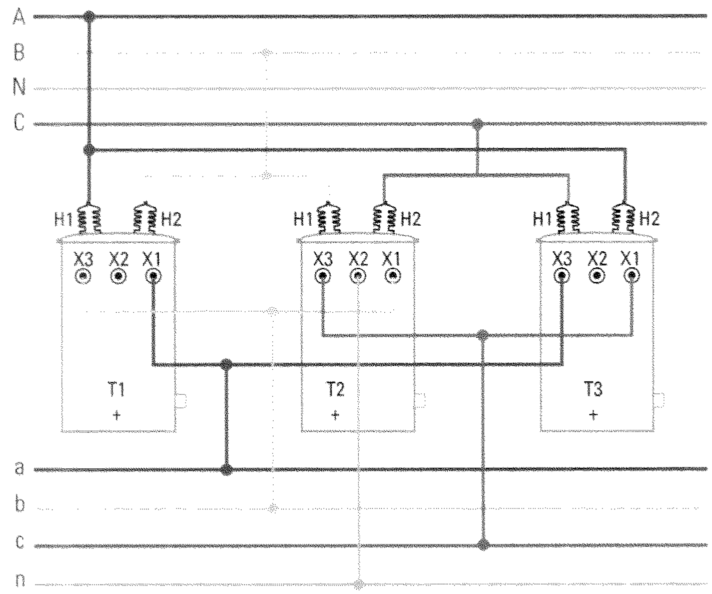
Transformer Nameplate Data

Polarity: Additive
Primary volts: 6,900/12,000Y
Secondary volts: 120/240

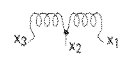


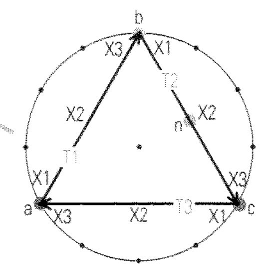
Primary Voltage Vectors

Measured line-to-line primary voltage: 6,900 volts.



Secondary coils are in series.





Customer Needs

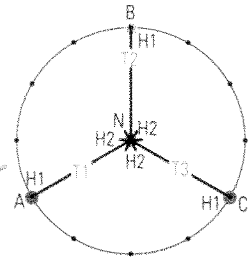
240 volts: a to b, b to c, c to a
120 volts: b to n, c to n

Secondary Voltage Vectors

Wye - Wye

12,000 to 120, 208 Volts

0° phase displacement



Primary Voltage Vectors

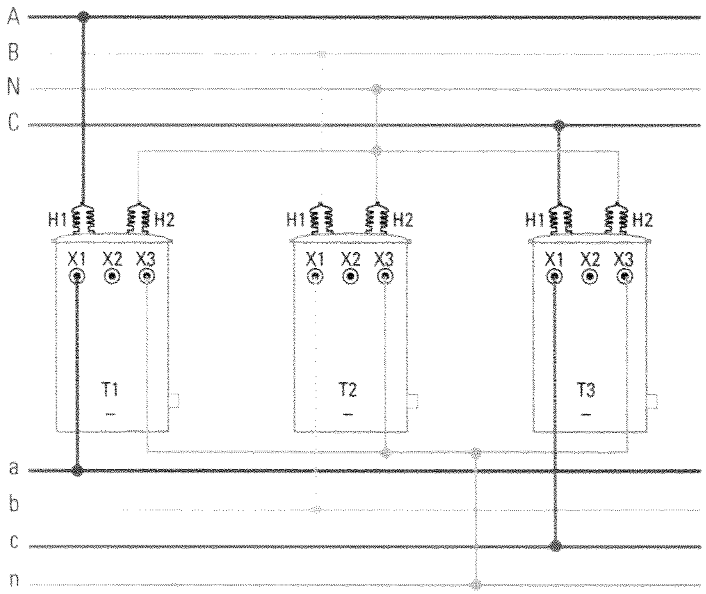
Transformer Nameplate Data

Polarity: Subtractive

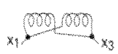
Primary volts: 12,000/21,000Y

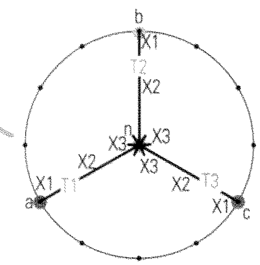
Secondary volts: 120/240

Measured line-to-line primary voltage: 21,000 volts.



Secondary coils are in parallel.





Secondary Voltage Vectors

Customer Needs

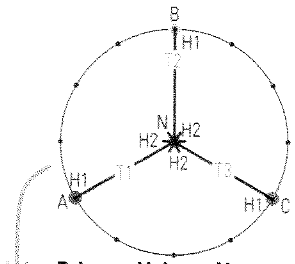
120 volts: a to n, b to n, c to n

208 volts: a to b, b to c, c to a

Wye - Wye

24,940 to 120, 208 Volts

0° phase displacement



Primary Voltage Vectors

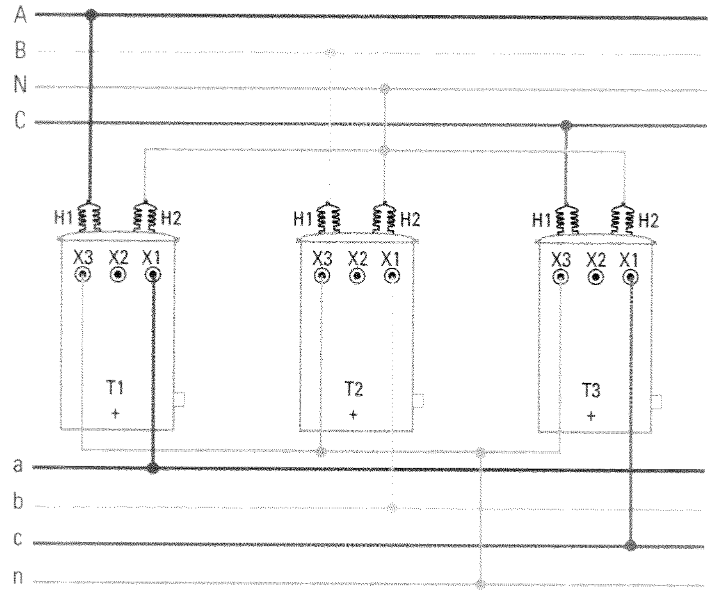
Transformer Nameplate Data

Polarity: Additive

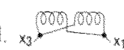
Primary volts: 14,400/24,940Y

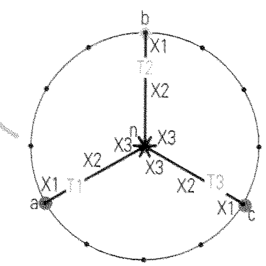
Secondary volts: 120/240

Measured line-to-line primary voltage: 24,940 volts.



Secondary coils are in parallel.





Secondary Voltage Vectors

Customer Needs

120 volts: a to n, b to n, c to n

208 volts: a to b, b to c, c to a

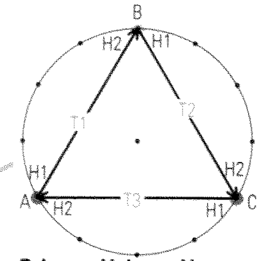
Delta - Wye

12,000 to 120, 208 Volts

30° phase displacement

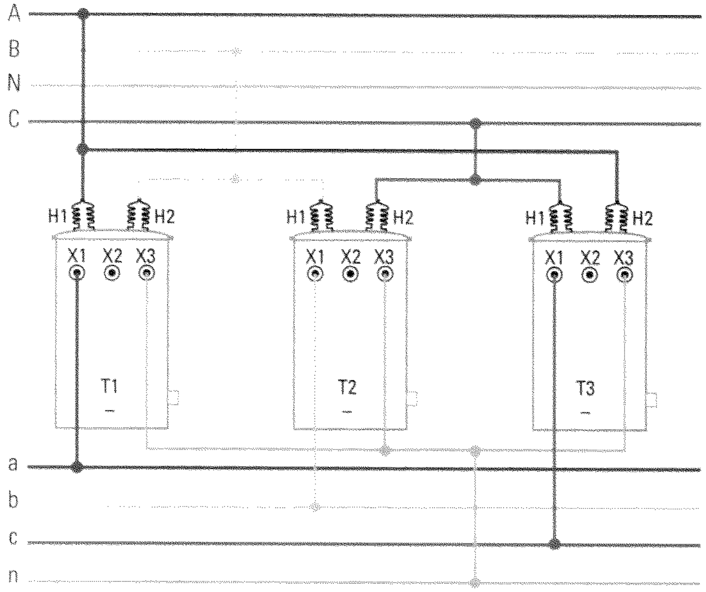
Transformer Nameplate Data

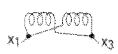
Polarity: Subtractive
Primary volts: 12,000
Secondary volts: 120/240



Primary Voltage Vectors

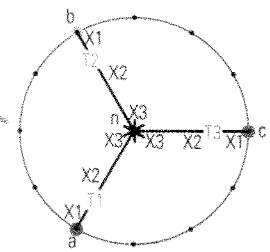
Measured line-to-line primary voltage: 12,000 volts.



Secondary coils are in parallel. 

Customer Needs

120 volts: a to n, b to n, c to n
208 volts: a to b, b to c, c to a



Secondary Voltage Vectors

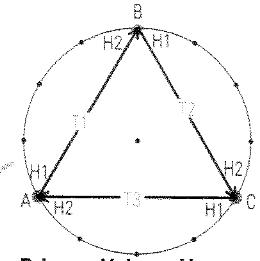
Delta - Wye

7,200 to 120, 208 Volts

30° phase displacement

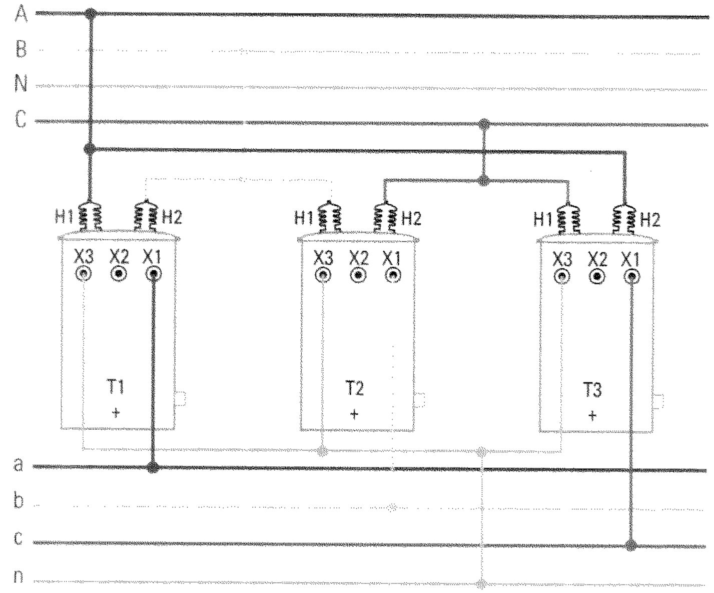
Transformer Nameplate Data

Polarity: Additive
Primary volts: 7,200
Secondary volts: 120/240



Primary Voltage Vectors

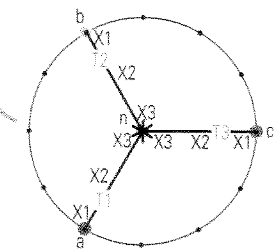
Measured line-to-line primary voltage: 7,200 volts.



Secondary coils are in parallel. 

Customer Needs

120 volts: a to n, b to n, c to n
208 volts: a to b, b to c, c to a

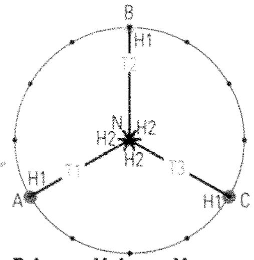


Secondary Voltage Vectors

Wye -Delta

7,200 to 120, 240 Volts

30° phase displacement

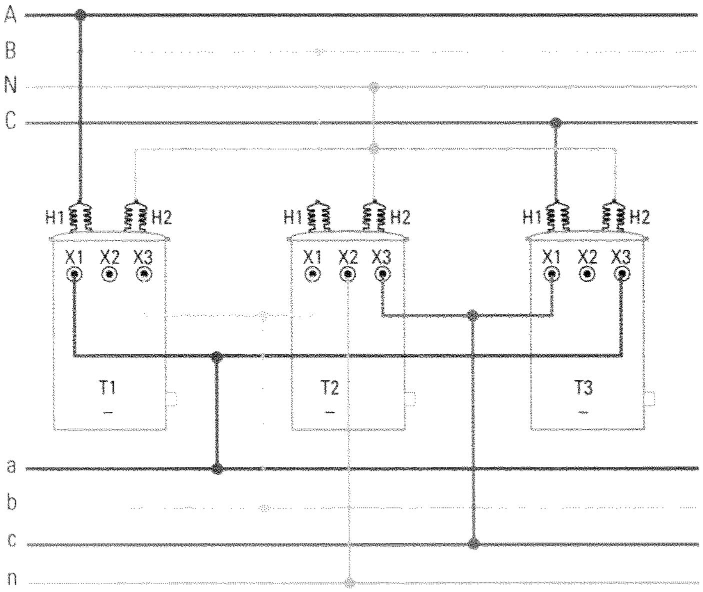


Primary Voltage Vectors

Transformer Nameplate Data

Polarity: Subtractive
Primary volts: 4,160/7,200Y
Secondary volts: 120/240

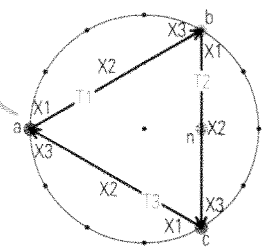
Measured line-to-line primary voltage: 7,200 volts.



Secondary coils are in series.

Customer Needs

240 volts: a to b, b to c, c to a
120 volts: b to n, c to n

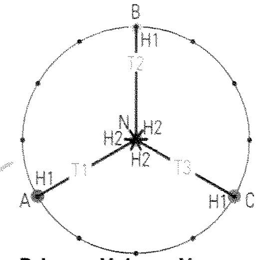


Secondary Voltage Vectors

Wye -Delta

34,500 to 120, 240 Volts

30° phase displacement

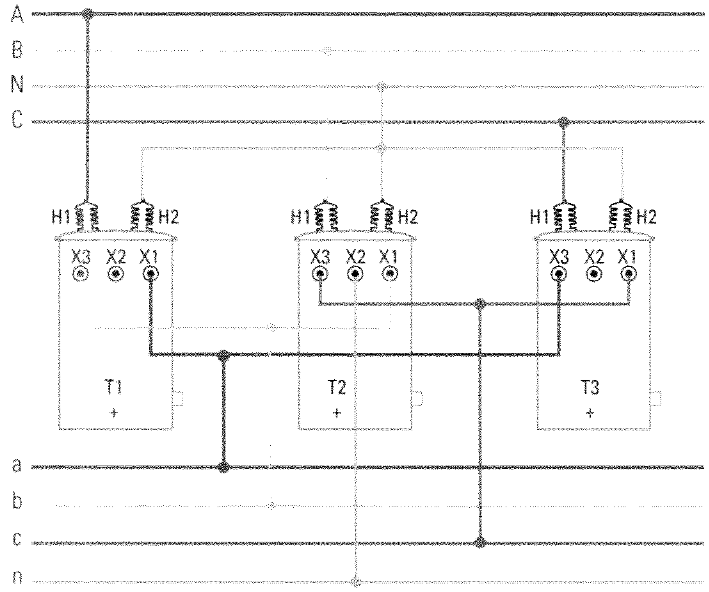


Primary Voltage Vectors

Transformer Nameplate Data

Polarity: Additive
Primary volts: 19,900/34,500Y
Secondary volts: 120/240

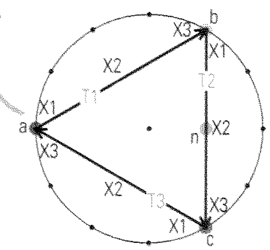
Measured line-to-line primary voltage: 34,500 volts.



Secondary coils are in series.

Customer Needs

240 volts: a to b, b to c, c to a
120 volts: b to n, c to n



Secondary Voltage Vectors

Delta - Wye

7,200 to 277, 480 Volts

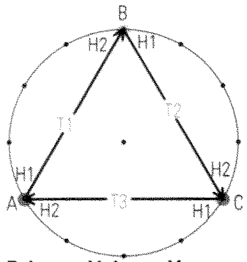
30° phase displacement

Transformer Nameplate Data

Polarity: Subtractive

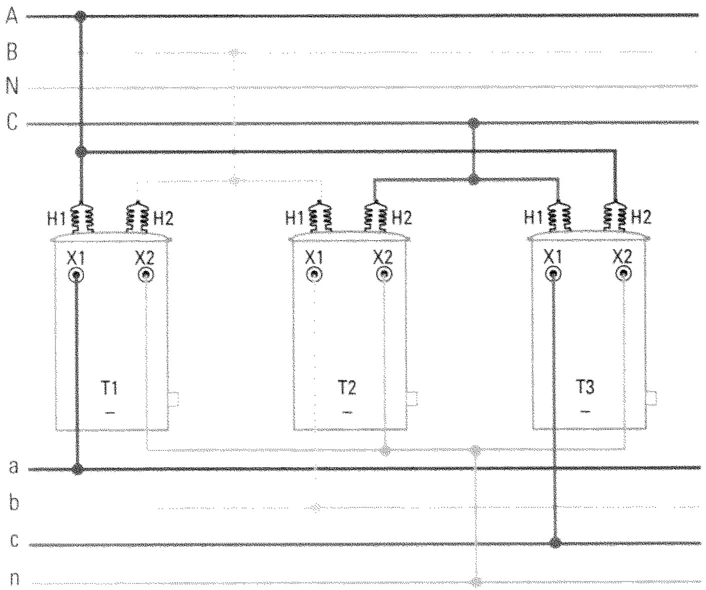
Primary volts: 7,200/12,460Y

Secondary volts: 277/480Y

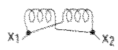


Primary Voltage Vectors

Measured line-to-line primary voltage: 7,200 volts.



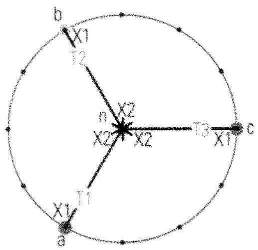
Secondary coils are in parallel.



Customer Needs

480 volts: a to b, b to c, c to a

277 volts: a to n, b to n, c to n



Secondary Voltage Vectors

Wye -Delta

24,940 to 120, 240 Volts

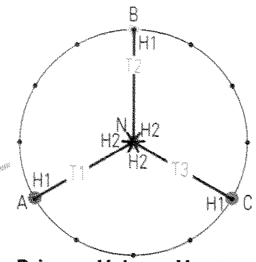
30° phase displacement

Transformer Nameplate Data

Polarity: Subtractive

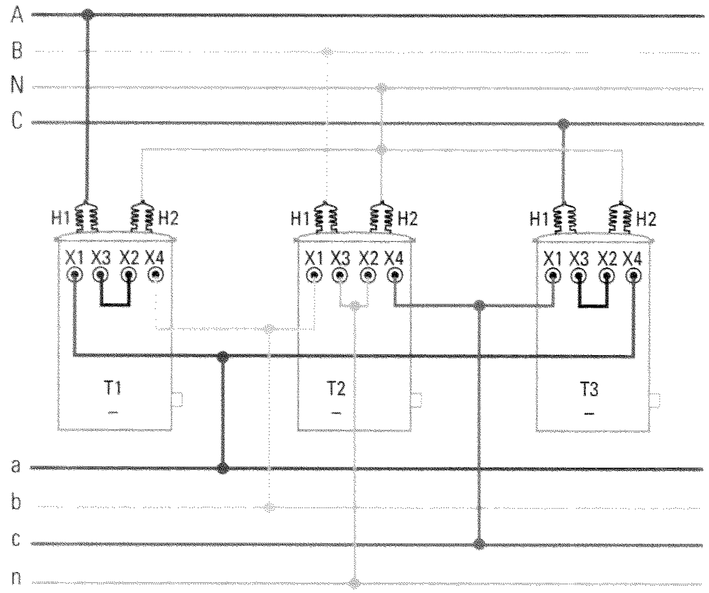
Primary volts: 14,400/24,940Y

Secondary volts: 120/240



Primary Voltage Vectors

Measured line-to-line primary voltage: 24,940 volts.

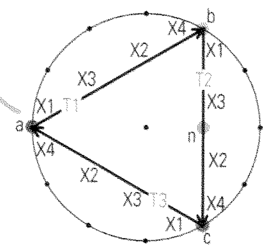


Secondary coils are in series.

Customer Needs

240 volts: a to b, b to c, c to a

120 volts: b to n, c to n



Secondary Voltage Vectors

Delta - Wye

6,900 to 120, 208 Volts

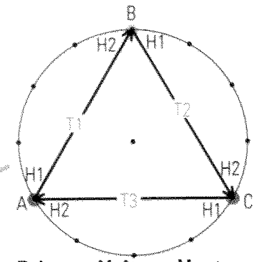
30° phase displacement

Transformer Nameplate Data

Polarity: Additive

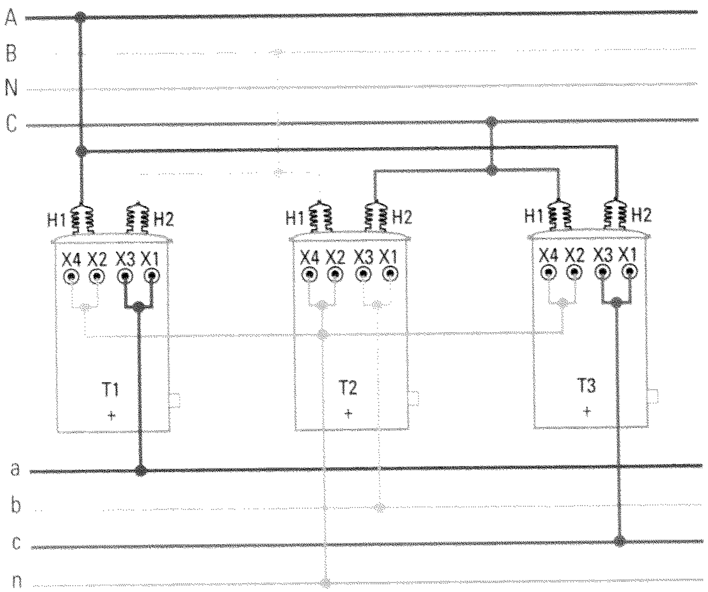
Primary volts: 6,900

Secondary volts: 120/240

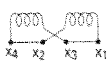


Primary Voltage Vectors

Measured line-to-line primary voltage: 6,900 volts.



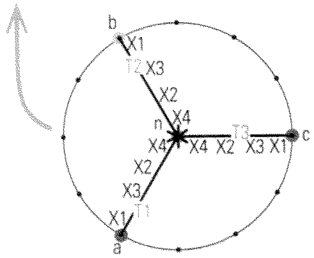
Secondary coils are in parallel.



Customer Needs

120 volts: a to n, b to n, c to n

208 volts: a to b, b to c, c to a



Secondary Voltage Vectors

Wye - Wye

12,460 to 120, 208 Volts

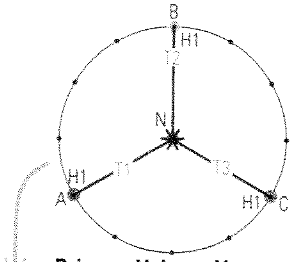
0° phase displacement

Transformer Nameplate Data

Polarity: Subtractive

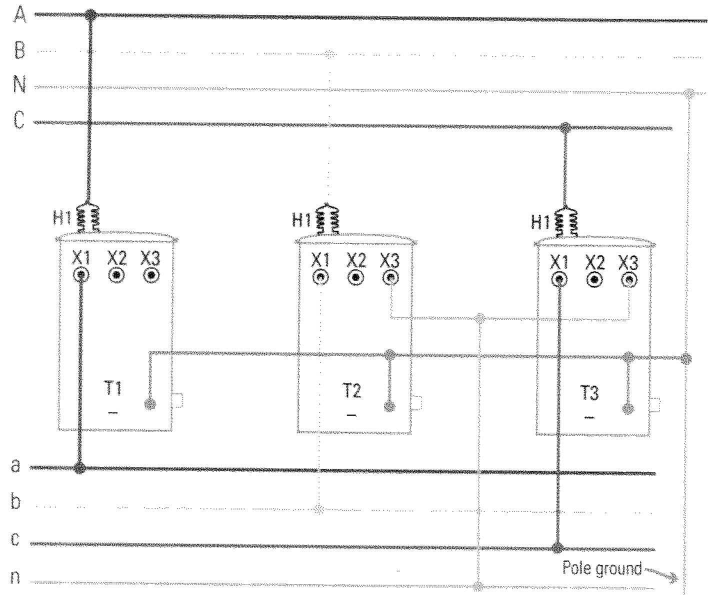
Primary volts: 7,200/12,460Y

Secondary volts: 120/240



Primary Voltage Vectors

Measured line-to-line primary voltage: 12,460 volts.

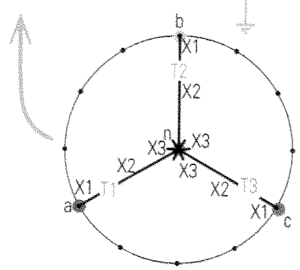


Secondary coils are in parallel.

Customer Needs

120 volts: a to n, b to n, c to n

208 volts: a to b, b to c, c to a



Secondary Voltage Vectors

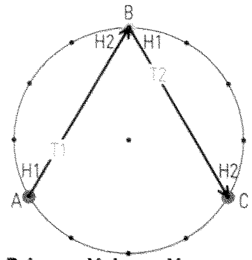
Open Delta - Open Delta

12,000 to 120, 240 Volts

0° phase displacement

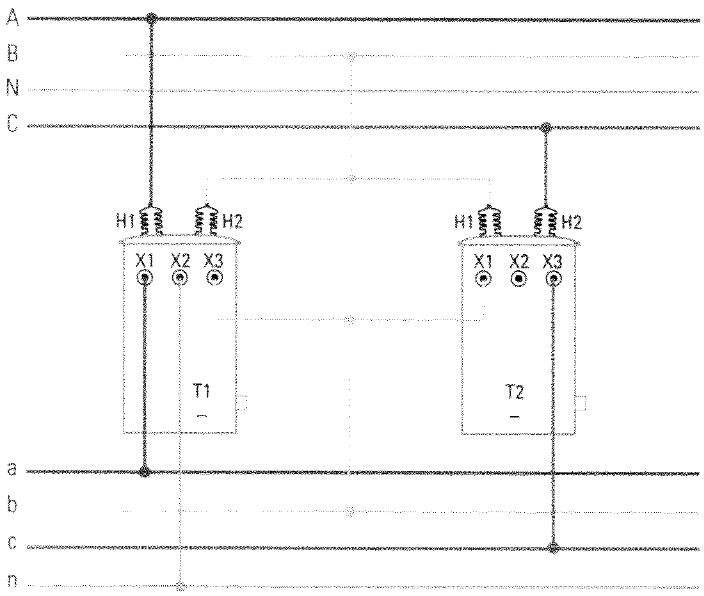
Transformer Nameplate Data

Polarity: Subtractive
Primary volts: 12,000
Secondary volts: 120/240



Primary Voltage Vectors

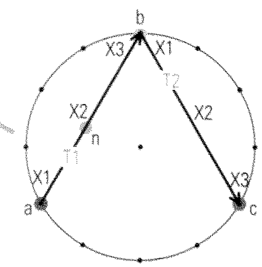
Measured line-to-line primary voltage: 12,000 volts.



Secondary coils are in series.

Customer Needs

240 volts: a to b, b to c, c to a
120 volts: a to n, b to n



Secondary Voltage Vectors

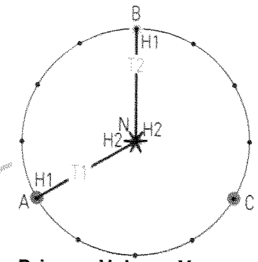
Open Wye - Open Delta

24,940 to 120, 240 Volts

30° phase displacement

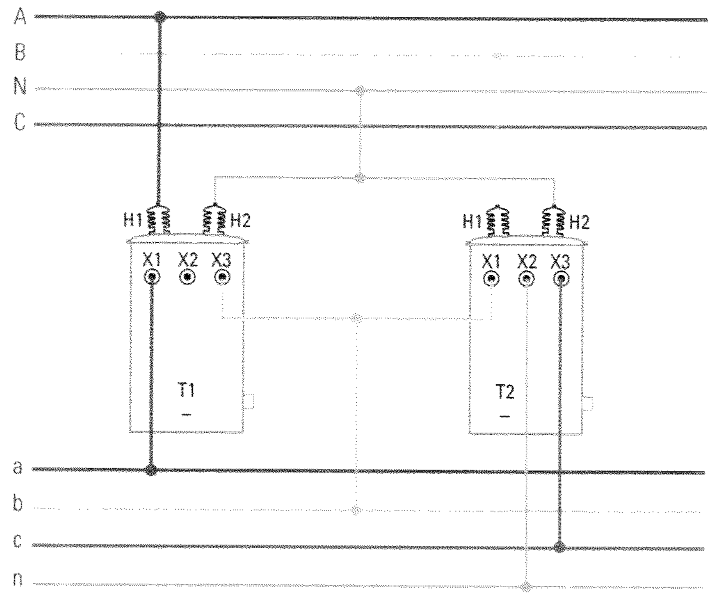
Transformer Nameplate Data

Polarity: Subtractive
Primary volts: 14,400/24,940Y
Secondary volts: 120/240

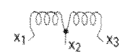


Primary Voltage Vectors

Measured line-to-line primary voltage: 24,940 volts.

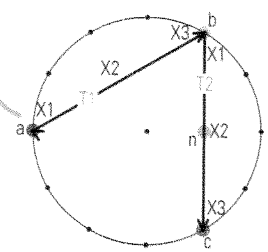


Secondary coils are in series.



Customer Needs

240 volts: a to b, b to c, c to a
120 volts: b to n, c to n



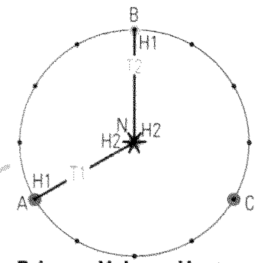
Secondary Voltage Vectors

Open Wye - Open Delta

7,200 to 480 Volts

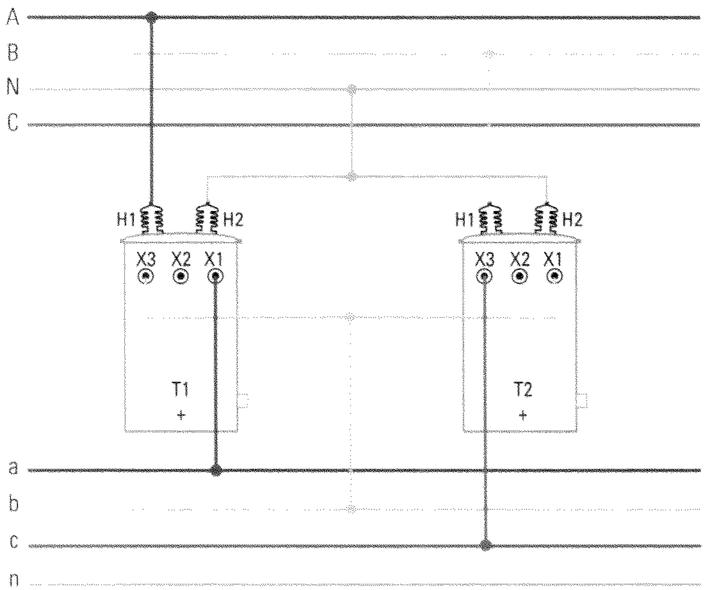
0° phase displacement

Transformer Nameplate Data
Polarity: Additive
Primary volts: 4,160/7,200Y
Secondary volts: 240/480



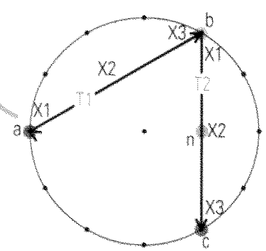
Primary Voltage Vectors

Measured line-to-line primary voltage: 7,200 volts.



Secondary coils are in series. X_3 X_2 X_1

Customer Needs
480 volts: a to b, b to c, c to a



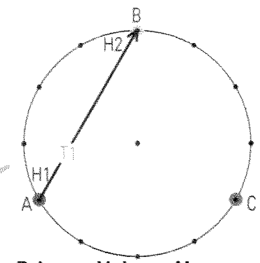
Secondary Voltage Vectors

Single Phase

4,800 to 120, 240 Volts

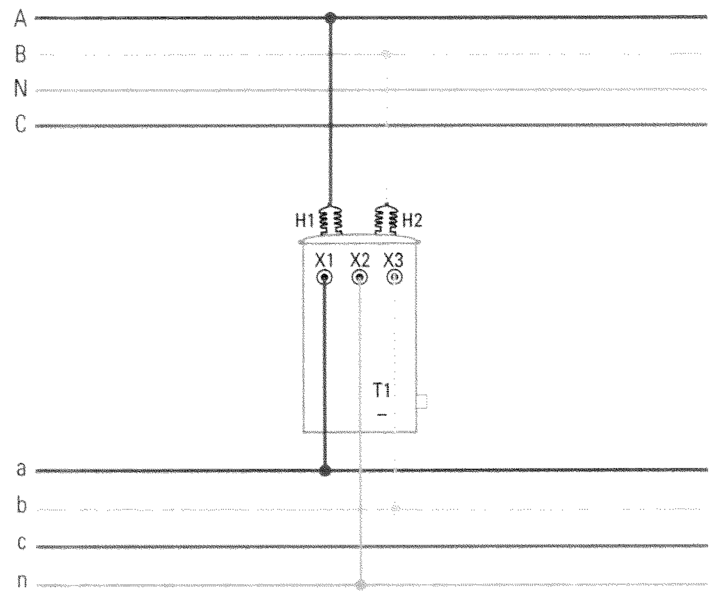
0° phase displacement

Transformer Nameplate Data
Polarity: Subtractive
Primary volts: 4,800
Secondary volts: 120/240



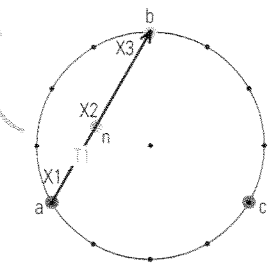
Primary Voltage Vectors

Measured line-to-line primary voltage: 4,800 volts.



Secondary coils are in series. X_1 X_2 X_3

Customer Needs
240 volts: a to b
120 volts: a to n, b to n



Secondary Voltage Vectors

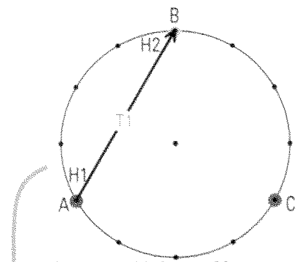
Single Phase

6,900 to 120, 240 Volts

0° phase displacement

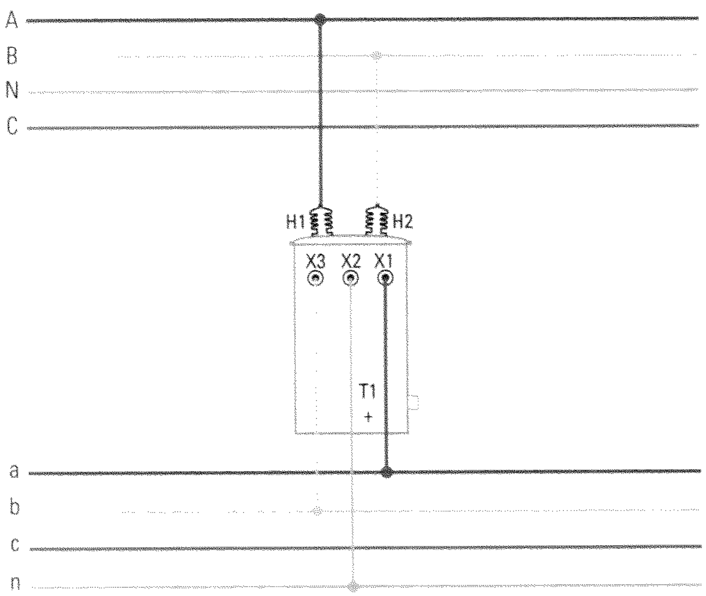
Transformer Nameplate Data

Polarity: Additive
Primary volts: 6,900
Secondary volts: 120/240



Primary Voltage Vectors

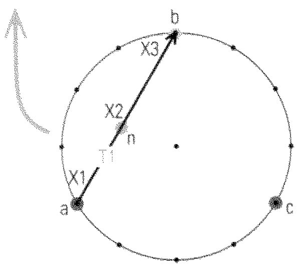
Measured line-to-line primary voltage: 6,900 volts.



Secondary coils are in series.

Customer Needs

240 volts: a to b
120 volts: a to n, b to n



Secondary Voltage Vectors

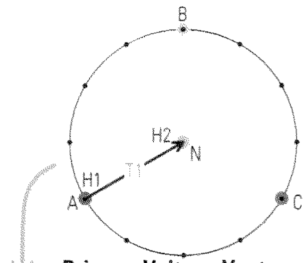
Single Phase

12,400 to 120, 240 Volts

0° phase displacement

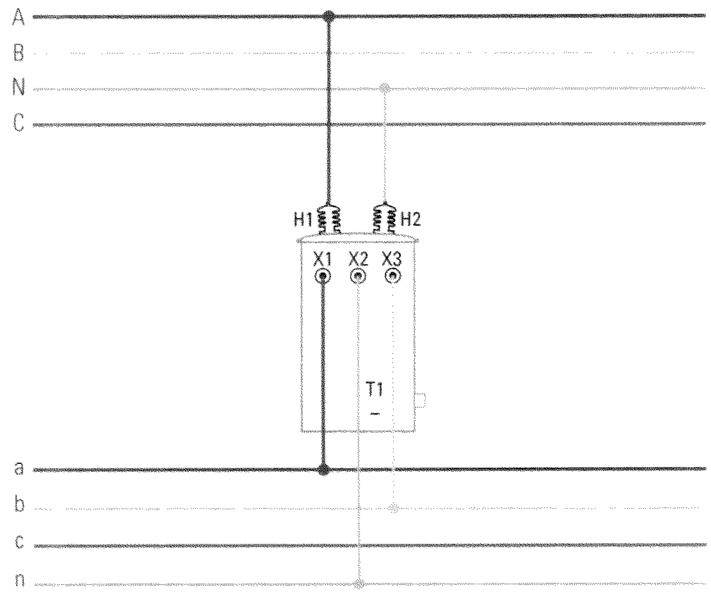
Transformer Nameplate Data

Polarity: Subtractive
Primary volts: 7,200/12,460Y
Secondary volts: 120/240



Primary Voltage Vectors

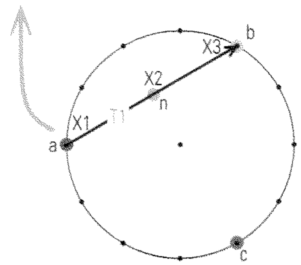
Measured line-to-line primary voltage: 12,460 volts.



Secondary coils are in series.

Customer Needs

240 volts: a to b
120 volts: a to n, b to n

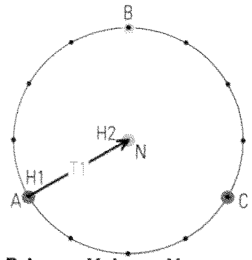


Secondary Voltage Vectors

Single Phase

24,940 to 120, 240 Volts

0° phase displacement

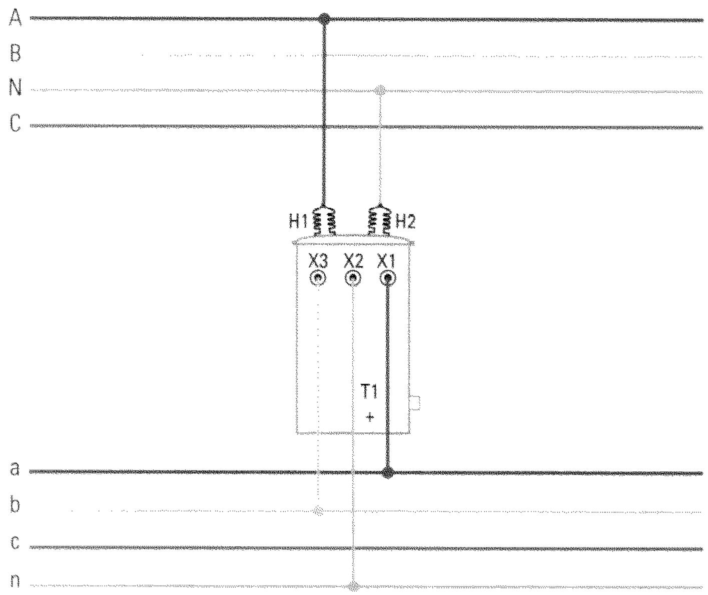


Primary Voltage Vectors

Transformer Nameplate Data

Polarity: Additive
Primary volts: 14,440/24,940Y
Secondary volts: 120/240

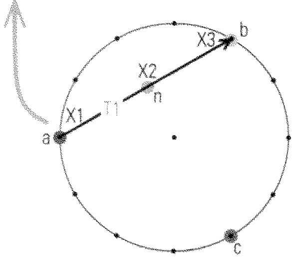
Measured line-to-line primary voltage: 24,940 volts.



Secondary coils are in series.

Customer Needs

240 volts: a to b
120 volts: a to n, b to n

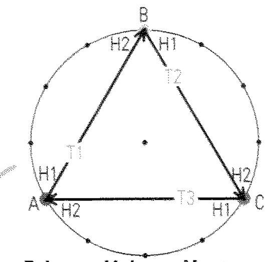


Secondary Voltage Vectors

Delta -Delta

4,800 to 480 Volts

0° phase displacement

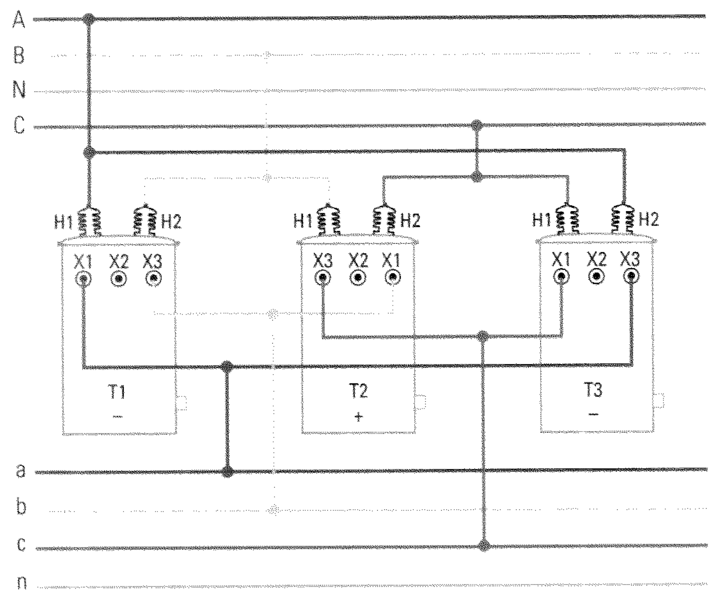


Primary Voltage Vectors

Transformer Nameplate Data

Polarity: Mixed
Primary volts: 4,800
Secondary volts: 240/480

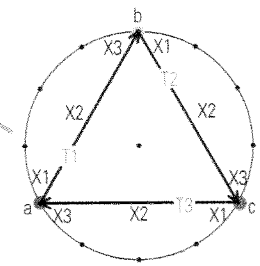
Measured line-to-line primary voltage: 4,800 volts.



Secondary coils are in series.

Customer Needs

480 volts: a to b, b to c, c to a



Secondary Voltage Vectors

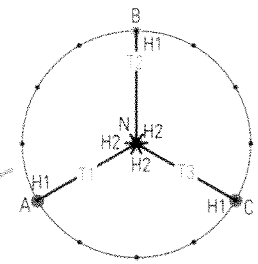
Wye - Wye

24,940 to 277, 480 Volts

0° phase displacement

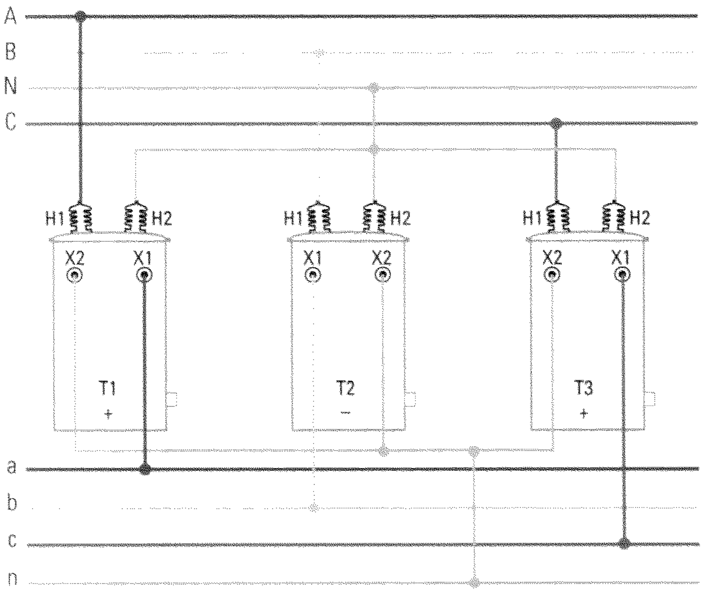
Transformer Nameplate Data

Polarity: Mixed
Primary volts: 14,400/24,940Y
Secondary volts: 277 (277/480Y)

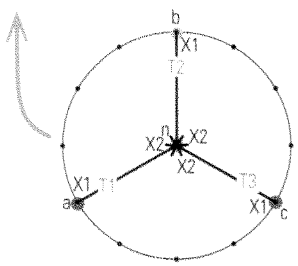


Primary Voltage Vectors

Measured line-to-line primary voltage: 24,940 volts.



One secondary coil.



Secondary Voltage Vectors

Customer Needs

277 volts: a to n, b to n, c to n
480 volts: a to b, b to c, c to a

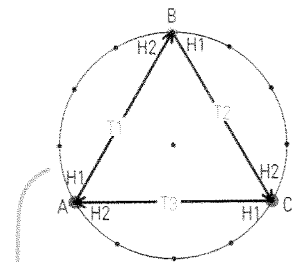
Delta - Wye

4,800 to 120, 208 Volts

30° phase displacement

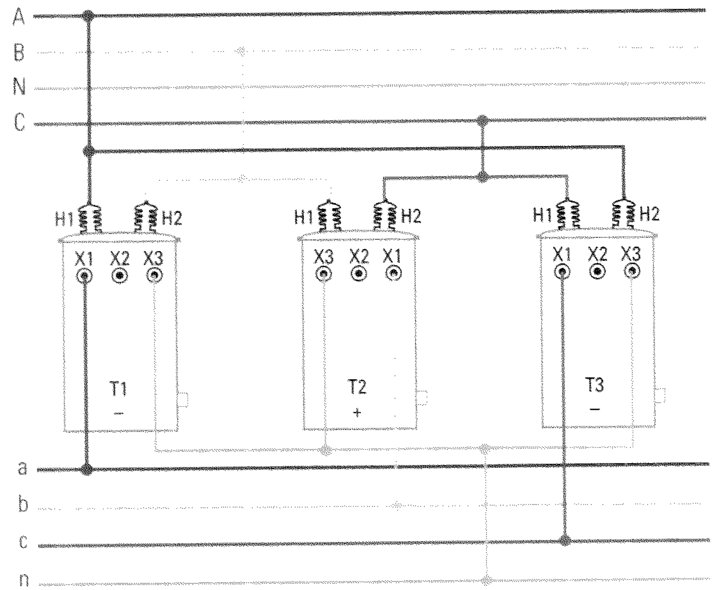
Transformer Nameplate Data

Polarity: Mixed
Primary volts: 4,800
Secondary volts: 120/240



Primary Voltage Vectors

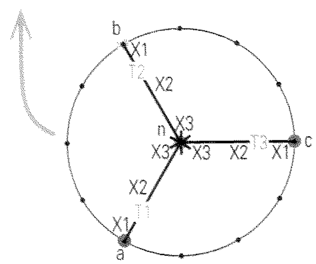
Measured line-to-line primary voltage: 4,800 volts.



Secondary coils are in parallel.

Customer Needs

120 volts: a to n, b to n, c to n
208 volts: a to b, b to c, c to a



Secondary Voltage Vectors

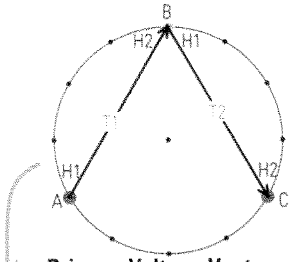
Open Delta - Open Delta

4,800 to 120, 240 Volts

0° phase displacement

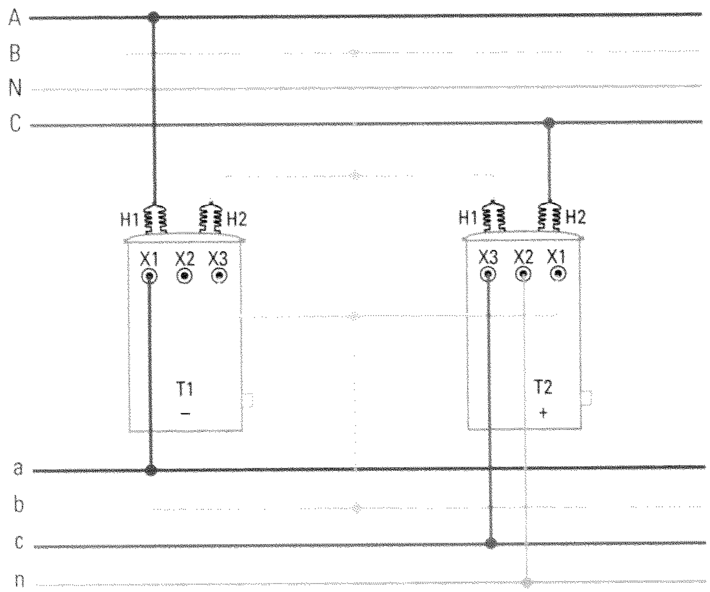
Transformer Nameplate Data

Polarity: Mixed
Primary volts: 4,800
Secondary volts: 120/240

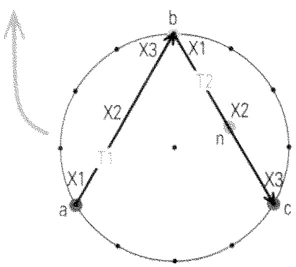


Primary Voltage Vectors

Measured line-to-line primary voltage: 4,800 volts.



Secondary coils are in series. 



Secondary Voltage Vectors

Customer Needs

240 volts: a to b, b to c, c to a
120 volts: b to n, c to n

Notes

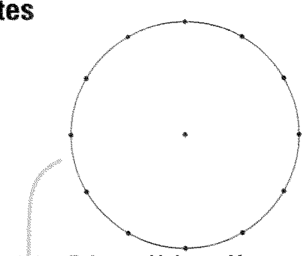
____

____________ to ____________ Volts

_______° phase displacement

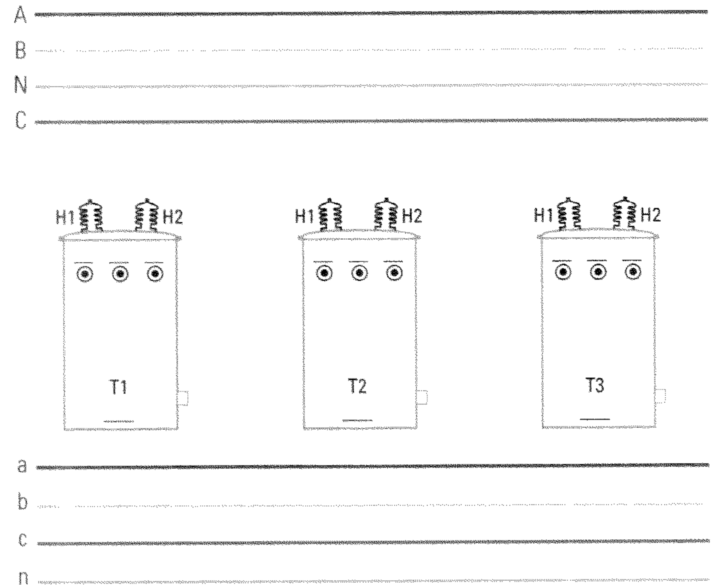
Transformer Nameplate Data

Polarity: _______________
Primary volts: _______________
Secondary volts: _______________

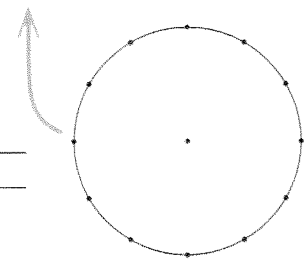


Primary Voltage Vectors

Measured line-to-line primary voltage: __________



Secondary coils are in _______________.



Secondary Voltage Vectors

Customer Needs

________volts measured __________________
________volts measured __________________

Notes

______ to ______ **Volts**

______ ° phase displacement

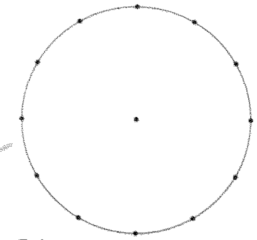
Transformer Nameplate Data

Polarity: ______

Primary volts: ______

Secondary volts: ______

Measured line-to-line primary voltage: ______



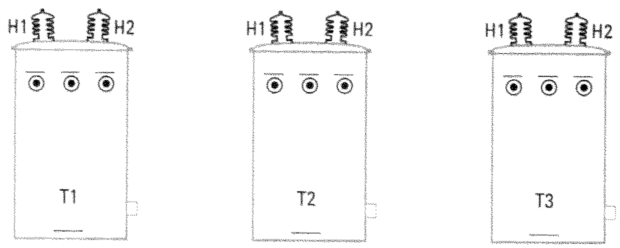
Primary Voltage Vectors

A

B

N

C



a

b

c

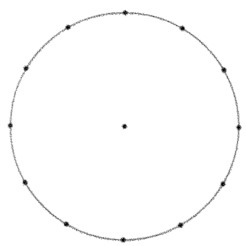
n

Secondary coils are in ______.

Customer Needs

______ volts measured ______

______ volts measured ______



Secondary Voltage Vectors

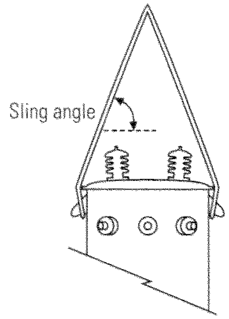
CHAPTER

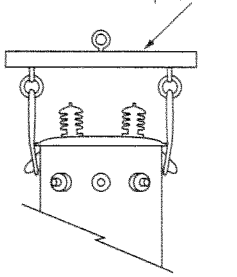
3

INSTALLING TRANSFORMERS

Lifting and Handling Transformers

Lift overhead transformers by their lifting lugs only, using a nylon web sling or a rope sling. Sling angles of greater than 45° are preferred. Avoid sling angles of less than 30° because of the high tension in the sling. If the vertical clearance above the transformer is limited, use a spreader bar in place of a sling, and install cover-up on any energized conductors nearby.





Do not lift a transformer from beneath a bushing, pressure relief valve, drain plug, or any other attachment not specifically designed for lifting.

Do not move or shift a transformer by grasping the bushings, fins, or plugs. Porcelain bushings can be damaged during handling in ways not visually obvious, then fail after the unit is put into service.

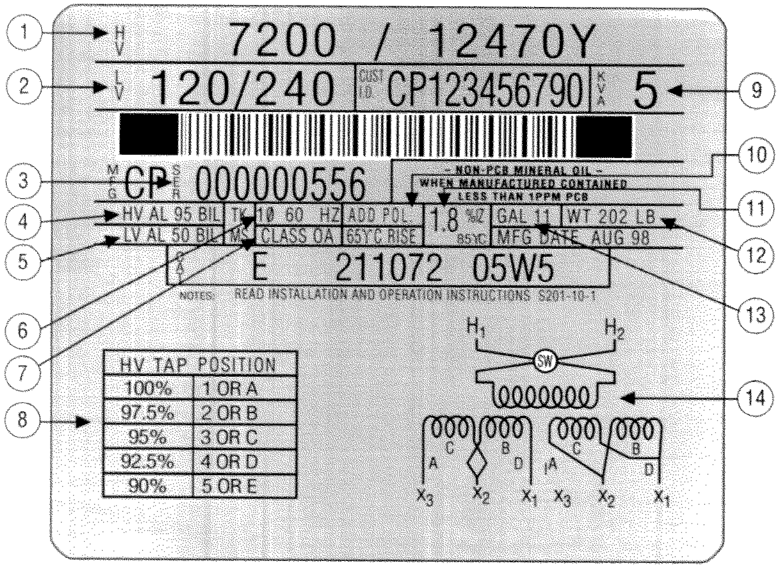
The windings can be damaged if the transformer is dropped or severely jolted.

When handling a transformer, take care to not damage the tank finish. Paint scratches can lead to rust.

Nameplates

Each transformer has a manufacturer's nameplate, also called a data plate, with important technical information. When installing a transformer, you need to know its high voltage rating (HV), low voltage rating (LV), and polarity (POL).

The nameplate shown here is for an overhead single-phase transformer.



(1) HV – High-voltage (primary) winding. The low number (7200) is the voltage across the primary coil. If this transformer is installed in a wye bank, 7200 is the voltage from line to neutral and the high number (12470) is the voltage from line to line. If this transformer is installed in a delta bank, 7200 is the voltage from line to line. ***Note:*** On nameplates for padmount transformers and single-bushing overhead transformers, the low number appears last instead of first.

(2) LV – Low-voltage (secondary) winding delivers 120 and 240 volts.

(3) SER – Serial number, for inventory tracking purposes.

(4) HV – High-voltage windings are aluminum with 95 BIL insulation.

(5) LV – Low-voltage windings are aluminum with 50 BIL insulation.

(6) 1Φ60 HZ – Single phase, 60 hertz.

(7) Class OA – Oil filled, air cooled without fans.

(8) Tap positions on the high-voltage winding.

(9) KVA – This transformer is rated 5 kVA.

(10) ADD POL. – This transformer has additive polarity. If it is banked or paralleled, the polarity of the other transformers must be considered.

(11) %Z – Percent impedance. If this transformer is banked or paralleled, the impedance of the other transformers must be very close to 1.8%.

(12) WT – Weight, for rigging considerations.

(13) GAL – Oil capacity.

(14) The schematic shows this transformer primary has a switch, SW, which allows the lineman to change the voltage across the primary winding in five steps shown in the table, HV Tap Position. The transformer secondary has two coils. At the lower left, the secondary coils are connected in series. This provides 120 volts between X1 and X2 and between X2 and X3, and 240 volts between X1 and X3. At the lower right, the secondary coils are connected in parallel. This provides only 120 volts and not 240 volts, but it can deliver twice as much current at 120 volts, compared with the other connection. Here, the secondary coils are connected to X1 and X2, and X3 is abandoned. Some utilities connect the secondary coils to X1 and X3, and abandon X2.

Safety Tips

These tips are from experienced field lineworkers, but some might not apply to you. Always follow your company's operating procedures and safe work practices.

- Never climb above an energized transformer.
- Watch out for lightning arrestors. Many arrestors look alike but have different voltage ratings. Check the arrestor yourself, before installing it.
- Even if someone says the primary or secondary is dead, check it yourself.
- Don't use the transformer bracket or bolts to support services. Keep supports separate, for future maintenance.
- Some transformers have two tank grounds: a ground strap from the center bushing of the secondary, and a tank ground to the pole ground wire.
- Use only copper wire on bolt-type transformer lugs. Aluminum wire is soft, and can flow under bolted connections and come loose. Aluminum is OK for spade-type compression connectors.
- Never put two solid wires on the same bolt-type lug. One solid wire with one stranded wire is OK, but two solid wires can loosen and become an intermittent connection.
- If you replace a transformer on a hot day when everybody's air conditioner is on, the initial current surge will be large. The solution is not to over-fuse. Instead, temporarily reduce the initial load. Go around and open some customers' main breakers (if you have access to them), or pull some meters.
- Don't mix conventional transformers with CSPs in the same bank.
- Don't use CSPs in lighting and power banks.
- When installing bird guards, leave a gap around the bottom for water to drain out. Otherwise, water can build up and leak down through the bushing, into the tank.
- Watch out for transformers with PCB oil. If any oil spills, follow all clean-up procedures, exactly.

- Some transformers have tap changers down in the oil, so you have to put your hands in the oil to change taps. Check first, for PCBs.
- After hanging a transformer, check it over before making it hot. Check the nameplate, primary and secondary leads, arrestor, and remove all temporary grounds.
- When closing a cutout, follow these steps:
  1. Check the cutout assembly for cracks and loose connections (very important).
  2. Place yourself directly in front of, and slightly below the cutout.
  3. Use ear, eye, and head protection.
  4. Place the hotstick in the eye of fuse.
  5. Close in one fluid motion, while averting your eyes slightly away from a possible flash.
- Be aware, when closing an open disconnect on a transformer near a substation, the closer you are to a substation, the greater the available fault current.
- When the bank has a single-phase lighting load and a three-phase power load, close the lighting transformer first when going on-line, and open it last when going off-line. Exception: Use the opposite sequence when closing in on a floating wye-delta bank. Sequencing the single-phase and three-phase loads provides better voltage stability and reduces fuse-blowing.
- When opening a padmount or totally underground transformer, don't be on your knees. There might be a snake or lizard in there and you need to be ready to run.
- When opening a padmount transformer, stand on a rubber blanket and wear rubber gloves with sleeves, in case a primary line or elbow has come loose inside the door.
- To avoid mistakes, order transformers by their complete primary voltage rating. Example: "12470 grounded wye 7200" not just a "12470 transformer."
- Make a habit of doing things the same, every time, so your pole buddy knows what you're doing – even when he can't see you. You'll each know what the other is doing, and will work rings around others who don't, and do it safer.

Installation Procedure for Overhead Transformers

Follow these steps to install an overhead transformer.

Step	Action
1	Select a pole with these features: • Near the center of the electrical load • Capable of supporting the weight of the combined equipment • Not already occupied by other large equipment • Space is available which will not obstruct climbing, and will allow adequate working space
2	Inspect the transformer • Nameplate: kVA, primary voltage, secondary voltage, impedance, weight, polarity. *Note:* The primary (high) voltage rating on the nameplate usually shows two voltages: the phase-to-phase voltage and the phase-to-neutral voltage. Example: "7200/12470Y" means the transformer can be connected across two phases in a 7200-volt delta system, or it can be wye-connected at 7200 volts on a 12470 wye system. • Physical condition: Gaskets, bushings, tank, and paint are in good condition. Drain plug is tight. Pressure relief valve (if any) has not activated.
3	Check the transformer for continuity • The resistance of the primary winding is nearly a short circuit. • The resistance of the secondary winding is nearly a short circuit. • The resistance between the primary and secondary windings is an open circuit.
4	For three-phase installations, while the transformer is on the ground, build the secondary wiring for the transformer bank. Train all wires to not pull on the porcelain bushings.
5	If paralleling transformers, review pages 26 and 57-61.
6	Install the transformer, and primary cutout if required.
7	Connect the primary leads. Do not connect the secondary leads to the service conductors at this time.
8	Install the neutral and ground connections. See pages 64-69.
9	Energize the transformer. Check the voltages at the secondary terminals. • If the voltages are correct, use compression connectors to connect the secondary leads to the service conductors. • If the voltages are not correct, check the windings and the terminal connections. If still not correct, replace the transformer.
10	For three-phase installations: Check the phase sequence, then label it (ABC or CBA) on the center transformer.
11	When replacing three-phase transformer banks, to avoid damaging customer motors and other equipment, the phase sequence (the order of successive voltage peaks of a three-phase service) must remain unchanged. Before disconnecting the old secondary, determine the phase sequence using a phase sequence indicator. Then, before re-energizing service, test it again to confirm that the sequence is the same. *Note:* Be sure to attach the test leads to the test points in the same order.

Single-Phase Transformer Loads

Full Load Current

This table lists full load current, by transformer kVA rating and voltage, for balanced single-phase transformers.

Trans. Rating (kVA)	Secondary Voltage 120V (Amps)	240V (Amps)	480V (Amps)	Primary Voltage 2400V (Amps)	7200V (Amps)	14,400V (Amps)	19,920V (Amps)
3	25.0	12.5	6.25	1.25	0.42	0.21	0.02
5	41.7	20.8	10.4	2.08	0.69	0.35	0.25
10	83.3	41.7	20.8	4.17	1.39	0.69	0.50
15	125	62.5	31.3	6.25	2.08	1.04	0.75
25	208	104	52.1	10.4	3.47	1.74	1.26
37.5	313	156	78.1	15.6	5.21	2.60	1.88
50	417	208	104	20.8	6.94	3.47	2.51
75	625	313	156	31.3	10.4	5.21	3.77
100	833	417	208	41.7	13.9	6.94	5.02
167	1392	696	348	69.6	23.2	11.6	8.38
250	2083	1042	521	104	34.7	17.4	12.6
333	2775	1338	694	139	46.3	23.1	16.8
500	4167	2083	1042	208	69.4	34.7	25.1

$$\text{Full load current} = \frac{\text{kVA} \times 1{,}000}{\text{circuit voltage}}$$

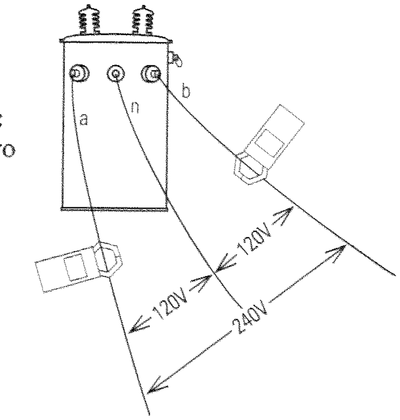
Rule of Thumb: For balanced loads, when a single-phase transformer is fully loaded, the current is:

Voltage	Current
120V	8.3 × kVA rating of the transformer
240V	4.2 × kVA rating of the transformer
480V	2.1 × kVA rating of the transformer

Example: A 25 kVA, 240-volt transformer supplies balanced 120-volt loads. When this transformer is loaded to 100% of its nameplate rating, each phase will carry approximately: 4.2 × 25 = 105 amps.

Load Checks on Single-Phase Transformers

Quick Check



To determine the approximate kVA load on a single-phase transformer:

1. Measure the current in the two line conductors
2. Add the amps together
3. Multiply by 120
4. Move the decimal point three places to the left

Example: If the readings are 55A and 60A:

$$\begin{array}{r} 55\text{A} \\ +60\text{A} \\ \hline 115\text{A} \end{array}$$

115 × 120 = 13,800

The load is 13.8 kVA

Note: Don't use this quick check if there is considerable imbalance between the two current readings. Instead, use the Complete Calculation, and verify that each load is less than half the kVA rating of the transformer.

Complete Calculation

Calculate the load on each half of the transformer separately, then add them together to determine the full load.

$$\text{Total load in kVA} = \frac{\text{current a} \times \text{voltage a-to-n}}{1{,}000} + \frac{\text{current b} \times \text{voltage b-to-n}}{1{,}000}$$

Example: The readings on a 25 kVA transformer are 30A and 160A:

$$\text{Total load in kVA} = \frac{30 \times 120}{1{,}000} + \frac{160 \times 120}{1{,}000} = 3.6 + 19.2 = 22.8\text{ kVA}$$

The total load is within the transformer rating, but one secondary winding exceeds 12.5 kVA and is severely overloaded.

Three-Phase Transformer Loads

Transformer	Secondary Voltage					Primary Voltage			
Rating (kVA)	208V (Amps)	240V (Amps)	347V (Amps)	480V (Amps)	600V (Amps)	4160V (Amps)	12,470V (Amps)	24,900V (Amps)	34,500V (Amps)
30	83.3	72.2	49.9	36.1	28.9	4.16	1.39	0.70	0.50
45	125	108	74.9	54.1	43.3	6.24	2.08	1.04	0.75
75	208	180	124	90.2	72.2	10.4	3.47	1.74	1.26
112.5	312	271	187	135	108	15.6	5.20	2.61	1.88
150	416	361	250	180	144	20.8	6.94	3.48	2.51
225	625	541	374	271	217	31.2	10.4	5.22	3.77
300	833	722	499	361	289	41.6	13.9	6.96	5.02
500	1388	1203	832	601	481	69.4	23.2	11.6	8.37
750	2082	1804	1248	902	722	104	34.7	17.4	12.6
1000	2776	2406	1664	1203	962	139	46.3	23.2	16.8
1500	4164	3608	2496	1804	1443	208	69.5	34.8	25.1
2000	5552	4811	3328	2406	1925	278	92.6	46.4	33.5

$$\text{Full load current per phase} = \frac{\text{kVA} \times 1{,}000}{\text{voltage (line to line)} \times 1.73}$$

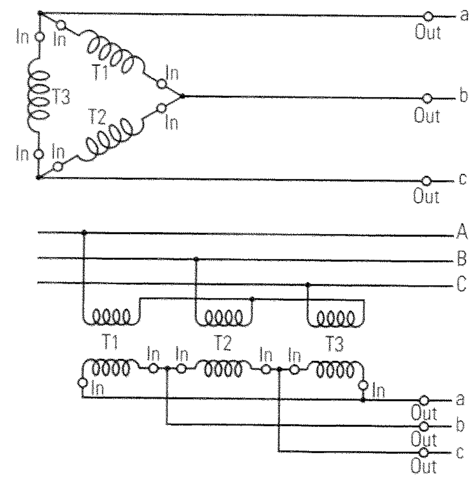
Load Checks on Delta, Wye Banks

For a delta-connected bank:

In a delta connection, the current outside the delta is the resultant of the currents of two windings.

Winding current times 1.73 = line current

Line current divided by 1.73 = winding current



○ In = Current reading inside the delta. ○ Out = Current reading outside the delta.

For bank load calculations, the current readings can be taken either inside or outside the delta:

$$\text{Total bank load in kVA} = \frac{\text{average current Outside} \times E \times 1.73}{1{,}000}$$

For an individual transformer load calculation, take the current reading inside the delta:

$$\text{Individual transformer load in kVA} = \frac{\text{current Inside} \times E}{1{,}000}$$

To calculate the total bank load in kVA using this method, calculate the load for each transformer, then add the three kVA loads together.

For a wye-connected bank:

To calculate the kVA load for a three-phase wye bank, calculate the load for each transformer, then add the three kVA loads together.

$$\text{Transformer load A in kVA} = \frac{\text{I} \times \text{E(phase to neutral)}}{1{,}000}$$

$$\text{Transformer load B in kVA} = \frac{\text{I} \times \text{E(phase to neutral)}}{1{,}000}$$

$$\text{Transformer load C in kVA} = \frac{\text{I} \times \text{E(phase to neutral)}}{1{,}000}$$

$$\text{Total bank load in kVA} = \text{Load A} + \text{Load B} + \text{Load C}$$

This method allows you to determine if any individual transformer is overloaded.

Alternate method

$$\text{Total bank load in kVA} = \frac{\text{I(average)} \times \text{E(line to line)} \times 1.73}{1{,}000}$$

For an open wye, open delta bank:

To calculate the kVA load for an open wye, open delta bank, calculate the load for each transformer, then add the two kVA loads together.

$$\text{Individual transformer load in kVA} = \frac{\text{I} \times \text{E}}{1{,}000}$$

Note: This bank is 87% efficient. For example, if the transformers are rated at 100 kVA each, each could deliver 87 kVA plus an overload factor, and the total capacity of the bank would be 174 kVA.

Note: If an open wye, open delta bank was originally a bank of three equally sized transformers, and was converted to an open wye, open delta by removing one transformer and grounding the open wye mid-point, the remaining bank of two transformers has a capacity of only 58% (two-thirds of 87%) of the original bank. A load check must be taken to avoid excessive overload and possible burn-out.

Make or Break Parallel Circuits at Transformer Banks

Make a Parallel Circuit

To connect a new transformer bank in parallel with an existing secondary:

Step	Action
1	Check the physical installation to see that it is correct and complete.
2	Secure the secondary conductors in the clear.
3	Energize the bank.
4	Proceed with the steps on page 58 or page 60.

Break a Parallel Circuit

To break parallel at a transformer bank:

Step	Action
1	Be sure the remaining bank can carry the load without excessive overload.
2	Disconnect the secondary phase conductors and secure them in the clear. Caution: Secondary phases are still energized.
3	Open the disconnects. Remove any risers.

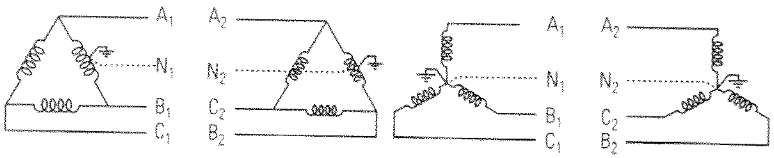
It is now safe to work on the transformer bank.

Phasing and Paralleling Three-Phase Installations

Voltage measurements are taken to match phases, prior to connecting transformers in parallel.

Phasing and Paralleling Circuits With a Field Neutral

This illustration shows typical delta and wye circuits with field neutrals. The circuits could be secondaries or primaries. Either circuit at the left can be paralleled with either circuit at the right. The neutral is dashed to indicate the connection could be through the earth or a conductor.



Typical circuits with a field neutral.

Equipment required: Voltmeter (if paralleling secondaries) or phasing stick (if paralleling primaries) rated for twice the phase-to-phase voltage, or higher.

Follow these steps when phasing and paralleling installations with a field neutral.

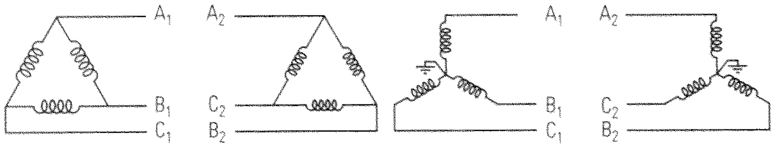
Step	Action
1	Measure each circuit for normal phase-to-phase voltages and phase-to-neutral voltages.
2	If the secondary is being paralleled to maintain temporary customer service while another transformer bank is being rebuilt, take load checks to be sure the bank remaining in service will not be overloaded excessively.
3	If there is not a continuous system neutral, measure for voltage between the neutrals of the two circuits.
4	If no voltage exists, or if a small voltage exists (5% or less), you may connect the two neutrals. *Note:* Make a sketch of the circuits showing the proper connections. Then proceed.

5	Measure the voltage from A1 to a phase on circuit #2 that gives a near-zero voltage reading (5% or less). This is A2. Check the voltage from A1 to B2 and from A1 to C2. These should read normal phase-to-phase voltages. *Note:* On delta-connected, combination lighting and power banks, if you do not get the above readings, you have a transformer mid-tapped that is connected to different phases in each bank. An outage will be required on one bank to correct this condition. The primary or secondary connections may be altered to provide uniformity between the two banks. *Note:* When paralleling wye or delta banks, each phase angle must be the same. Phase angle differences between banks will be indicated by higher than required voltages during tests. ***Caution:*** When replacing a bank, the original phase sequence must be maintained to avoid damage to customer equipment.
6	Measure the voltage from B1 to a phase in circuit #2 that gives a near-zero reading. This is B2. Check voltages from B1 to A2 and from B1 to C2. These should read normal phase-to-phase voltages.
7	Measure the voltage from C1 to a phase in circuit #2 that gives a near-zero reading. This is C2. Check voltages from C1 to A2 and from C1 to B2 These should read normal phase voltages.
8	It is now safe to connect A1 to A2, B1 to B2, and C1 to C2.

Note: When taking these readings, small voltage differences may exist between the two circuits because of unequal loads; service lines with different lengths, conductor sizes, and voltage drops; and unequal transformer impedances.

Phasing and Paralleling Circuits Without a Field Neutral

This illustration shows typical delta and wye circuits without field neutrals. The circuits could be secondaries or primaries. Either circuit at the left can be paralleled with either circuit at the right.



Typical circuits without a field neutral.

Equipment required: Voltmeter (if paralleling secondaries) or phasing stick (if paralleling primaries) rated for twice the phase-to-phase voltage, or higher.

Follow these steps when phasing and paralleling installations without a field neutral.

Step	Action
1	Measure each circuit for normal phase-to-phase voltages and phase-to-neutral voltage. If there is no neutral, such as on a delta system, measure phase-to-ground to determine if there are any unintentional ground faults. If there are, do not proceed with paralleling until the ground faults are cleared.
2	If the secondary is being paralleled to maintain temporary customer service while another transformer bank is being rebuilt, take load checks to be sure the bank remaining in service will not be overloaded excessively. *Note:* Make a sketch of the circuits, showing the proper connections. Then proceed.
3	Measure the voltage from A1 to a phase on circuit #2 that gives a near-zero voltage reading, or the lowest indeterminate voltage reading (anywhere from zero to phase voltage). This might be A2. Connect A1 and A2. *Note:* If a voltage greater than phase-to-phase voltage is found on any of the following measurements, repeat Step 3 – you have connected A1 to B2 or to C2. If, after three attempts at Steps 3 and 4 you cannot find near-zero readings, a phase angle difference exists and the circuits will not parallel. *Note:* Changes in primary or secondary connections may be necessary to facilitate paralleling. Caution: When replacing a bank, the original phase sequence must be maintained to avoid damage to customer equipment.
4	Measure the voltage from B1 to a phase in circuit #2 that gives a near-zero reading. This is B2. Check voltages from B1 to A2 and from B1 to C2. These should read normal phase voltages.
5	Measure the voltage from C1 to a phase in circuit #2 that gives a near-zero reading. This is C2. Check voltages from C1 to A2 and from C1 to B2. These should read normal phase voltages.
6	It is now safe to connect A1 to A2, B1 to B2, and C1 to C2.

Note: When taking these readings, small voltage differences may exist between the two circuits because of unequal loads; service lines with different lengths, conductor sizes, and voltage drops; and unequal transformer impedances.

Distribution Transformer Trivia

Year U.S. patent issued	1886 to George Westinghouse
First commercial installation	1886 in Buffalo, New York
Original name for transformers	secondary generators
How many installed in the U.S. and Canada	26 million
How many more installed each year	1 million
Number of residential customers served by one transformer	4-6
Transformer life	30+ years
Cost of a basic, single-phase transformer	overhead: $500
(both approximate)	padmounted: $1500

Minimum Pole Class Guidelines

These tables present guidelines only. Stronger poles than those specified here may be required depending on the pole location, other equipment on the pole, and conductor weights and tensions.

For pole-mounted, single-phase transformers:

Single-Phase Transformer		Pole Height			
Rating (kVA)	Approx. Weight (lbs.)	40 ft. (Class)	45 ft. (Class)	50 ft. (Class)	55 ft. (Class)
15	230-340	5	5	5	4
25	350-475	5	5	5	4
37.5	575-600	5	5	5	4
50	700-710	5	5	5	4
75	875-960	5	5	4	4
100	1010-1145	5	4	4	3
167	1500	4	3	3	2

For pole-mounted, three-phase transformer banks:

Three-Phase Transformer Bank		Pole Height			
Rating (kVA)	Approx. Weight (lbs.)	40 ft. (Class)	45 ft. (Class)	50 ft. (Class)	55 ft. (Class)
45	790-1120	5	5	5	4
75	1150-1525	5	4	4	3
112.5	1525-1900	4	3	2	2
150	2200-2230	3	2	2	1
225	2275-2980	3	2	1	H1
300	3130-3435	2	1	1	H1
500	4600	1	H1	H2	H3

Strength of Wood Poles

The following table lists the horizontal force that common pole classes must exceed, without failing at the groundline. The force is applied two feet from the top of the pole.

Pole Class	Horizontal Force (lbs.)	Min. Circumference at Top (in.)
H5	10,000	37
H4	8,700	35
H3	7,500	33
H2	6,400	31
H1	5,400	29
1	4,500	27
2	3,700	25
3	3,000	23
4	2,400	21
5	1,900	19

Wood Pole Setting Depths

This table lists generally accepted minimum pole setting depths for various conditions. The general rule for the embedment depth of a pole is 10% of the length of the pole, plus 2 feet. Two common exceptions are 30 and 35 feet, which are 10% plus 2-1/2 feet.

Length of Pole (ft)	In Soil (ft)	In Poor Soil (ft)	In Solid Rock (ft)
25	5	6-1/2	3-1/2
30	5-1/2	7	3-1/2
35	6	7-1/2	4
40	6	8	4
45	6-1/2	8-1/2	4
50	7	9	4-1/2
55	7-1/2	9-1/2	5
60	8	10	5
65	8-1/2	10-1/2	5-1/2

Grounding Transformers

Each distribution transformer is grounded to an electrode in the earth near the base of the pole or the pad. The ground provides a path for return current in the event of a fault.

"Ground" means the complete path from the connection at the transformer, to the grounding conductor, to the grounding electrode in the earth.

The transformer ground is in addition to grounds on the system neutral. During normal operations:

- Current does flow in the system neutral
- Current does not flow in the transformer ground

Usually, transformers are grounded by means of the lug provided on the transformer case for that purpose.

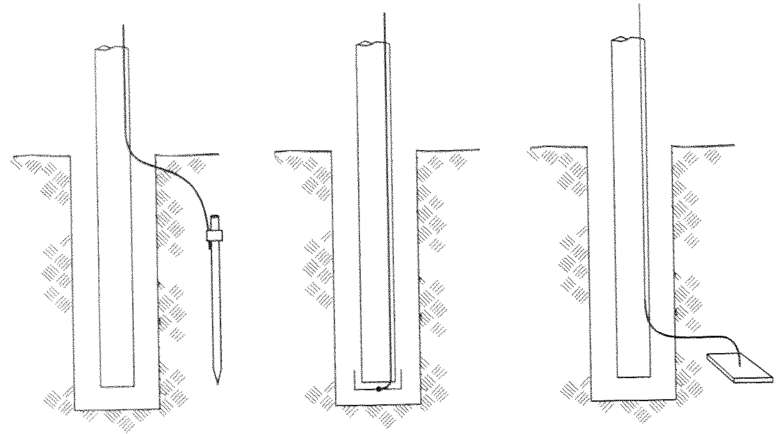
Do not remove a transformer ground unless the transformer fuse(s) are open.

When grounding an overhead transformer, run the grounding conductor from the tank ground to the neutral, then from the neutral down the pole on the same side as the neutral conductor and opposite the climbing space. On three-transformer banks, the tank grounding lugs are interconnected, then connected to the neutral.

The grounding conductor is a minimum wire size of #4 copper.

Use compression connectors for all connections to the pole ground conductor or the system neutral. Don't use bolted connectors or hot taps. Don't press more than one conductor under the same connector – each conductor has its own connection to the pole ground or the neutral.

Earth Grounds for Pole-Mounted Transformers



Drive the ground rod at least 24" out from the pole, in undisturbed earth. For safety, drive the top of the ground rod flush with or below grade level.

Nail ground plate to pole butt. Fold ends back over side of pole.

Bury ground plate a minimum of 5 feet below grade level.

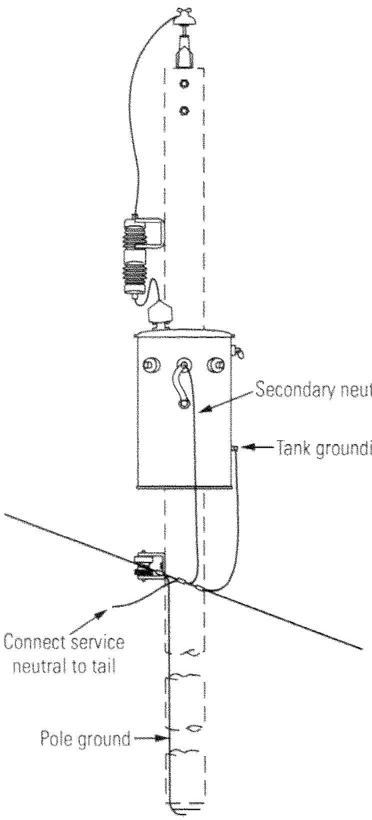
The grounding electrode is a driven ground rod, or a ground plate. If conditions are poor, two electrodes in parallel, may be required.

Conditions which affect the ability of the electrode to dissipate surges:

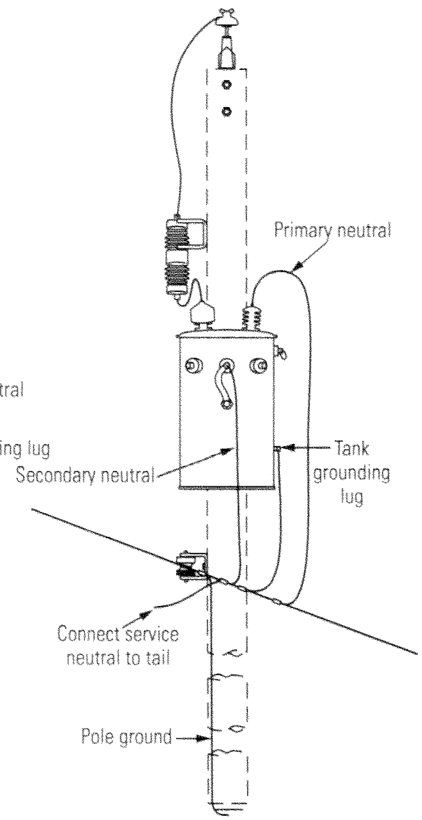
- Soil type. Examples: Clay soil has high conductivity, which is good. Gravel has low conductivity, which is bad.
- Soil condition. Damp is good, contact with the water table is very good, high salt contact is good, frozen soil is bad.
- Surface area of the ground rod or plate. The larger the surface area, the better.
- Material of the ground rod or plate. Copper is better than steel. Copper-clad steel is better than steel alone.
- Resistance of clamps and connections.

Note: The integrity of in-ground connections can deteriorate over time.

Grounding Single-Phase Transformers Neutral on the Pole

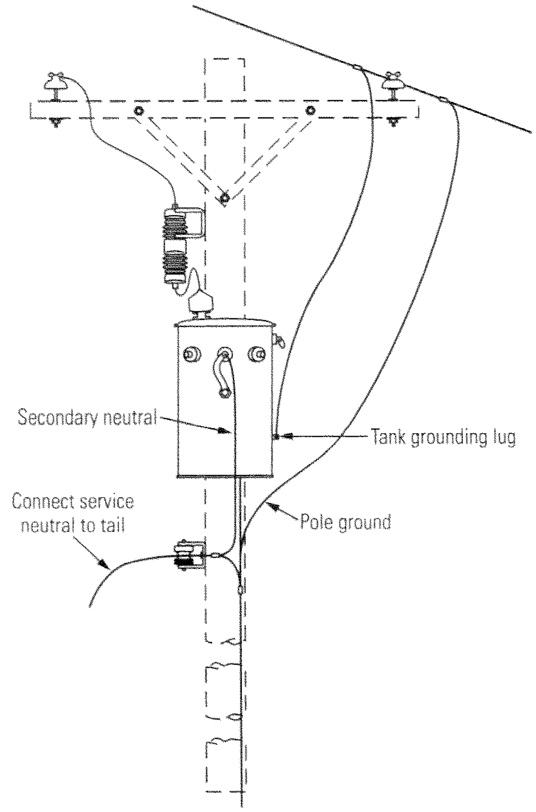


Transformer with One Primary Bushing



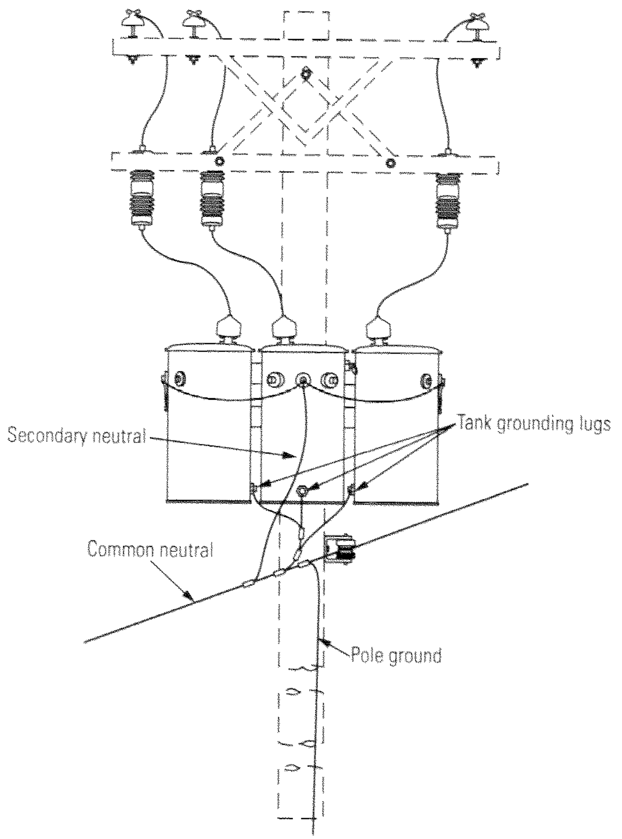
Transformer with Two Primary Bushing

Grounding Single-Phase Single-Bushing Transformers Neutral on the Crossarm



Caution: Keep the primary neutral separate and distinct from the many other connections at the secondary rack. Failure to keep the primary neutral separated introduces the high risk of inadvertently cutting the primary neutral while the transformer is energized. This will result in a primary voltage across the cut!

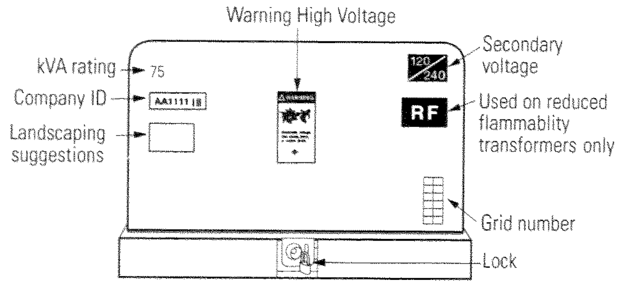
Grounding Three-Phase Wye-Wye Banks Single-Bushing Transformers Neutral on the Pole



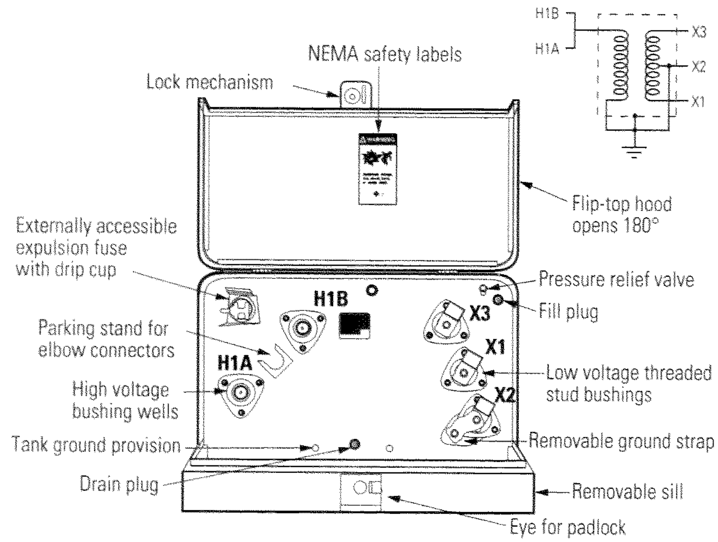
Padmount Transformer Installations

The transformers illustrated here are typical, but many different configurations exist.

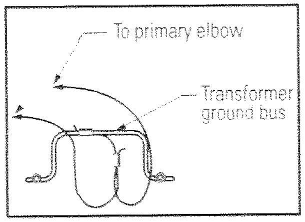
All padmount transformers have primary connections on the left side of the panel, secondary connections on the right.



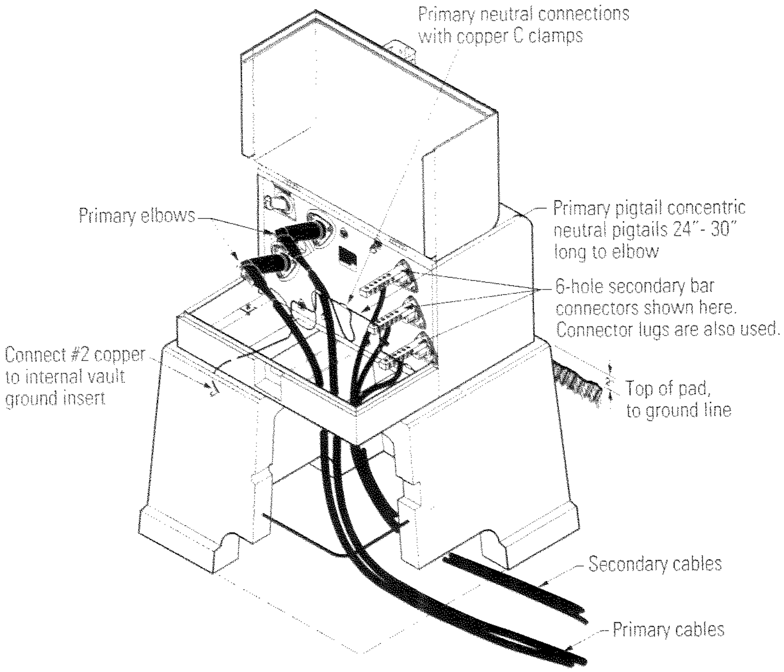
Single-phase minipad transformer labeling.



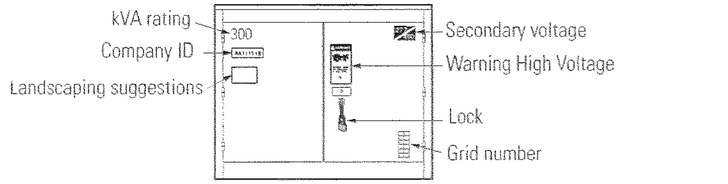
Single-phase minipad transformer layout.



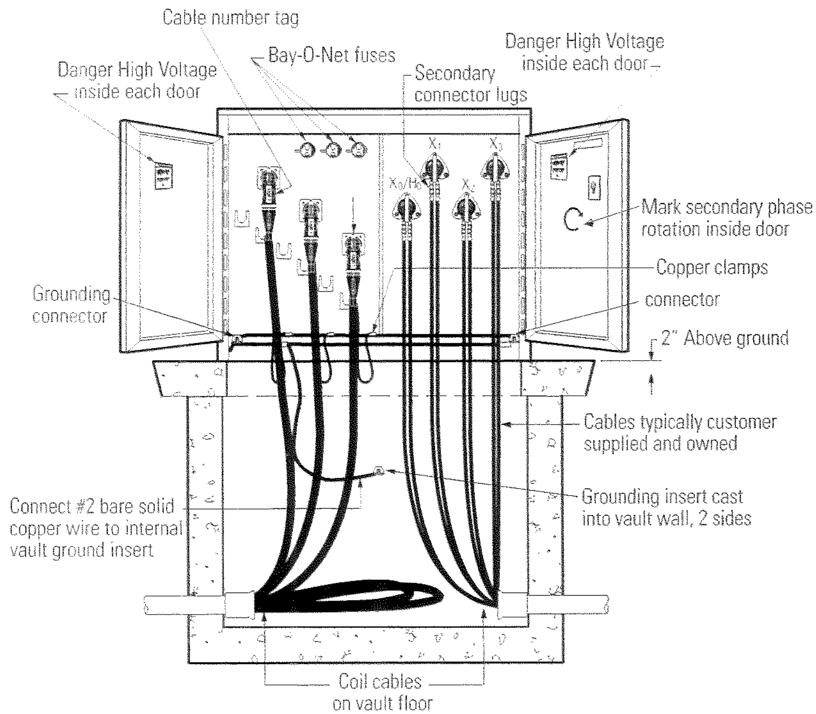
Primary Neutral Connection Detail



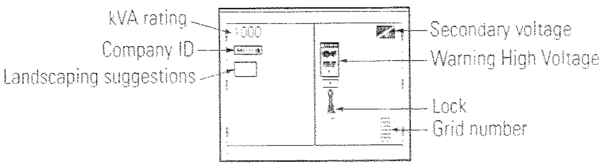
Single-phase minipad transformer cabling.



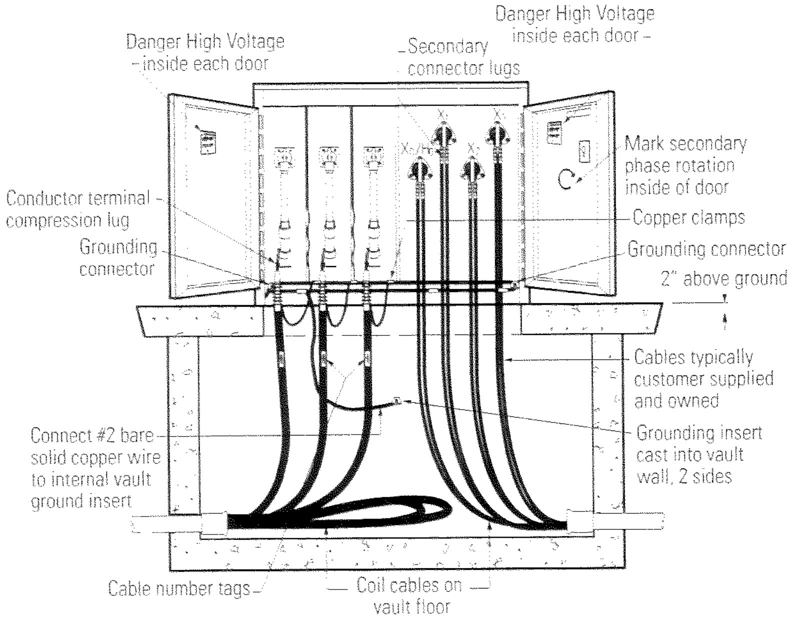
Labeling



Three-phase dead-front transformer.



Labeling



Three-phase live-front transformer.

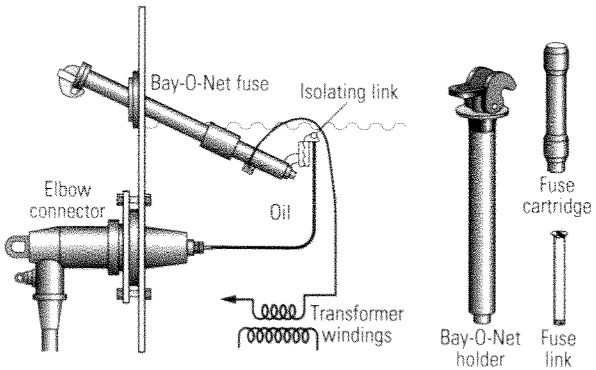
Fusing Padmount Transformers

The Bay-O-Net fuses listed below are typical sizes for use with single-phase padmount transformers.

Transformer Rating (kVA)	System Voltage 2,400 V (fuse)	7,200 V (fuse)	19,920 V (fuse)
10	C10	C03	—
15	C10	C03	—
25	C10	C05	C03
37.5	C10	C08	C03
50	C12	C08	C05
75	C14	C10	C05
100	C14	C10	C05
167	C14	C12	C05

To Install a Bay-O-Net Fuse

Step	Action
1	Attach the handle eye of the inner fuse holder assembly to the hotstick.
2	Place the fuse holder into the Bay-O-Net outer tube assembly.
3	When the inner fuse holder assembly is inserted as far as possible, push down and rotate the locking handle, hooking it over the shoulder of the outer tube assembly. When the handle is in the locked position, make sure the stainless steel cover-washer is seated against the shoulder of the outer tube assembly. If this is not done, the electrical contacts on the fuse holder will not line up with the matching contacts in the canister and arcing will develop.
4	Re-energize the transformer from a remote location. For example, one vault or transformer away. Don't use a Bay-O-Net fuse to energize a transformer.



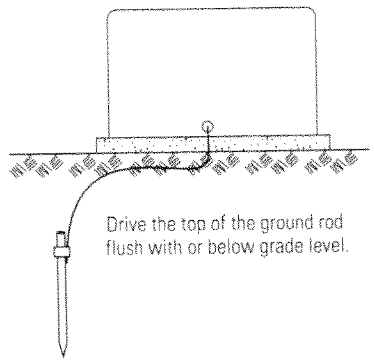
To Remove a Bay-O-Net Fuse

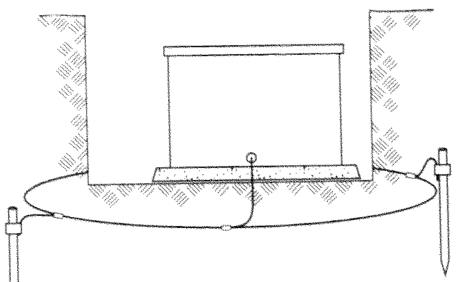
Step	Action
1	De-energize the transformer by standing off the elbow or opening the gang-operated loadbreak switch serving the transformer.
2	Release the internal air pressure, using the pressure release valve. ***Caution:*** If you open the fuse handle without releasing the pressure, the fuse can blow out sending flaming oil into the air, risking injury or death.
3	Attach a universal hotline tool or hookstick to the fuse handle eye. Stand to one side. Push down and rotate the handle 90 degrees in the tube. This releases any small pressure remaining inside the transformer, and breaks any adhesion between the seal gasket and the outer tube assembly.
4	Pull out the fuse holder approximately 3 inches and wait a few seconds for the oil to drain into the tank. The inner fuse holder assembly can now be removed without dripping excess oil. The total length of the inner fuse holder assembly, including fuse element cartridge, is 14 inches.
5	Wipe any oil from the holder before removing fuse cartridge and fuse link element. Unscrew the fuse cartridge, remove end plug, and inspect fuse link element. Each link is clearly marked with a series size, type, and number. If not legible on the blown fuse, refer to stencil on transformer cover or other specifications. Remove the fuse link (element) from the cartridge by forcing from the plug end. ***Note:*** If the Teflon tube is not melted, straighten the tulip tip (serrated end).
6	Inspect the cartridge bore to make sure it is clean.
7	Insert a new fuse link (element) into the cartridge from either end.
8	Be sure the formed end ferrule of the fuse element is secured in place between the fuse cartridge and the holder, and tightened before the end plug is inserted.

9 Tighten the end plug to expand the scalloped end ferrule. Complete the reassembly of the Bay-O-Net inner fuse cartridge holder.

The fuse assembly is now ready for refusing.
Note: Do not use a wrench on the brass ferrules of the cartridge. A wrench may be used on the end plug.

Grounding Padmount Transformers





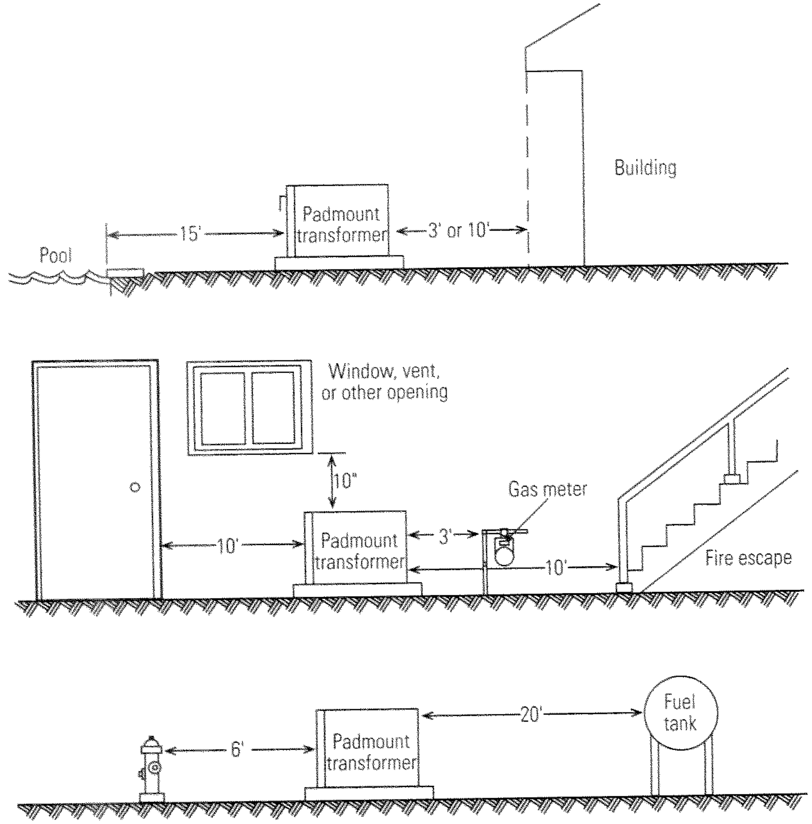
A continuous ground around the transformer protects personnel by reducing step and touch potentials.

Safety Clearances Around Padmount Transformers

Clearances from padmount transformers to structures are measured from the nearest metal portion of the transformer, to the structure or any overhang.

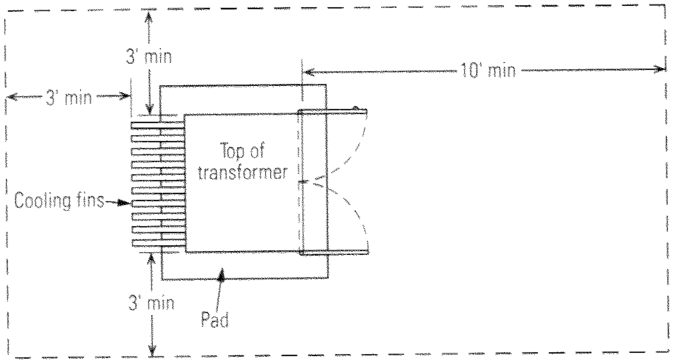
The clearance from a building is 3 feet if the building has non-combustible walls (brick, concrete, steel, or stone), 10 feet if the building has combustible walls (including stucco).

The clearances shown below and on the next page apply to any oil-filled equipment.

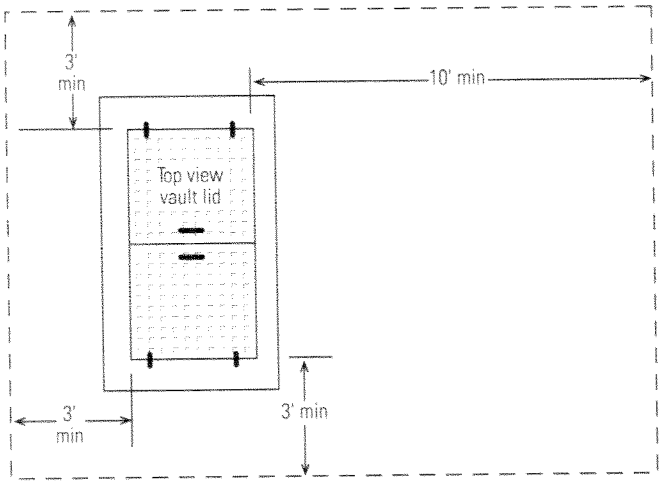


Work Clearances Around Padmount Transformers

A minimum clearance of 10 feet of clear, level, unobstructed working space is required in front of a padmount transformer, to allow use of hot sticks.



Padmounted transformer work clearances.



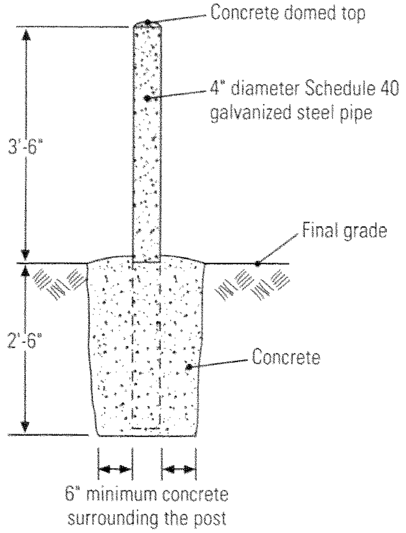
Totally underground transformer work clearances.

Guard Posts

Guard posts are required where a padmount transformer is exposed to vehicular traffic, and where minimum clearances around equipment cannot be met.

If several guard posts are used, locate them no more than 5 feet apart. For extra visibility, paint the posts traffic yellow.

In some situations a 6-inch diameter post is required, not the 4-inch post illustrated here.

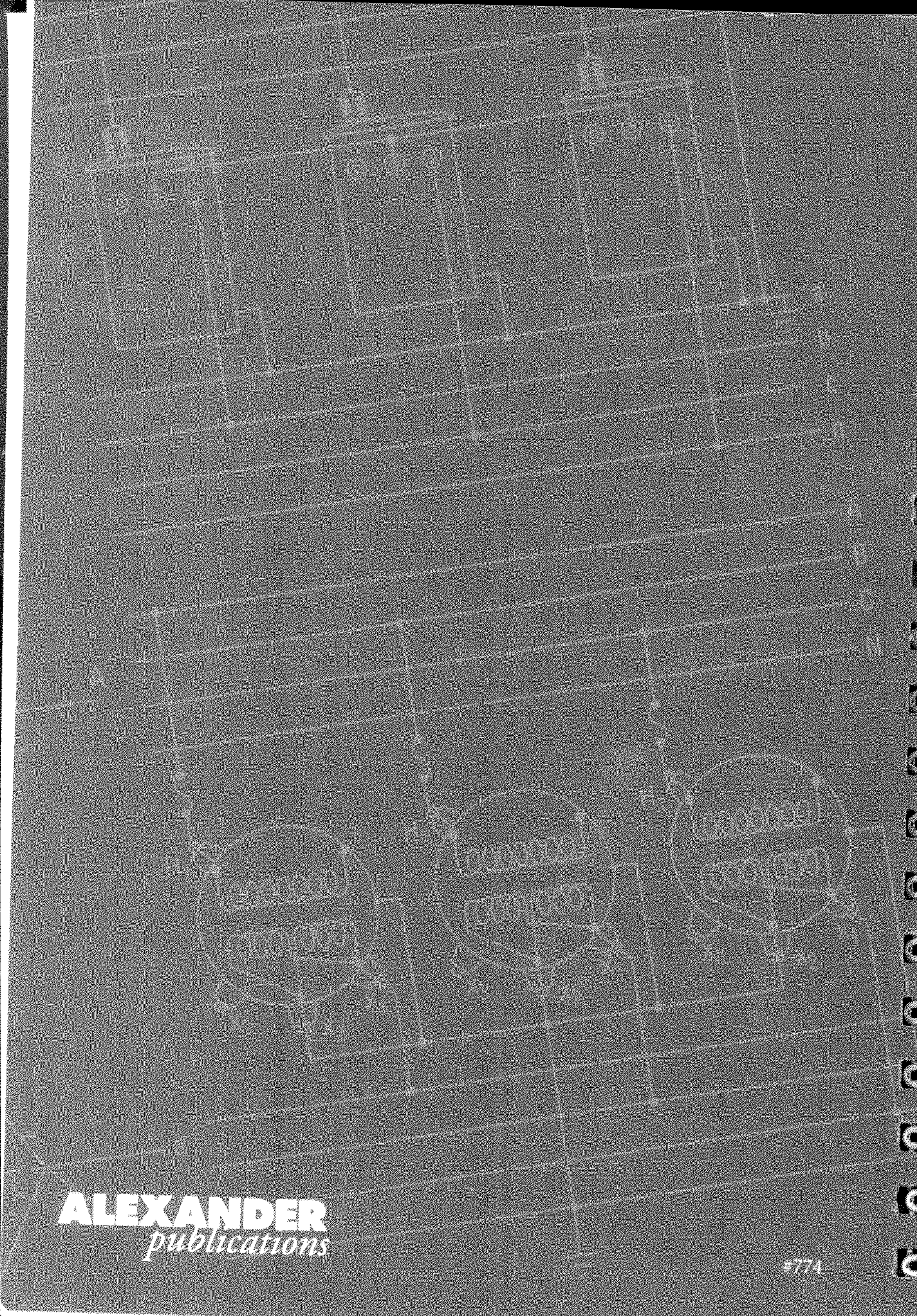


The Mystery of Transformations

Distribution transformers use magnetic force to convert electric power from one form into a new and more valuable form. But no one actually sees electricity or magnetism – we are aware of them only through their effects.

In our daily lives, we occasionally have experiences which prove transforming. We can't see the forces behind these wonderful events either, but we surely notice their powerful effects.

Whether transformations are electrical or spiritual, there is something mysterious about them. While we don't fully understand how they function, we are delighted that they do.



ALEXANDER
publications

#774

Distribution Transformer Handbook

FIFTH EDITION