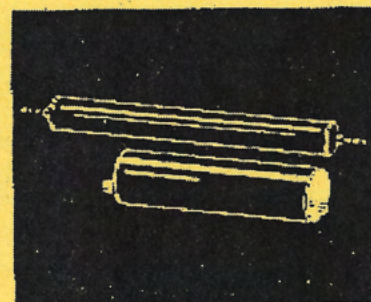
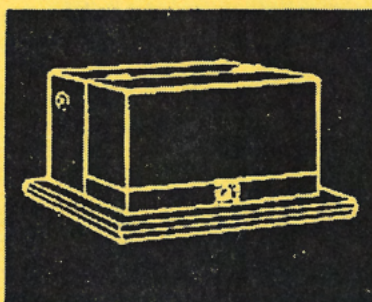
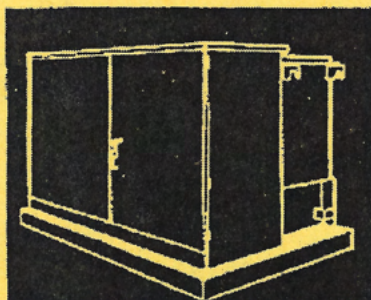


AET 1285 - TRANSFORMERS



AET- 1285

TRANSFORMERS

Name: _____

HAND IN COMPLETED PAGE TO THE INSTRUCTOR WHEN DUE (WILL NOT ACCEPT AFTER DUE DATE)

Question #	Date	Initials	Brief Description
Question #1			Procedure
Question #2 & #3			Transformer Polarity and Terminal markings
Question #4 & #5			Single Phase Trans Supplying Single- Phase Loads
Question #6			Delta- Delta 0 degree phase shift
Question #7			Delta-Delta 0 degree Phase Shift Versus 0 degree
Question #8			Delta-Delta 0 degree Phase Shift Versus 180 degree
Question #9 & #10			Open- Delta 0 degree Phase Shift
Question #11			Open- Delta 0 degree Phase Shift Versus Open-Delta
Question #12			Open- Delta 0 degree Phase Shift Versus Open-Delta
Question #13			Wye-Delta 30 degrees Phase Shift
Question #14			Wye-Delta 30 degrees Phase Shift Versus Wye-Delta
Question #15			Wye-Delta 30 degrees Phase Shift
Question #16			Wye-Delta 30 degrees Phase Shift Versus Wye-Delta
Question #17			Wye-Delta 30 degrees Phase Shift Grounded - Y
Question #18			Wye-Delta 30 degrees 30 degrees Phase Shift
Question #19			Wye-Delta 30 degrees 0 degrees Phase Shift
Questions			List of Faults

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Distribution Transformer Trainer

The trainer is designed to operate from a three-phase network connected in a Y configuration, and having a nominal voltage of 120 V. This configuration allows reading 208 V between the phases. The network delivers the three phases, neutral, and ground. Two jacks are provided in the neutral line to allow neutral current measurements.

The trainer is equipped with three lamps that provide an indication of the relative voltage of a given transformer configuration. The lamps are rated at 25 W and can operate at 230 V.

When the voltage supplied by a given configuration is unknown, it is best to connect two lamps in series to carry out the initial measurement. They should be connected as shown in Figure 1-1.

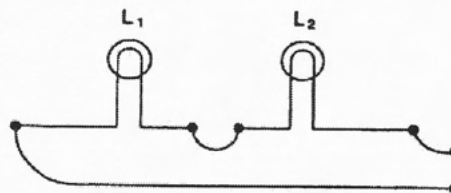


Figure 1-1. Two lamps in series.

When it is determined that the voltage does not exceed the rated voltage of a single lamp, a single lamp can be used to observe the voltage.

To help in observing the relative brightness of the measuring lamp, you can use a second lamp as a reference. Connect the expected voltage to the reference lamps, and compare the brightness of the measuring lamp to the reference lamp.

PROCEDURE

- ☐ 1. Turn on the Distribution Transformer Trainer, and determine the voltages across the terminals, as indicated in Table 1. Note the voltage and the relative brightness of the lamps in Table 1.

Distribution Transformer Trainer

TERMINALS	VOLTAGE (V)	LAMP BRIGHTNESS
A - N		
B - N		
C - N		
A - B		
B - C		
C - A		

Table 1.

Turn off the Distribution Transformer Trainer.

Transformer Polarity and Terminal Markings

- 2. The polarity of a transformer is indicated by different means depending on the usage of the transformer. On an instrument transformer, the polarity is indicated by a dot beside one end of each winding having the same instantaneous polarity. It could also be indicated with an "x" on the end of each winding having the same polarity. The dot or the "x" is called the **polarity mark**.

On a distribution transformer (power transformer), according to industry standards, H_1 and X_1 have the same polarity (see Figure 1-2).

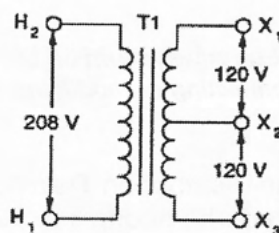


Figure 1-2. Distribution transformer.

A transformer is said to have additive polarity, when the bushings H_1 and X_1 are opposite each other. Similarly, a transformer has subtractive polarity when H_1 is adjacent to X_1 (see Figure 1-3).

Distribution Transformer Trainer

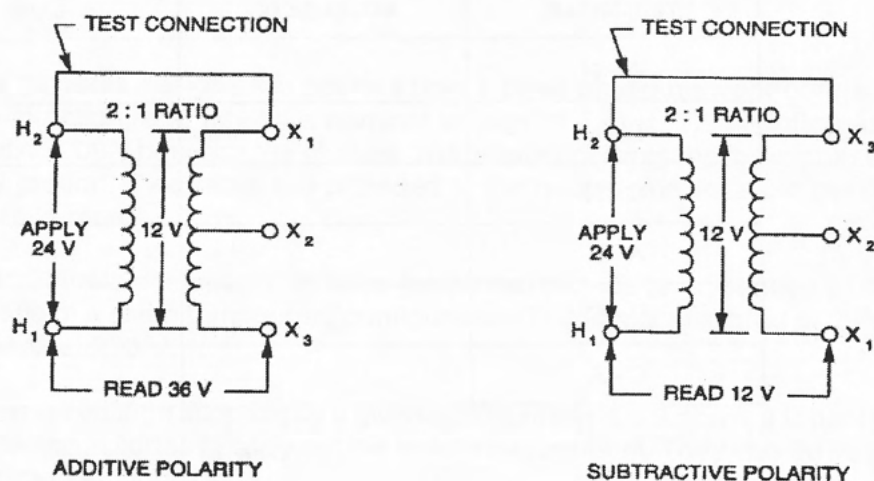


Figure 1-3. Additive and subtractive polarities.

For single-phase transformers with additive polarity, the low voltage bushing X_1 is diametrically opposite to H_1 and is the right-hand bushing when facing the low voltage side.

For transformers with subtractive polarity, X_1 is on the left when facing the low voltage side, and X_1 is adjacent to H_1 .

- ☐ 3. On transformer T1 of the Distribution Transformer Trainer, connect H_1 to line A, and H_2 to line B. Interconnect H_2 and X_1 .

Note: Always turn off the Distribution Transformer Trainer when connecting or modifying a circuit.

Turn on the Distribution Transformer Trainer. Determine if the transformer is connected with additive or subtractive polarity by observing the relative brightness of the lamps or by measuring the voltage between terminals H_1 and X_2 (use two lamps in series if you determine the voltage by observing the relative brightness of the lamp).

☐ Additive ☐ Subtractive

Repeat your observation on transformer T4.

Calculate the expected voltage between H_1 and X_2 if the voltage applied to H_1 and H_2 is doubled.

$$E_{H1-X2} = \underline{\hspace{2cm}}$$

Distribution Transformer Trainer

Turn off the Distribution Transformer Trainer.

Note: The trainer is built with transformers having their primary winding rated at 208 V. The trainer uses a configuration where the two secondary windings of each transformer are connected in series to supply 120/240 V. This represents the voltages in use in North America. The transformer winding interconnections are permanently made in the transformer tank.

Single-Phase Transformers Supplying Single-Phase Loads

- ☐ 4. When connecting the primary winding of one of the trainer transformers between lines A and B, the rated voltage is applied. When the same winding is connected between lines A and N, only 120 V is applied to the primary winding.

In this particular case, what is the percentage of the full voltage applied to the primary winding?

Percentage = _____

Considering that H_1 and H_2 are connected between lines A and N, calculate the voltage between terminals

X_1 and X_2 _____

X_2 and X_3 _____

X_1 and X_3 _____

- ☐ 5. Connect the circuit shown in Figure 1-4 using transformer T1.

Distribution Transformer Trainer

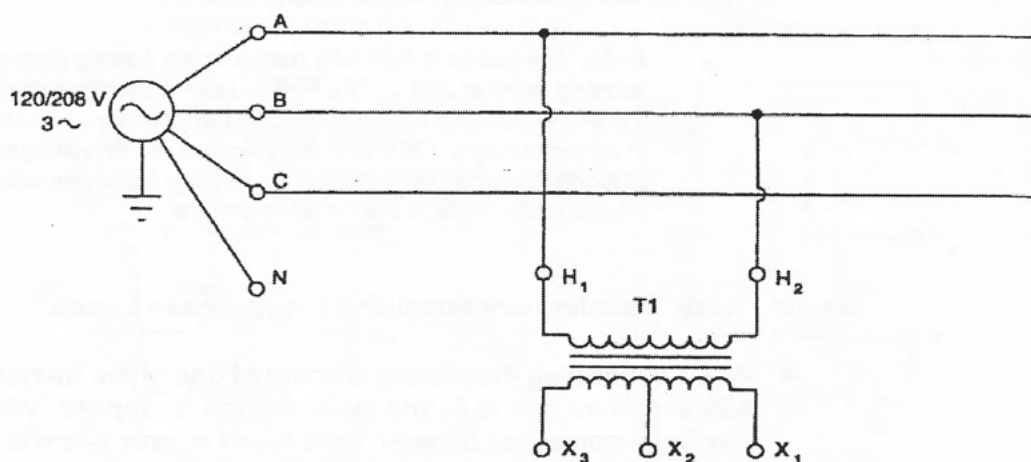


Figure 1-4. Single-phase transformer.

Turn on the Distribution Transformer Trainer and determine the voltage between terminals X_1 and X_2 .

$$E_{X_1-X_2} = \underline{\hspace{2cm}}$$

Turn off the Distribution Transformer Trainer and connect the primary winding of transformer T1 between lines A and N.

Turn on the Distribution Transformer Trainer and determine the voltage across terminals X_1 and X_2 .

$$E_{X_1-X_2} = \underline{\hspace{2cm}}$$

Turn off the Distribution Transformer Trainer.

Note: Depending on the load voltage requirements and on the transformer type, different transformer connection configurations apply. Connection configurations for single-bushing and two-bushing transformers for 120, 240 and 120/240-V services are shown in Appendix B.

Single-Phase Parallelling

When greater capacity is desired, two transformers may be connected in parallel. Single-phase transformers of either additive or subtractive polarity may be paralleled successfully if the following conditions are met:

- Voltage ratings are identical;
- Tap settings are identical;
- Percent impedance of one is between 92½% and 107½% of the other;
- Frequency ratings are identical.

Distribution Transformer Trainer

Note: Connection configuration for two-bushing transformers for 120/240-V service is shown in Appendix C as an example of transformer paralleling.

Three-Phase Banking of Single-Phase Transformers

When three single-phase transformers are used to transform a three-phase voltage, the windings can be connected in several ways. The primaries may be connected in delta and the secondaries in wye, or vice versa. As a result, the ratio of the three-phase input voltage to the three-phase output voltage depends not only upon the turns ratio of the transformers, but also upon how the windings are connected. The Figure 1-5 shows various connection configurations.

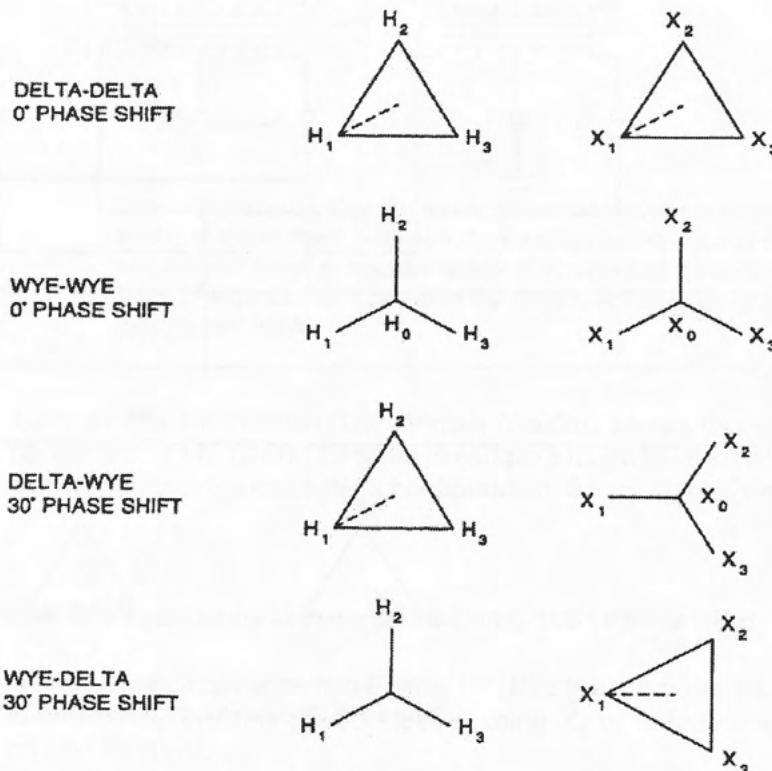


Figure 1-5. Transformer connection configurations.

A three-phase transformer bank can also produce a phase shift between the three-phase input voltage and the three-phase output voltage. The amount of phase shift depends on the turns ratio of the transformers, and on how the primary and secondary windings are interconnected.

Distribution Transformer Trainer

Delta-Delta, 0° Phase Shift

- ☐ 6. Connect the circuit shown in Figure 1-6. Use transformers T1, T2, and T3 and lines a_1 , b_1 , and c_1 . Connect bushing X_2 of transformer T1 to the ground terminal.

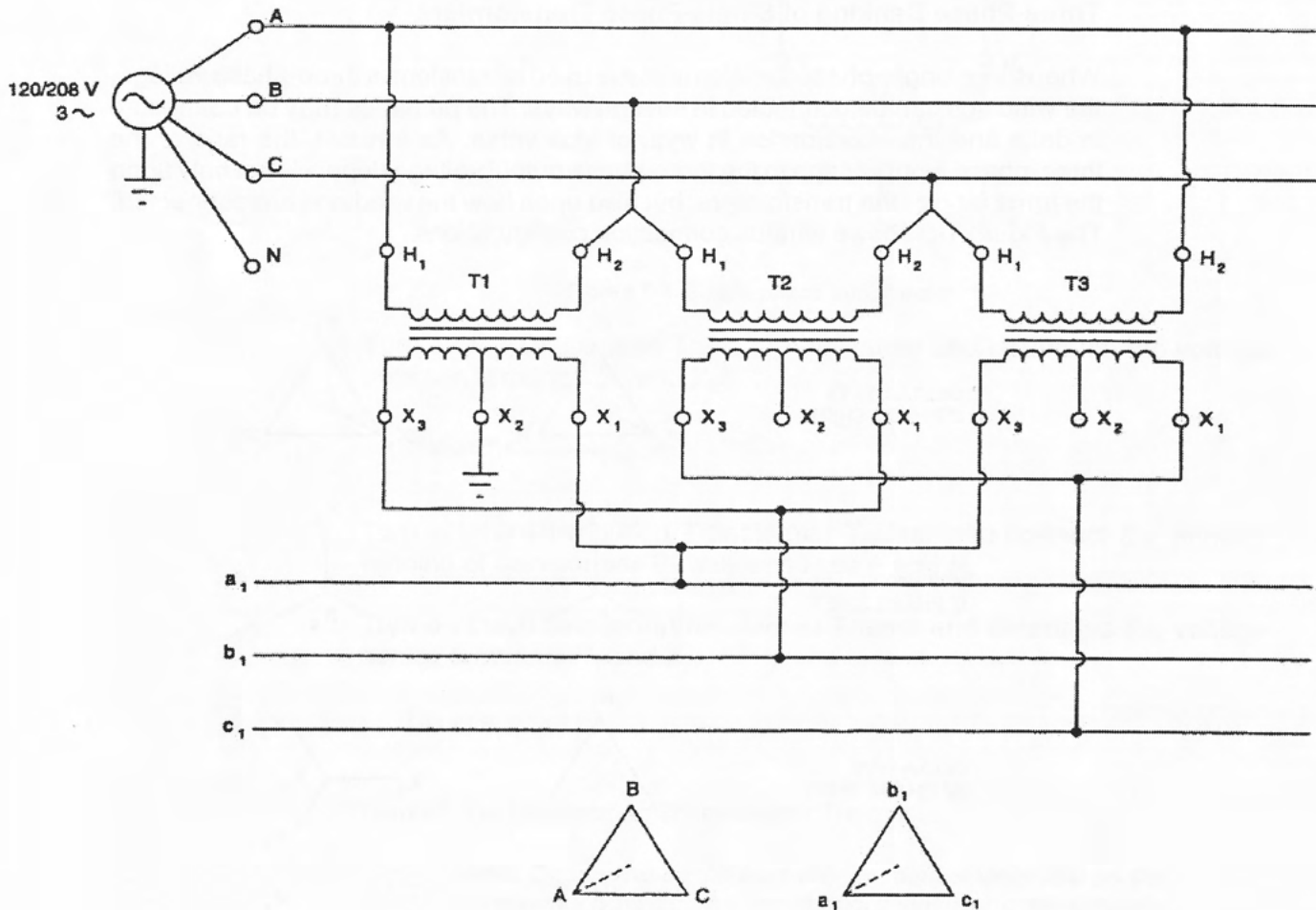


Figure 1-6. Delta-delta, 0° phase shift.

Turn on the Distribution Transformer Trainer and determine the voltage between lines

a_1 and b_1 _____

b_1 and c_1 _____

c_1 and a_1 _____

Turn off the Distribution Transformer Trainer. Leave this configuration connected so as to compare it with the next configuration.

Distribution Transformer Trainer

Note: Connection configuration for two-bushing transformers, delta-delta, 240-V service, 0° phase shift, is shown in Appendix D.

Delta-Delta, 0° Phase Shift Versus Delta-Delta, 0° Phase Shift

- ☐ 7. Repeat the circuit shown in Figure 1-6. Use transformers T4, T5, and T6 and lines a_2 , b_2 , and c_2 . Connect bushing X_2 of transformer T4 to the ground terminal.

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

a_1 and a_2 _____

b_1 and b_2 _____

c_1 and c_2 _____

Note: Considering that the two transformer banks are identical, and that the voltage between the corresponding lines of each transformer bank is approximately 0 V, one can assume that there is no phase shift between the corresponding lines of each transformer bank.

Turn off the Distribution Transformer Trainer. Leave the configuration connected to T1, T2 and T3 so as to compare it with the next configuration, and disconnect the delta-delta configuration, 0° phase shift on T4, T5 and T6.

Delta-Delta, 0° Phase Shift Versus Delta-Delta, 180° Phase Shift

- ☐ 8. Connect the circuit shown in Figure 1-7. Use transformers T4, T5, and T6 and lines a_2 , b_2 , and c_2 . Connect bushing X_2 of transformer T4 to the ground terminal.

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

a_2 and b_2 _____

b_2 and c_2 _____

c_2 and a_2 _____

Distribution Transformer Trainer

Determine the voltage between lines

a_1 and a_2 _____

b_1 and b_2 _____

c_1 and c_2 _____

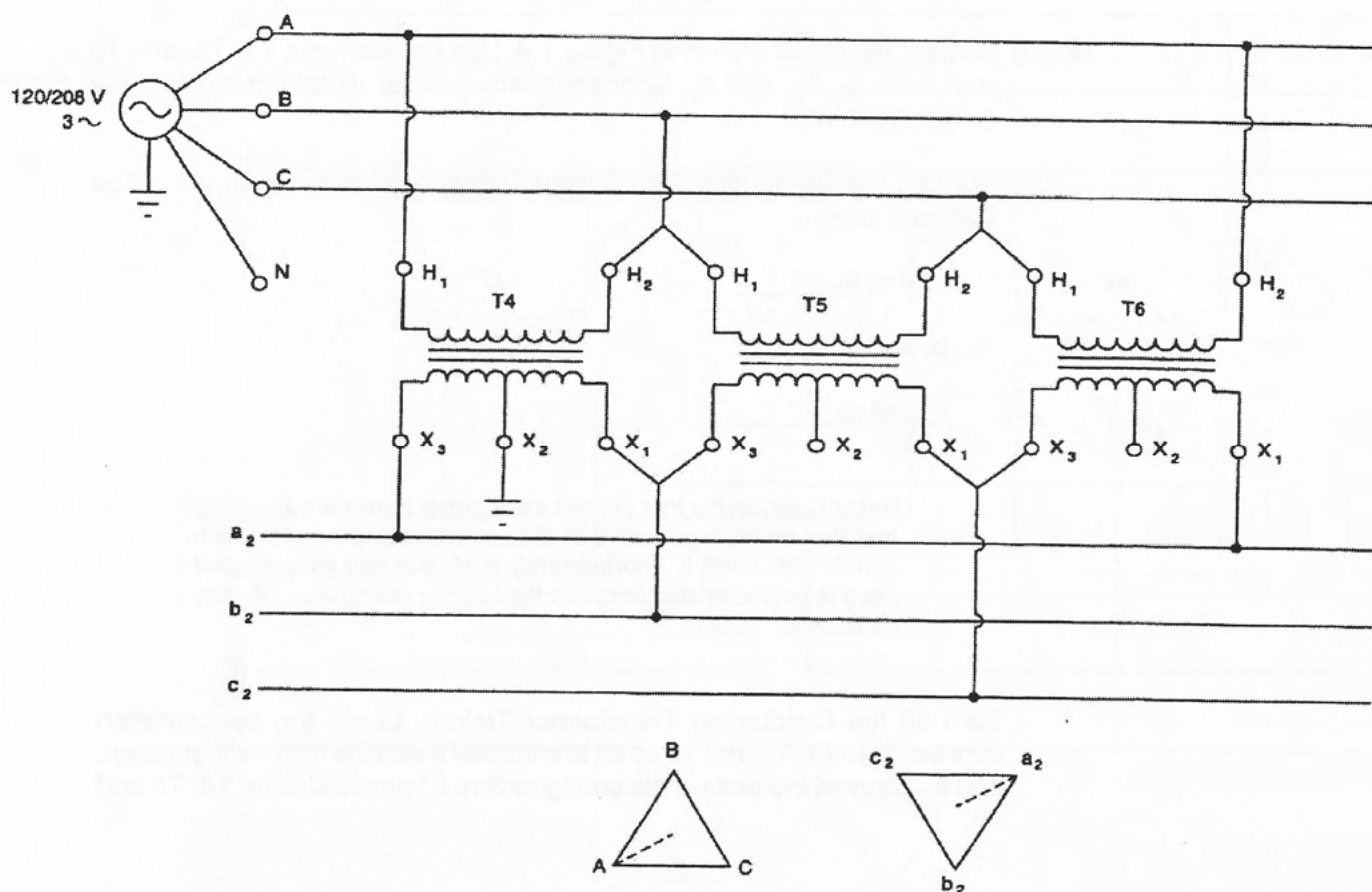


Figure 1-7. Delta-delta, 180° phase shift.

What can you conclude about the phase shift between lines a_1 and a_2 ?

Turn off the Distribution Transformer Trainer.

Distribution Transformer Trainer

Note: Figures D-3 and D-4 in Appendix D illustrate a delta-delta configuration that delivers 120 V between line a and N and between b and N while maintaining 240 V between lines a and b.

Open-Delta, 0° Phase Shift

The open-delta configuration offers the possibility of running a three-phase bank with only two transformers. Note that the total capacity of the bank is reduced.

- 9. Connect the circuit shown in Figure 1-8. Use transformers T1, and T2 and lines a₁, b₁, and c₁. Connect bushing X₂ of transformer T1 to the ground terminal.

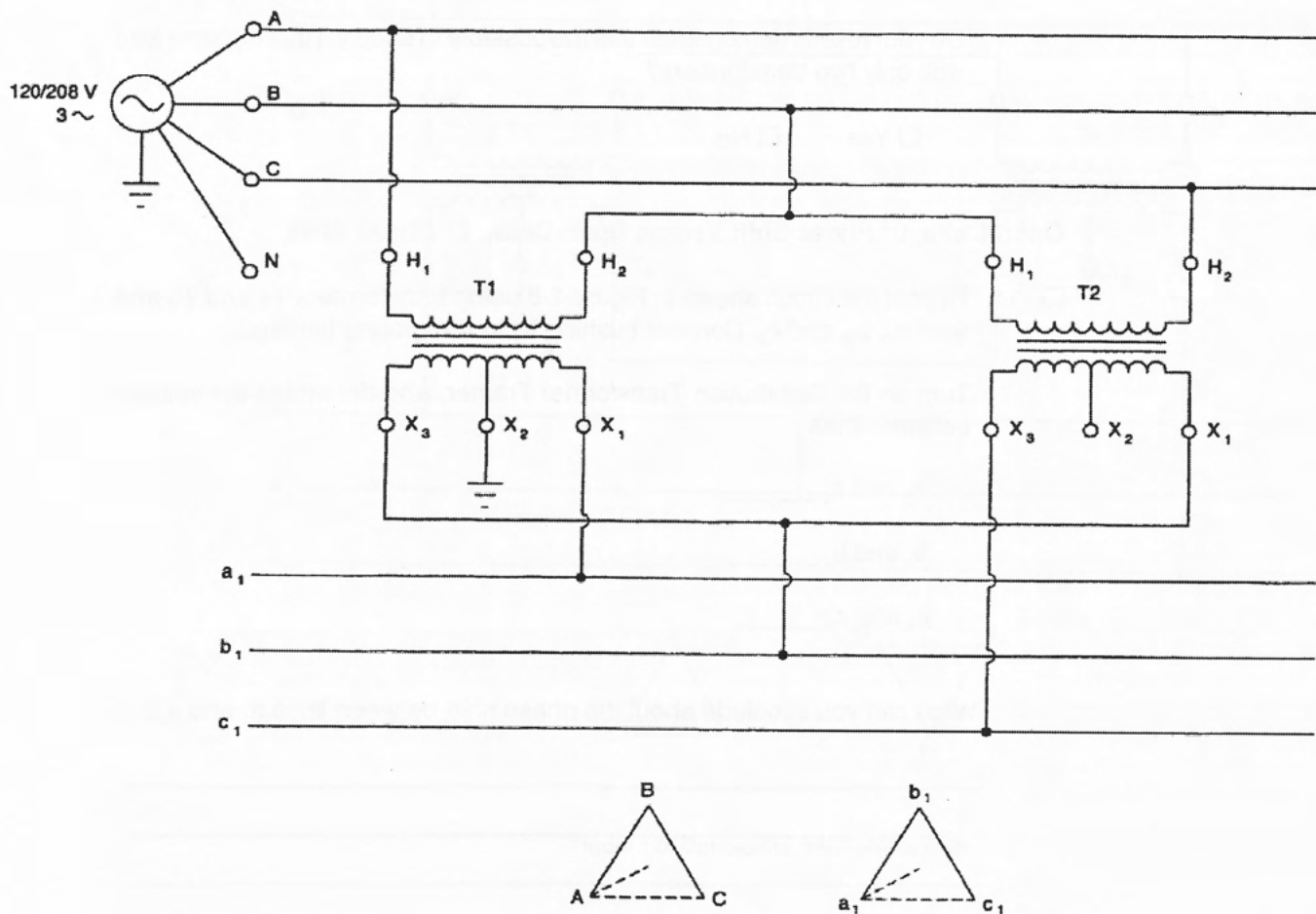


Figure 1-8. Open-delta, 0° phase shift.

Distribution Transformer Trainer

- ☐ 10. Turn on the Distribution Transformer Trainer and determine the voltage between lines

a₁ and b₁ _____

b₁ and c₁ _____

c₁ and a₁ _____

Turn off the Distribution Transformer Trainer.

Do your results demonstrate that it is possible to supply a three-phase load with only two transformers?

☐ Yes ☐ No

Open-Delta, 0° Phase Shift Versus Open-Delta, 0° Phase Shift

- ☐ 11. Repeat the circuit shown in Figure 1-8 using transformers T4 and T5 and lines a₂, b₂, and c₂. Connect bushing X₂ to the ground terminal.

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

a₁ and a₂ _____

b₁ and b₂ _____

c₁ and c₂ _____

What can you conclude about the phase shift between lines a₁ and a₂?

Turn off the Distribution Transformer Trainer. Leave the open-delta configuration connected to T1 and T2 so as to compare it with the next configuration. Disconnect the open-delta configuration, 0° phase shift on T4 and T5.

Distribution Transformer Trainer

Open-Delta, 0° Phase Shift Versus Open-Delta, 180° Phase Shift

- 12. Connect the circuit shown in Figure 1-9. Use transformers T4 and T5, and lines a_2 , b_2 , and c_2 . Connect bushing X_2 of transformer T4 to the ground terminal.

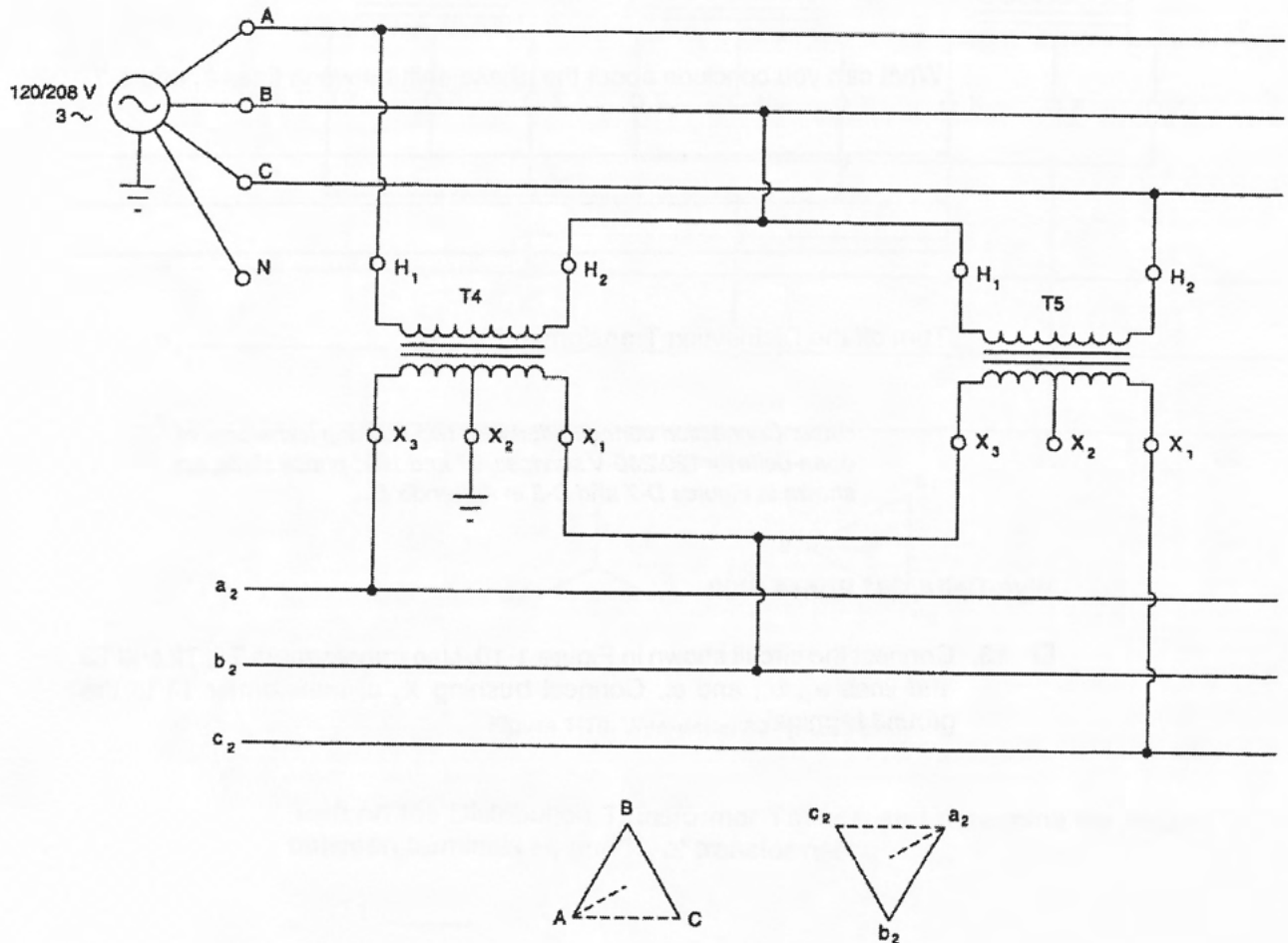


Figure 1-9. Open-delta, 180° phase shift.

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

a_2 and b_2 _____

b_2 and c_2 _____

c_2 and a_2 _____

Distribution Transformer Trainer

Determine the voltage between lines

a_1 and a_2 _____

b_1 and b_2 _____

c_1 and c_2 _____

What can you conclude about the phase shift between lines a_1 and a_2 ?

Turn off the Distribution Transformer Trainer.

Note: Connection configurations for two-bushing transformers, open-delta for 120/240-V services, 0° and 180° phase shifts, are shown in Figures D-7 and D-8 in Appendix D.

Wye-Delta, 30° Phase Shift

- ☐ 13. Connect the circuit shown in Figure 1-10. Use transformers T1, T2 and T3 and lines a_1 , b_1 , and c_1 . Connect bushing X_2 of transformer T1 to the ground terminal.

Distribution Transformer Trainer

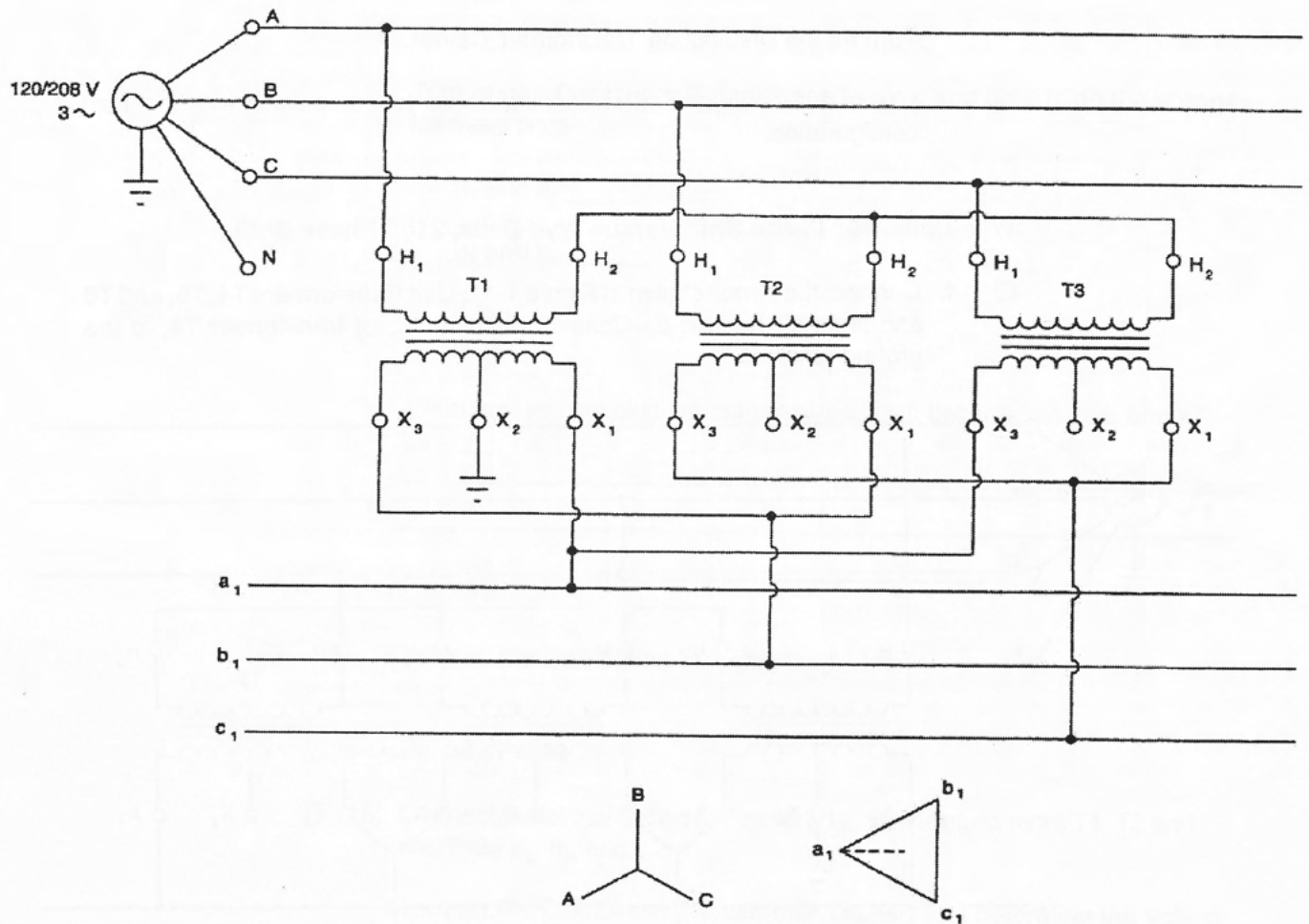


Figure 1-10. Wye-delta, 30° phase shift.

Turn on the Distribution Transformer Trainer, and determine the voltage between terminals H₁ and H₂ of transformer

T1 _____

T2 _____

T3 _____

Determine the voltage between lines

a₁ and b₁ _____

b₁ and c₁ _____

c₁ and a₁ _____

Distribution Transformer Trainer

Turn off the Distribution Transformer Trainer.

Leave this configuration connected so as to compare it with the next configuration.

Wye-Delta, 30° Phase Shift Versus Wye-Delta, 210° Phase Shift

- 14. Connect the circuit shown in Figure 1-11. Use transformers T4, T5, and T6 and lines a_2 , b_2 , and c_2 . Connect bushing X_2 , of transformer T4, to the ground terminal.

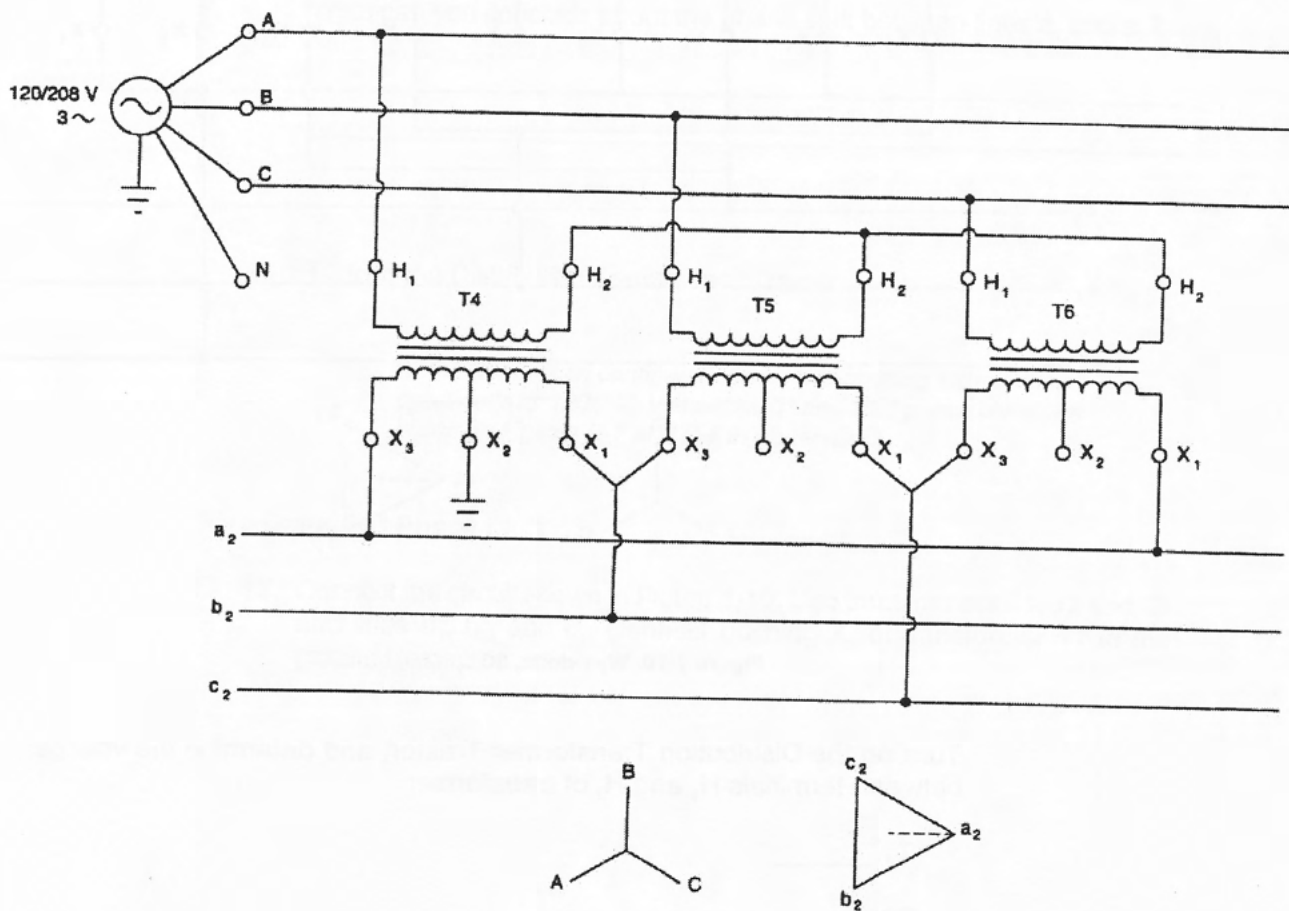


Figure 1-11. Wye-delta, 210° phase shift.

Distribution Transformer Trainer

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

a_1 and a_2 _____

b_1 and b_2 _____

c_1 and c_2 _____

What can you conclude about the phase shift between lines a_1 and a_2 ?

Turn off the Distribution Transformer Trainer.

Wye-Delta, 30° Phase Shift

- ☐ 15. Connect the circuit shown in Figure 1-12. Use transformers T1, T2 and T3 and lines a_1 , b_1 , and c_1 .

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

a_1 and b_1 _____

b_1 and c_1 _____

c_1 and a_1 _____

a_1 and N _____

b_1 and N _____

c_1 and N _____

Turn off the Distribution Transformer Trainer.

Leave this configuration connected so as to compare it with the next configuration.

Distribution Transformer Trainer

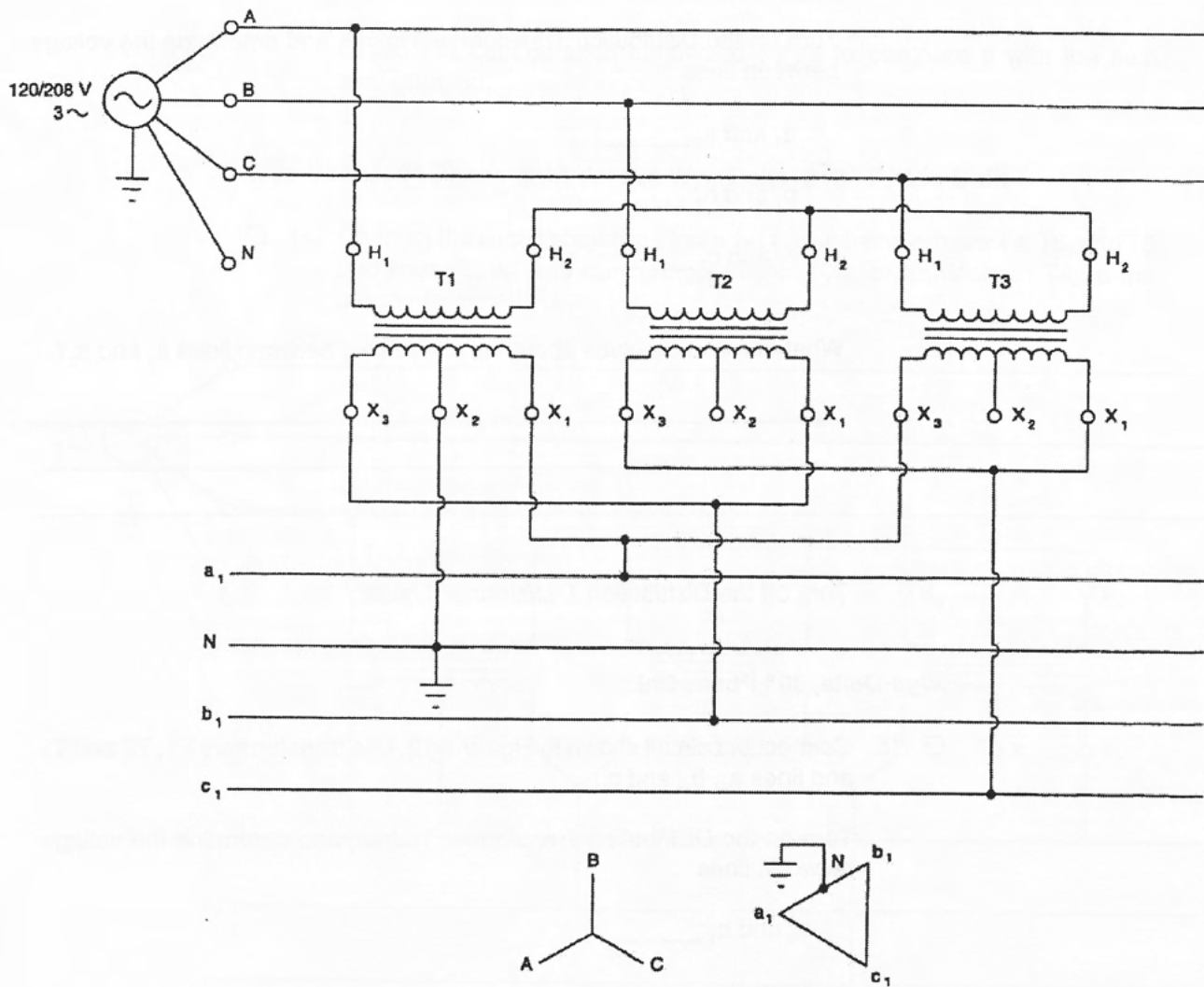


Figure 1-12. Wye-delta, 30° phase shift.

Wye-Delta, 30° Phase Shift Versus Wye-Delta, 210° Phase Shift

- 16. Connect the circuit shown in Figure 1-13. Use transformers T4, T5 and T6 and lines a_2 , b_2 , and c_2 .

Distribution Transformer Trainer

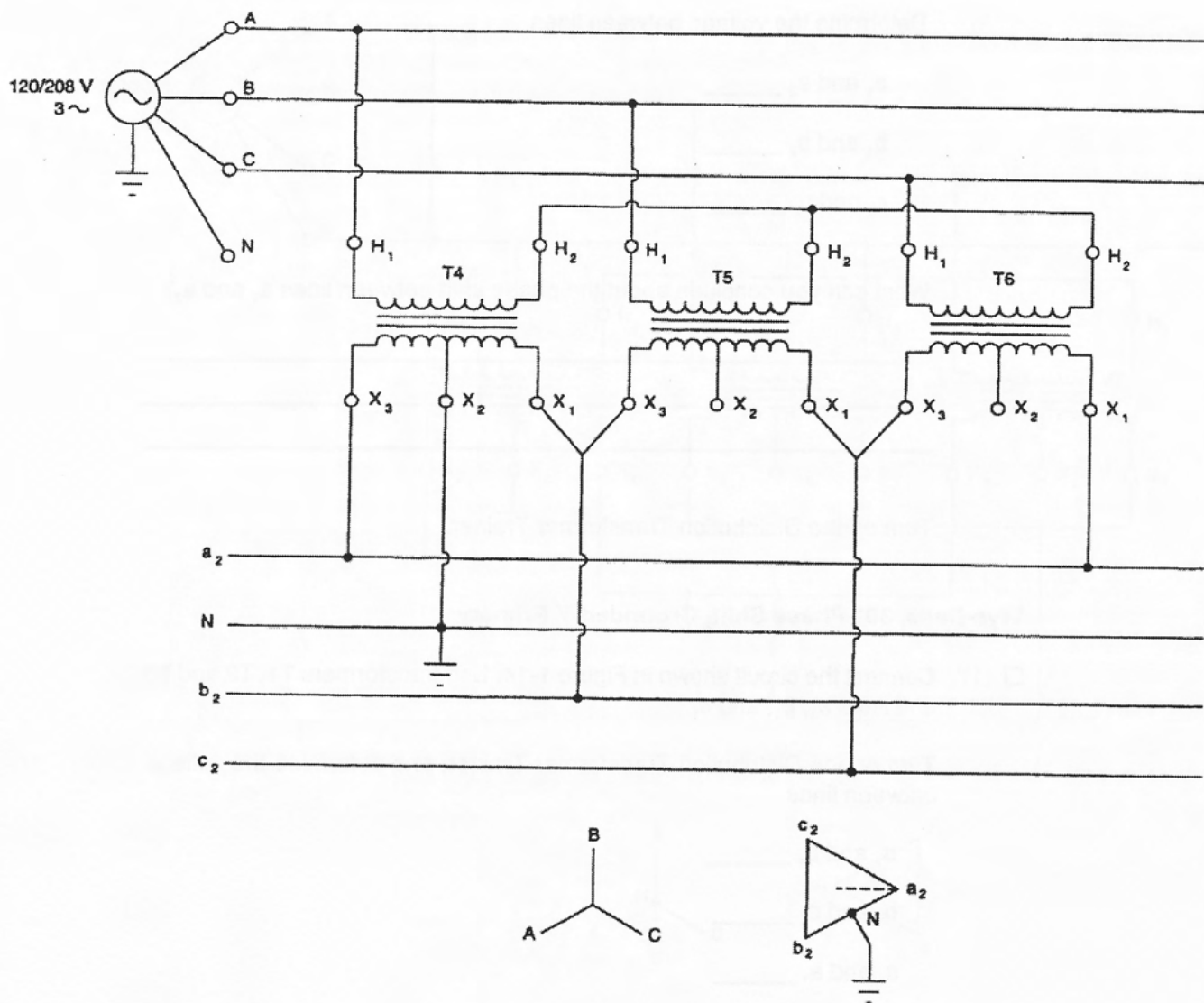


Figure 1-13. Wye-delta, 210° phase shift.

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

a₂ and b₂ _____

b₂ and c₂ _____

c₂ and a₂ _____

a₂ and N _____

b₂ and N _____

c₂ and N _____

Distribution Transformer Trainer

Determine the voltage between lines

a_1 and a_2 _____

b_1 and b_2 _____

c_1 and c_2 _____

What can you conclude about the phase shift between lines a_1 and a_2 ?

Turn off the Distribution Transformer Trainer.

Wye-Delta, 30° Phase Shift, Grounded-Y Primary

- ☐ 17. Connect the circuit shown in Figure 1-14. Use transformers T1, T2 and T3 and lines a_1 , b_1 , and c_1 .

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

a_1 and b_1 _____

b_1 and c_1 _____

c_1 and a_1 _____

Turn off the Distribution Transformer Trainer.

Disconnect the primary of T1.

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

a_1 and b_1 _____

b_1 and c_1 _____

c_1 and a_1 _____

Distribution Transformer Trainer

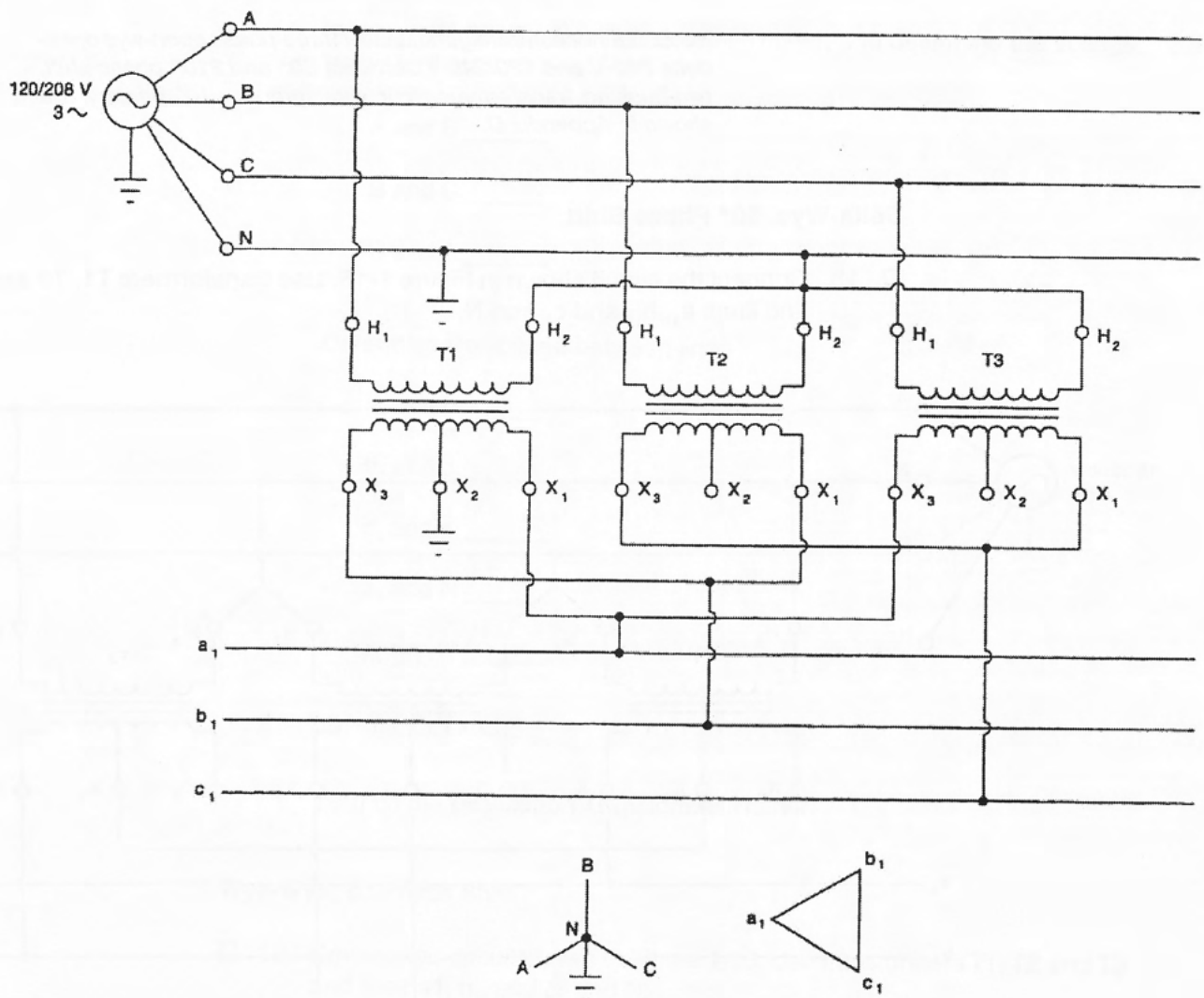


Figure 1-14. Wye-delta, 30° phase shift, grounded-Y primary.

Do your results demonstrate that it is possible to supply a three-phase load with only two transformers?

☐ Yes ☐ No

Turn off the Distribution Transformer Trainer.

Note: Connection configurations for three-phase wye-delta 240-V and 120/240-V services, 30° and 210° phase shift, two-bushing transformers, four wire, grounded-Y primary are shown in Appendix D.

Distribution Transformer Trainer

Note: Connection configurations for three-phase open-wye open-delta 240-V and 120/240-V services, 30° and 210° phase shift, two-bushing transformers, four wire, grounded-Y primary are shown in Appendix D.

Delta-Wye, 30° Phase Shift

- 18. Connect the circuit shown in Figure 1-15. Use transformers T1, T2 and T3 and lines a_1 , b_1 , and c_1 and N.

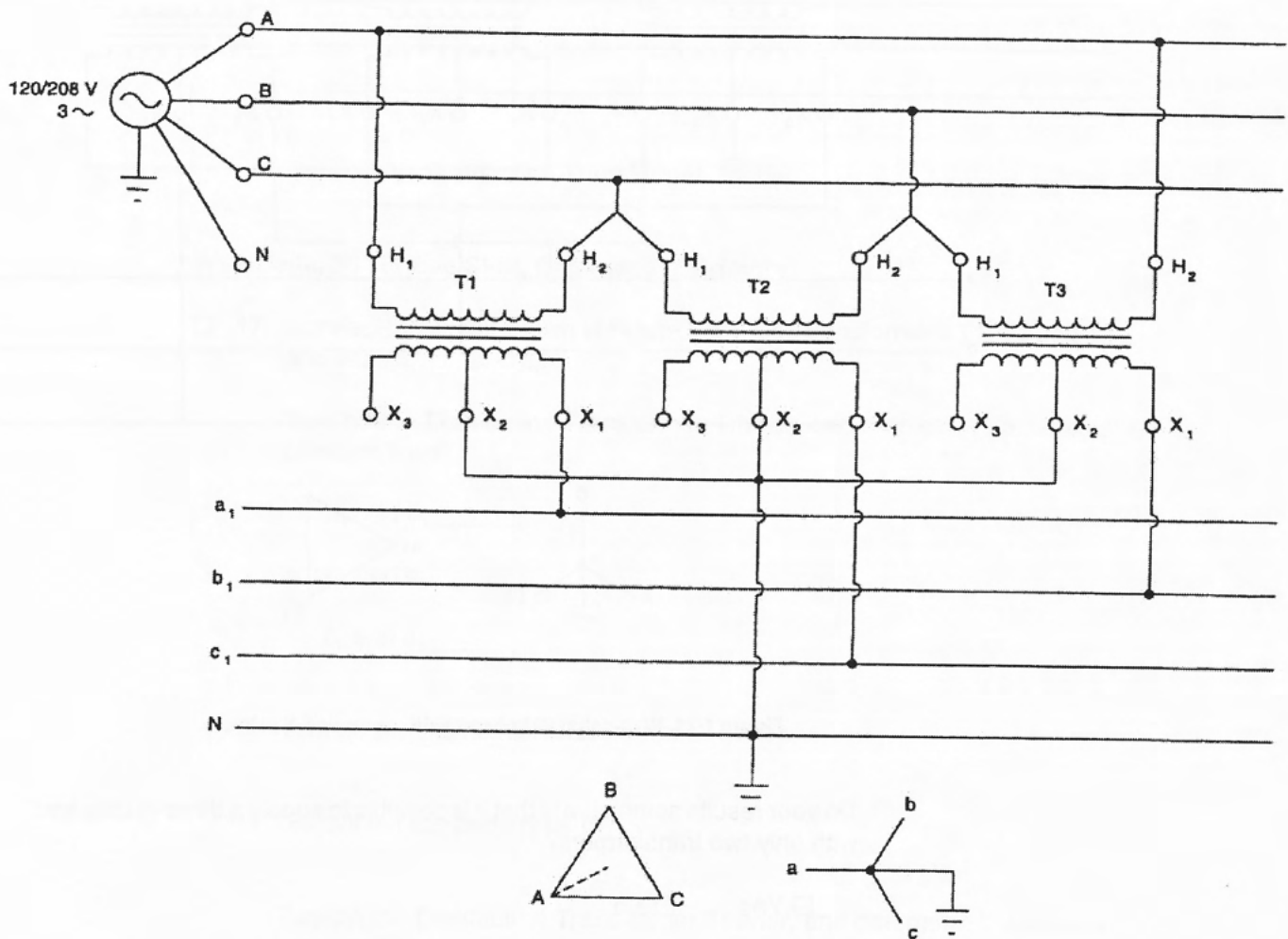


Figure 1-15. Delta-wye, 30° phase shift.

Distribution Transformer Trainer

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

A and B _____

B and C _____

C and A _____

Determine the voltage between lines

a_1 and b_1 _____

b_1 and c_1 _____

c_1 and a_1 _____

a_1 and N _____

b_1 and N _____

c_1 and N _____

Turn off the Distribution Transformer Trainer.

Wye-Wye, 0° Phase Shift

- ☐ 19. Connect the circuit shown in Figure 1-16. Use transformers T1, T2 and T3 and lines a_1 , b_1 , and c_1 and N.

Turn on the Distribution Transformer Trainer, and determine the voltage between lines

A and B _____

B and C _____

C and A _____

Determine the voltage between lines

a_1 and b_1 _____

b_1 and c_1 _____

c_1 and a_1 _____

Distribution Transformer Trainer

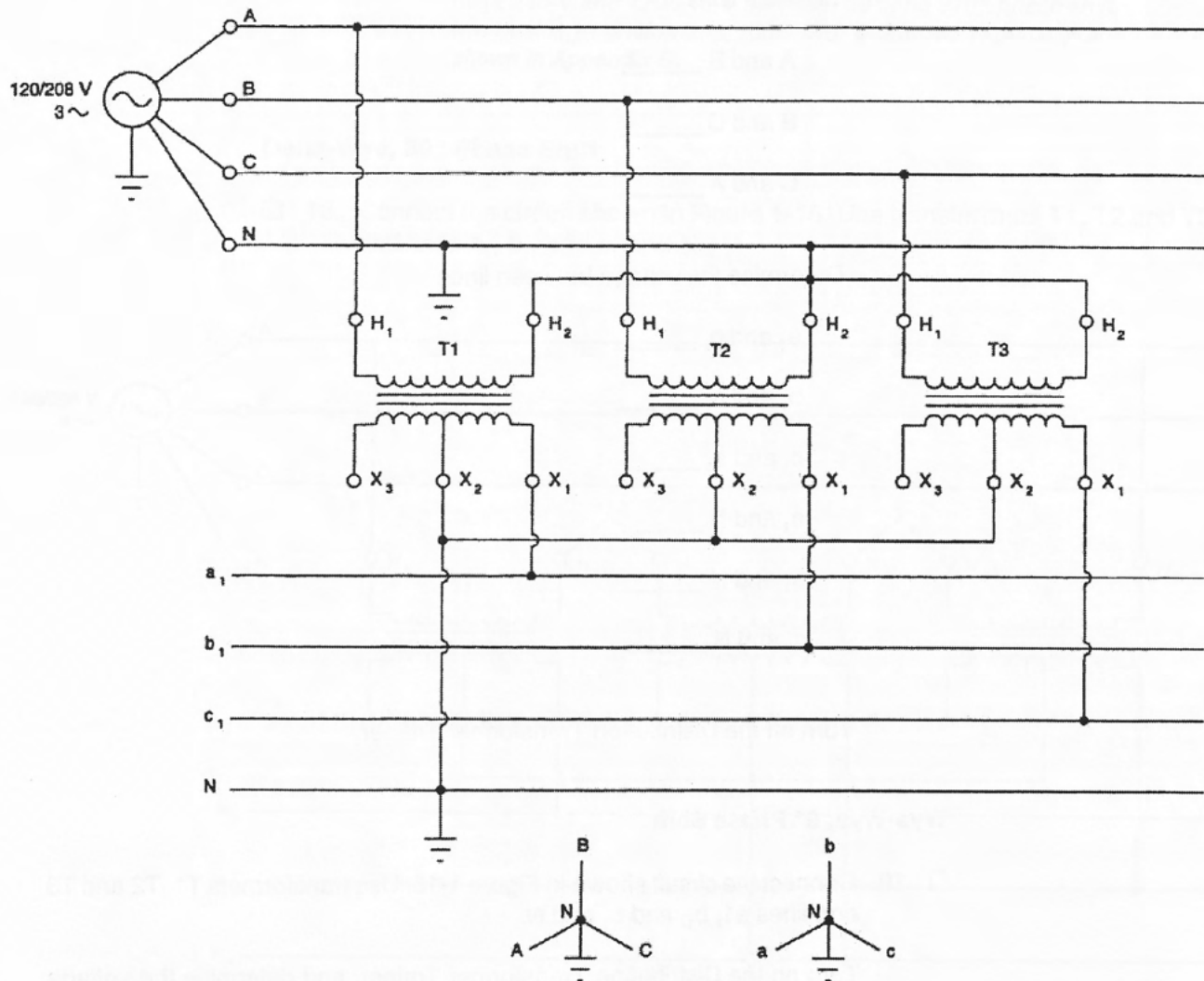


Figure 1-16. Wye-wye, 0° phase shift.

- ☐ 20. Turn off the Distribution Transformer Trainer.

List of Faults

- F_1 _____
- F_2 _____
- F_3 _____
- F_4 _____
- F_5 _____
- F_6 _____
- F_7 _____
- F_8 _____

Single-Phase Transformers with Single-Phase Loads

Two-Bushing Transformer for 120-V Service

Used to supply customers who require only 120 V single-phase power. For modern homes, this connection is usually not considered adequate.

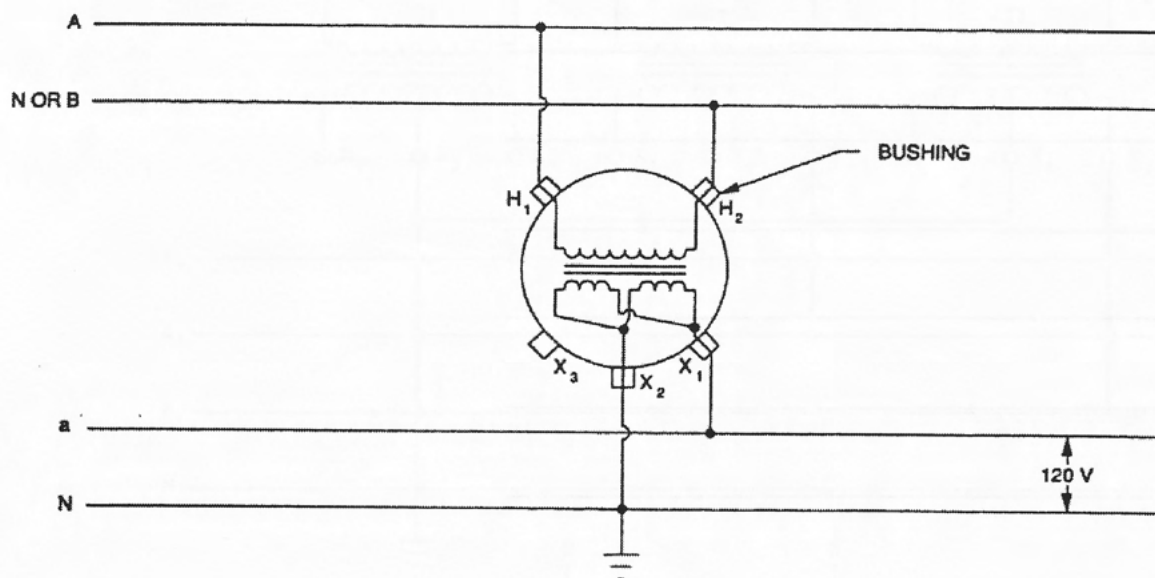


Figure B-1.

Single-Phase Transformers with Single-Phase Loads

Single-Bushing Transformer for 120-V Service

Used to supply customers who require only 120 V single-phase power. For modern homes, this connection is usually not considered adequate.

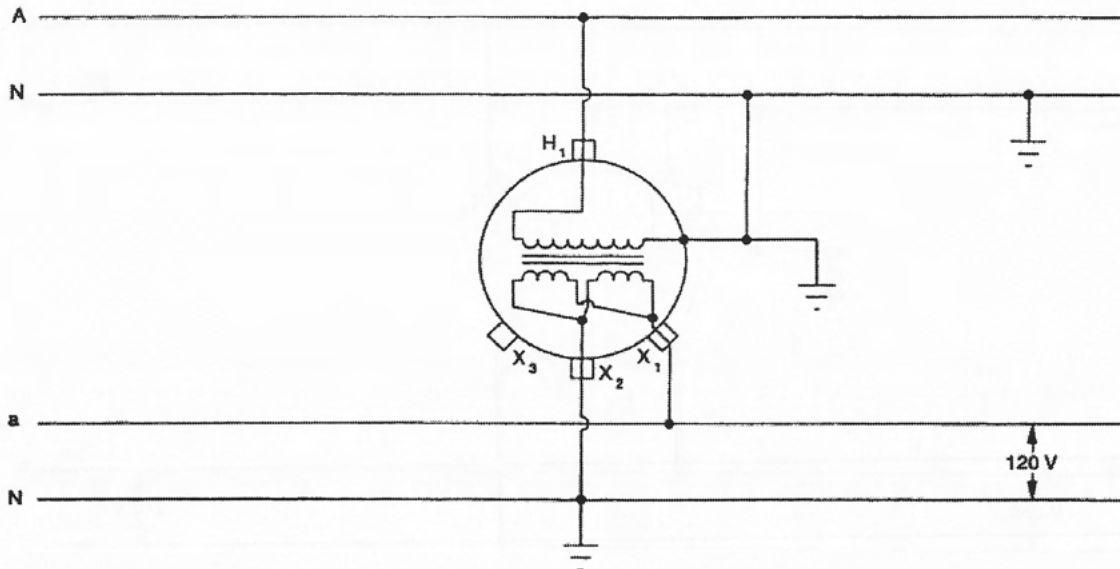


Figure B-2.

Single-Phase Transformers with Single-Phase Loads

Two-Bushing Transformer for 240-V Service

Used to supply customers who require only 240 V single-phase power. If a ground is required, it may be placed on the X_2 bushing.

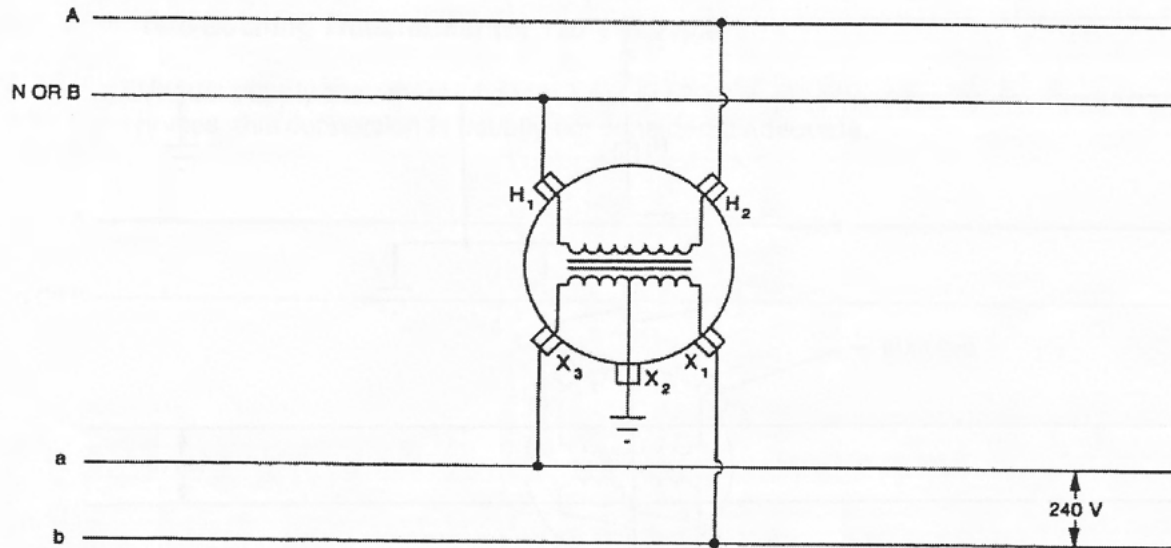


Figure B-3.

Single-Phase Transformers with Single-Phase Loads

Single-Bushing Transformer for 240-V Service

Used to supply customers who require only 240 V single-phase power. If a ground is required, it may be placed on the X_2 bushing.

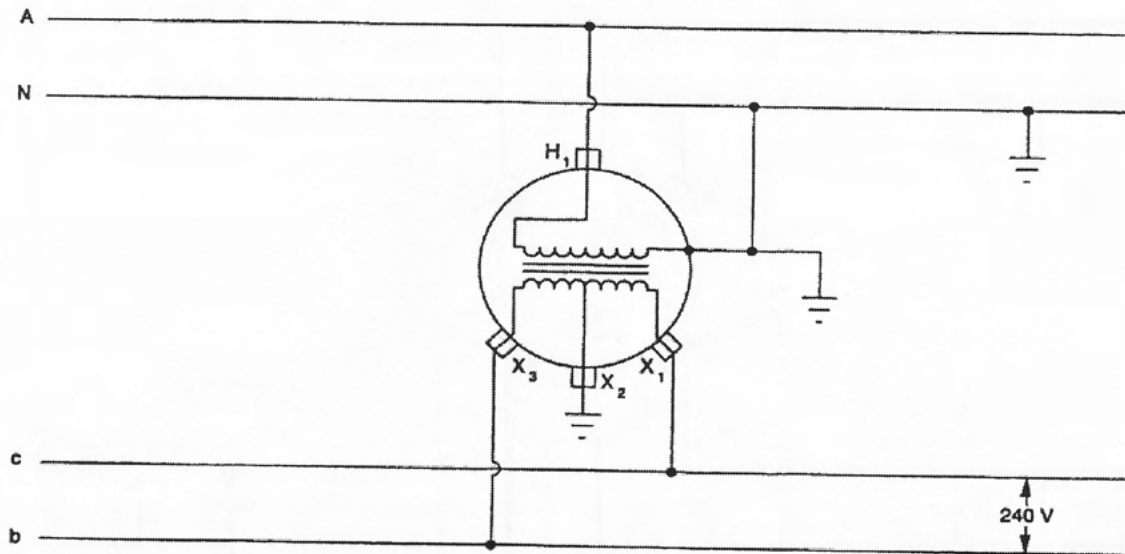


Figure B-4.

Single-Phase Transformers with Single-Phase Loads

Two-Bushing Transformer for 120/240-V Service

Used to supply customers who require 120 V and 240 V single-phase power.

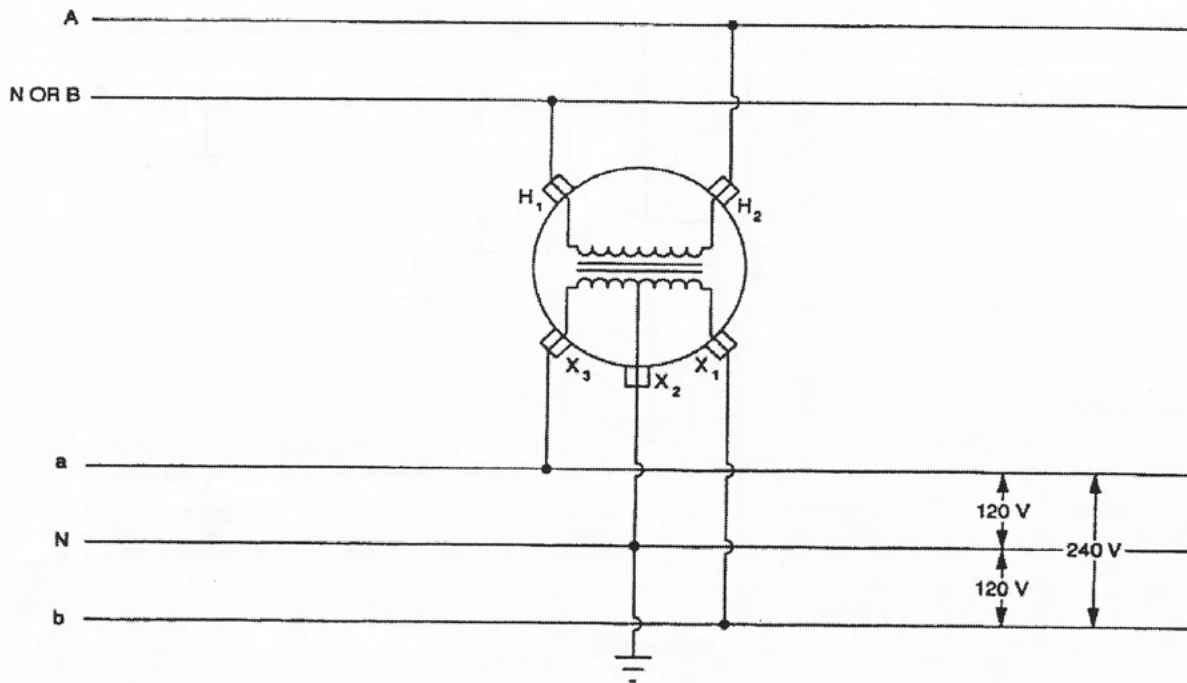


Figure B-5.

Single-Phase Transformers with Single-Phase Loads

Single-Bushing Transformer for 120/240-V Service

Used to supply customers who require 120 V and 240 V single-phase power.

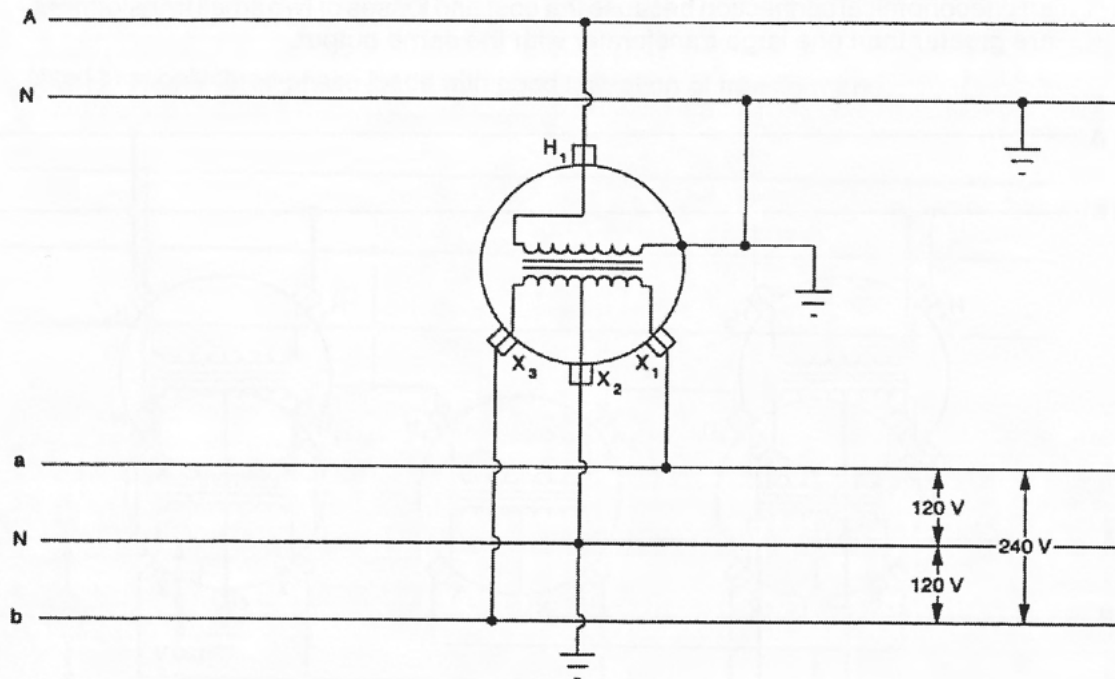


Figure B-6.

Single-Phase Paralleling

Two-Bushing Transformers for 120/240-V Service

Used to supply increased demands for 120 V and 240 V single-phase power. It is an uneconomical connection because the cost and losses of two small transformers are greater than one large transformer with the same output.

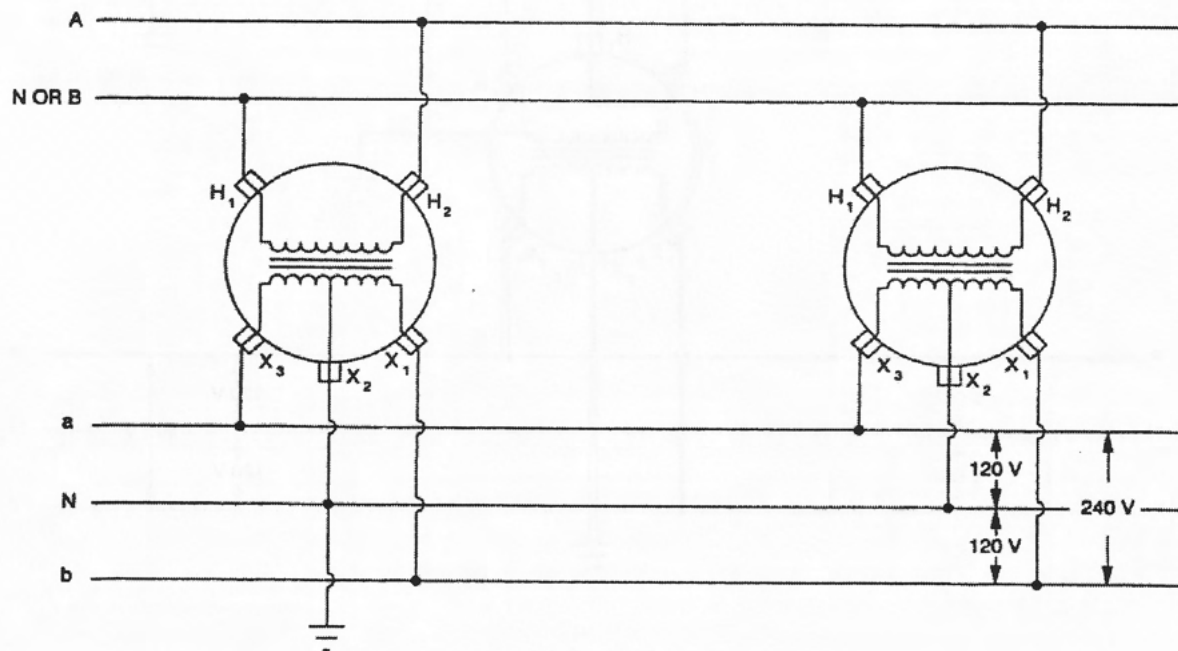


Figure C-1.

Three-Phase Banking of Single-Phase Transformers

Three-Phase Delta-Delta for 240-V Service, 0° Phase Shift, American Standard Connection

Used to supply three-phase loads with good utilization of transformers.

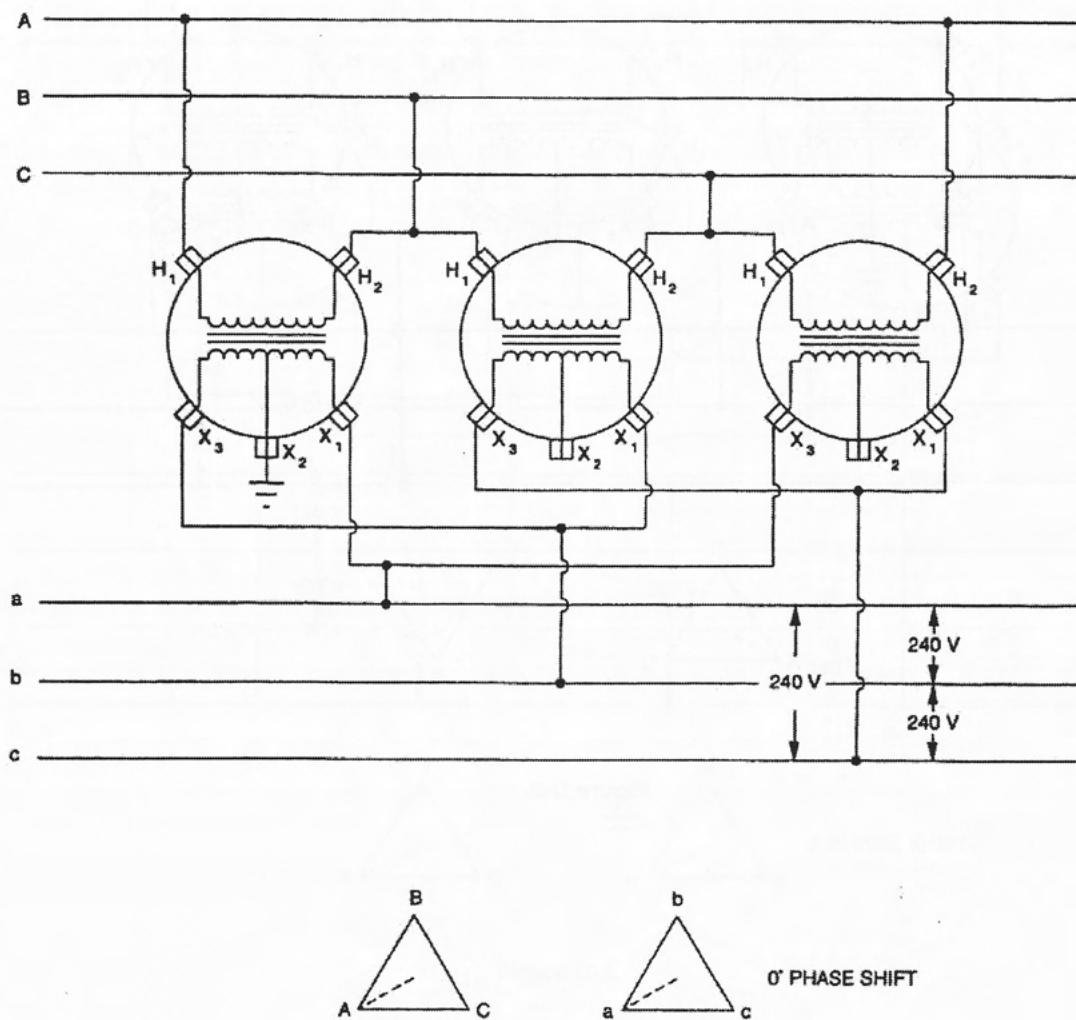


Figure D-1.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Delta-Delta for 240-V Service, 180° Phase Shift

Used to supply three-phase loads with good utilization of transformers.

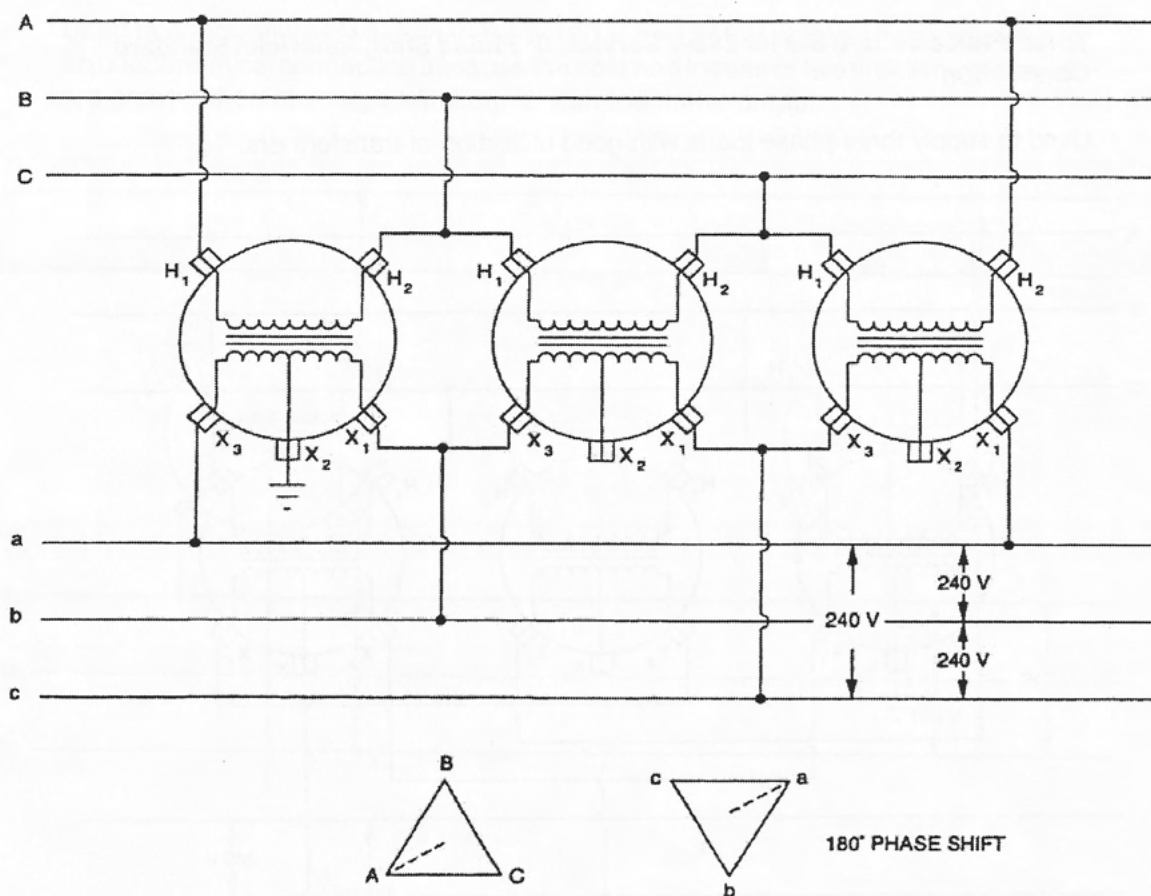


Figure D-2.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Delta-Delta for 120/240-V Service, 0° Phase Shift, American Standard Connection

Used to supply three-phase 240-V loads with small amounts of 120/240-V single-phase load.

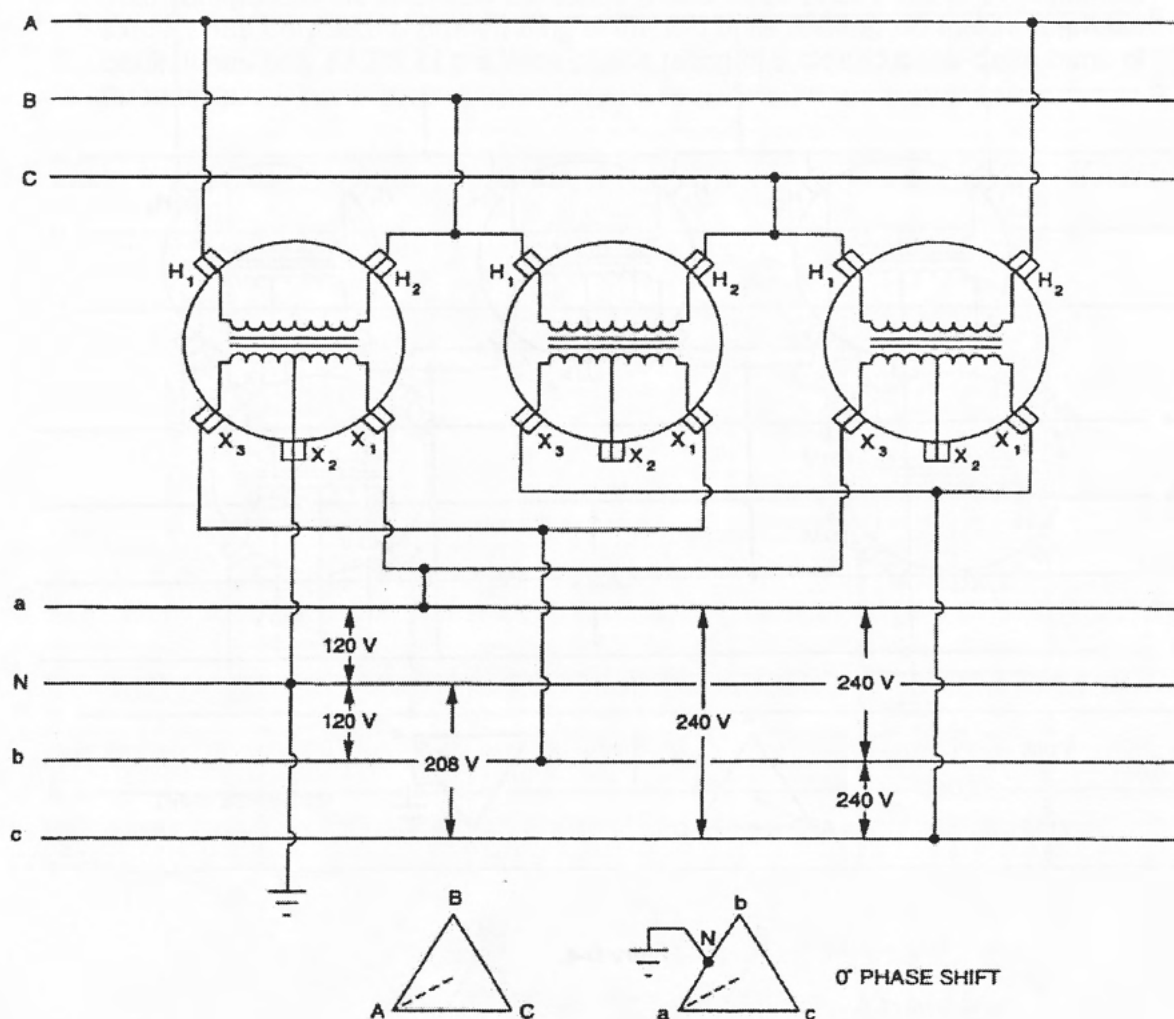


Figure D-3.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Delta-Delta for 120/240-V Service, 180° Phase Shift

Used to supply three-phase 240-V loads with small amounts of 120/240-V single-phase load.

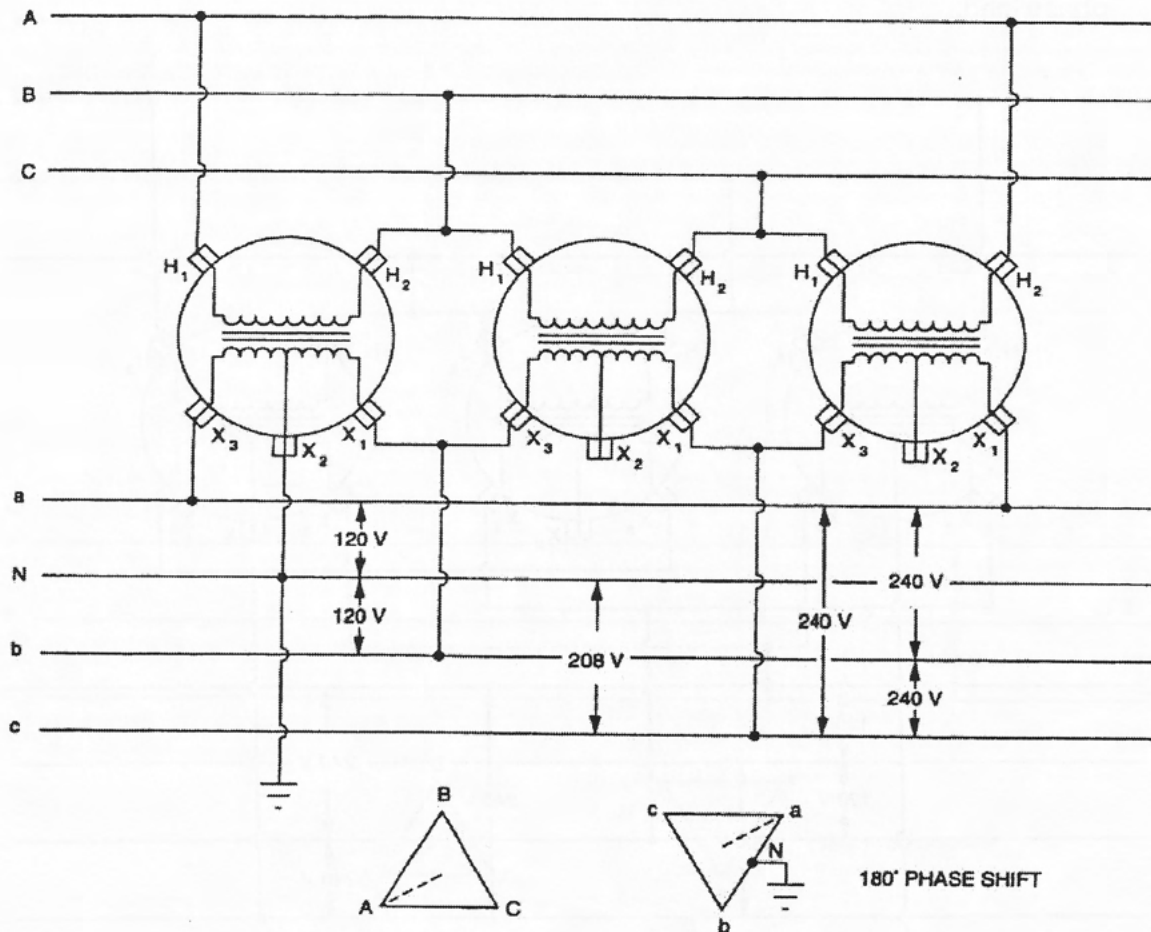


Figure D-4.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Open-Delta for 240-V Service, 0° Phase Shift, American Standard Connection

Used to supply large single-phase power loads with small amounts of three-phase loads. Also used for emergency operation when one unit of a delta-delta bank is disabled. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

This configuration is relatively inefficient where three-phase loads predominate since it has only 86.6% of the rating of the two units making up the three-phase bank. It has only 57.7% of the three-phase rating of a closed delta-delta bank of three units.

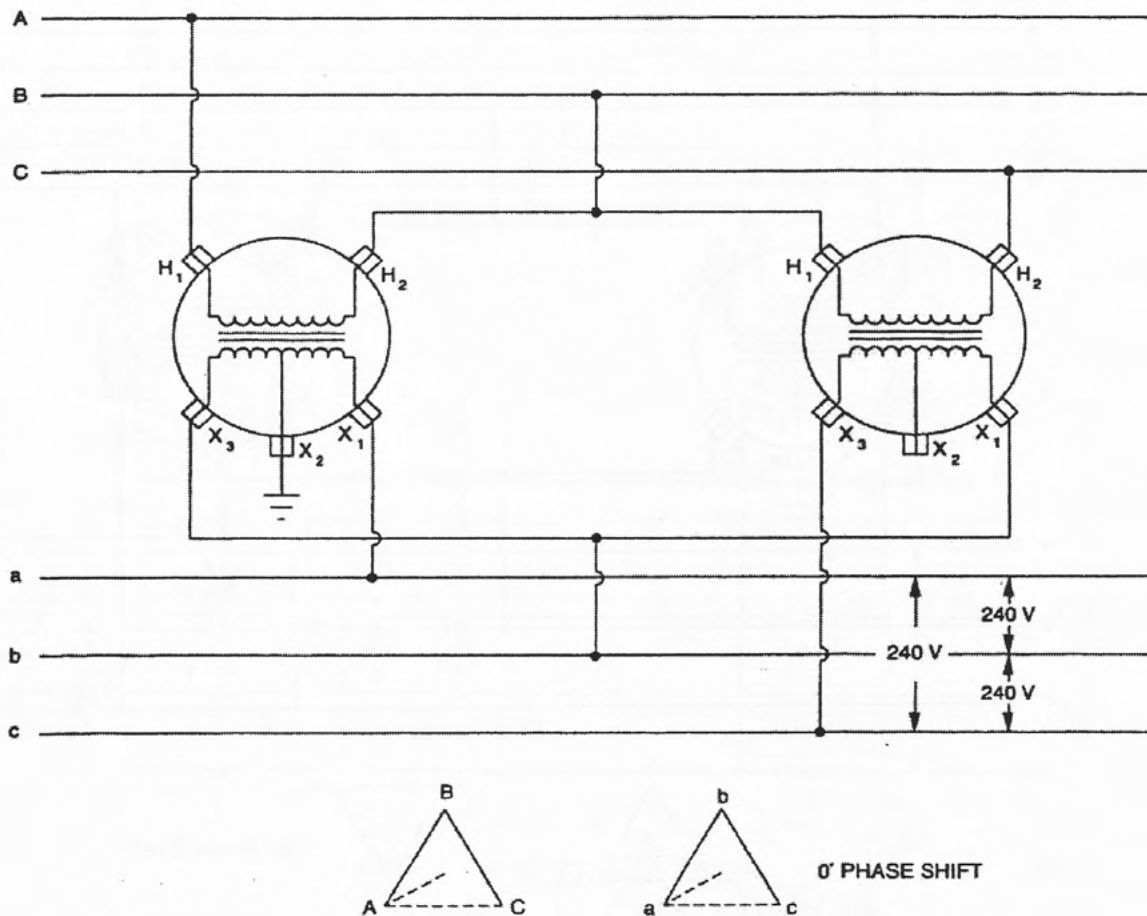


Figure D-5.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Open-Delta for 240-V Service, 180° Phase Shift

Used to supply large single-phase power loads with small amounts of three-phase loads. Also used for emergency operation when one unit of a delta-delta bank is disabled. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

This configuration is relatively inefficient where three-phase loads predominate since it has only 86.6% of the rating of the two units making up the three-phase bank. It has only 57.7% of the three-phase rating of a closed delta-delta bank of three units.

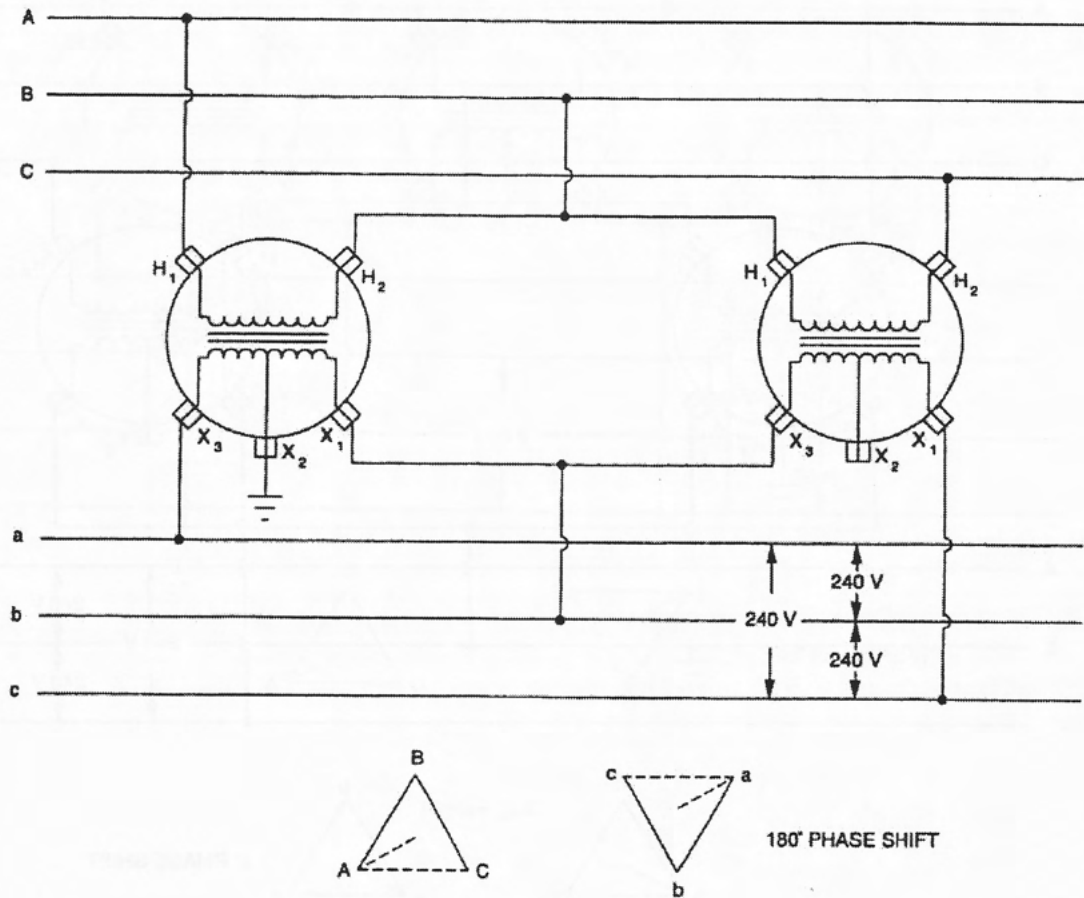


Figure D-6.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Open-Delta for 120/240-V Service, 0° Phase Shift, American Standard Connection

Used to supply large 240-V and 120-V single-phase loads with small amounts of three-phase loads. Also used for emergency operation when one unit of a delta-delta bank is disabled.

This configuration is relatively inefficient where three-phase loads predominate since it has only 86.6% of the rating of the two units making up the three-phase bank. It has only 57.7% of the three-phase rating of a closed delta-delta bank of three units.

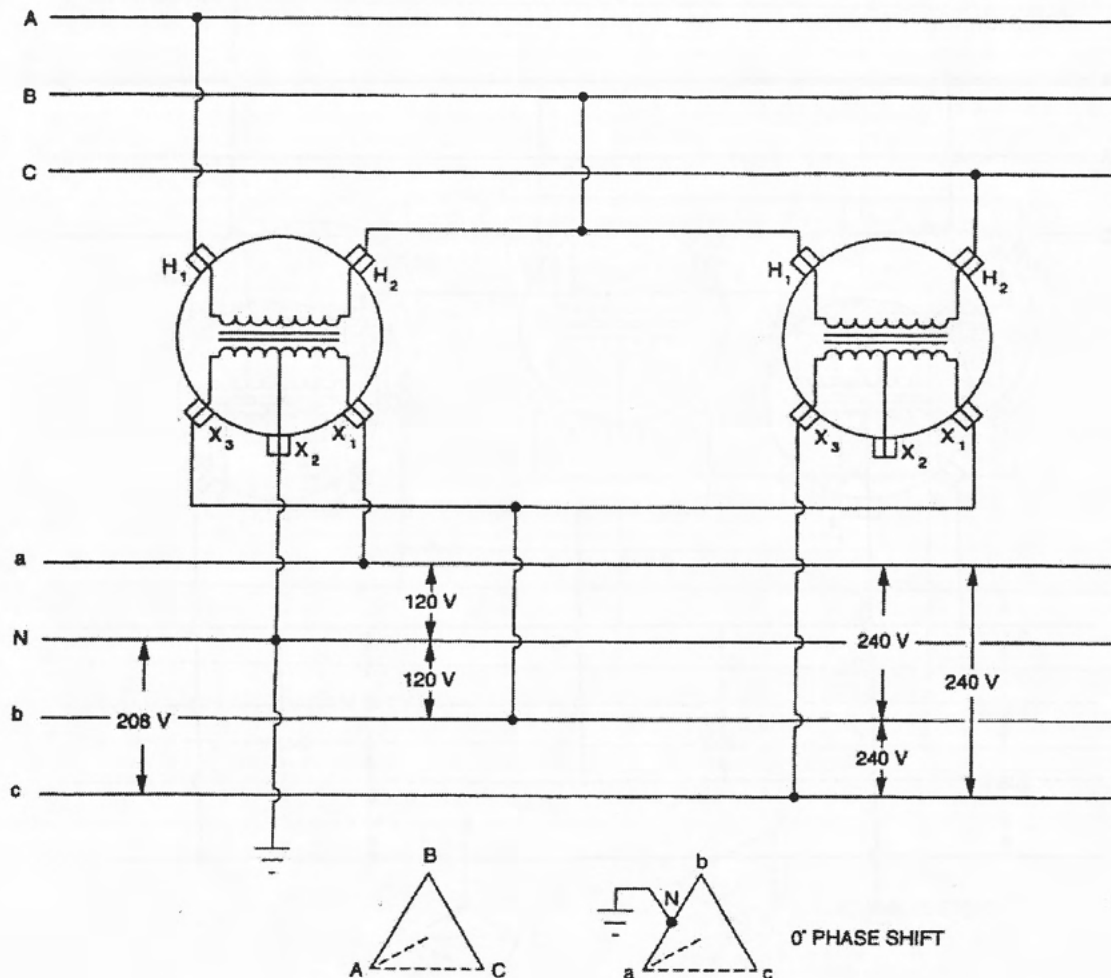


Figure D-7.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Open-Delta for 120/240-V Service, 180° Phase Shift

Used to supply large 240-V and 120-V single-phase loads with small amounts of three-phase loads. Also used for emergency operation when one unit of a delta-delta bank is disabled.

This configuration is relatively inefficient where three-phase loads predominate since it has only 86.6% of the rating of the two units making up the three-phase bank. It has only 57.7% of the three-phase rating of a closed delta-delta bank of three units.

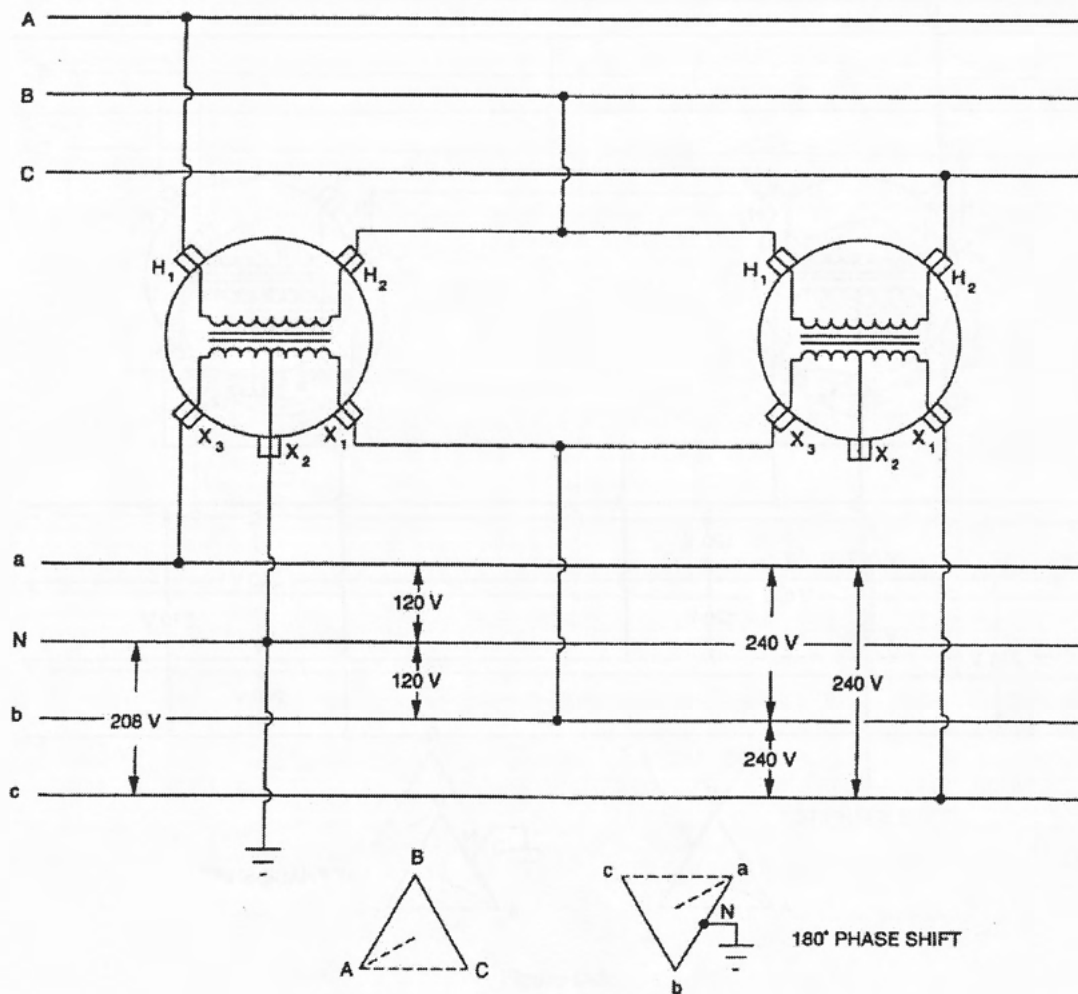


Figure D-8.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Wye-Delta for 240-V Service, 30° Phase Shift, American Standard Connection

Used to supply three-phase loads. No excessive circulating currents when transformers of unequal impedance and ratio are banked. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

Maximum safe bank rating for balanced three-phase loads is three times the kVA of the smallest unit.

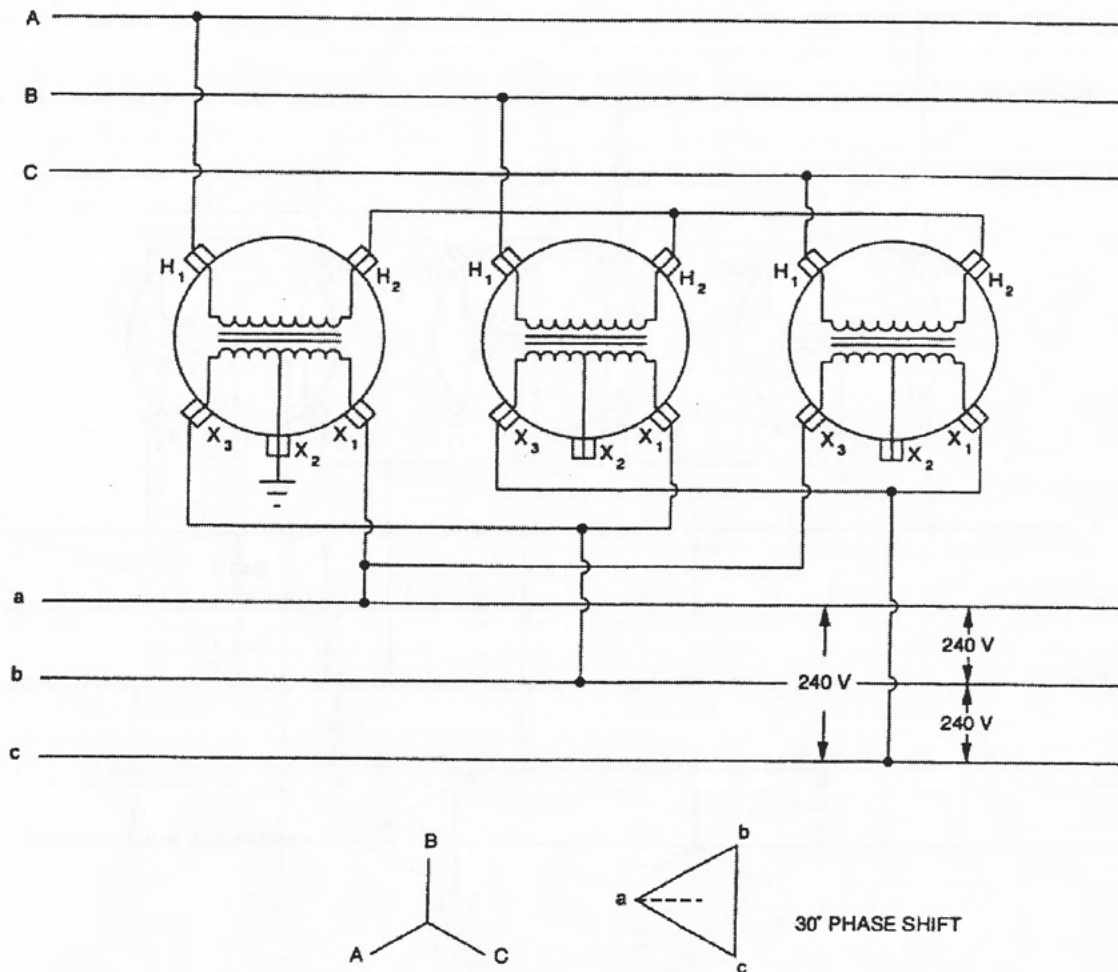


Figure D-9.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Wye-Delta for 240-V Service, 210° Phase Shift

Used to supply three-phase loads. No excessive circulating currents when transformers of unequal impedance and ratio are banked. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

Maximum safe bank rating for balanced three-phase loads is three times the kVA of the smallest unit.

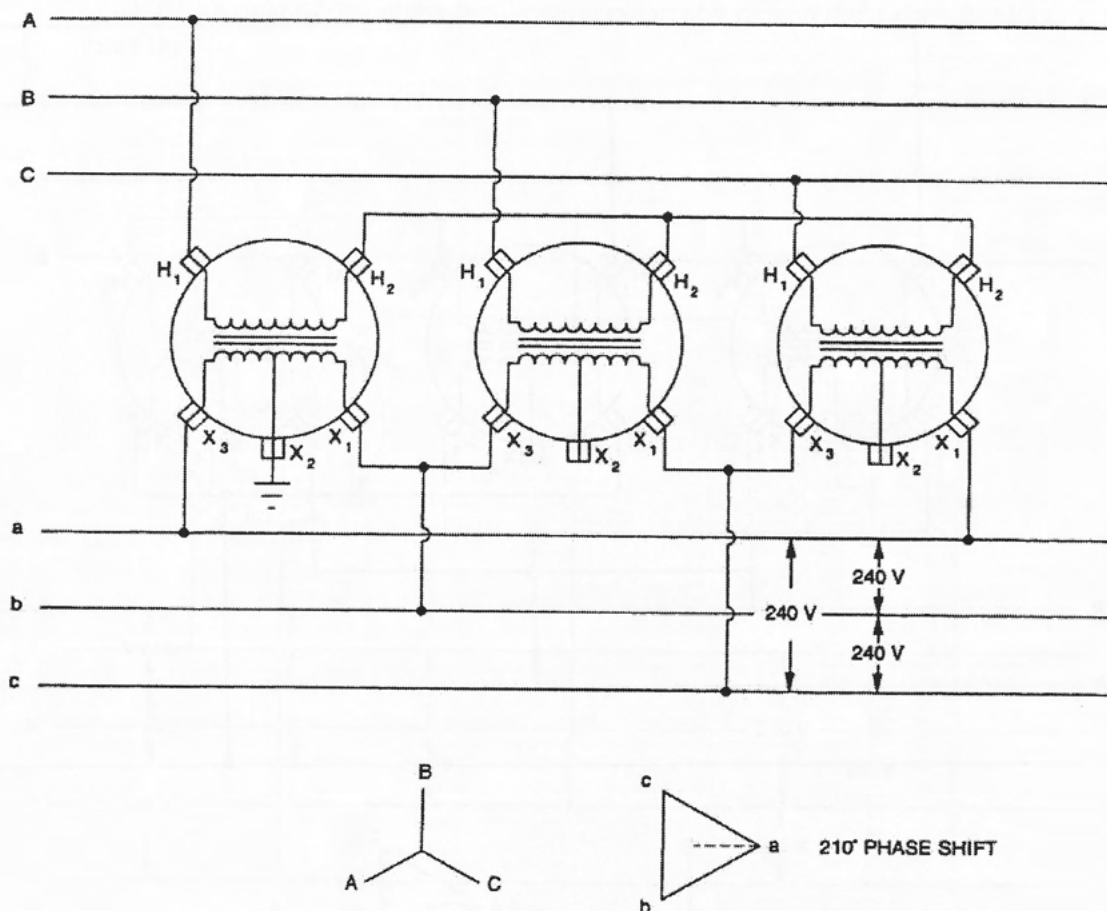


Figure D-10.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Wye-Delta for 120/240-V Service, 30° Phase Shift, American Standard Connection

Used to supply three-phase 240-V loads with small amount of 120/240-V single-phase loads. No excessive circulating currents when transformers of unequal impedance and ratio are banked. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

The secondary neutral bushing can be grounded only on one of the three transformers.

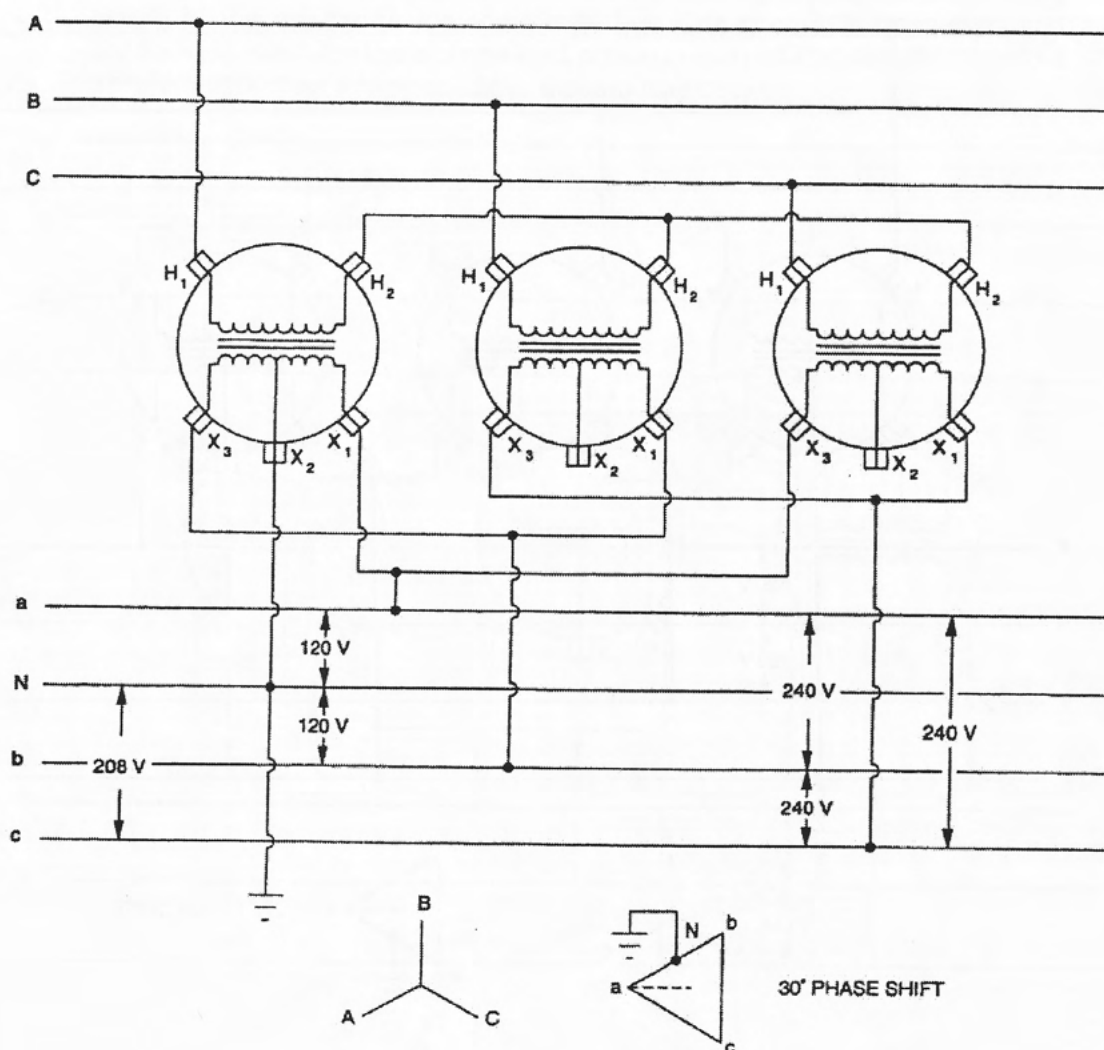


Figure D-11.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Wye-Delta for 120/240-V Service, 210° Phase Shift

Used to supply three-phase 240-V loads with small amount of 120/240-V single-phase loads. No excessive circulating currents when transformers of unequal impedance and ratio are banked. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

The secondary neutral bushing can be grounded only on one of the three transformers.

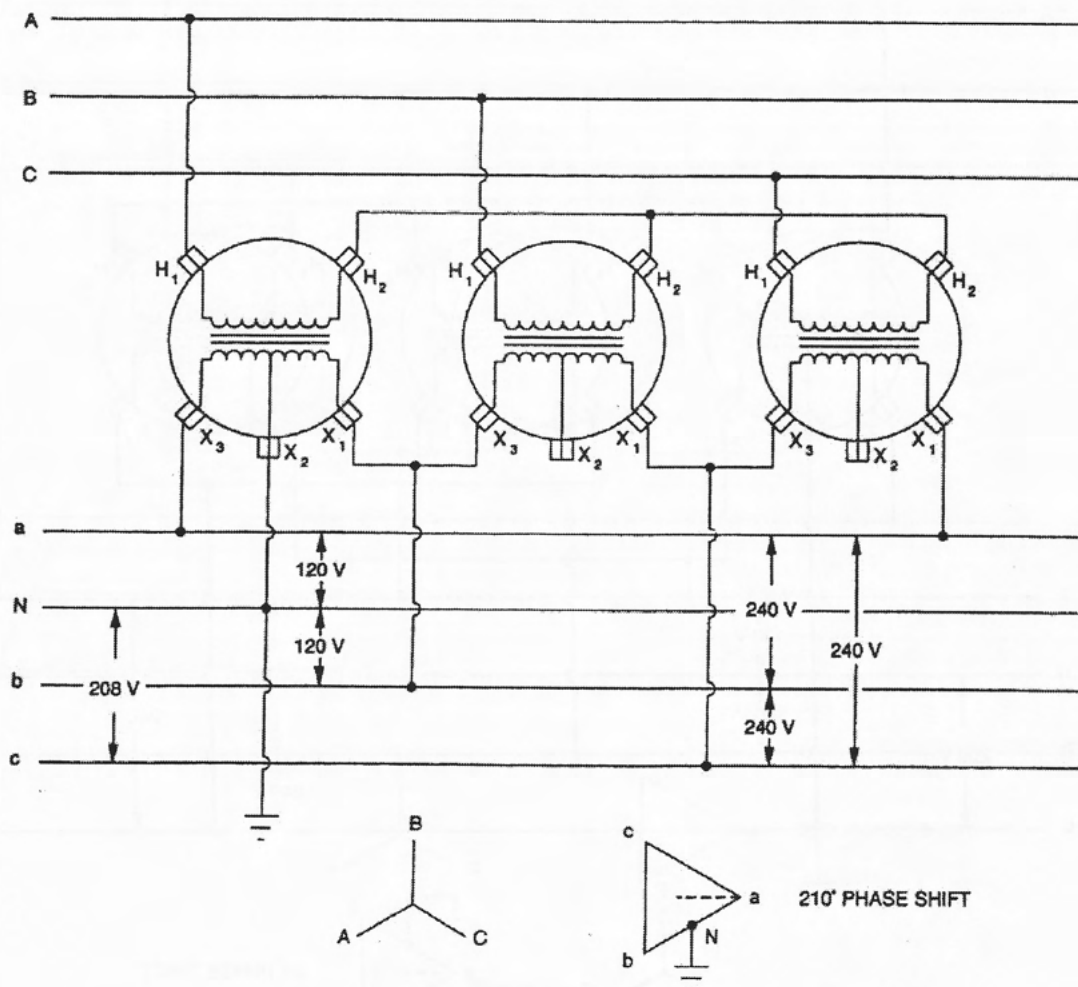


Figure D-12.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Wye-Delta for 240-V Service, 30° Phase Shift, American Standard Connection - Two-Bushing Transformer - Four Wire Grounded-Y Primary

Used to supply three-phase 240-V loads: With a disabled unit, bank can be reconnected in open-wye, open-delta for emergency service. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

The transformers are susceptible to burnouts on primary faults. A transformer may act as a grounding transformer for unbalanced primary conditions, reducing its own capacity for connected load, with a possible burnout. If one phase of the primary supply is opened, the bank automatically becomes open-wye, open-delta and continues to supply the three-phase load, although with reduced capacity. Possible transformer burnout and sympathetic tripping may occur.

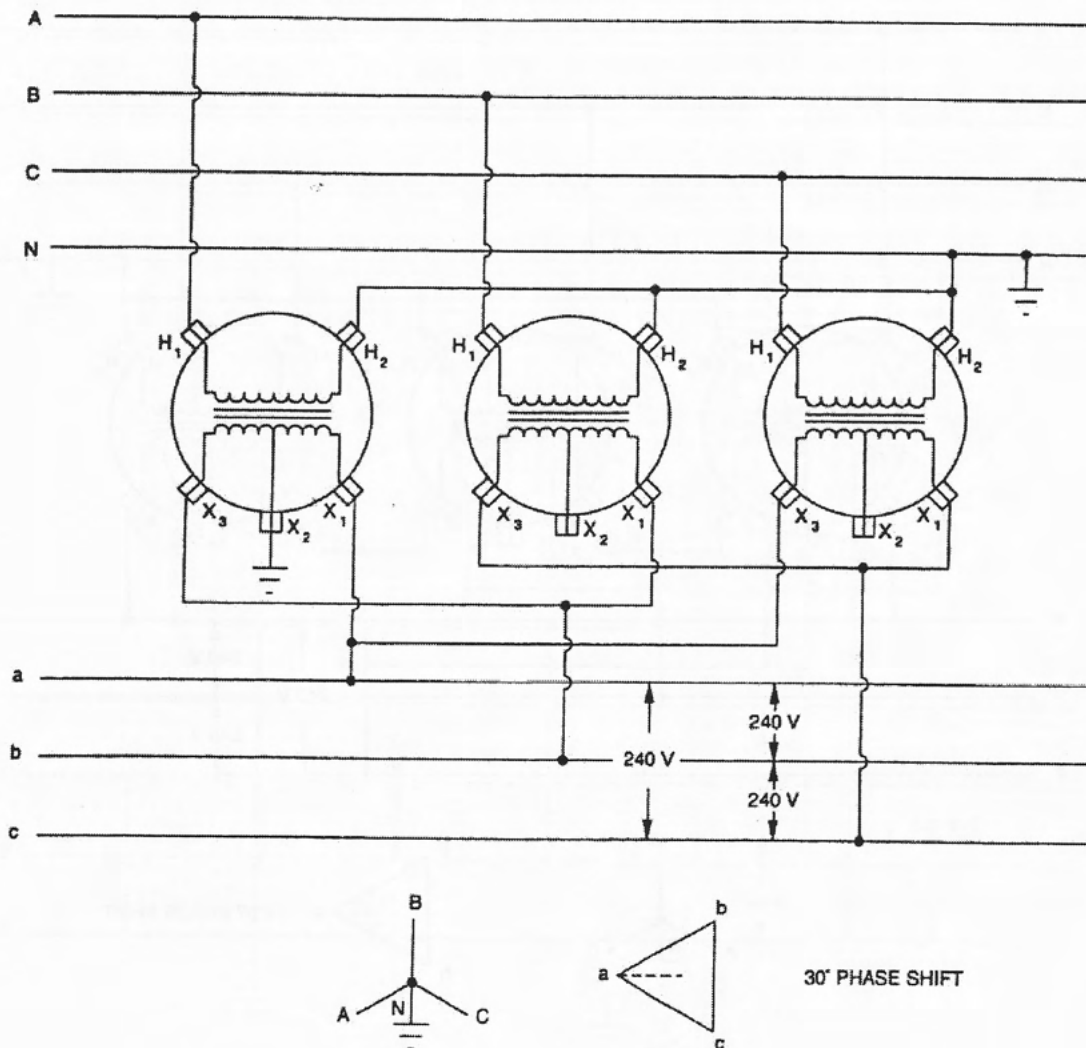


Figure D-13.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Wye-Delta for 240-V Service, 210° Phase Shift, American Standard Connection - Two-Bushing Transformer - Four Wire Grounded-Y Primary

Used to supply three-phase 240-V loads. With a disabled unit, bank can be reconnected in open-wye, open-delta for emergency service. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

The transformers are susceptible to burnouts on primary faults. A transformer may act as a grounding transformer for unbalanced primary conditions, reducing its own capacity for connected load, with a possible burnout. If one phase of the primary supply is opened, the bank automatically becomes open-wye, open-delta and continues to supply the three-phase load, although with reduced capacity. Possible transformer burnout and sympathetic tripping may occur.

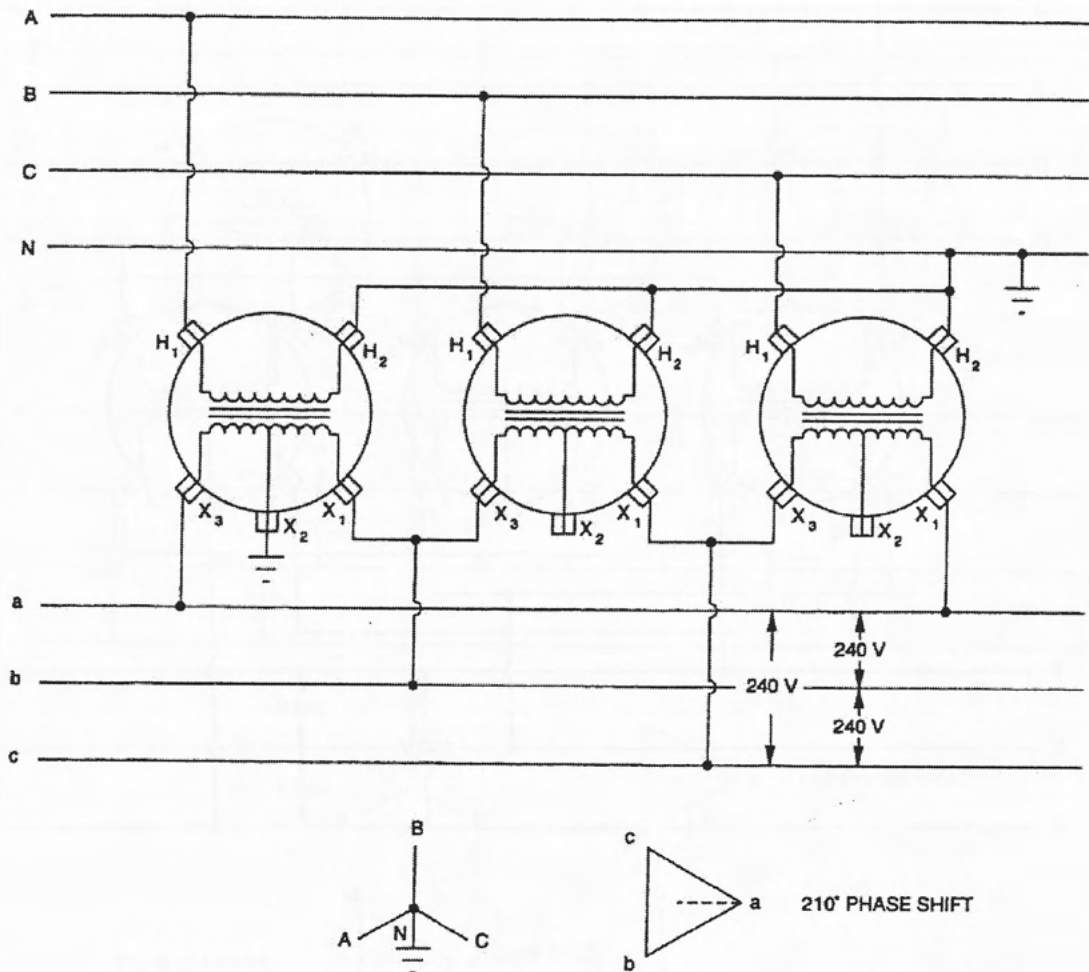


Figure D-14.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Wye-Delta for 120/240-V Service, 30° Phase Shift, American Standard Connection - Two-Bushing Transformers - Four Wire Grounded-Y Primary

Used to supply three-phase 240-V loads with small amounts of 120/240-V single-phase loads. With a disabled unit, bank can be reconnected in open-wye, open-delta for emergency service.

The transformers are susceptible to burnouts on primary faults. A transformer may act as a grounding transformer for unbalanced primary conditions, reducing its own capacity for connected load, with a possible burnout. If one phase of the primary supply is opened, the bank automatically becomes open-wye, open-delta and continues to supply the three-phase load, although with reduced capacity. Possible transformer burnout and sympathetic tripping may occur.

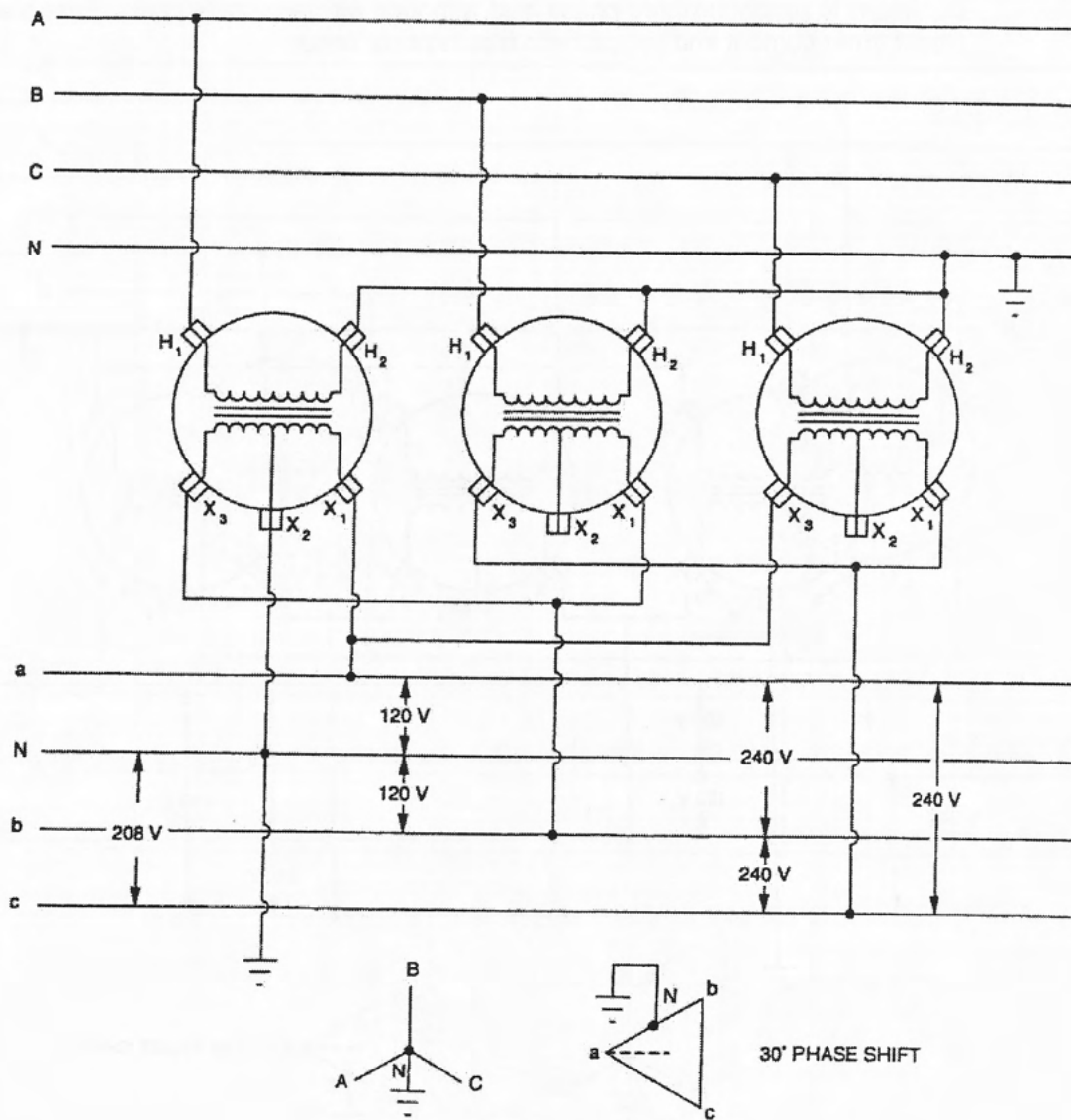


Figure D-15.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Wye-Delta for 120/240-V Service, 210° Phase Shift, American Standard Connection - Two-Bushing Transformers - Four Wire Grounded-Y Primary

Used to supply three-phase 240-V loads with small amounts of 120/240-V single-phase loads. With a disabled unit, bank can be reconnected in open-wye, open-delta for emergency service.

The transformers are susceptible to burnouts on primary faults. A transformer may act as a grounding transformer for unbalanced primary conditions, reducing its own capacity for connected load, with a possible burnout. If one phase of the primary supply is opened, the bank automatically becomes open-wye, open-delta and continues to supply the three-phase load, although with reduced capacity. Possible transformer burnout and sympathetic tripping may occur.

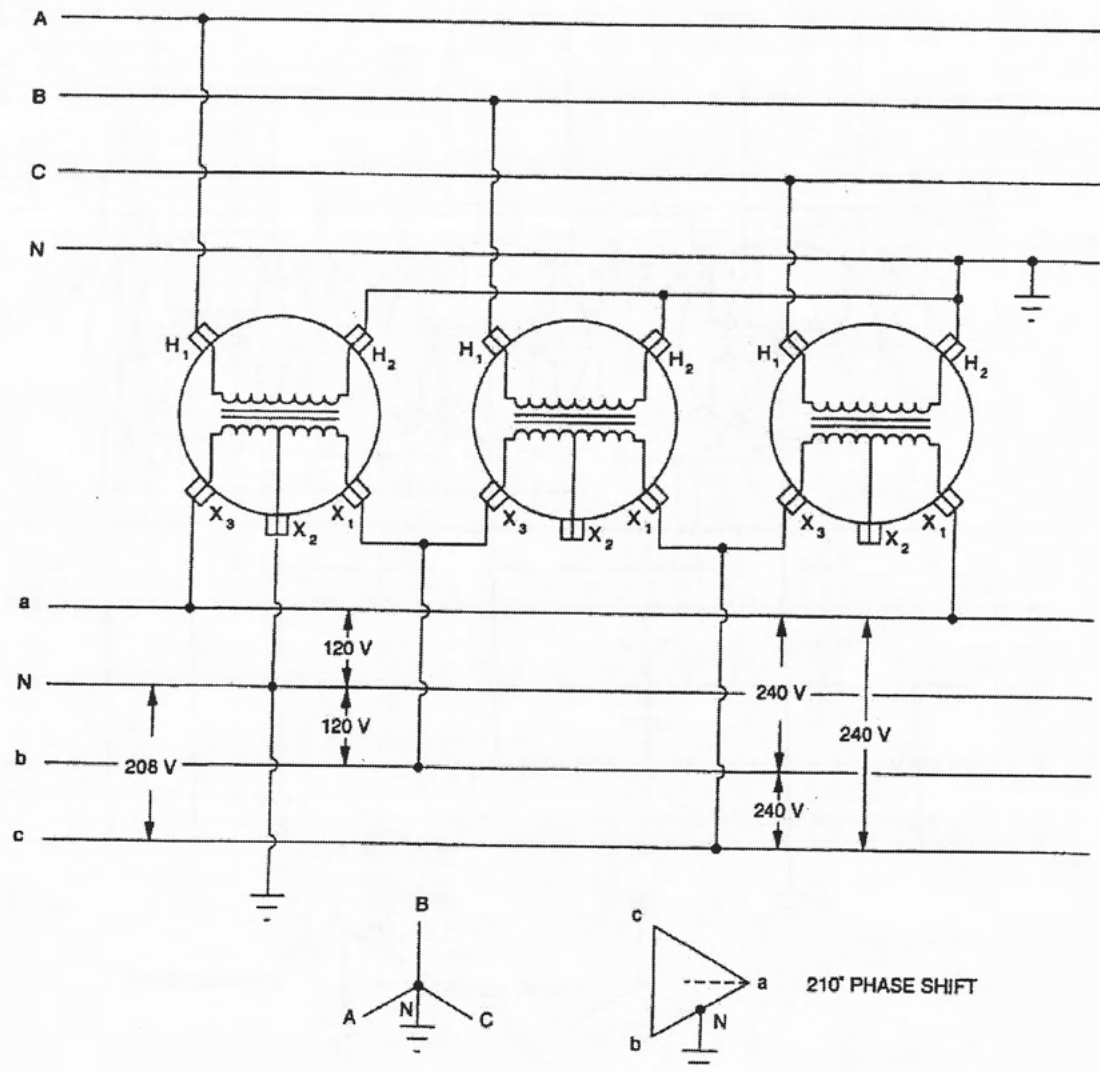


Figure D-16.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Open-Wye Open-Delta for 240-V Service, 30° Phase Shift, American Standard Connection - Two-Bushing or Single-Bushing Transformers - Four Wire Grounded-Y Primary

Used to supply large single-phase 240-V loads with small amounts of three-phase loads. Also used for emergency operation when one unit of a four-wire primary, wye-delta bank is disabled. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

This configuration is relatively inefficient where three-phase loads predominate since it has only 86.6% of the rating of the two units making up the three-phase bank. It has only 57.7% of the three-phase rating of a closed delta-delta bank of three units.

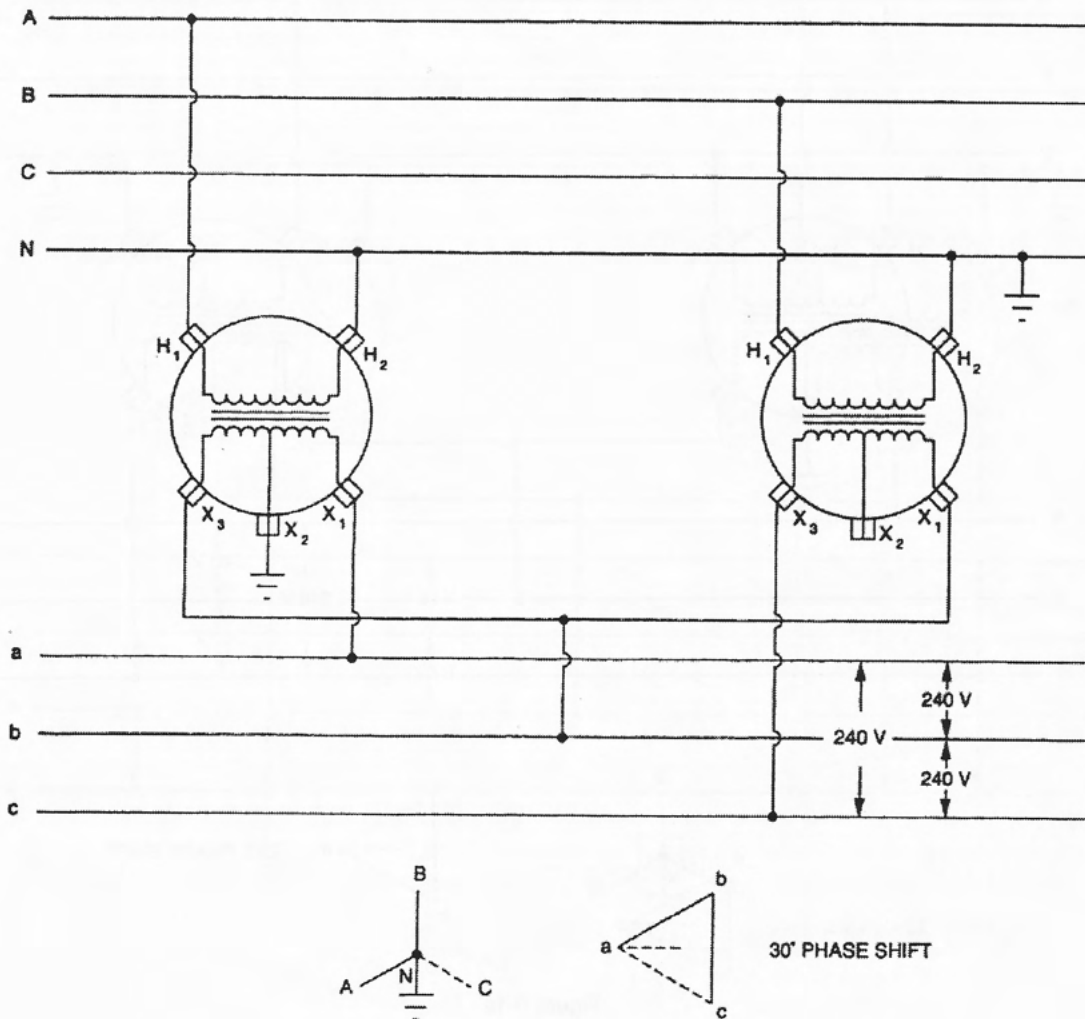


Figure D-17.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Open-Wye Open-Delta for 240-V Service, 210° Phase Shift - Two-Bushing or Single-Bushing Transformers - Four Wire Grounded-Y Primary

Used to supply large single-phase 240-V loads with small amounts of three-phase loads. Also used for emergency operation when one unit of a four-wire primary, wye-delta bank is disabled. If a ground is required, it may be placed on either an X_1 or an X_2 bushing as shown.

This configuration is relatively inefficient where three-phase loads predominate since it has only 86.6% of the rating of the two units making up the three-phase bank. It has only 57.7% of the three-phase rating of a closed delta-delta bank of three units.

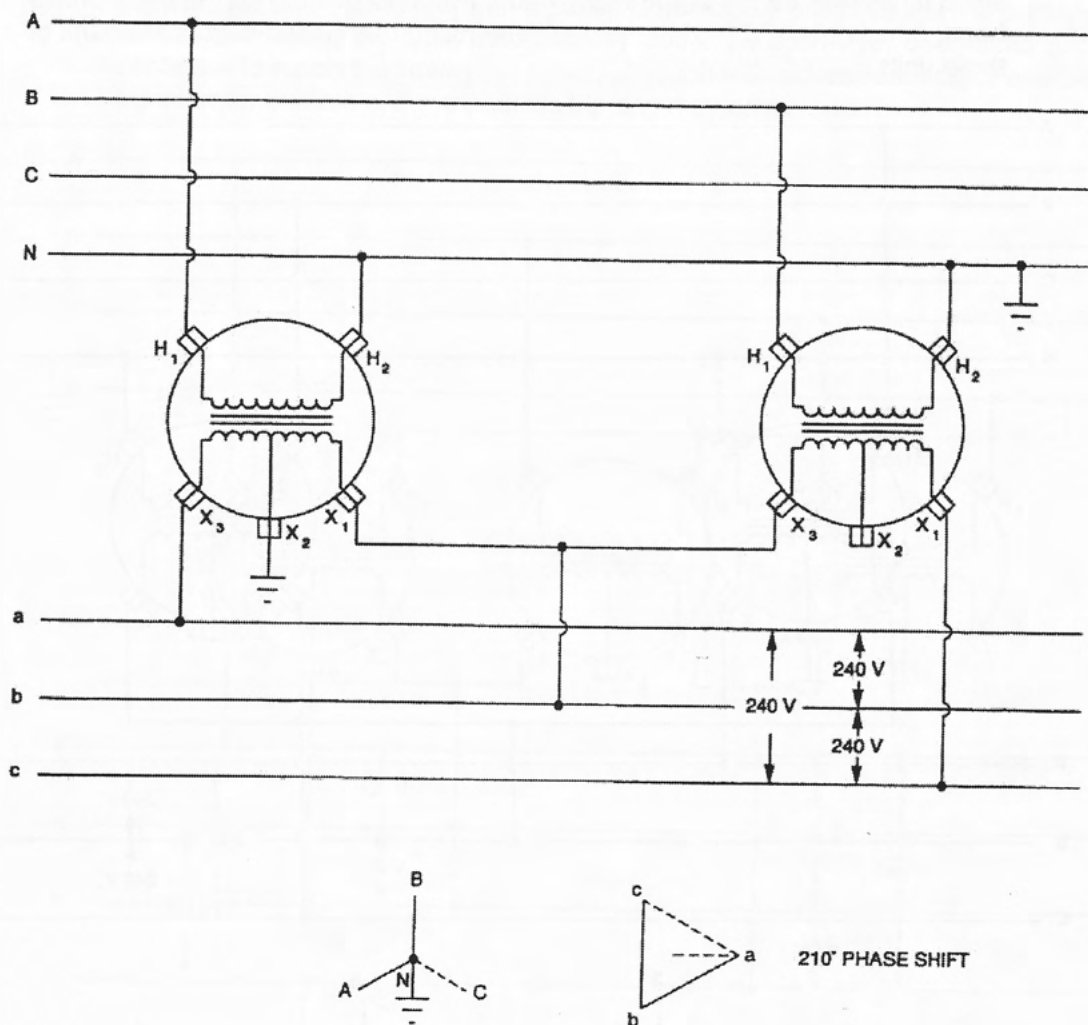


Figure D-18.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Open-Wye Open-Delta for 120/240-V Service, 30° Phase Shift, American Standard Connection - Two-Bushing or Single-Bushing Transformers - Four Wire Grounded-Y Primary

Used to supply large single-phase 240-V and 120/240-V loads with small amounts of three-phase loads. Also used for emergency operation when one unit of a four-wire primary wye-delta bank is disabled.

This configuration is relatively inefficient where three-phase loads predominate since it has only 86.6% of the rating of the two units making up the three-phase bank. It has only 57.7% of the three-phase rating of a closed delta-delta bank of three units.

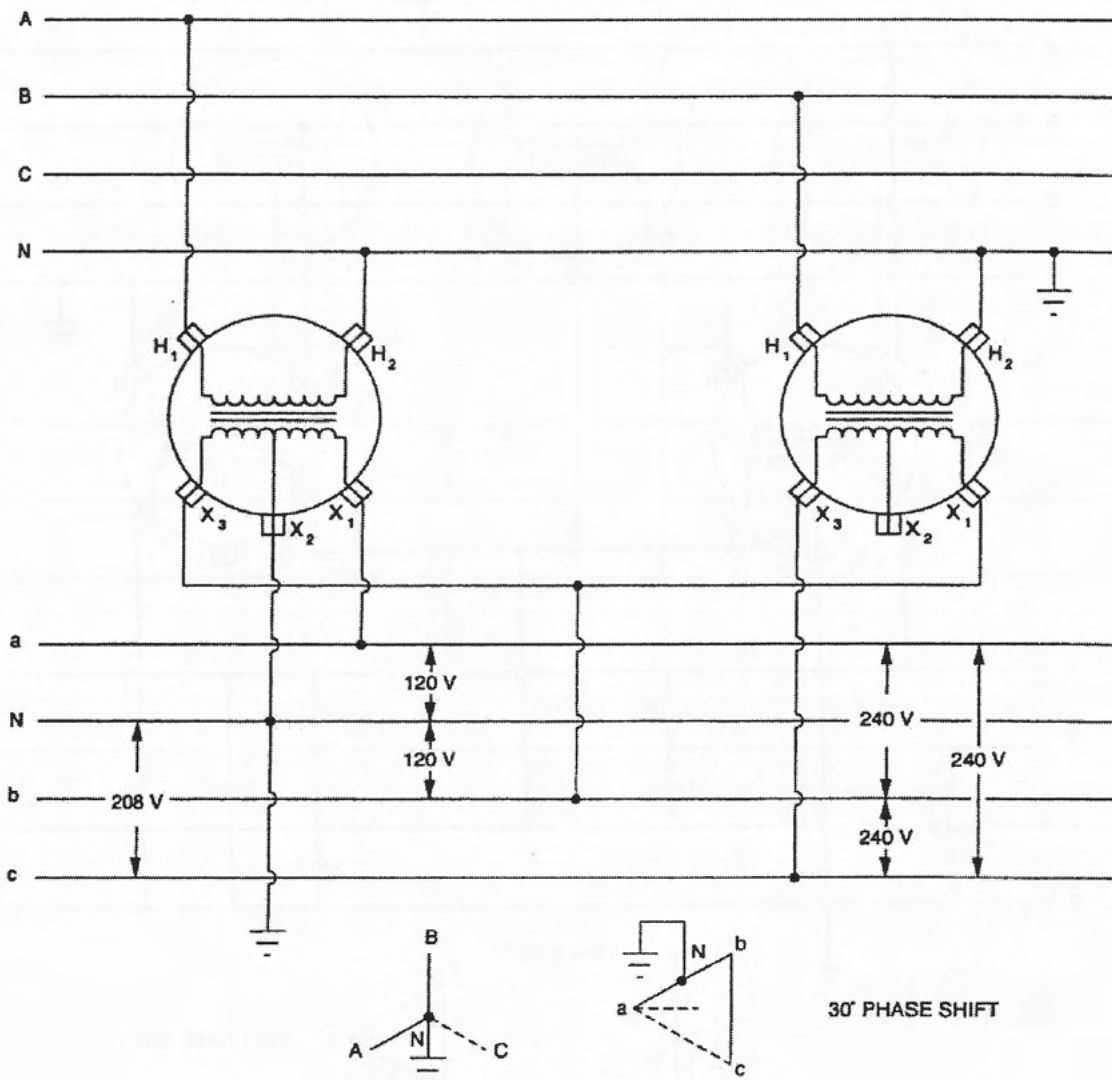


Figure D-19.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Open-Wye Open-Delta for 120/240-V Service, 210° Phase Shift - Two-Bushing or Single-Bushing Transformers - Four Wire Grounded-Y Primary

Used to supply large single-phase 240-V and 120/240-V loads with small amounts of three-phase loads. Also used for emergency operation when one unit of a four-wire primary wye-delta bank is disabled.

This configuration is relatively inefficient where three-phase loads predominate since it has only 86.6% of the rating of the two units making up the three-phase bank. It has only 57.7% of the three-phase rating of a closed delta-delta bank of three units.

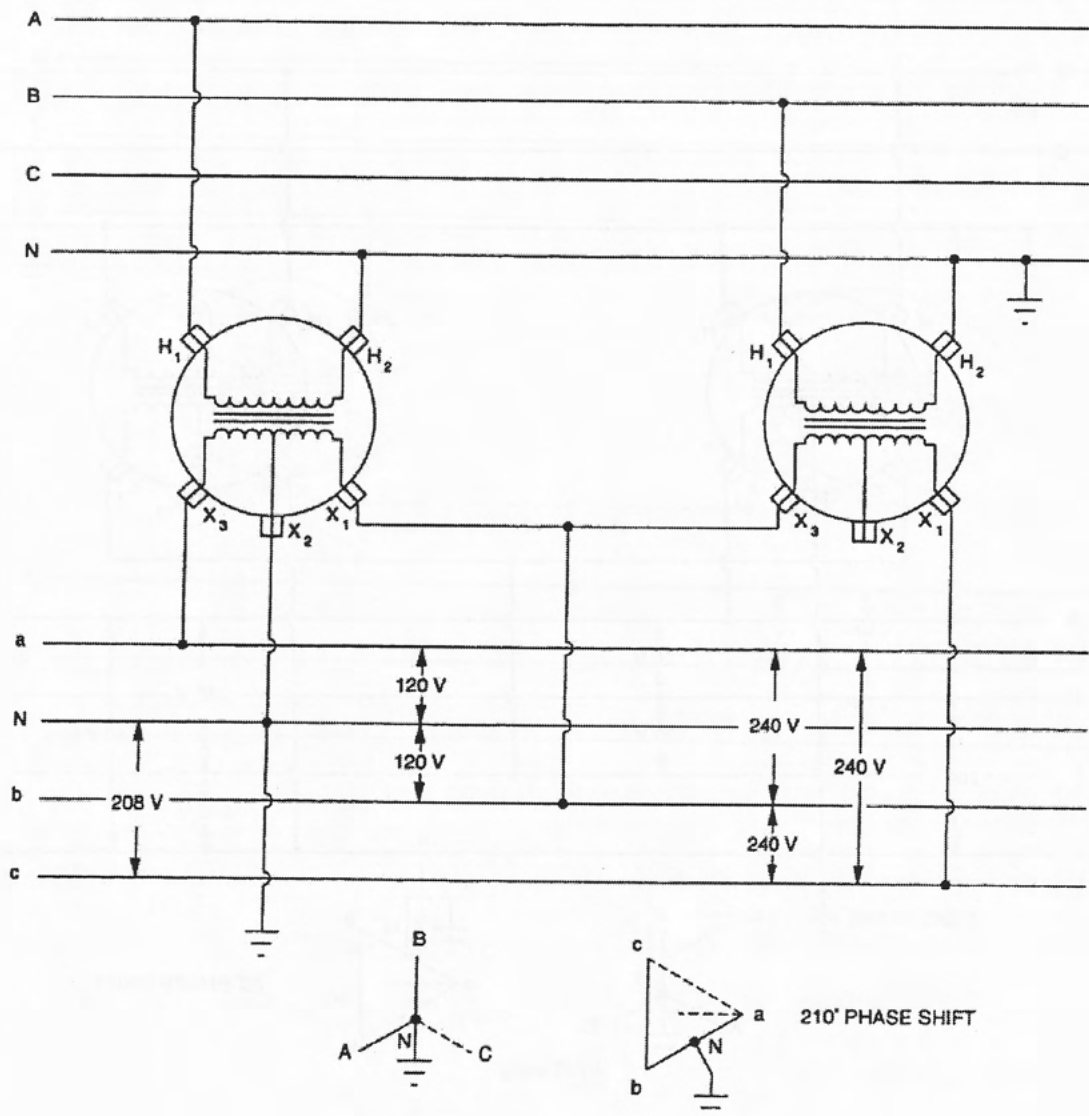


Figure D-20.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Delta-Wye for 120/208-V Service, 30° Phase Shift, American Standard Connection - Two-Bushing Transformers - Three-Wire Delta Primary

Used to supply 208 V and 120 V on systems where both can be taken from all three phases. This configuration permits balancing single-phase loads among the three phases.

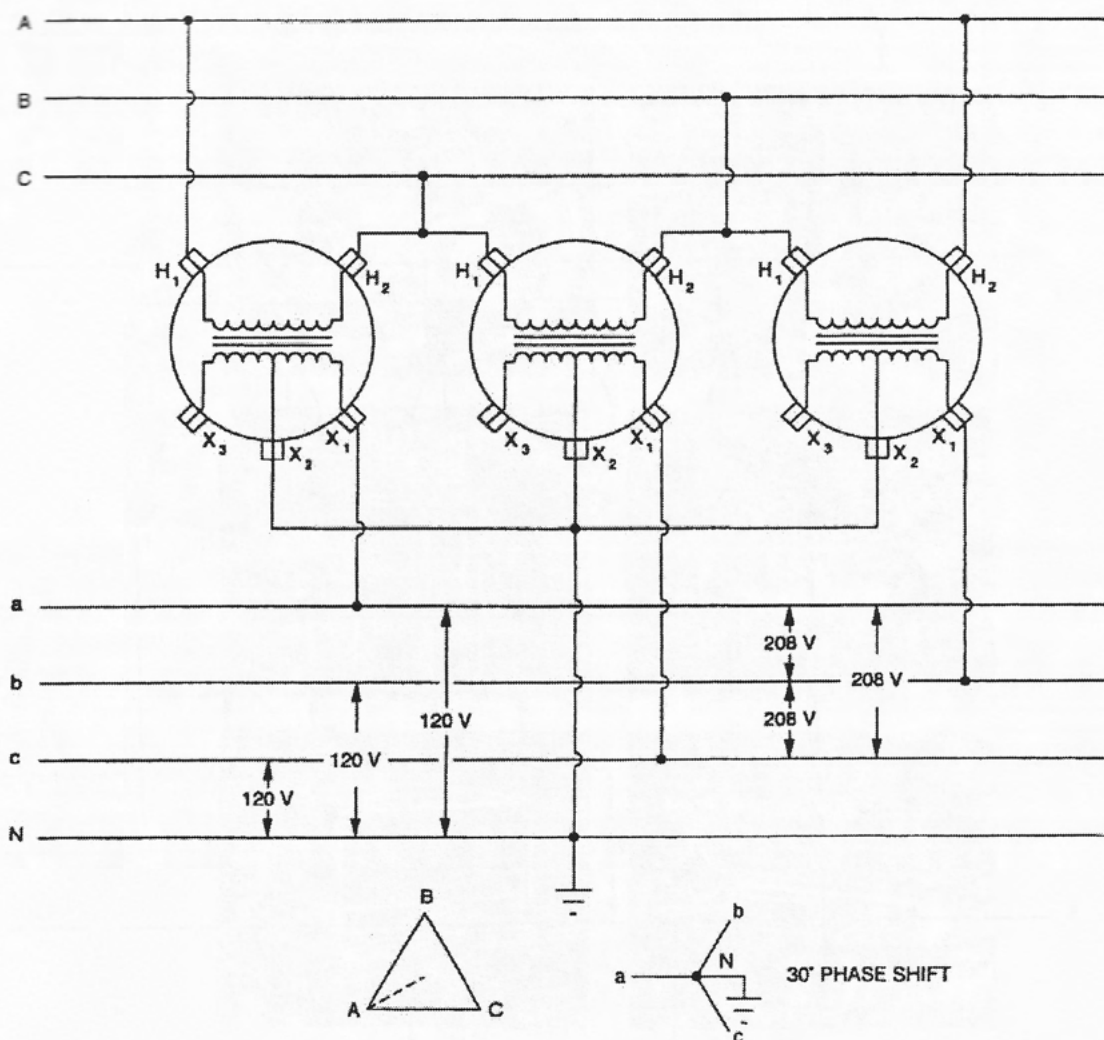


Figure D-21.

Three-Phase Banking of Single-Phase Transformer

Three-Phase Wye-Wye for 120/208-V Service, 0° Phase Shift, American Standard Connection - Two-Bushing or Single-Bushing Transformers - Four-Wire Grounded-Y Primary

Used to supply 208 V and 120 V on systems where both can be taken from all three phases. This configuration permits balancing single-phase loads among the three phases.

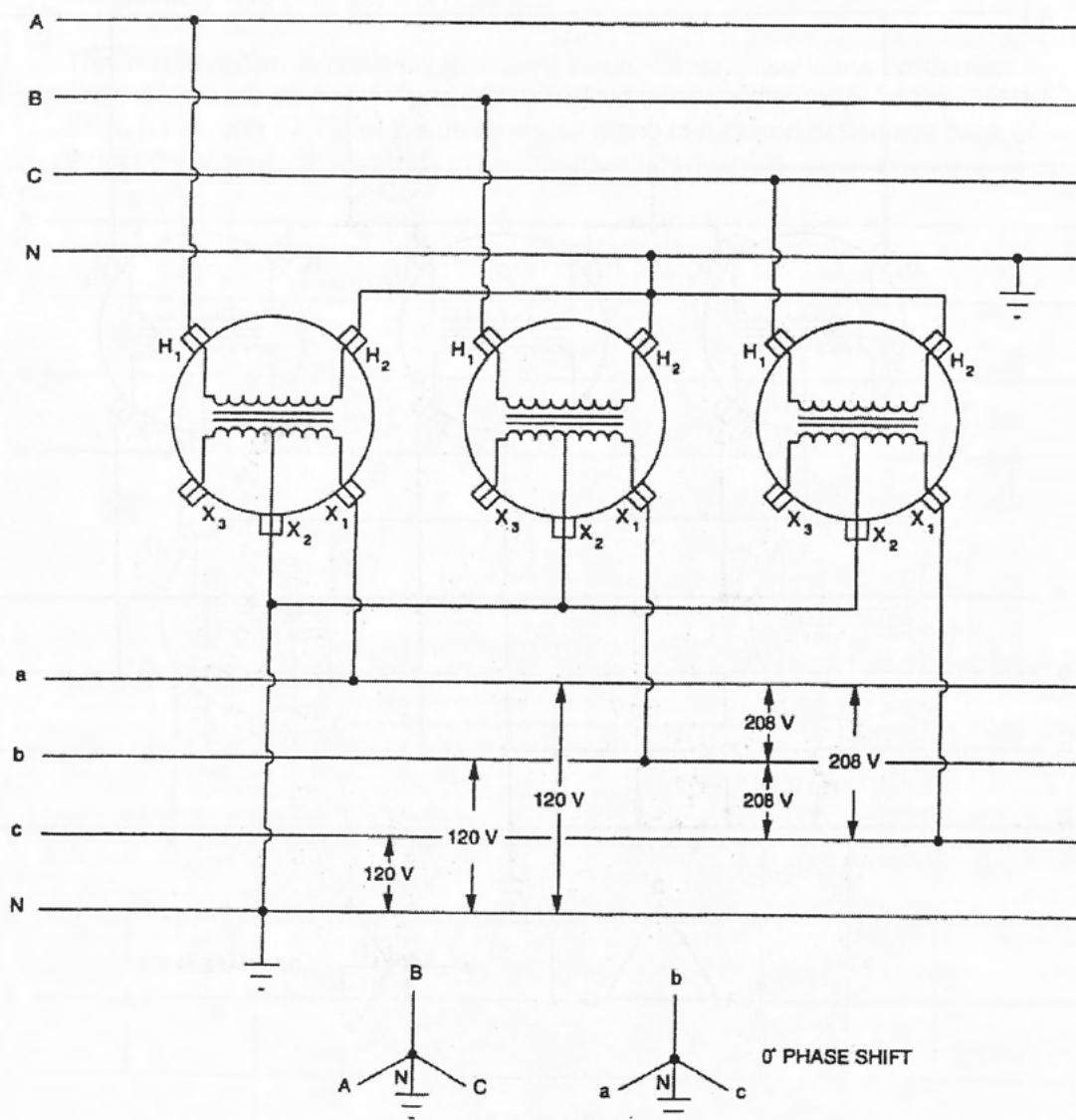


Figure D-22.