Type XT7-C
Electronic Automatic Synchronizer

Westinghouse Electric Corporation

Switchgear Division, East Pittsburgh, Pa.
I.B. 56-451-1 Effective January, 1964; Supersedes I.B. 56-450-1

Table of Contents

List of Illustrations

Reference Drawings

TYPE	STYLE	FREQUENCY	SCHEM. DIAG.	CONN. DIAG.
XT7-C	1810200-C (Flush Mtg.)	60	585C929	585C934
XT7-C	406D330G06 (Flush Mtg.)	50	585C929	585C934
Projection Mtg. Accessories	Add 1810201 to above styles	-	-	-

I. Purpose & Application

The XT7-C Automatic Synchronizer is used to close the connection between two power sources of slightly different frequency at a time when they are exactly in synchronism. The synchronizer is designed to energize the closing circuit of the connecting circuit breaker at a constant time before the point of synchronism is reached. This time is set equal to the breaker closing time. The synchronizer also limits the maximum phase angle before the point of synchronism at which the breaker closing circuit may be energized. Calibrated controls permit time settings adjustable between 0.1 and 0.8 seconds and maximum phase angle settings between 0 and 40 degrees before synchronism.

The above style synchronizers can be applied to one or more breakers, providing the breakers have identical closing times. For multiple breaker applications, whose closing times are unequal, refer to style 406D330G07 (not part of this book).

II. Description

The Type XT7-C Automatic Synchronizer is mounted in a relay case as shown in Figures 8 and 9. This case is suitable for either flush or projection mounting.

The intelligence for the synchronizer is taken from single phase, 120 volt secondaries of potential transformers connected to corresponding phases on each side of the breaker to be synchronized. Also an auxiliary, single phase, 120 volt, 60 cps source is required for power. The bus potential transformer may be used for this if desired.

The intelligence is used to obtain two voltage quantities as will be described in later paragraphs. One is a voltage proportional to the angular difference between the potentials on each side of the breaker. The other is the sum of voltage proportional to the angular difference between the potentials on each side of the breaker and a voltage proportional to the frequency difference between the potentials on each side of the breaker. The circuit to obtain these quantities is as follows:

Terminals XB-YB of transformer T3 are connected to the potential transformer on the bus side of the breaker to be synchronized and terminals XL-YL of transformer T2 are connected to the potential transformer on the line to generator side of the breaker to be synchronized. Refer to Figures 3 and 4. The secondaries of T2 and T3 are connected to give a dark lamp beat voltage across the full wave bridge rectifiers X1, X2, and X3. The wave form of the a.c. voltage across each of these rectifiers is shown in Figure 1a. The d.c. output voltage of these rectifiers is filtered by capacitors C4 and C6 and has a wave form as shown in Figure 1b. The magnitude of these d.c. voltages is at all times proportional to the sine of half the phase angle difference between the input voltages XB-YB and XL-YL. When the two input voltages are less than 40° out of phase, the d.c. output of these rectifiers is proportional to half the phase angle difference between the input voltages, since for angles less than 20°, the sine of an angle nearly equals the angle in radians.

Refer to Figure 3. The grid voltage of tube No. 3 is made up of the sum of the voltages across P1, R2, P2 and R6 and is applied through grid current limiting resistor R5. Relay 25A is connected in the plate circuit of tube No. 3. P1 is set so that the negative bias on the grid of tube No. 3 allows just enough current to flow in the plate circuit to cause relay 25A to pick up when there is no voltage across P2 and R6. Refer to Figure 2a. The voltage across R6 is always in a direction to apply a negative voltage to the grid of tube No. 3 and is constantly changing in such a way, that it is getting less negative as the phase angle decreases. The voltage across P2 is in a direction to apply a positive voltage to the grid of tube No. 3 and is constant. When these two voltages are equal, relay 25A picks up, since the two voltages cancel out to zero and only the voltage across P1, which allows 25A to pick up, is left. The resistance of P2 is such that the voltage across it may be varied from zero up to a value equal to the voltage across R6 when the two inputs XB-YB and XL-YL are 40° out of phase. Relay 25A, therefore, picks up at a constant phase angle difference between the two inputs independent of the frequency difference between the two inputs. Refer to Figure 2a. The phase angle difference at which 25A picks up can be adjusted from 0° to 40° by changing the setting of P2. It will be noted that the potentiometer P2 is calibrated directly in degrees of advance angle.

The grid voltage of tube No. 4 is made up of the sum of the voltages across P4, R13, R14 and R15, and R10 applied through grid current limiting resistor R11. Relay 25B is connected in the plate circuit of tube No. 4. P4 is set so that the negative bias on the grid of tube No. 4 allows just enough current to flow in the plate circuit to cause relay 25B to pick up, if there is no voltage across R14 and R15 and R10. The wave form of the voltage across C5 and R14 and R15 is shown in Figure 1b. The wave form of the resulting voltage across R14 and R15 and the wave form of the voltage across R10 are shown in Figure 2b. The sum of these two voltages is equal to zero at a constant time before the two input voltages are in synchronism regardless of the frequency difference between them. Therefore, relay 25B picks up at a constant time before synchronism. The time before synchronism at which relay 25B picks up may be varied by changing the multiplier knob which changes the value of the C5, R14 and R15 time constant or by varying P3 which changes the ratio of voltage across the C5, R14 and R15 circuit to the voltage across R10. In this manner the time before synchronism at which 25B closes may be varied from 0.1 to 0.8 seconds. It will be noted that P3 is calibrated directly in terms of seconds required for the breaker to close.

Potentiometers P1 and P4 provide compensation for variation in circuit components. In particular they render the device independent of variations in relay pickup and tube characteristics. P1 should be reset at the time of installation of the synchronizer and every time tube No. 3 is changed. P4 is a zero set for the advance circuit. P4 should be reset at the time of installation of the synchronizer and every time tube No. 4 is changed.

Should the voltages XB-YB and XL-YL be unequal in magnitude, the wave shape of Figure 2b will not return to zero by a negative amount proportional to their different voltages. To insure closure at a maximum desired difference in XB-YB and XL-YL voltages, P4 setting must be compensated as described in Section VII, 1, i.

Relay 25C is set by means of resistor R18 to pick up when the voltage across rectifier X3 is 85% ± 5% of the voltage that would exist across X3 at 120 V on both XL-YL and XB-YB at a point of 180° phase displacement one from the other. Once relay 25C picks up, it seals itself in through resistor R16 with the d.c. voltage between S1 and 14.

Relay 25 is a type SG relay which operates to energize the breaker closing circuit when system conditions are correct for synchronizing. From Figure 3 it can be seen that relays 25A, 25B, and 25C are interlocked so that relay 25 can close to energize the breaker closing circuit only if relay 25A operates before relay 25B. This will occur only if the frequency difference between the two input voltages is less than a predetermined amount. Because relay 25B closes at a constant time before the two input voltages are in phase, relay 25 will be energized at a time in advance of synchronism by an amount corresponding to the closing time of the breaker to be closed.

Inspection of Figure 3 shows three other relays in the synchronizer circuit. Tube No. 2 is a non-adjustable thermostatic time delay which functions to prevent operation of the synchronizer until the tubes have had time to warm up (approximately 30 seconds). Relays 27L and 27B are voltage checking relays connected across the two inputs to the synchronizer. If either of the input voltages drops below approximately 80% of its normal value, these relays will drop out and render the synchronizer in-operative. It should be noted that relay 27B is connected across the bus input voltage by means of a normally closed auxiliary contact on the breaker so that 27B will be de-energized after the breaker closes. See Figures 3 and 4. When 27B is de-energized, its contacts open to de-energize all of the synchronizer circuits.

The power supply for the synchronizer is derived from a constant voltage transformer T1 connected to a single phase, 120 volt, 60 cycle per second source. The a.c. supply voltage from winding 13-14-15 of T1 is rectified by the full wave diode tube No. 1 type 5Y3 GT. This rectifier voltage is smoothed out by a π section filter consisting of capacitors C2 and C3 and reactor L1. The 11-12 winding of T1 is connected to the filament of of Tube No. 1. The X1-X2 winding of T1 is connected to the filaments of the 6V6 tubes and the thermostatic time delay relay.

III. Operation

The sequence of operations when the synchronizer is given control by the master relay or synchronizing switch is as follows: (See Figure 3) Relay 27B picks up permitting the plate circuits and filaments of the tubes in the synchronizer to be energized. Immediately relay 25B picks up. This allows 27L to pick up and seal itself in which will cause the correct voltages to be applied across rectifiers X1, X2 and X3. Relay 25B will drop out as soon as 27L picks up. After voltage has been applied across rectifier X1 and the input voltages to the synchronizer have gone through the 180° out of phase point, relay 25C will pick up and seal in. Meanwhile the thermostatic time delay relay, tube No. 2 starts timing through its interval after 27B has picked up. The function of this time delay is to prevent operation of the synchronizer during the warm-up period of the tubes. This time delay is set for 30 seconds and is not adjustable. The time delay relay, relay 27L, and relay 25C must all be picked up before the synchronizer can operate.

The synchronizer is designed so that relay 25, the relay which causes the circuit breaker to close, cannot pick up unless both relays 25A and 25B are picked up. Relay 25A picks up at a fixed phase angle before synchronism and relay 25B picks up at a fixed time before synchronism. The relationship between the time before the point of synchronism at which relay 25B picks up and the phase angle before the point of synchronism at which relay 25B picks up is this. The phase angle before synchronism in degrees equals the time before synchronism in seconds times the frequency difference between the two intelligence voltage in cycles per second times 360 degrees. Since relay 25B picks up at a constant time before synchronism, the phase angle before synchronism at which it picks up is proportional to the frequency difference.

Consider the situation in which the frequency difference between the two input voltages is so large that the angle before synchronism at which relay 25B picks up is greater than the angle before synchronism at which relay 25A picks up. Relay 25C will have been previously picked up when the two input voltages were 180° out of phase. As soon as relay 25B picks up it causes relay 25C to drop out. This in turn prevents relay 25A from picking up and hence 25 from picking up. Now consider the situation in which the frequency difference between the two input voltages is small enough that the angle before synchronism at which relay 25B picks up is smaller than that at which relay 25A picks up. Relay 25C will have been previously picked up when the two input voltages are 180° out of phase. The fact that relay 25C is picked up allows relay 25A to pick up and seal itself in. When 25B then picks up at the proper time before synchronism it causes relay 25 to pick up. Relay 25 causes the circuit breaker to close. When relay 25B picks up, it also causes relay 25C to drop out but since relay 25A has sealed itself in it is not affected by relay 25C dropping out. The purpose of relay 25C is to force the two input voltages to go through the 180° out of phase point before synchronizing can be accomplished.

IV. Sensitivity

The synchronizer is designed to close the breaker within ± 3° of synchronism at equal voltages of the bus and line to generator inputs and at frequencies of the two inputs between 58 and 62 cps. The ± 3° error is due to operating tolerances.

The synchronizer is designed to operate up to a tolerance of 15% difference between the two input voltages. With this much voltage difference and with the zero adjusting potentiometer P4 set for equal input voltages, the maximum error is ± 5°.

It is recommended, however, to set potentiometer P4 for the expected maximum voltage difference. For otherwise, at a very short breaker closing time (0.1 to 0.2 seconds) and at a beat frequency that is approaching zero, the synchronizer will fail to activate the breaker.

With P4 set to the maximum expected voltage difference, the synchronizer will always operate. At equal inputs, however, the breaker will close early. The amount of additional error is small and can be determined from Figure 6.

Example: Assume the maximum expected voltage difference were 10% and the zero setting potentiometer P4 were set to compensate for this much difference in the inputs. With the two input voltages actually having this much difference, the breaker closing tolerance would be between ± 3° of synchronism.

With the two input voltages actually being equal and with P4 still set as above, the additional error would be 4°. This means, since this error is in a direction to cause the circuit breaker to close too soon, the breaker closing tolerance would be between 7° to 1° before synchronism rather than between 3° before and 3° after synchronism.

For instructions of how to set the zero adjusting potentiometer P4, refer to Section VII.

V. Burdens

These synchronizers are designed to operate from potential transformers having 120 volt, 60 cps secondaries. The intelligence circuits impose a maximum burden on each potential transformer of 15 volt amperes at 120 volts. The maximum burden at terminals X-Y or X-Y1 (the auxiliary power) is approximately 60 volt amperes at 120 volts, 60 cps.

VI. Installation and Calibration Instructions

1. Check that synchronizer is properly connected per the application diagram, Figure 4.

2. Adjust and set the "Zero Setting" controls per Section VII Part 1.

3. Measure the breaker closing time and set the synchronizer controls as follows.

(a) Clear the breaker by opening it and its disconnect switches on both sides of breaker.

(b) Measure the breaker closing time from time of initiation of closing circuit to closure of main contacts.

(c) Refer to Section VII and make synchronizer control settings as desired.

(d) Open breaker and continue tests per following Step 4.

4. Overall Circuit Checking of Synchronizer with Breaker and Potentials.

(a) With the breaker and its disconnects closed assuring equal and in-phase potentials to both sides of the synchronizer, close the synchronizer control switch or other means to place the synchronizer in service. Nothing should happen.

(b) Jumper synchronizer terminals "52b" and "YB". Relay 27B will pickup immediately; relay 25B will pickup after a short warmup, followed by pickup of relay 27L. If relay 25B drops out after pickup of 27L, the potentials to the synchronizer are not in proper phase relationship or some other fault exists.

(c) Momentarily operate relay 25C mechanically by hand. Relay 25A will operate and seal in; relay 25 will operate and energize the breaker closing circuit (with the breaker already closed, only the breaker trip-free circuitry will be energized). Relay 25C will drop out when released by hand, but relays 25A, 25B, 25, 27B and 27L will remain energized.

(d) Remove jumper from terminals "52b" to "YB". All relays will drop out.

NOTE #1 The sequence of relay operations above is not the same as would occur for actual synchronizing, but is made here only for purpose of checking circuitry.

NOTE #2 The synchronizer will not close an open breaker with both potentials in phase without at least one slip-cycle of operation.

VII. Settings and Adjustments

These should be accomplished at time of installation; at time of tube replacements; and at maintenance intervals of approximately 1 to 2 years.

1. Adjust and set the "zero setting" controls as follows:

(a) Remove external leads from terminal pairs XL-YL, XB-YB and 52b-YB. Also remove external lead from CL1 (breaker close circuit).

(b) Connect terminals XL and XB to terminal X by jumpers.

(c) Connect terminals YL, YB and 52b to terminal Y by jumpers.

(d) Turn P1 (Advance Angle Zero Set) and P4 (Breakers Closing Time Zero Set) to their extreme clockwise position.

(e) Apply 120 V, 60 cps to terminals X & Y. (This applies power to the synchronizer and equal and in phase voltages to XL-YL and XB-YB). Relay 27B will pickup immediately. After a warm-up time, relay 25B will pickup and will be followed immediately by 27L which will seal-in and drop relay 25B.

(f) Operate relay 25C by hand; it will seal-in. Relays 25A, 25B and 25 should be de-energized and 27B and 27L should now be operated.

(g) Turn P1 (Advance Angle Zero Set) counterclockwise until relay 25A operates. Lock P1 in this position.

(h) Turn P4 (Closing Time Zero Set) counterclockwise until relay 25B operates. This should cause relay 25 to operate and relay 25C to drop out. With a 20,000 ohm/volt voltmeter (multimeter), read and record the voltage between terminals 46(+) and 14(-) as V_{46-14} = ____ .

(i) Determine from Figure 6 the volts below the balance point voltage V_{46-14} of (h) above, that corresponds to the maximum percentage difference between the bus (XB-YB) and line (XL-YL) voltages for which synchronizing is desired. Turn P4 counterclockwise and set to give a voltage between terminals 46 and 14 equal to V_{46-14} of (h) above, less the determined value from Figure 6. Lock P4 in place.

(j) Remove jumpers and restore normal connections.

2. Setting of Advance Angle and Breaker Closing Time. After the exact closing time of the breaker has been determined (Section

VI Part 3) use curves of Figure 5 to make the final adjustments of the synchronizer, that is setting of the advance angle (P2) and breaker closing time (P3) as follows:

(a) Select the curve of Figure 5 that corresponds to the frequency difference above which it is desired that the synchronizer prevent the breaker from closing.

(b) Find the point on the abscissa of Figure 5 that corresponds to the breaker closing time and draw from there a vertical line to the curve selected in (a) above.

(c) From the intersection of the two lines draw a line horizontally which will intersect the ordinate at the necessary phase angle setting.

EXAMPLE:

Given: Breaker closing time = 0.4 seconds
Desired lock out frequency difference = 0.2 cps.

Wanted: Advance angle setting
Draw a line vertically from 0.4 sec. on the abscissa to the line representing 0.2 cps frequency difference. A line drawn horizontally from the intersection meets the ordinate at a point of 28.8° advance angle setting.

(d) Set the advance angle and breaker closing time controls to their respective values.

VIII. Special Notes

The type XT7-C synchronizer is not applicable for closing breakers where there is no frequency difference between the voltages on the two sides of the breaker such as occurs with the last open breaker in a transmission loop. Under these conditions there will be no phase rotation between the two voltages although there may be a phase angle displacement between them. A type CVE synchroverifier relay is recommended for synchronizing under such conditions.

The Type XT7-C automatic synchronizer S#1810200C is a flush mounting unit. By the addition of the projection mounting accessories S#1810201 the flush mounted synchronizer can be converted to a projection mounted synchronizer.

IX. Detailed Test Instructions

These instructions are not required for installation unless difficulties are encountered. Their purpose is for overall calibration and checking. Before proceeding with the following checks and tests it is presumed that the synchronizer has been checked for insulation strength.

Remove all tubes.

Check the following resistances with an ohmmeter:

X. Renewal Parts Data RP 56-451

Item numbers refer to Drawing 406-D-330, Group 1.

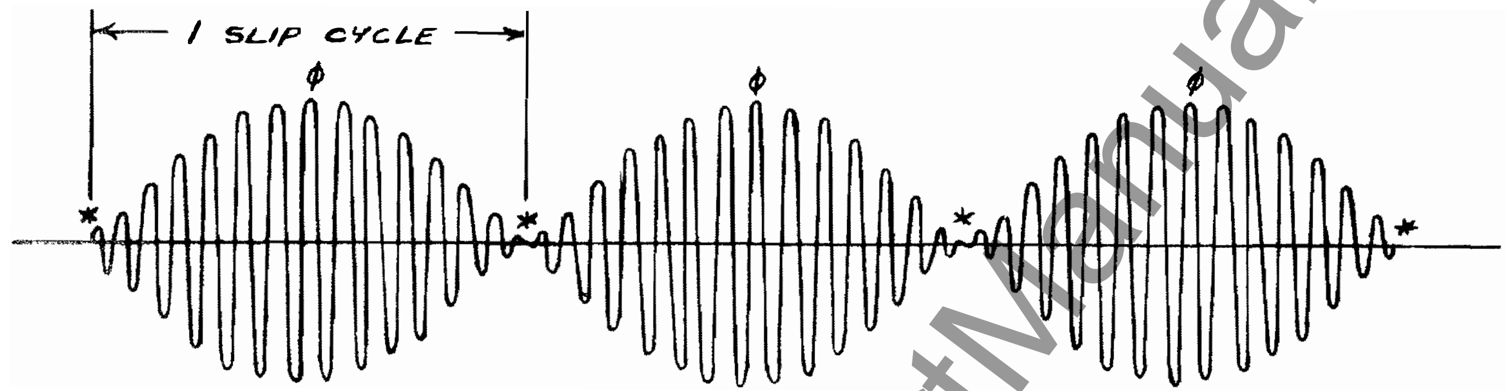
Item No.	Unit Quan.	Style Number	Description
-	1	1810 200-C	Automatic Synchronizer
1	1	Dwg.21A8971	Cover (Items 4 to 12-15)
-	1	21A8971H09	Glass
2	1	1489 517	Case
14	1	19B2419G02	Reactor (L1)
15	1	1210 936	Type SG Relay (25)
-	1	1155 128	Operating Coil - 250 Volt DC
17	1	---- ---	Type 5Y3 Tube (No. 1)
18	2	---- ---	Type 6V6 Tube (No. 3-4)
19	1	---- ---	Thermostatic Delay Relay(No.2)Amperite(Cat.#6No45
20	4	1486 541	Tube Socket
21	1	---- ---	Transformer & Capacitor (T1-C1) Sola(Cat.#-7104)
22	2	1346 529	Capacitor - .1 Mfd. (C4 and C6)
28	2	1346 526	Capacitor - 6 Mfd. (C2-C3)
31	2	1584 354	Potentiometer - 500 Ohm, 2 Watt (P1-P4)
33	1	1584 359	Potentiometer - 10,000 Ohms, 2 Watt (P2)
35	2	---- ---	Potentiometer Knob for(Item 33-34)(Cat.#242-2230)
36	1	---- ---	Selector Switch (Cat. #47-174C)
38	2	---- ---	Rectifier (X1)(Part #29B9452-22)
39	4	---- ---	Rectifier (X2)(Part #29B9452-28)
42	1	126A472H01	Type A Relay (27B)
43	3	757 495	Type 2-D-11-AA-9-6G D-C Relay (25A-25B-25C)
49	2	1589 844	Resistor - 250 Ohm, 10 Watt (R2-R13)
50	2	1611 941	Resistor - 7500 Ohms, 10 Watt (R1-R12)
53	2	1767 213	Resistor - 1 Megohm, 2 Watt (R5-R11)
54	2	1736 129	Resistor - .1 Megohm, 2 Watt (R3)
65	4	667 585	Thumb Nut
79	1	1767 213	Resistor - 1 Megohm, 2 Watt (R6)
88	1	126A472H03	Type A Relay (27B)
96	2	428A050G01	Rectifier (X3) (Cat.#13V14KIDI)
99	1	1767 180	Resistor - 22,000 Ohm, 2 Watt
102	2	30B5375A44	Transformer (T2-T3)
108	1	125A520H31	Resistor - 5000 Ohms, 50 Watt (R18)

Reference: -
Drawing 406-D-330
Connection Diagram 585-C-934
Schematic Diagram 585-C-929

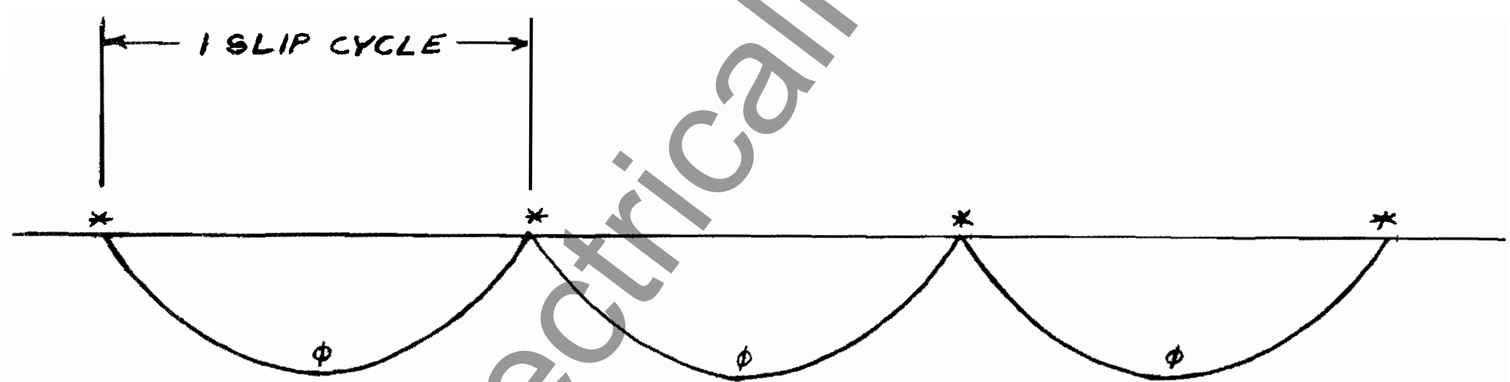
Note: No attempt should be make to replace Resistors R7,R8,R9,R10,R14,R15, Potentiometer P3, or Capacitor C5. Synchronizer should be returned to factory if these components need to be replaced.

note: Parts indented are included in the part under which they are indented. Order part by name and identification number — give complete nameplate reading.

Supersedes R.P.D. 56-450 AS-0200C Dated December 1962. January 1964.

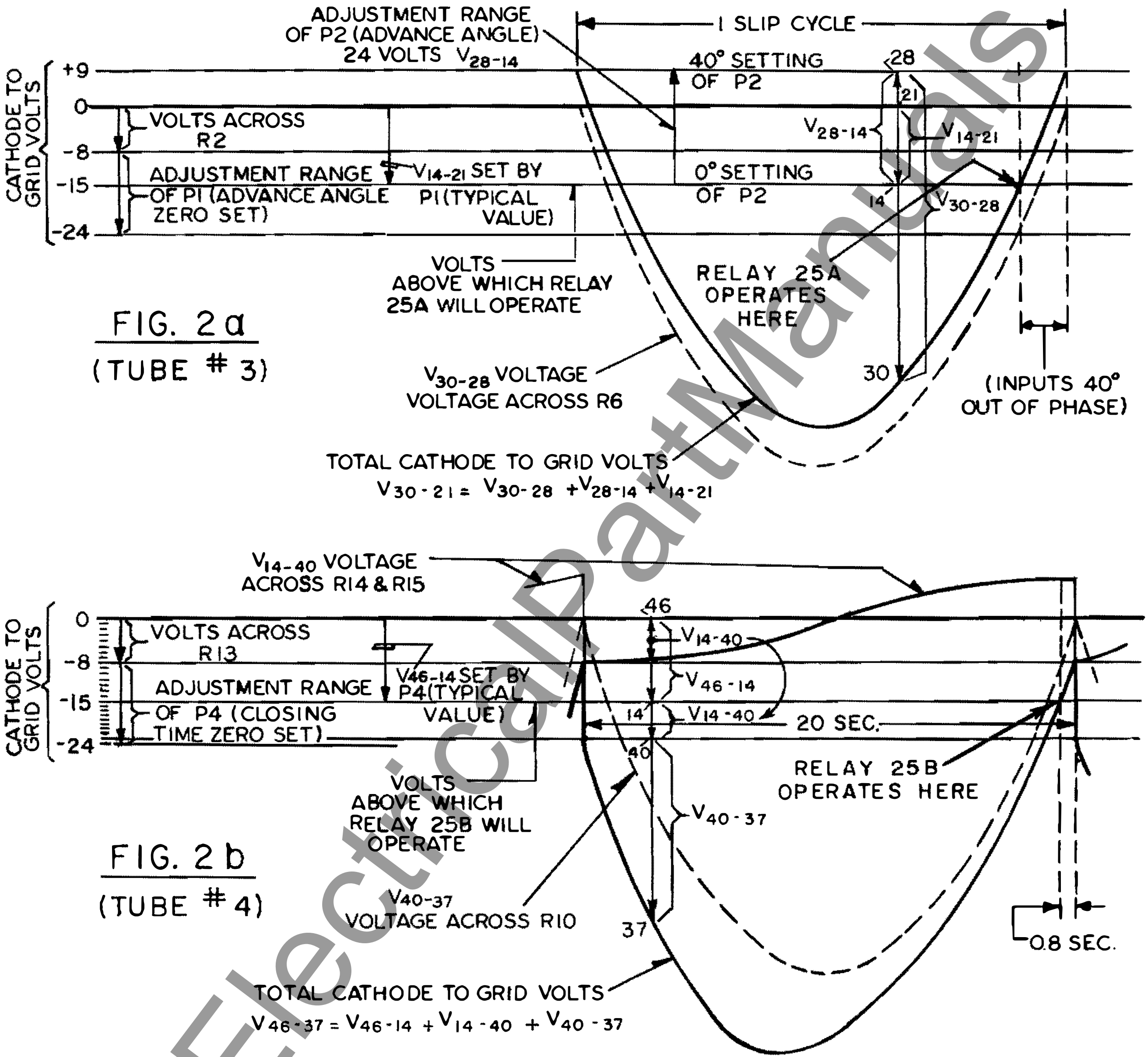


WAVE FORM OF VOLTAGES 31-35 AND 41-33
* XB-YB AND XL-YL IN PHASE
ϕ XB-YB AND XL-YL 180° OUT OF PHASE



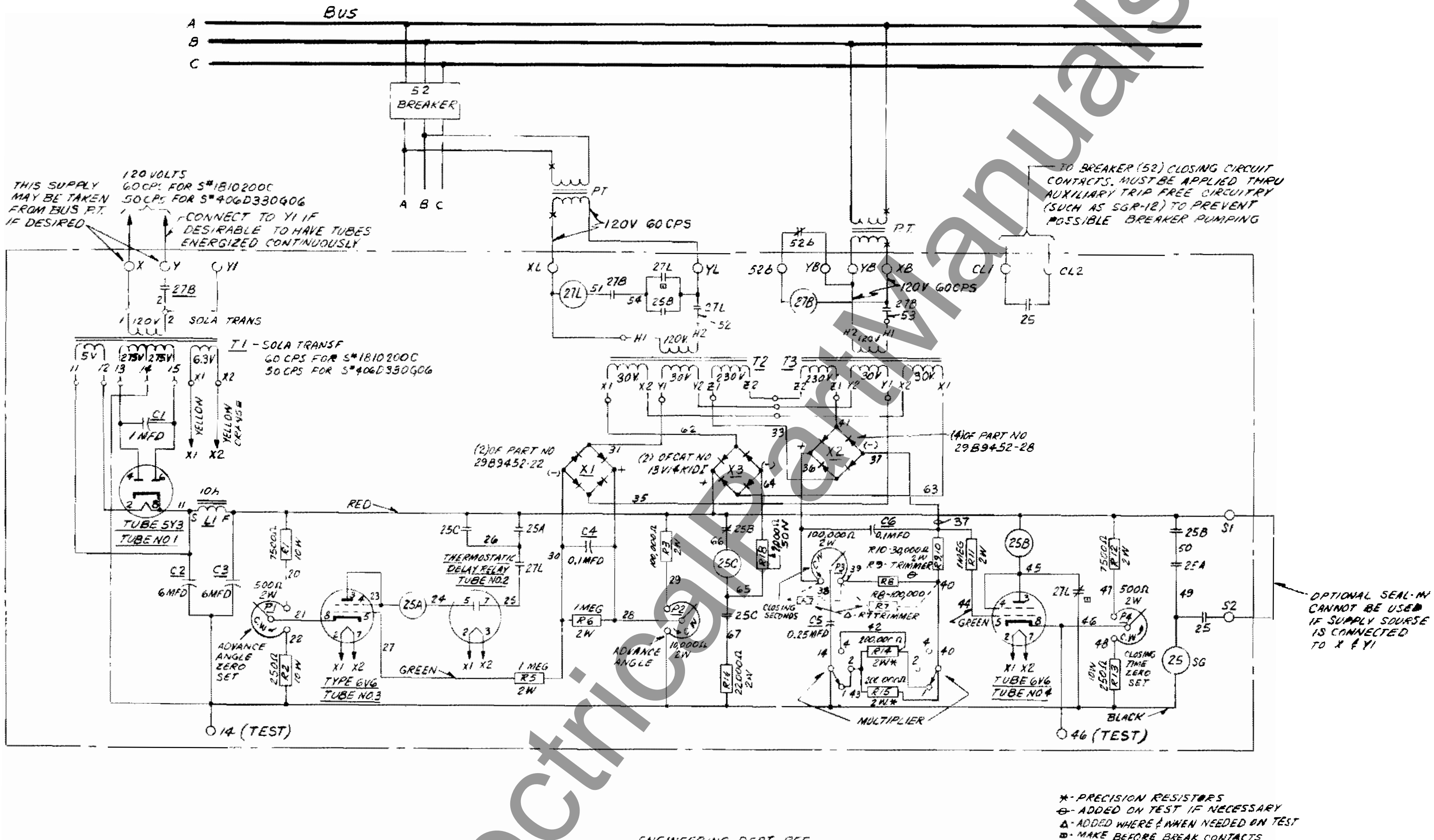
WAVE FORM OF VOLTAGE ACROSS C4, C6, AND D-C OF X3

Fig. 1 - Typical Wave Forms
(taken from dwg. 657A652-1)



NOTE: THIS FIG. SHOWS SYNCHRONIZER SET FOR 0.8 SEC. BREAKER CLOSING TIME AND 40° ADVANCE ANGLE. BEAT FREQUENCY SHOWN IS 0.05 CYCLES / SECOND

Fig. 2 - Grid Signals to Tubes 3 & 4
(taken from dwg. 657A649-1)



ENGINEERING DEPT. REF

XT7-C	60CPS	50CPS
STYLE NO	1810200C	406D330G06
GEN DWG	406D330	406D330
CONN DWG	585C934	585C934
APP DIAG	586C202	586C202
OUTLINE (FLUSH)	126A379	126A379
OUTLINE (PROJ)	126A380	126A380

Fig. 3 - Schematic Diagram
(taken from dwg. 585C929-7)

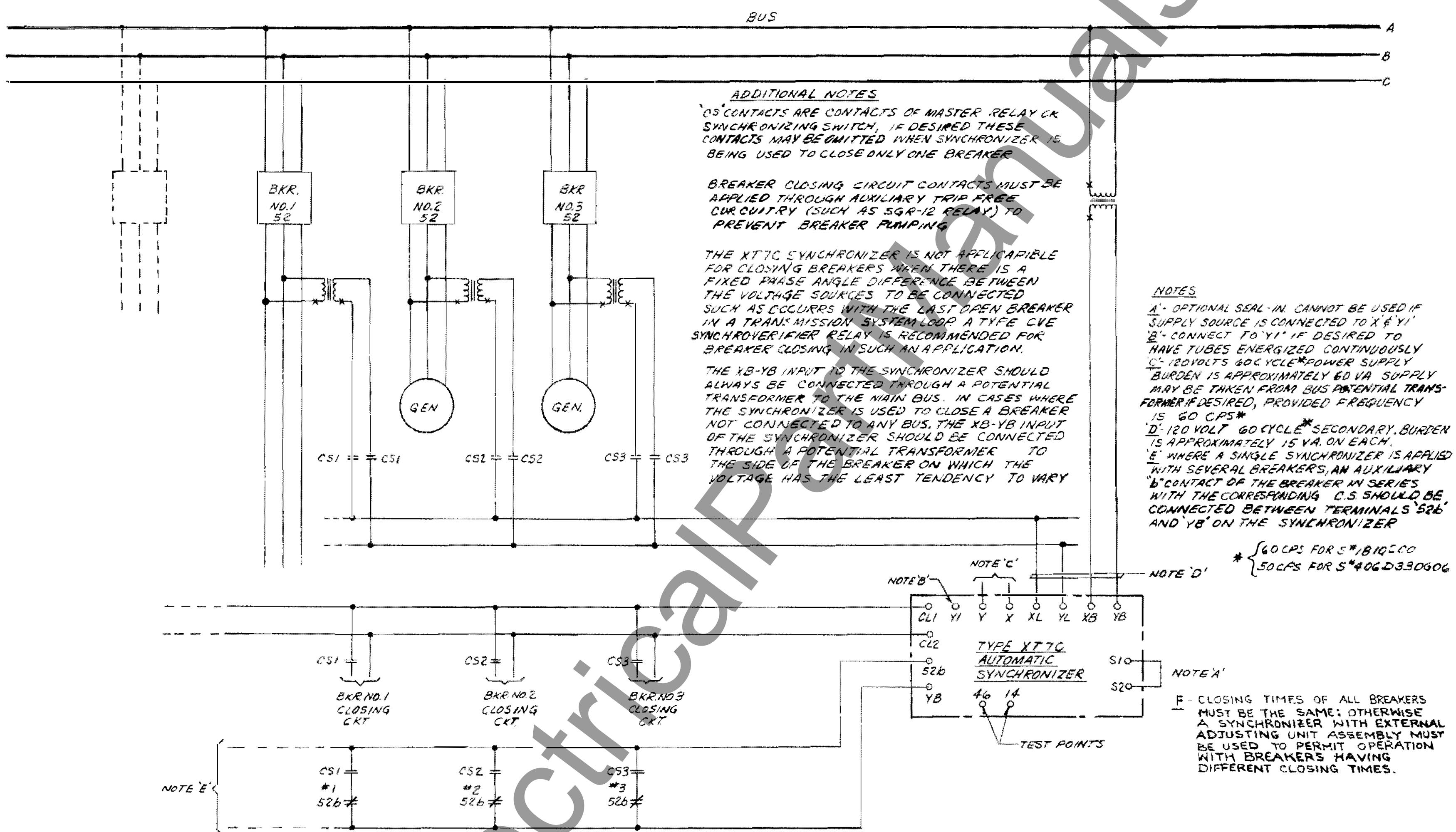


Fig. 4 - Application Diagram
(taken from dwg. 586C202-3)

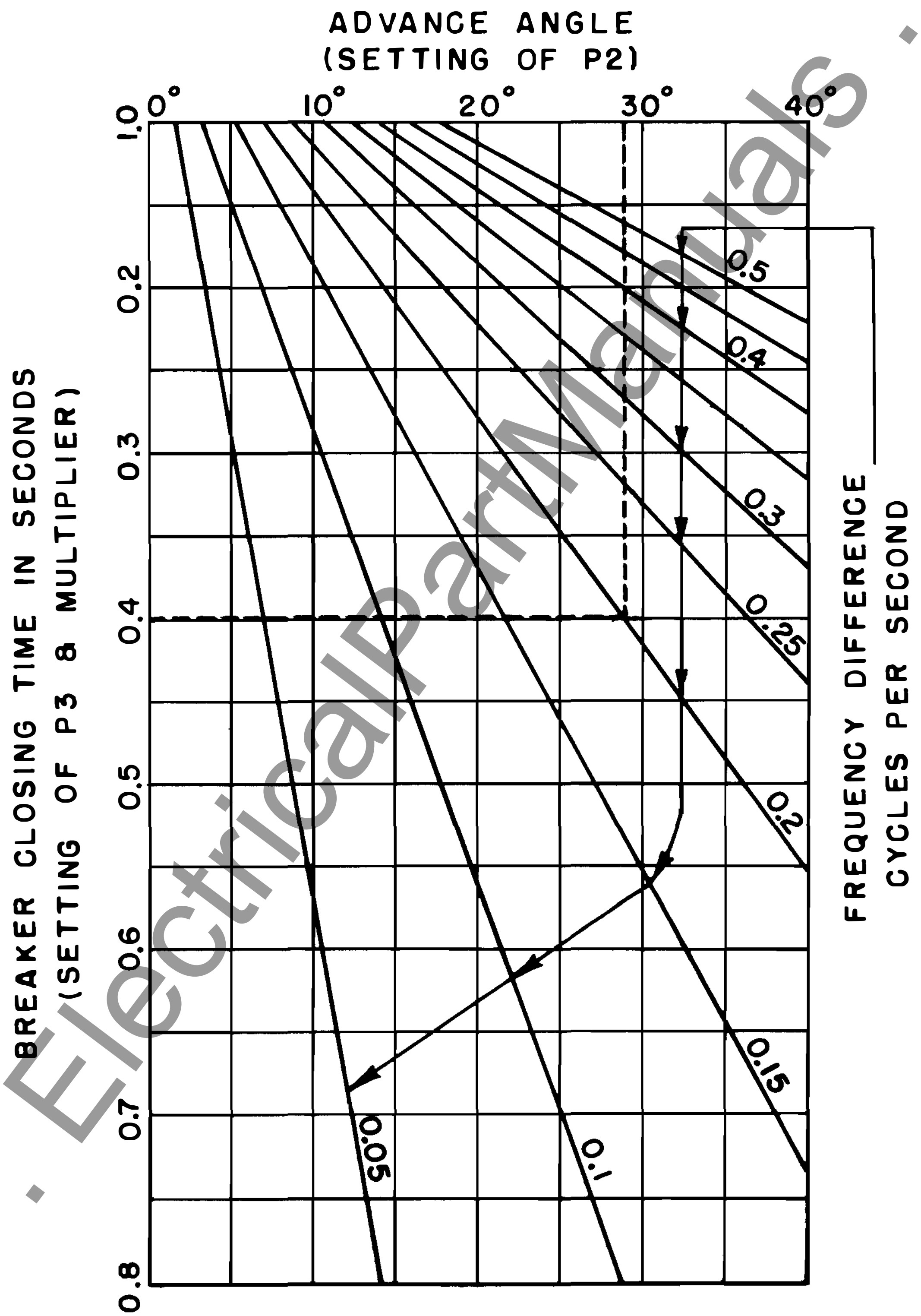


Fig. 5 - Calibration Curves
(taken from dwg. 657A651-1)

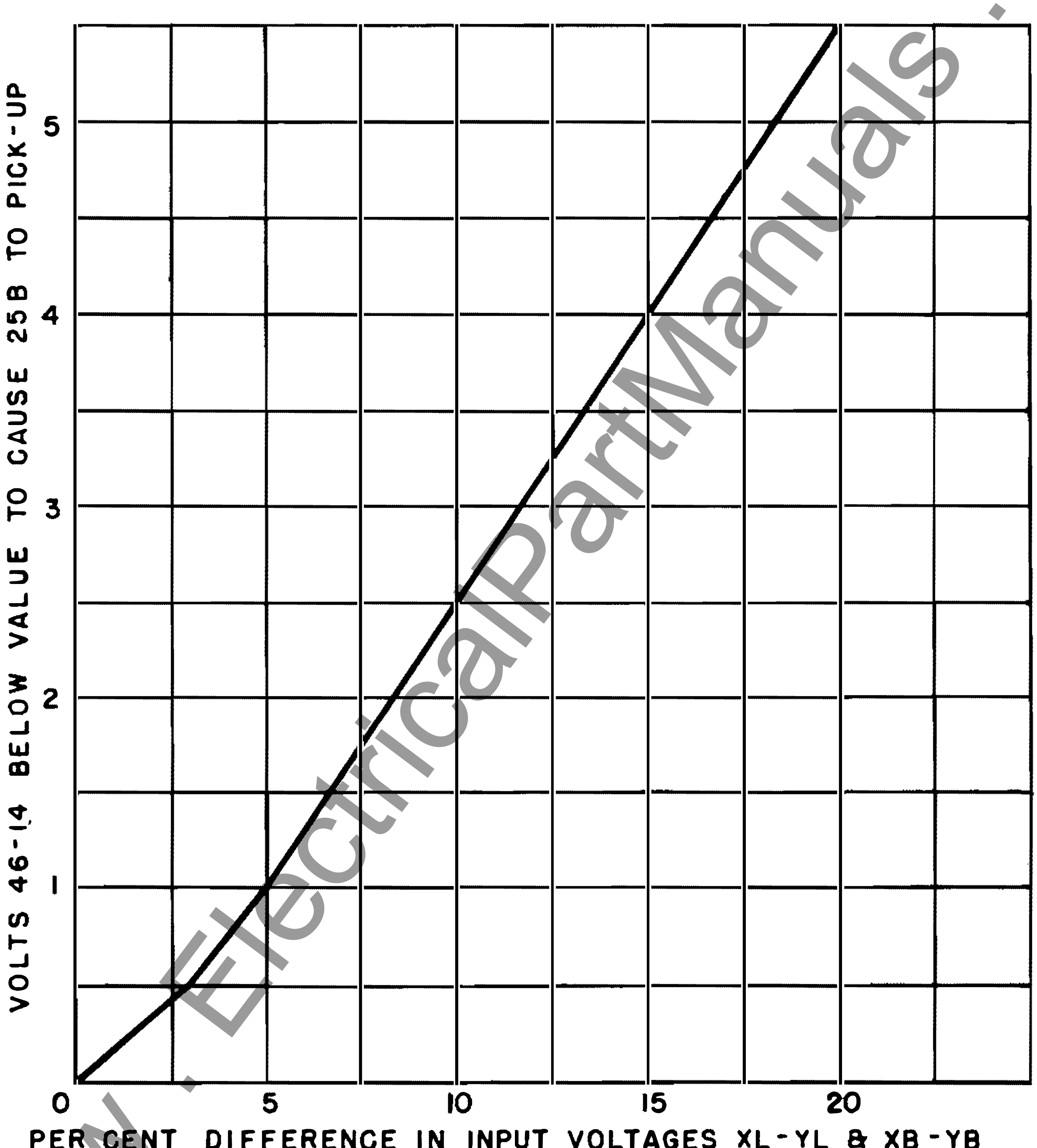


Fig. 6 - Zero Set Voltage Difference vs Percent Differential in Input Voltage Curve (taken from dwg. 657A650-1)

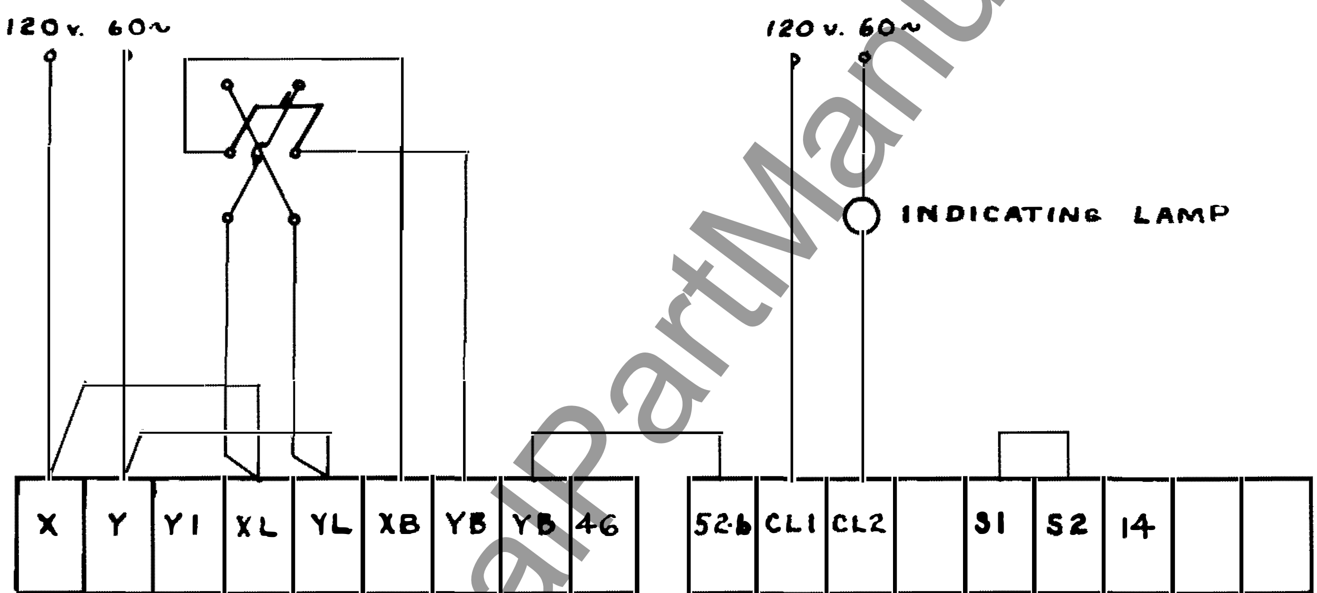


Fig. 7 - Synchronizer Test Connections
(taken from dwg. 129A464-2)

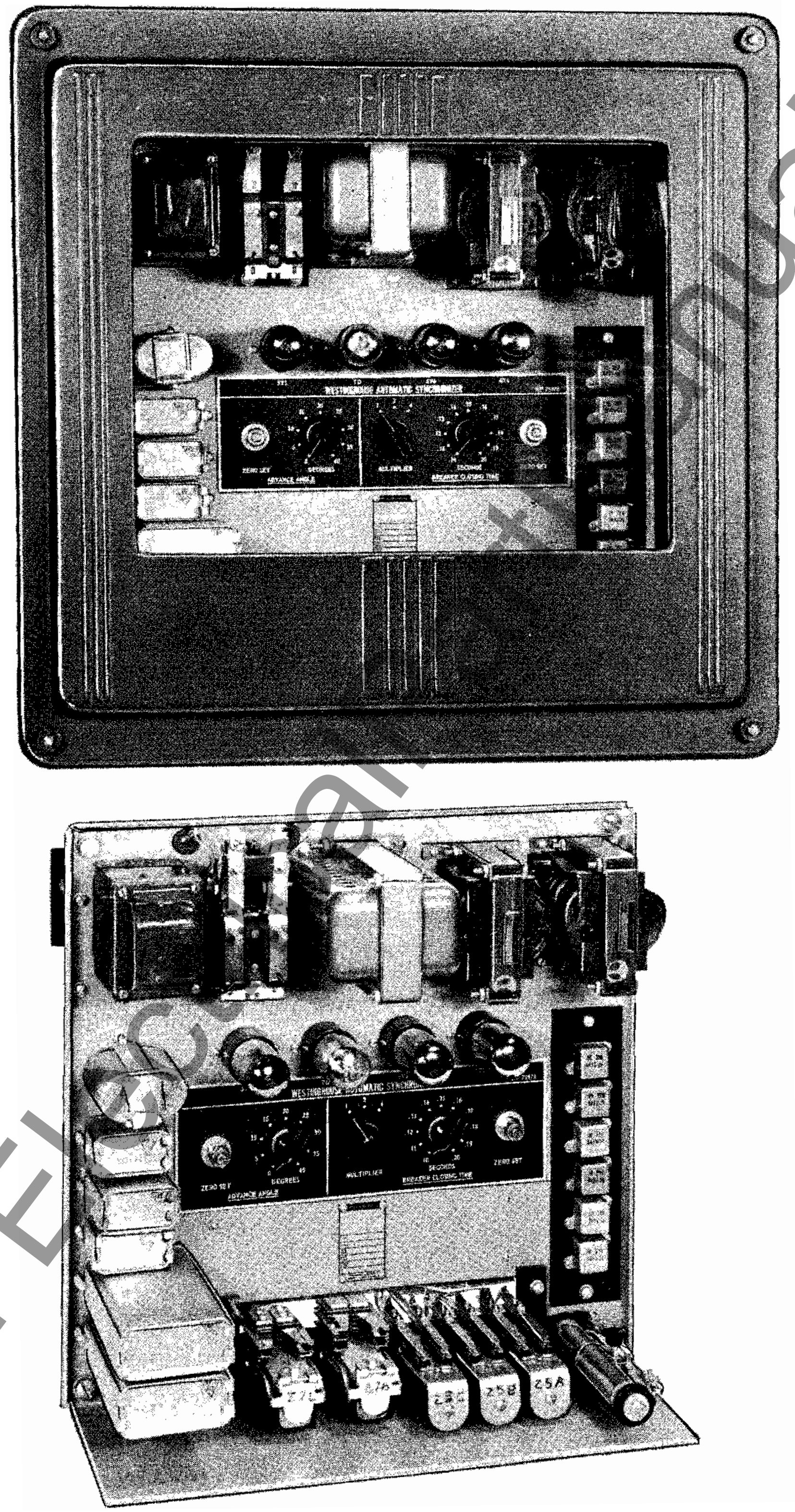


Fig. 8 - XT7-C With and Without Case
Front View

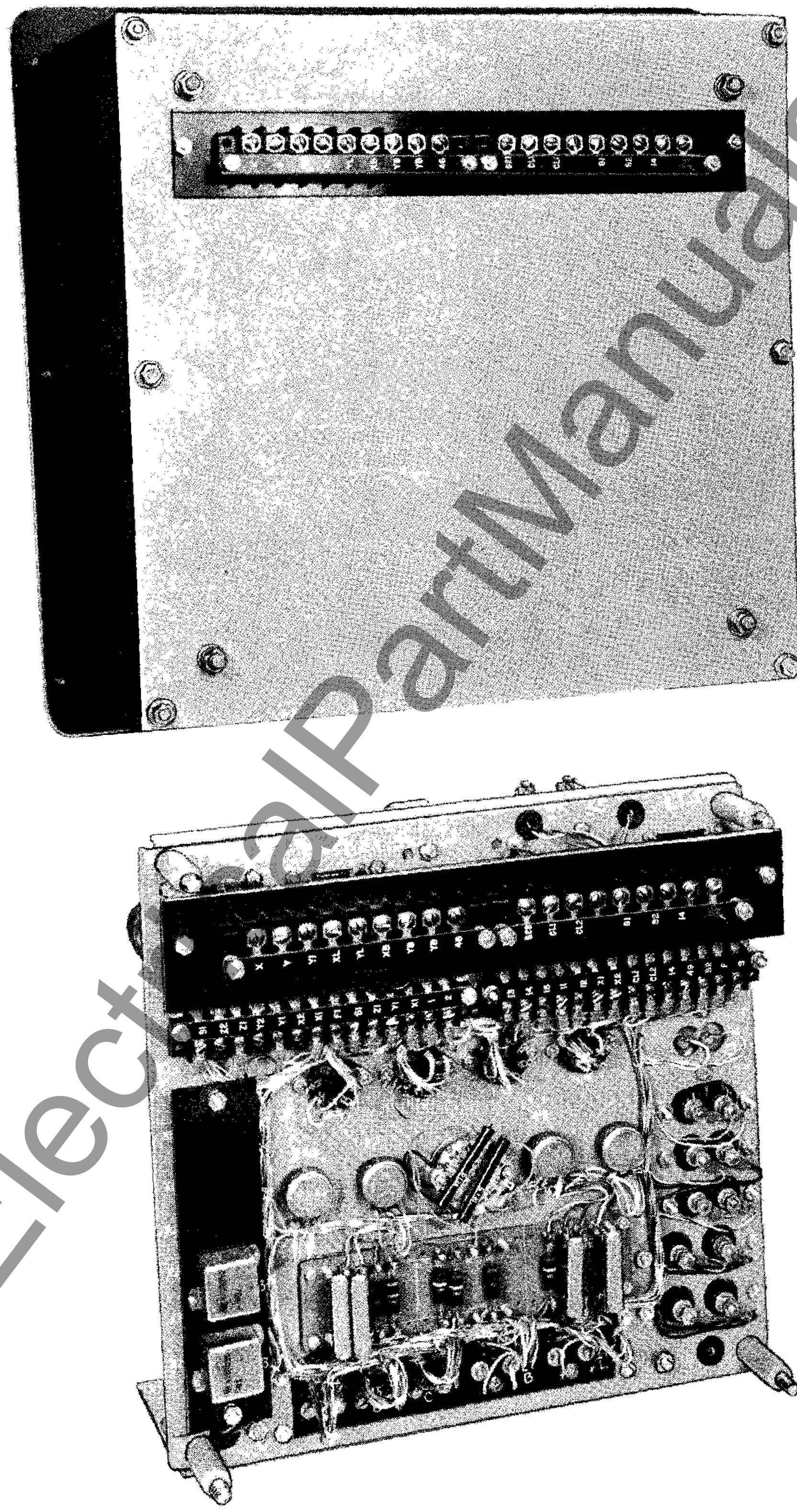


Fig. 9 - XT7-C With and Without Case
Rear View

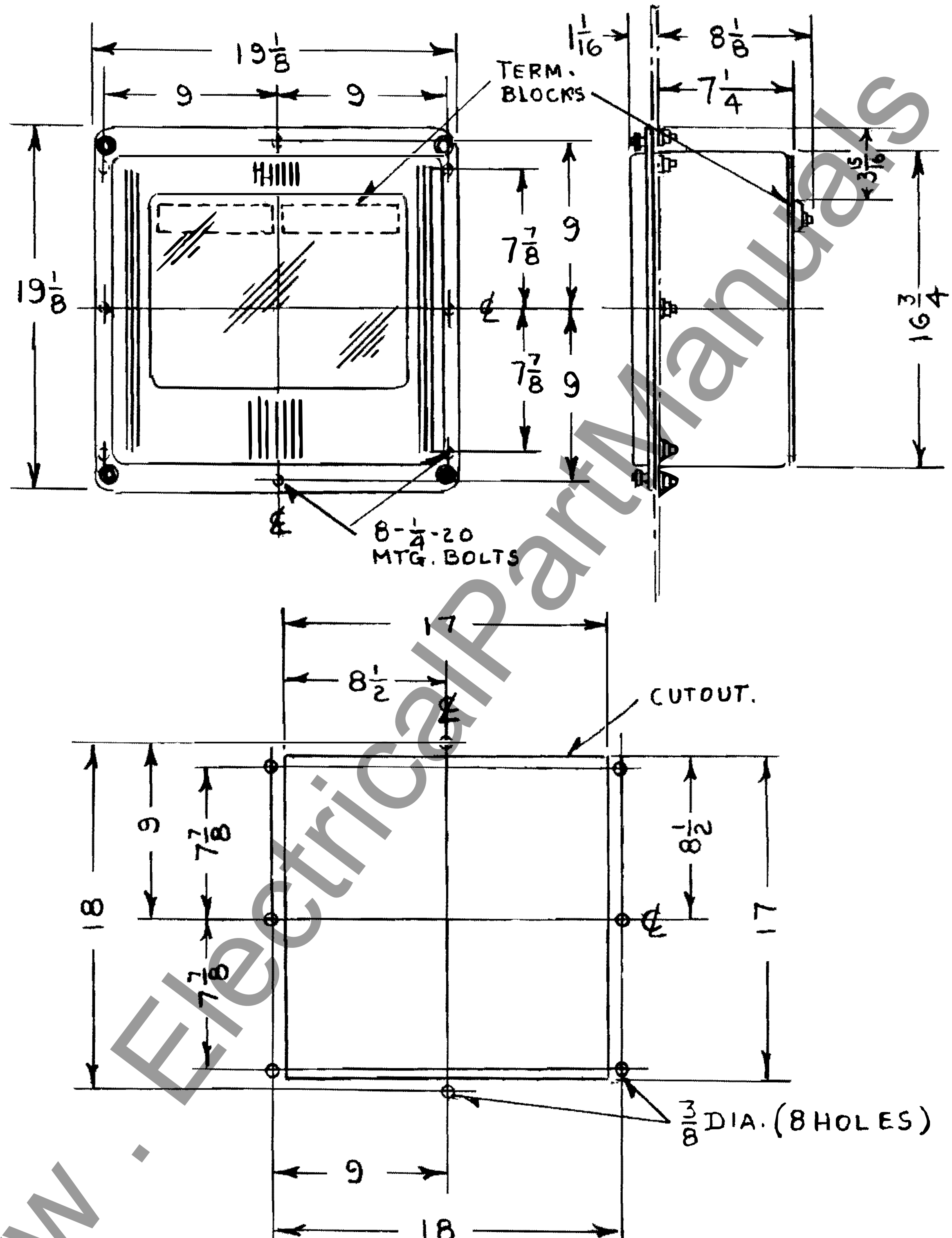


Fig. 10 - Outline and Drilling Plan - Flush
(taken from dwg. 126A379-2)

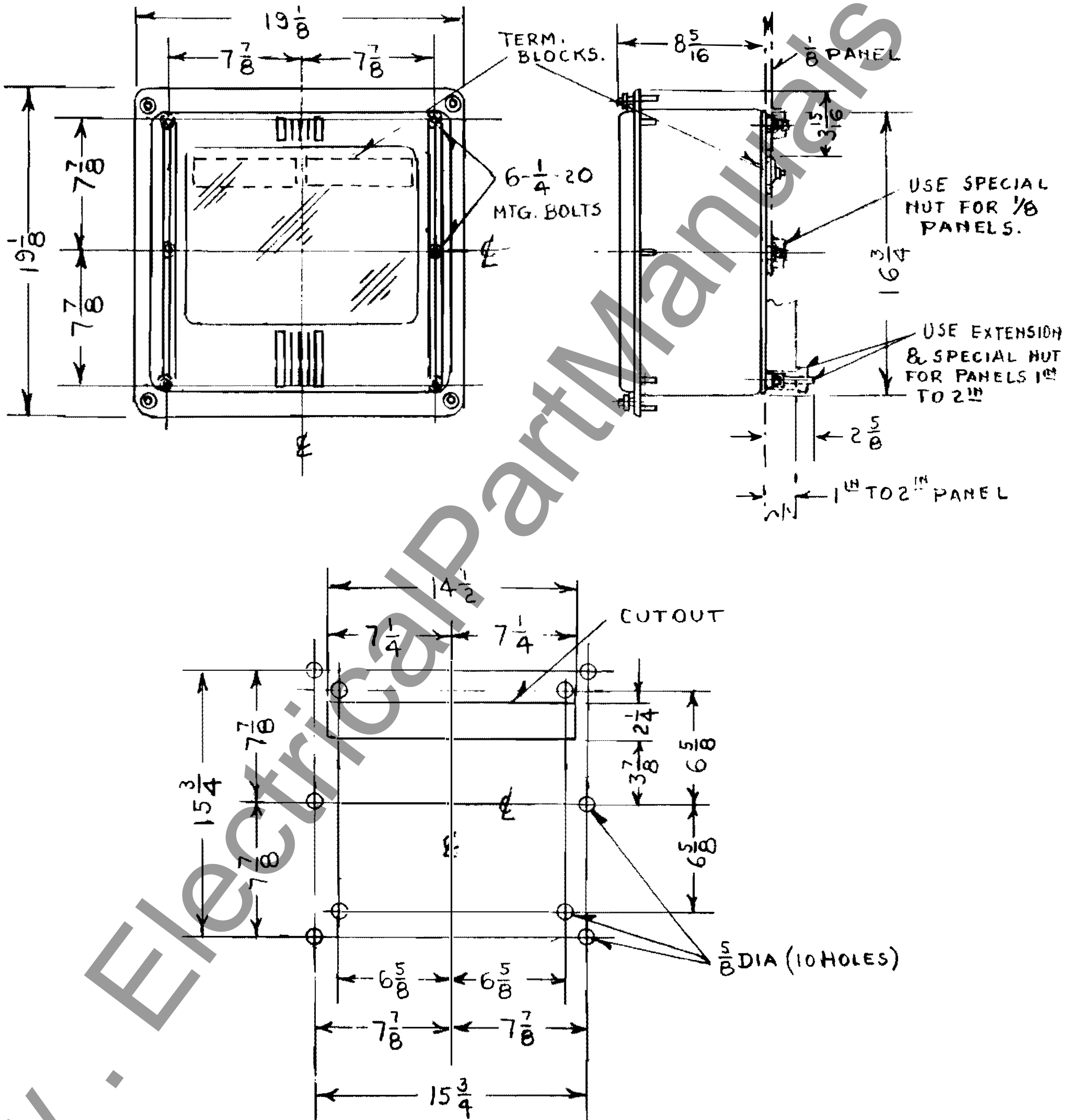


Fig. 11 - Outline and Drilling Plan - Projection
(taken from dwg. 126A380-2)