CATERPILLAR®

ENGINE DATA SHEET

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Date 5-88

Caterpillar Zero Droop Voltage for Parallel Operation

Scope

This engine data sheet provides detailed technical guidance for installing and adjusting the Caterpillar automatic voltage regulators (AVRs) to operate various Cat Generators with zero droop voltage in parallel operation.

General Introduction

For parallel operation, there are two fundamentally different reactive power equalization methods — individual open-loop compensation (which is the standard method on Caterpillar Generators) and a feedback method called differential compensation.

The individual compensation method, also known as reactive droop correction, is described in the Operation and Maintenance Manual, SEBU5717-02, so it will not be considered further here.

In the differential compensation method, also known as crosscurrent compensation, the regulator is biased by the difference in reactive current outputs of the paralleled generators. When reactive current is shared equally, there is no biasing effect and a flat voltage characteristic is obtained. The biasing exists only during transient periods when unequal or unproportional reactive load sharing exists.

The Caterpillar automatic voltage regulator can be wired for zero droop voltage, no load to full load, and maintain volts-per-Hertz regulation to prevent engine stall due to heavy block loads. To make this feature more attractive, zero droop voltage control is possible with Cat Generators paralleled with Cat Generators of same or different sizes and competitive generators of same and different sizes. Crosscurrent compensation makes this possible. Any type of droop or isochronous governor can be used.

The combination of zero droop voltage control and volts-per-Hertz regulation makes Cat Generator Sets extremely versatile when selecting parallel power for any installation. Output voltage is unchanged after loads have been applied or rejected and generators have again reached steady-state operation. This is the advantage to zero droop. Voltage at any point in time during steady load operations of units in parallel is unchanged — regardless of the load. Regulators operating with voltage droop, on the other hand, allow system voltage to change with addition and subtraction of load after steady-state conditions are reached.

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LEKX8142
Supersedes LEKX7086

Standard Cat SR4s, SRCRs, and VR3s use 5%. adjustable droop. Zero droop voltage control with volts-per-Hertz regulation is illustrated below.

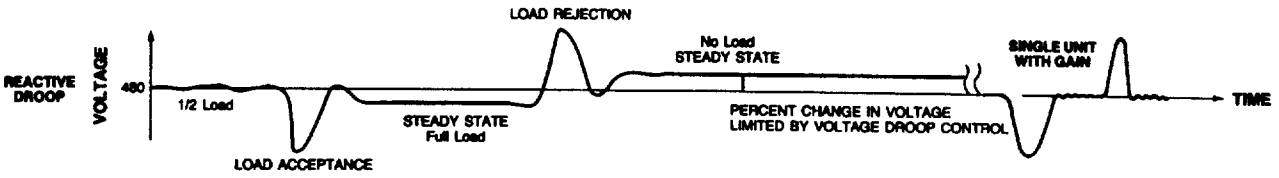


Figure 1

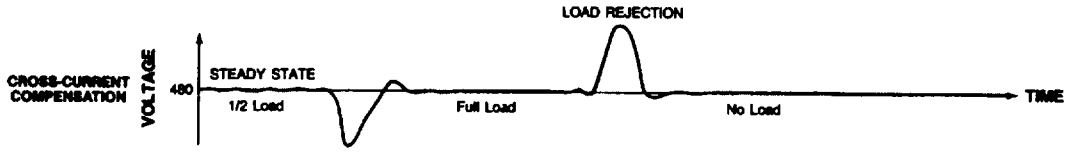


Figure 2

Important: *Treat VR3 se/f-excited or permanent magnet similar to the singlephase, half-wave excitation (A1-/A2-type AVR). See Figure 3.*

Crosscurrent Compensation

Basic Principles:

Each generator's current is measured with a current transformer (CT) in one line, usually T2. When paralleling, all CTs must be in the same line of each generator. Also, all CTs must be correctly polarized such that all the secondaries connections are series additive. See Figure 3.

If the generators are of different sizes, the CT ratios should be proportional to their ratings such that for rated output the secondary currents are equal. For example, see Table 1:

Rated kW	Rated pf	Volts	Rated Amp	C.T. Ratio	Secondary Current at Rated Load
100	0.8	480	150	150:5	5.0 Amps
200	0.8	480	300	300:5	5.0 Amps
50	0.8	480	75	75:5	5.0 Amps

Table 1

Note: *CTs supplied with Caterpillar Generators have 0.25 amp secondary and are already matched to the generator ratings.*

Each CT has a droop variable resistor (droop rheostat) across its output. The voltage developed across this resistor is sensed by the regulator to provide a signal to reduce or increase the field excitation. All rheostats (potentiometers) must have the same Ohmic value. When one generator is run individually, the voltage developed across the potentiometer will cause the generator output voltage to *droop* as the lagging reactive current is increased.

When the reactive compensation circuits of two or more generators are connected together in a series mode, if the currents in the two generators are equal (or proportionally equal) and in phase, then the CT secondary currents will be equal and in phase and there will be no differential current flow in the potentiometer. Thus there will be no voltage drop across those resistors and no droop in generator output voltage will result.

If the generator currents become unbalanced, the CT secondary currents will no longer be the same. in the generator with the higher current, this will result in a forward voltage across its droop potentiometer which will reduce the excitation. The other generator regulator will see a reverse voltage which will increase its excitation. This action will cause the currents to return to a balanced state.

Important Notes and Procedures on Adjustments for Crosscurrent Compensation

1. kW load sharing is a function of the engine governor only. Adjust governor setting for proper kW balance before attempting to adjust reactive KVAR unbalance.
2. For parallel operation, the following adjustments must be made following crosscurrent compensation wiring between the voltage regulators and crosscurrent transformers.
   - Turn the gain potentiometer to the full CCW position.
   - Turn the droop potentiometer to the full CCW position.

- On each generator, adjust the voltage level potentiometer to the rated no load voltage.
- Apply full rated load with 0.8 pf to the individual generator.
- Adjust the gain potentiometer to compensate for voltage drop due to governor speed droop at rated load, if the governor is not an isochronous governor.
- Adjust the droop potentiometer to obtain 5% droop when operating as a single unit at full load 0.8 pf.
- Remove the load.
- Parallel the generators at no load and adjust for minimum circulating current, if any, using the voltage level potentiometer.
- Apply full rated resistive and reactive loads.
- Adjust to minimum circulating current using the droop potentiometer.

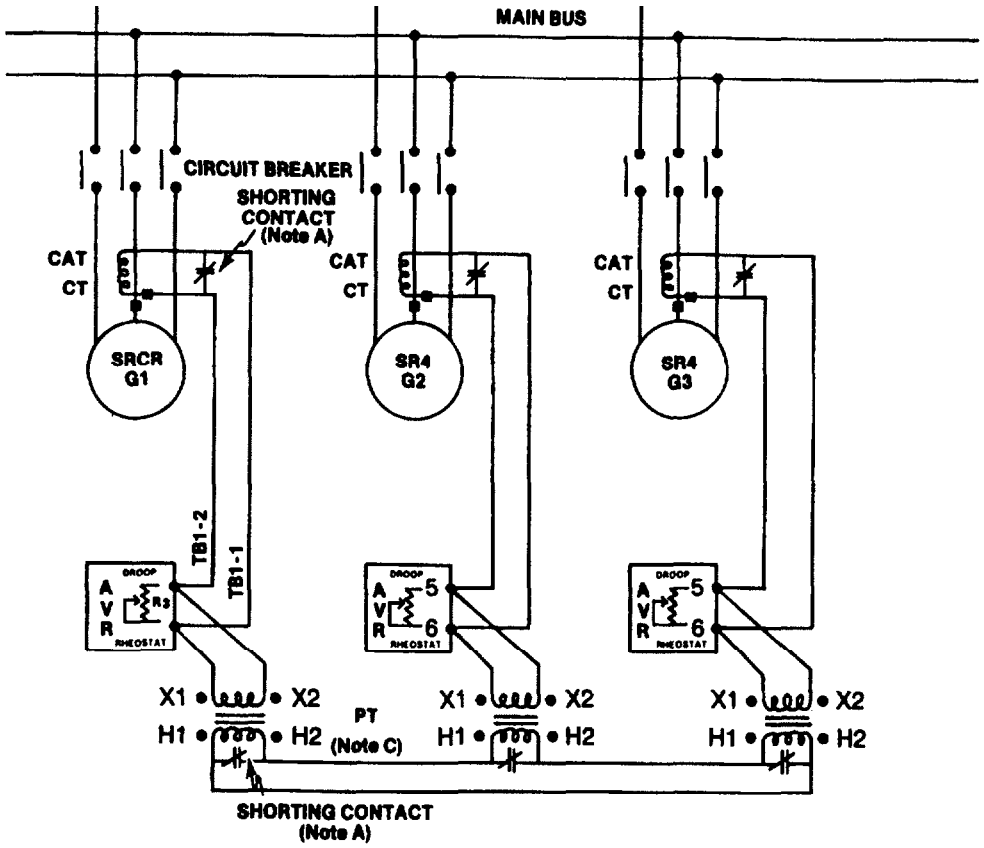


Figure 3

Paralleling two or more Cat Generators with a minimum of one SRCR generator or a generator equipped with single-phase, half-wave regulators (A1-A2-type or VR3). Isolation transformers required for each generator. (See Table 2 for potential transformer selection.)

Note A: *The shorting contact for the current* transformers *(CTs) is to be open only when corresponding main line circuit breaker is closed. A slave relay may be used for shorting contact, piloted by a main line circuit breaker auxiliary contact. The shorting contacts for the potential transformers is a "nice to have" rather than a "must to have".*

Note B: *On single-phase, half-wave regulators (tan A1I A2 AVRs) built before May 1984, the "droop" resistor is connected as a rheostat (see Figure 6). On May 1984 and later regulators (black A1/A2 AVRs), this resistor is connected as a potentiometer. (See Figure 7)*

Note C: *If only two generators are in system, two transformers as described in Table 1 are needed or only one 1:1 ratio/10 VA transformer is sufficient. The winding resistance must not exceed 0.25 Ohm at both primary and secondary.*

When using similar regulators, the proceeding instructions will provide correct operation.

With a combination of pre- and post- May 1984 regulators (tan and black Als) or a combination of new Cat and competitive regulators, the newer models (black A1/A2) should be modified to make them electrically similar to the earlier models by adding a link from the center to the clockwise end of the droop potentiometer. (See Figure 8)

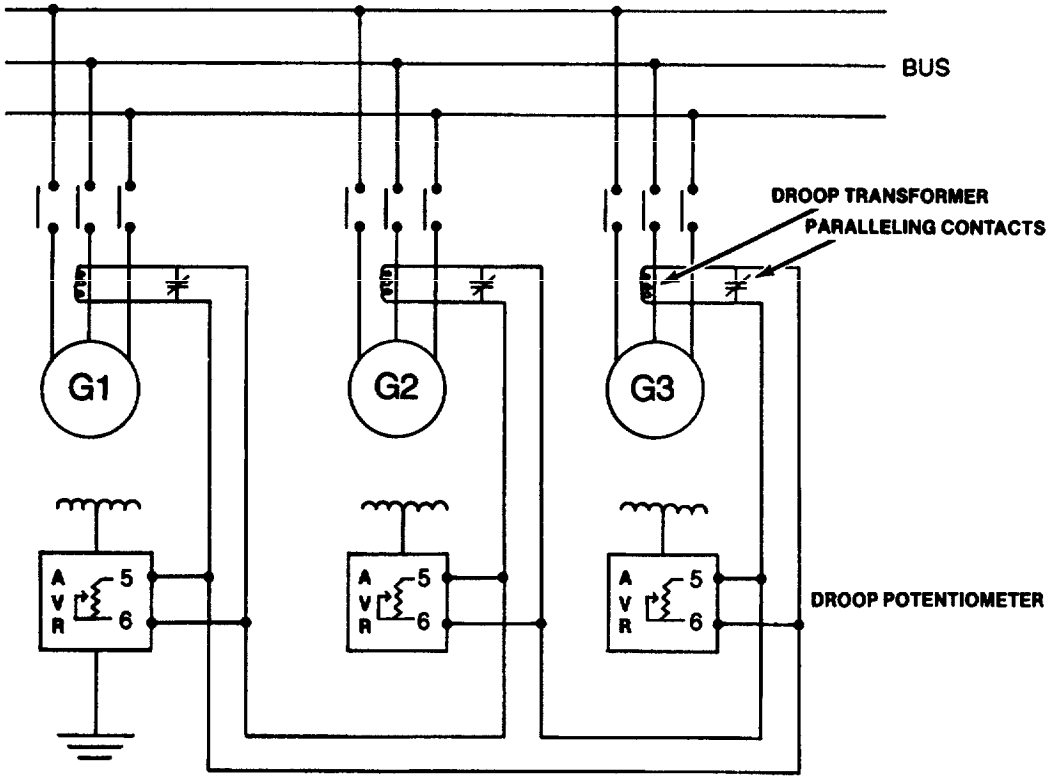


Figure 4

Two or more generators with 3-phase full wave regulators (multi-card only, not VR3) have no isolation transformer requirement. Only one regulator is grounded to minimize circulating currents.

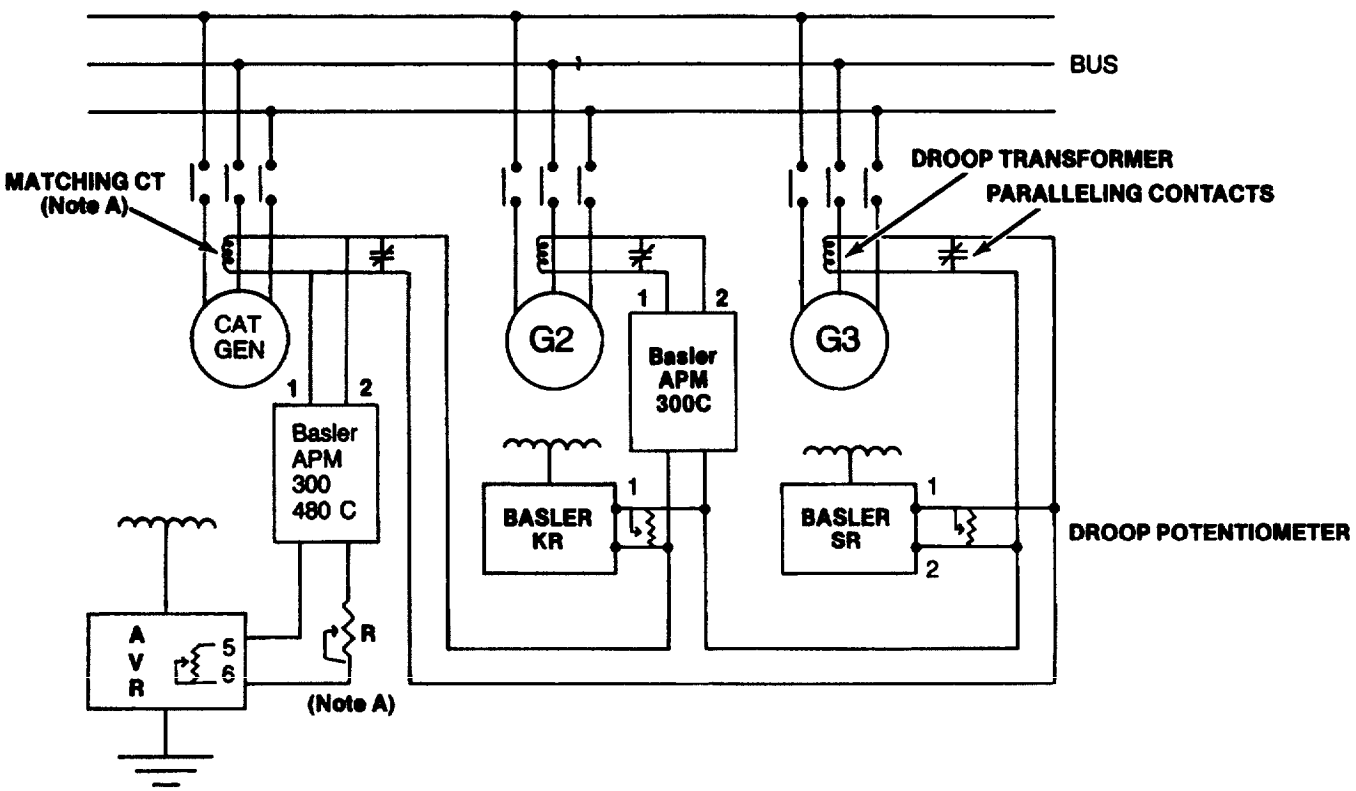
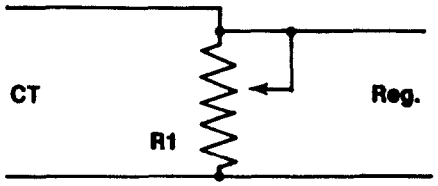


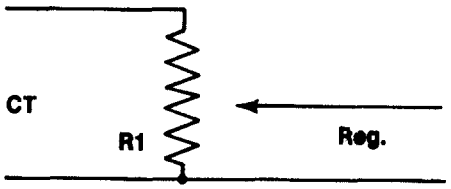
Figure 5

Note A: *When using the APM 300, the Cat CT must be replaced by a 5 amps secondary CT. The resistor R (25 Ohms, 10 W) will be set to approximately 16 Ohms.*



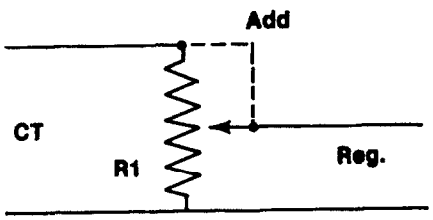
PRE-MAY 1984
(RHEOSTAT CONNECTION)

Figure 6



POST-MAY 1984
(POTENTIOMETER TYPE CONNECTION)

Figure 7



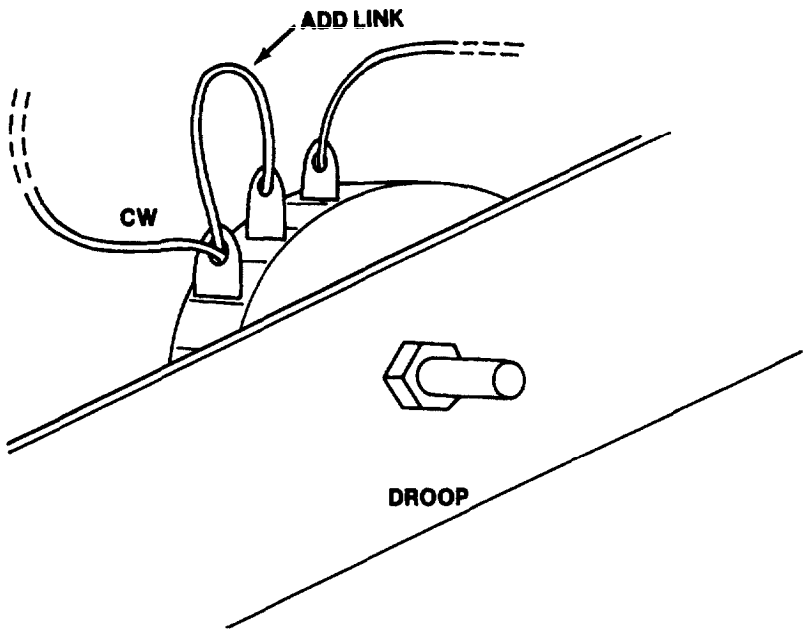
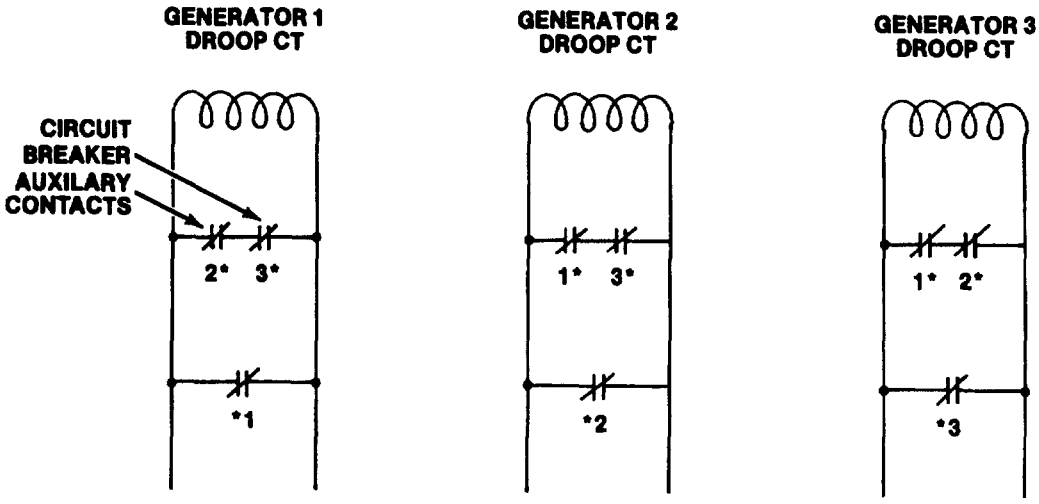


Figure 8

Paralleling Multiple Generators (Under the Standard Method [Open Loop] on Caterpillar Generators) With Automatic Shofting Contacts

When paralleling several generators with the Caterpillar *standard reactive droop control,* the voltage of the first generator on the line will drop due to the reactive load. The second unit on the line will now be at a much higher voltage and may not parallel, depending on how the switchgear is set up.

Shown in Figure 9 is a scheme that provides zero droop when multiple units are paralleled in an automatic droop control. When generator No. 1 is in single unit operation, its droop CT is shorted by the other generators (Nos. 2 and 3) off the line, the same time its own droop shorting contact is open. Contacts 1 in parallel with Series 2 and 3 across CT No. 1 are not needed. They only add safety.



***Normally closed contacts open** when corresponding generator circuit breaker is closed,

Figure 9

Transformers From Newark Catalog No. 106

594	05F509	P8657	117	12.0	2.0	1.3	$7.43	Stancor
594	01F120	P8130	117	12.6 ct	2.0	1.4	8.09	Stancor
600	05F1379	F.44X	115	12.6 ct	2.0	1.25	8.84	Triad-Utrad
604	81N5372	R1900	117	12.0	2.0	1.3	7.43	Criterion
604	81N5374	R1525	117	12.6 ct	2.0	1.1	8.09	Criterion

Table 2: Transformer selection for Figure 3 only (see Note C for Figure 3).

Note: ct = Center Tap — Do Not Use — Tape Loose End

Ž Transformers must be identical, i.e., same stock number.

• Transformers must be polarized, i.e., both primary and secondary must be connected for same polarity. If transformer has polarity markings, use these markings. If not polarity marked, determine polarity by attached procedure.

Transformer Polarity Verification

1. Select a transformer and call it Trans #l.
2. Identify the primary winding (115 V).
3. Arbitrarily select one of the primary winding leads and mark it H1. Mark the other primary winding lead H2.
4. Arbitrarily select one of the secondary winding leads and mark it Xl. Mark the other secondary winding lead X2. If the secondary winding has a center tap, do not use; but tape end of wire for insulation.
5. Connections for polarity test.
6. Preliminary test of transformers:
   a. Apply 115 V AC across H; and H2 (see Figure 10). Measure this applied voltage.
   b. Measure voltage of Trans #1 from Xl to X2. This will be approximately 12 V AC.
   c. Measure voltage from H2 to Xl. If polarity is marked correctly, the measured voltage is equal to the sum of the H1 to H2 voltage (Step 6a.) and the Xl and X2 voltage (Step 6b). If measured voltage is equal to the difference of the two voltages, the polarity marking is incorrect. To correct marking, reverse Xl and X2 marking and reconnect wire from H1 to X2 and retest to verify that the voltage adds.
   d. Trans #1 now has correct polarity markings.
7. Select a second transformer and call it Trans #2. Be sure Trans #1 and Trans #2 have the same stock number.
8. For Trans #2, repeat Steps 2,3, and 4.
9. Connections for polarity test of Trans #1 and #2:
   a. Connect the H1 leads together and then connect the H2 leads together (see Figure 11).
   b. Connect the X2 lead of Trans #1 to the Xl lead of Trans #2 (see Figure 11).
10. Preliminary test of transformers:
   a. Apply 115 V AC across H1 and H2 (see Figure 11).
   b. Measure voltage of Trans #2 from Xl to X2. This will be approximately 12 V AC.
   c. If both transformers have the same secondary voltage, 12 V AC, proceed to Step 11. If transformers are different, need to obtain same type of transformer.
11. Polarity test of transformers:
   a. Repeat Step 10, Line a.
   b. Measure voltage from Trans #1, Xl to Trans #2, X2. If measured voltage is O V AC, then transformers have incorrect polarity marking. If measures 24 V AC, the polarity is correct.
   c. If polarity marking is correct, install transformers. If polarity marking is incorrect on Trans #2, reverse Xl and X2 lead markings. Reconnect Trans #2 to agree with connection diagram. Retest. If voltage measures 24 V AC, then polarity is correct and transformer may be installed.
12. If another transformer is required, repeat Steps 7 through 11.

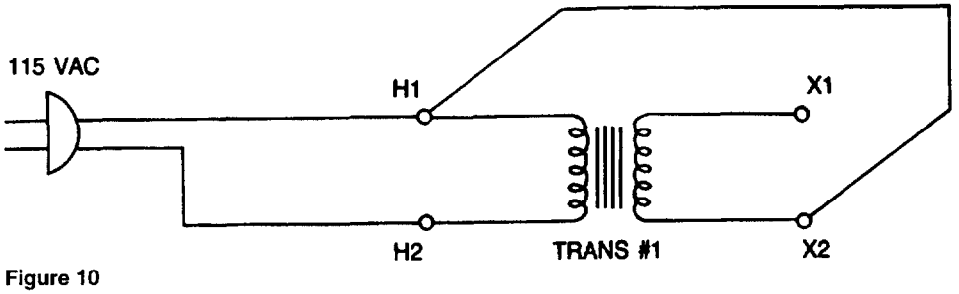


Figure 10

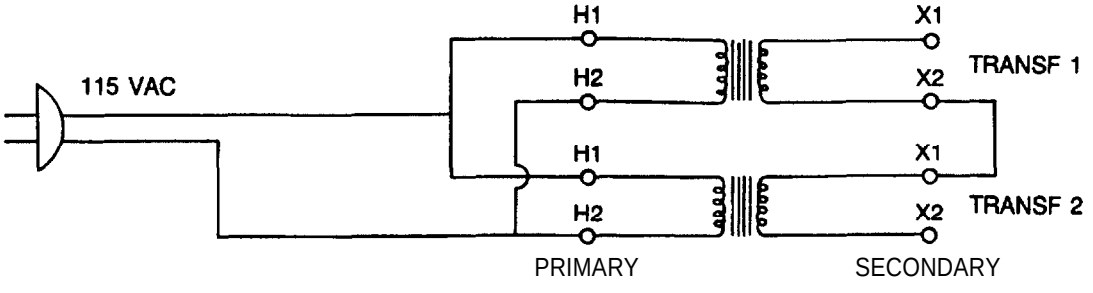


Figure 11