ABB Power T&D Company Inc.
Relay Division
Coral Springs, FL 33065

TYPE DGSH & DGSU GENERATOR STATOR GROUND DETECTOR RELAYS

CAUTION: Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The type DGSH and DGSU generator stator ground detector relays operate as third harmonic voltage comparators. The relays are intended to detect ground faults at or near the stator winding neutral. Such faults result in an unbalance of the third harmonic voltages between the neutral and terminal ends thereby operating the comparator circuit. The type DGSH and DGSU relays supplement the fundamental responsive overvoltage relay (type CV-8) to provide total stator winding ground-fault coverage.

Additional information is contained in Application Data 41-749 (E).

The type DGSH relay is supplied in the type FT-31 flexitest case for vertical mounting on panels.

The type DGSU relay is supplied in the type FTU-41D6 flexitest case for horizontal rack mounting.

With the exception of the case design both relay types are identical. Hereafter in this description DGSH and DGSU can be considered interchangeable.

OPERATION

The type DGSH relay is connected as shown in external schematic figure 5. The relay compares the absolute value of the third harmonic voltage at the neutral with the absolute value of the sum of the third harmonic voltages measured at the generator terminals. The secondary third harmonic voltages of the neutral and terminal ends are adjusted to be equal using the isolating/ratio matching transformer in the relay. These input voltages are then rectified and the difference voltage is applied to the relay operate element. The average current through the relay element is zero under balanced conditions. During the condition of a stator ground fault, the third harmonic voltage balance is upset and current flows through the relay element causing its contacts to close.

CONSTRUCTION

The type DGSH relay consists of a type D-3 dc current element, two bridge rectifiers, two third harmonic pass filters, one isolating/matching transformer, one tapped resistor, surge suppression capacitors C3, C4 and an indicating contactor switch (ICS).

D-3 ELEMENT

The type D-3 element is a d'Arsonval type dc contact making milliammeter (0.75-0-0.75 ma dc) consisting of a moving coil, permanent magnet, and contacts.

Permanent Magnet — The permanent magnet is a cylindrical core, consisting of an Alnico permanent magnet, two iron pole pieces and two brass spacer blocks. This magnet is mounted concentrically in the bore of a malleable iron frame.

The magnetic field is produced by the permanent magnet in the air gap between the magnet and the iron frame. The path of magnetic flux is from the Alnico magnet through the iron pole piece across the air gap to the iron frame. The return path of the flux is through the frame across the second air gap to the second pole piece. The pole pieces and the bore of the frame are shaped such that a uniform flux distribution is obtained in the air gaps.

Moving Coil — The moving coil rotates in the air gap between the core and the iron frame. Electrical connections are made to the coil through two springs located at the top of the element. One end of each spring is connected through a lever arm to a lead of the coil.The other end of each spring is fastened to posts mounted in a circular insulation plate. This plate can be rotated to permit adjustment of the zero position of the moving element.

A third spiral spring located at the bottom of the element provides a current path to the moving contact.

SUPERSEDES I.L. 41-749 (C) dated February 1984
EFFECTIVE MAY 1986
✶ = DENOTES CHANGES SINCE PREVIOUS ISSUE.

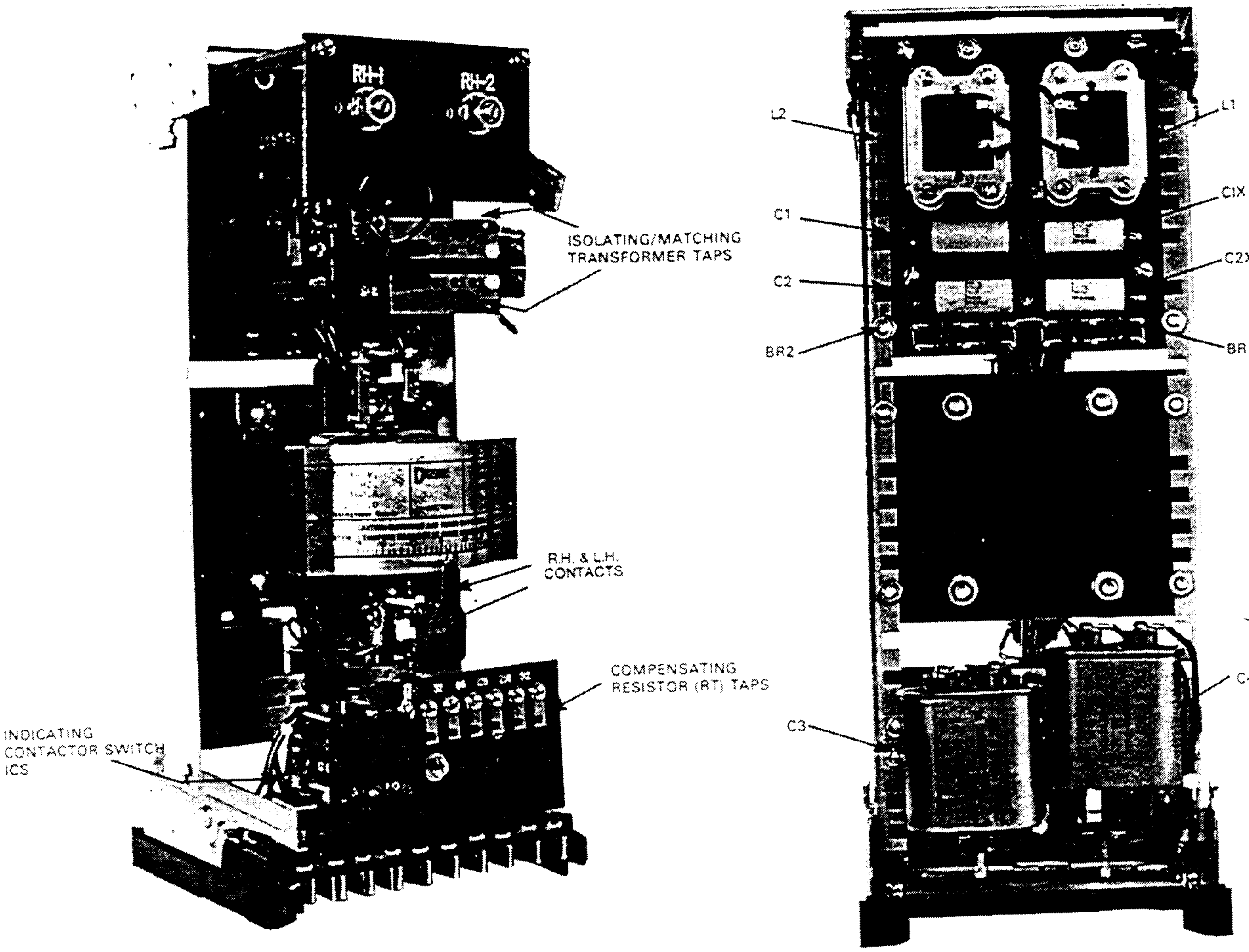


Figure 1 — Type DGSH Relay Chassis – Front and Back

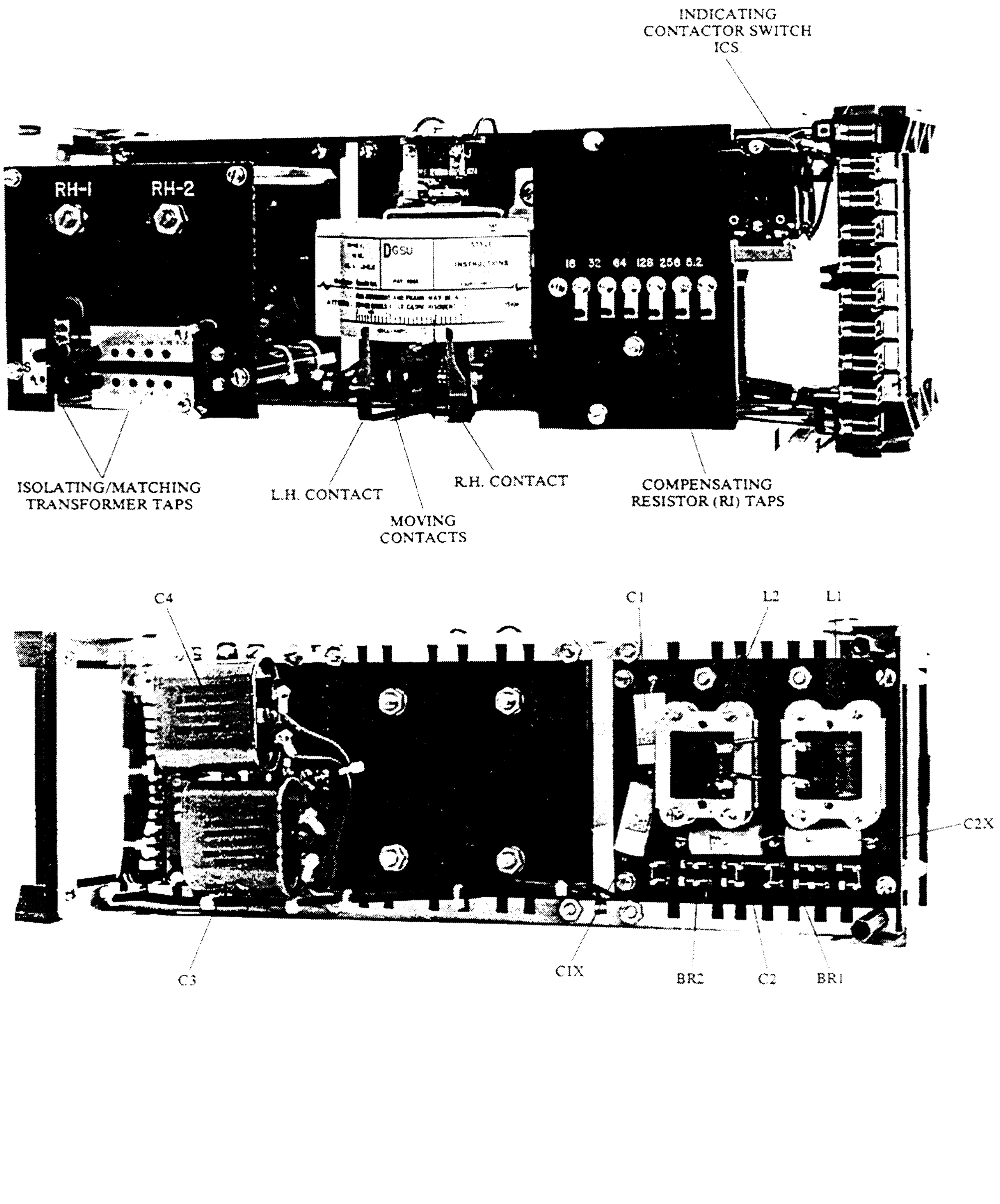


Figure 2 — Type DGSU Relay Chassis – Front and Back

BRIDGE RECTIFIERS AND THIRD HARMONIC PASS FILTER

The bridge rectifiers along with the capacitors (C_1, C_{1x}, C_2 and C_{2x}) and the inductors (L_1 and L_2) are mounted on a common sub panel which is accessible from the rear. The rheostats (RH-1 and RH-2) are mounted on another sub panel which is accessible from the front. Refer to Figures 1 and 2 for component locations. RH-1 and RH-2 are adjustments to provide a null balance for the D-3 element with balanced voltage inputs and eliminate slight mismatches.

ISOLATING/MATCHING TRANSFORMER

The isolating/matching transformer has a tapped primary winding and a multi-tapped secondary winding.

The primary and secondary taps are connected to the tap block in the relay. The primary taps are identified 1 and 2, the secondary has five coarse tap settings and five fine tap settings.

The step-up ratio from primary (input) to secondary (comparator voltage) is $S \times (C + F)$.

INDICATING CONTACTOR SWITCH (ICS)

The indicating contactor switch is a small dc operated clapper type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from outside the case by means of a push rod located at the bottom of the cover.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pickup of the switch.

RESISTOR TAPS

Non-inductive copper resistor taps of 16, 32, 64, 128, 256, 512 ohms nominal at 25°C are available to match the equivalent resistance of the isolating/matching transformer in the other side of the comparator circuit. This tapped resistor has shorting links for shorting out the sections of resistance which are not required.

EXTERNAL TRANSFORMER ASSEMBLY

When required a separate transformer assembly can be supplied for use with the generator terminal VTs. This assembly consists of three auxiliary VTs, 120-120 volts, mounted, and wired to a terminal strip, on a steel plate.

The complete assembly is designed for mounting on the rear of the type DGSH or DGSU relay case. (see fig. 13).

CHARACTERISTICS

RATIO ADJUSTMENT

The overall ratio is adjustable by means of primary and secondary taps on the Isolating and Matching Transformer.

The primary taps are identified S = 1, S = 2.

There are two sets of secondary taps:

Coarse taps "C" identified 1, 1.18, 1.36, 1.54, 1.72, 1.90.

Fine taps "F" identified 0,0.03, 0.06, 0.09, 0.12, 0.15.

This gives an overall ratio between 1 and 4.1 in 3% (or smaller) steps.

MAXIMUM INPUT LEVELS.

Terminal	Tap S	Taps C+F	Two Minute Rating (Volts, Fundamental)	Continuous Rating (Volts, Fundamental)
6 & 7	—	—	280	140
4 & 5	1	1	280	140
4 & 5	1	2.05	140	70
4 & 5	2	1	140	70
4 & 5	2	2.05	140	70

SENSITIVITY

See Figures 6 and 7 for typical DGSH relay characteristics at room temperature.

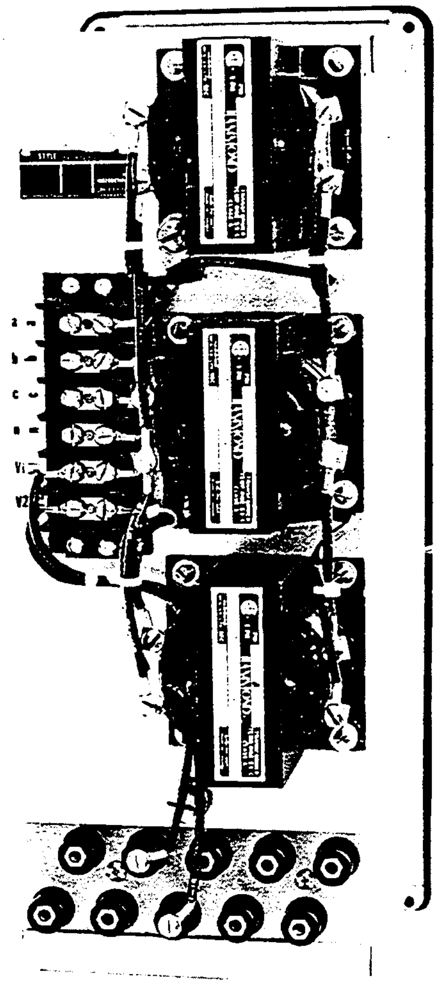
At −20°C, the single input voltage required to close the contacts is about 0.1 to 0.2 volts higher than values indicated by Figures 6 and 7.

At +50°C, the single input voltage required is about 0.1 to 0.2 volts lower than the curve values.

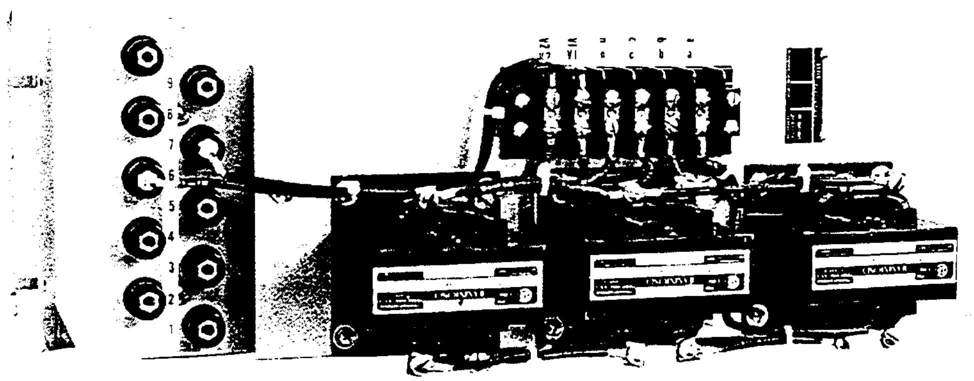
BALANCE:

With the isolating/matching transformer set for a 1:1 ratio (S = 1, C = 1, F = 0), identical inputs and with RH-1 set at its mid point and RH-2 adjusted for a balance the maximum deflections are as follow: (At other than 1:1 ratio, RH-1 or RH-2 must be readjusted).

Input Voltage	Input Frequency	Maximum Deflection From Balance (RH-1 at mid point, RH-2 adjusted for balance)
0. to 10 V	third harmonic	± 0.075 ma
10 to 15 V	third harmonic	± 0.15 ma
10 V	50 to 190 hz	± 0.075 ma



Type DGSH Relay



Type DGSU Relay

Figure 3 — External Transformer Assembly Mounted on Back of Relay Case

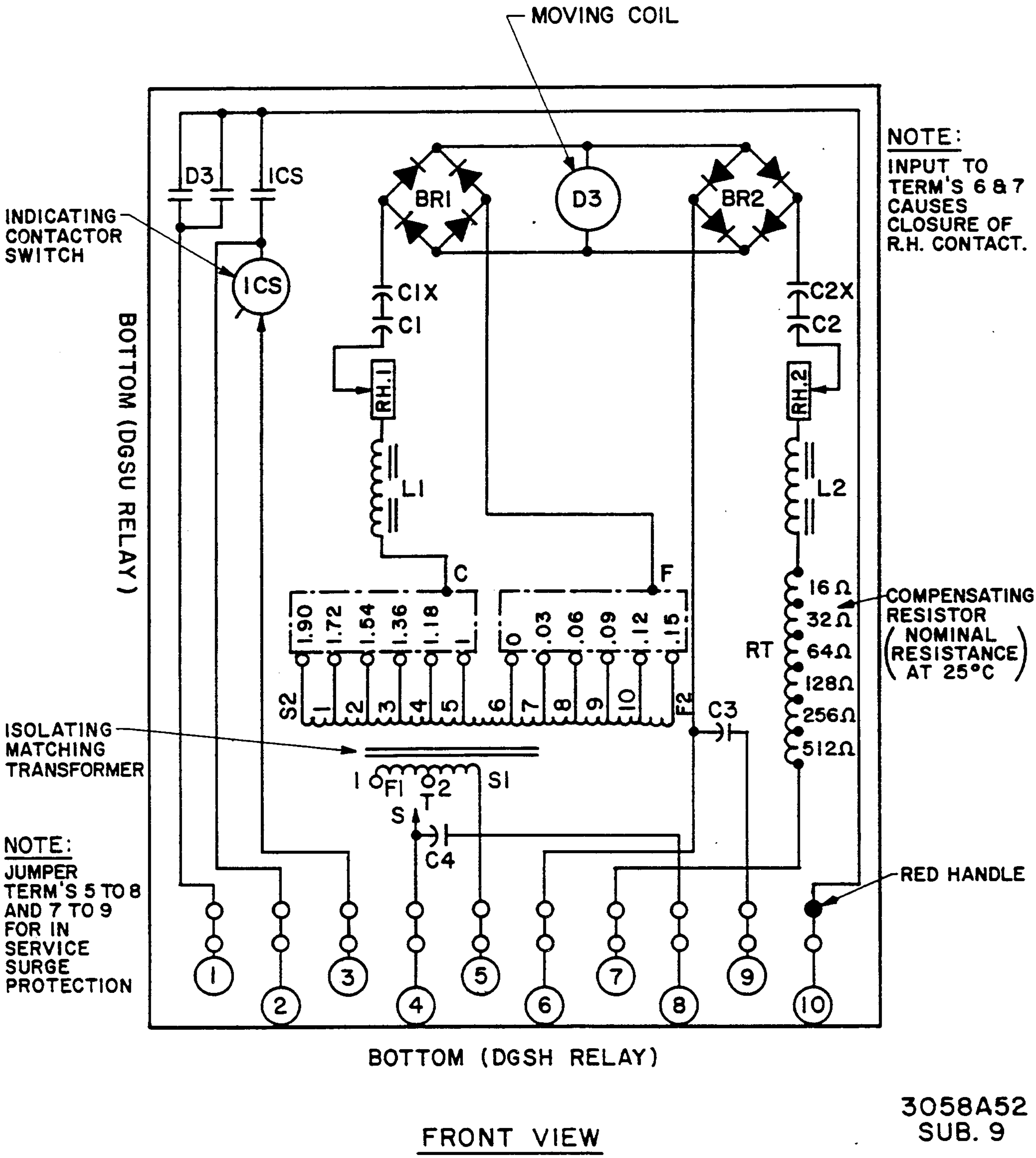
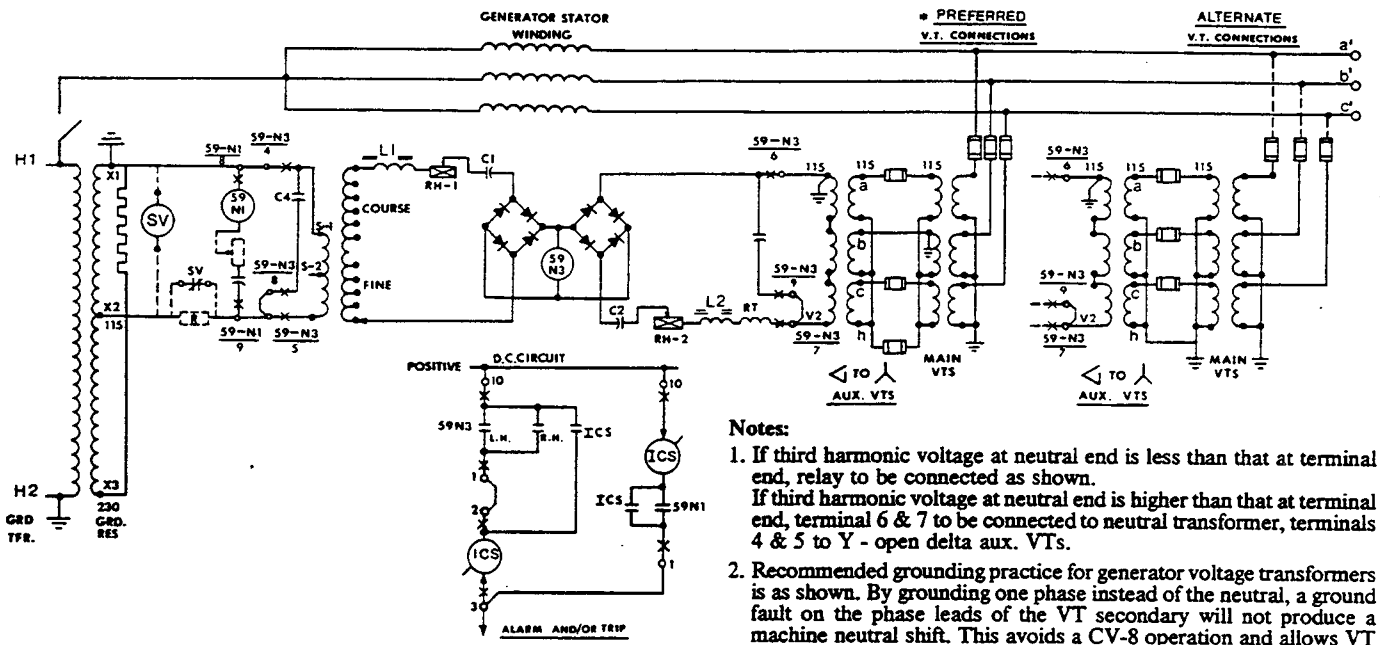


Figure 4 — Internal Schematic of Types DGSH/DGSU Relays in Types FT-31/FTU-41D6 Cases



Notes:

1. If third harmonic voltage at neutral end is less than that at terminal end, relay to be connected as shown.
   If third harmonic voltage at neutral end is higher than that at terminal end, terminal 6 & 7 to be connected to neutral transformer, terminals 4 & 5 to Y - open delta aux. VTs.
2. Recommended grounding practice for generator voltage transformers is as shown. By grounding one phase instead of the neutral, a ground fault on the phase leads of the VT secondary will not produce a machine neutral shift. This avoids a CV-8 operation and allows VT fuse operation. Ref. Power Apparatus and Systems, Jan./Feb. 1972, p. 24.
3. If **both** the CV-8 and DGSH relays are used for generator shutdown, (as opposed to alarm or timed shutdown), then the SV relay and accompanying resistor "R" can be omitted.

571 B 931 sub. 13

Device Designations:
59-N1 Over Voltage Relay Type CV-8 (See DB 41-200)
59-N3 Third Harmonic Voltage Comparator, Type DGSH
★ SV Voltage Relays (See DB 41-765).

Figure 5 — External Schematic of Type DGSH/DGSU Relay & Types CV-8 & SV Relays for Complete Generator Stator Ground Protection

BURDEN

COMPARATOR CIRCUIT - (inputs to terminals 4 & 5, 6 & 7).

The following burdens apply with the isolating/matching transformer set for a 1:1 ratio (S = 1, C = 1, F = 0).

Terminals	Frequency	Voltage	Impedance
4 & 5	Third Harmonic	10	1 to 2K*
4 & 5	Fundamental	10	10K
6 & 7	Third Harmonic	10	1 to 2K*
6 & 7	Fundamental	10	30K

*Third Harmonic Impedance is dependent upon setting of potentiometers RH-1 and RH-2.

ISOLATING/MATCHING TRANSFORMER

Primary	Start to Tap S = 2	42.5 ohms
	Start to Tap S = 1	87 ohms
Secondary	C = 1 to F = 0	120 ohms
	C = 1.9 to F = 0.15	232 ohms

An approximation of secondary values other than those above may be made by using the following formula:

$$R = 120\,(C + F)$$

INDICATOR CONTACTOR SWITCH — (ICS)

0.2 amp tap 6.5 ohms dc resistance
2.0 amp tap 0.15 ohms dc resistance

RESISTOR TAPS

Taps are brought out at 16, 32, 64, 128, 256 and 512 ohms nominal at 25°C.

SETTINGS

The relay taps S, C, and F are used to increase the lower of V_N/N_N or $3V_{OT}/N_T$. Assuming the lower quantity to be V_N/N_N, it is multiplied by S (C + F).

As indicated by Figures 6 and 7, RH-1 provides some sensitivity adjustment. Maximum sensitivity is with RH-1 at zero resistance. Minimum sensitivity is with RH-1 at maximum resistance.

GENERAL INFORMATION

For stator ground faults near the generator neutral the third harmonic voltage distribution will cause the DGSH contacts to close to the right, and for faults near the generator terminals the third harmonic voltage distribution tends to cause the left contacts to close.

The fundamental frequency primary voltage measured at the neutral will be one third the voltage measured at the terminal end of the generator, so that the direction of torque due to fundamental frequency is independent of fault location.

If S(C+F) multiplied by N_T (the terminal end VT ratio) is less than 3 times N_N (the neutral end VT ratio), the fundamental frequency voltage during a stator ground fault will tend to close the right hand contact. If S(C+F) N_T exceeds $3N_N$ a tendency to close the left contact will result.

For ground faults near the generator neutral the fundamental frequency voltage will be close to zero (the reason for using the DGSH) and this coupled with the fundamental frequency attenuation provided by the third harmonic tuned circuits means the third harmonic torque will predominate and DGSH contacts will close to the right.

For ground faults approximately midway between the neutral and the generator terminals there will be a 3rd Harmonic balance condition so that the fundamental frequency torque may produce operation. However it is not recommended that the fundamental frequency tuned relay (CV-8) be omitted.

For ground faults near the generator terminals, the third harmonic voltages will produce torque to the left. The fundamental frequency torque direction is unchanged but the magnitude will be substantially increased. Even though 3rd Harmonic is 10 or more times as effective as fundamental, the fundamental may cause the RIGHT contacts to close for faults near the generator terminals.

R_O, the ratio of third harmonic $3V_{OT}$ to V_N (generator terminal to generator neutral third harmonic voltages during no fault conditions), will probably not be constant over the operating range of the generator. It is therefore desirable to balance the DGSH relay at one operating condition, and set the relay contacts to accommodate the variation in R_O over the full range of generator output.

In view of the fact that the primary function of the DGSH relay is to detect stator ground faults near the neutral, and that a CV-8 relay is also used, it is reasonable to disable the left hand contact by setting it beyond the reach of the moving contact. It will then be possible to use an S(C+F) setting chosen so that all non fault moving contact departures from balance will be to the LEFT.

In this manner, a RIGHT hand contact setting can be used which is lower than the setting required if normal operation of the generator could cause moving contact excursions to both sides of centre.

This setting can be achieved using the following detailed procedure:

1. Obtain a series of readings for the third harmonic voltages available at the neutral and terminal ends of the generator as measured at terminals 4, 5 and 6, 7 of the DGSH relay.
2. Set S(C+F) to be equal to the highest value of the ratio V_{67}/V_{45}
3. Select copper resistor RT taps to balance copper resistance in both input circuits. Refer to table 1 showing RT taps corresponding to S(C+F) taps.
4. Set Right Hand stationary contact to 0.25 ma.
5. Set RH-2 to a value which ensures **Right Hand** contacts close when V_{45} is zero and V_{67} is equal to 3 times the lowest expected value of generated third harmonic volts per phase.
6. Apply V_{45} and V_{67} in the ratio for which S(C+F) settings were selected and set RH-1 to balance the DGSH relay.
7. With normal inservice connections, the DGSH relay moving contact should be observed as the generator is operated through the full range of third harmonic voltage. The right hand stationary contact should be set 0.15 ma or more beyond the largest moving contact deflection to the right. Similarly the left hand stationary contact should be set 0.15 ma or more beyond the largest moving contact deflection to the left.

If third harmonic data are available only at one value of generator output (e.g. full load) an alternate, but less sensitive, setting can be used. In this procedure minimum sensitivity setting is used on the relay (RH-1 set at maximum resistance), and the RIGHT hand contacts are set to 0.75 ma. The relay taps are then set on the basis of the third harmonic secondary voltage ratio at this generator output. The relay is installed and RH-2 adjusted for relay balance.

Since the ratio of third harmonic $3V_{OT}$ to V_N probably will not be constant over the complete range of machine loading, the DGSH relay when set in this manner may close its left hand contact at machine loads different from that at which the relay was balanced. Therefore, to prevent false tripping or alarm, the left hand contact of the relay should be disarmed by setting it beyond maximum travel.

In all cases the tapped resistor RT in the relay should be set to match the isolating/matching transformer equivalent resistance for the S, C and F values chosen. These values are listed in table 1.

After settings for right and left contacts have been established; a check for adequate damping can be made by opening all Flexitest switches to de-energize the relay and seeing that the moving contact will not swing to the right contact when released from the left contact position.

SETTING EXAMPLES:

1. Third harmonic voltage data available for full range of generator outputs. Relays balanced for highest value of ratio V_{67}/V_{45}. (As per detailed setting procedure).

In this example a smooth variation in third harmonic voltage is observed as generator load varies.

1. **Machine Data**

Load (MW)	V_{45} (Neutral End Volts)	V_{67} (Terminal End Volts)	V_{67}/V_{45}
0	0.89	1.1	1.24
25	1.05	1.4	1.33
50	1.45	1.75	1.21
75	1.69	2.4	1.42
100	2.15	2.72	1.27
125	2.5	3.2	1.28
150	2.77	3.6	1.3

N_N (generator neutral end voltage transformer ratio) = 87.5.

N_T (generator terminal end voltage transformer ratio) = 200.

Choose S(C+F) = V_{67}/V_{45} Max. = 1.42

2. Set S = 1; C = 1.36; F = 0.06
3. Set RT = 32 + 64 + 256 = 352 ohms
4. Set RIGHT hand stationary contact to 0.25 ma.
5. Set RH-2 to value which ensures RIGHT hand contacts close when V_{45} is zero and V_{67} is equal to 3 times the lowest expected value of generated third harmonic volts per phase. This will probably require the use of an A.C. signal generator or equivalent. Failing this RH-2 can be set at the minimum, i.e. maximum sensitivity.
6. With the relay installed and the generator operating at 75 MW (i.e. the value of the ratio V_{67}/V_{45} to which S(C+F) of the relay was set) adjust RH-1 to balance the relay.
7. With normal inservice connections, the DGSH relay moving contact should be observed as the generator is operated through the full range of third harmonic voltage. The right hand stationary contact should be set 0.15 ma. or more beyond the largest moving contact deflection to the right. Similarly the left hand stationary contact should be set 0.15 ma. or more beyond the largest contact deflection to the left.

   Figure 8 shows a plot of V_{67} versus V_{45} X S(C+F) for minimum sensitivity setting of the DGSH relay. The minimum sensitivity plot was used as this will produce the most pessimistic results when estimating relay reach.

   The maximum excursion to the right is zero, therefore the maximum sensitivity setting would be 0.15 ma. Similarly the left hand contact could be set at 0.15 ma. above the maximum excursion of 0.15 ma. for a setting of about 0.30 ma.

2. Third harmonic data available only at one value of generator output.

Given:

1. V_{67} = 5.42; V_{45} = 4.53; N_N = 60; N_T = 150
   Choose S(C+F) = V_{67}/V_{45} = 5.42/4.53 = 1.2
2. Set S = 1; C = 1.18; F = 0.3
3. Set RT = 16 + 256 = 272 ohms
4. Set RH-1 to maximum, i.e. minimum sensitivity
5. Set RIGHT hand stationary contacts to 0.75 ma.
6. With relay installed adjust RH-2 to obtain a balance.
7. Set LEFT hand beyond maximum travel of moving contact.

With this setting the relay sensitivity will be approximately as shown in Figure 6. That is a difference of 2.7 volts will produce a minimum deflection of 0.75 ma.

3. Third Harmonic data are available for several generator loading conditions. (Erratic variation in third harmonic voltages).

Given:

N_N = 60 N_T = 150

Operating Conditions	V_{45}	V_{67}	V_{67}/V_{45}	1.2 (V_{45})	1.4 (V_{45})	1.6 (V_{45})	1.92 (V_{45})
1	2.1	1.6	0.76	2.52	2.94	3.36	4.03
2	1.0	0.91	0.91	1.2	1.4	1.6	1.92
3	0.49	0.92	1.88	.59	0.69	.78	0.94
4	1.2	2.3	1.92	1.44	1.68	1.92	2.30
5	2.9	4.6	1.59	3.48	4.06	4.64	5.57
6	4.53	5.42	1.20	5.44	6.34	7.25	8.70
7	3.57	5.0	1.4	4.28	5.0	5.71	6.85

Figures 9 and 10 show the effect of balancing at operating conditions Numbers 6, 7, 5 or 4 using S(C+F) values of 1.2, 1.4, 1.6 and 1.92 respectively. Balancing for condition Number 4 results in contact movement only to the left for all other operating conditions. Balancing for condition Number 6 results in contact motion in both directions as generator output is varied.

RELAY COVERAGE:

Relay coverage for stator ground faults can be estimated as follows:

1. Estimate V_3, generator third harmonic voltage per phase, from;

   *$V_3 = (V_{OT} + V_N \underline{|45°})$

   where:

   V_{OT} = generator terminal end third harmonic voltage per phase.

   V_N = generator neutral end third harmonic voltage.

2. Calculate $V_{3\,(SEC)} = \dfrac{V_3}{N_T(\text{terminal end V.T. ratio})}$

★ 3. From fig. 6 (relay minimum sensitivity), or fig. 7 (relay maximum sensitivity) determine V_{67} volts at V_{45} S(C+F) = 0, for contact setting used. This will be the value $V_{(DIFF)}$ used in step 4.

4. From fig. 11 estimate M, relay coverage, in per unit distance of generator stator winding, measured from generator neutral using value $V_{3\,(SEC)}$ calculated in step 1, $V_{(DIFF)}$ from step 3, and the appropriate R_O curve.

   *The third harmonic generated voltage per phase is the phasor sum of 1/3 the voltage measured at the terminal end plus voltage measured at the neutral. Based on a value of R_G, the neutral grounding resistor, equal to the total capacitive reactance to ground, the net neutral impedance will have an angle in the order of 45 degrees at the third harmonic. Thus, the third harmonic voltage per phase is somewhat less than estimated by straight addition. For a ground fault at the neutral, the available operating voltage on the DGSH relay is 3 times the generated third harmonic volts per phase.

   The following example should serve to illustrate the usage of the foregoing procedure. The relay coverage will be estimated using "Setting Example 1".

1. $V_3 = (V_{OT} + V_N \underline{|45°})$

   $V_{OT} = V_{67}/3 \times N_T$

   $V_N = V_{45} \times N_N$

   We will estimate DGSH relay coverage at no load.

   Then: $V_3 = (1.1/3 \times 200) + (0.89 \times 87.5)\ \underline{|45°} = 140$

2. $V_{3(SEC)} = V_3/N_T$

   $= 140/200$

   $= 0.70$ volt

3. Using fig. 6 (minimum sensitivity), with a **right hand contact** setting of 0.15 ma, then the value of V_{67} with V_{45} S(C+F) = O is estimated to be about 1.2 volts ($V_{(DIFF)}$).

4. $R_O = V_{67}/V_{45} \times N_T/N_N$

   $= 1.1/0.89 \times 200/87.5$

   $= 2.83$

   From fig. 11 using R_O= 3.5 (closest to 2.83) $V_{3\,(SEC)}$ = 0.70 volt, and $V_{(DIFF)}$ = 1.2 volts, we can estimate relay coverage to be about 19% at no load.

   This result is conservative for the following reasons:

   (a) $V_{(DIFF)}$ was estimated from the minimum sensitivity characteristics curve of the DGSH relay.

   (b) The R_O = 3.5 curve was used to estimate relay coverage. Actual calculated R_O is 2.83.

Relay coverage can be determined for any of the other tabulated values of generator loading in a similar manner.

Likewise coverage can be determined for the relay set as per Examples 2, and 3 in a similar manner.

An inspection of figure 11 clearly demonstrates the effect of the ratio R_O on relay reach. As R_O increases, M (relay reach) decreases. However, in the region close to the stator neutral (M = 0 to 10%), the ratio of R_O has minimal effect on the relay reach.

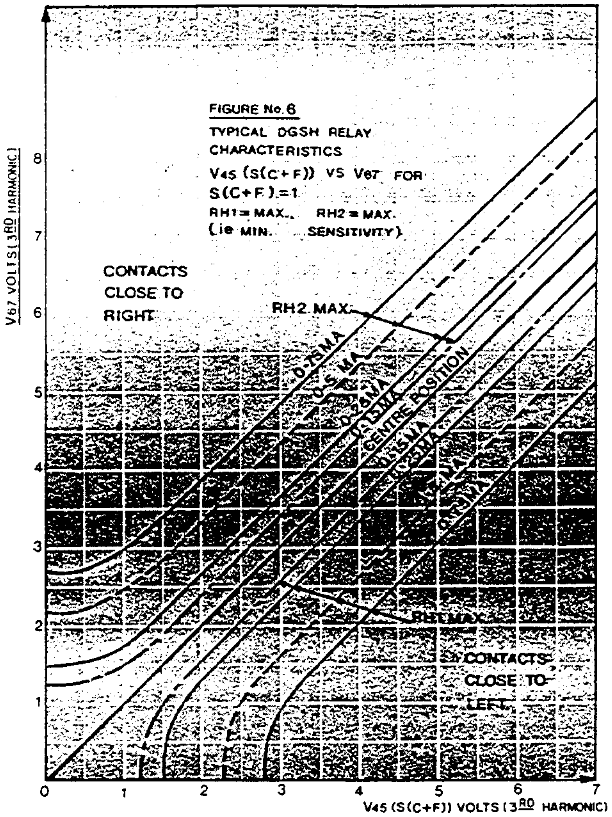


Figure 6

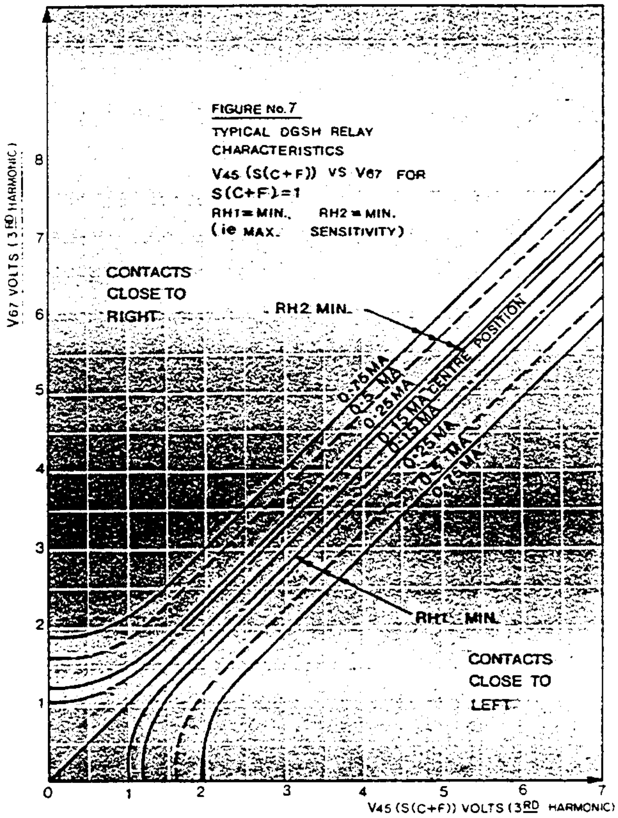


Figure 7

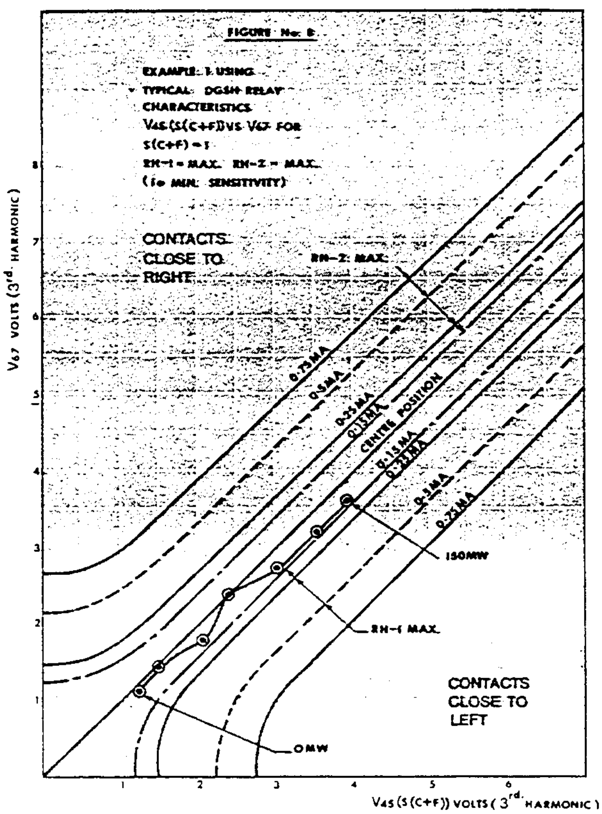


Figure 8

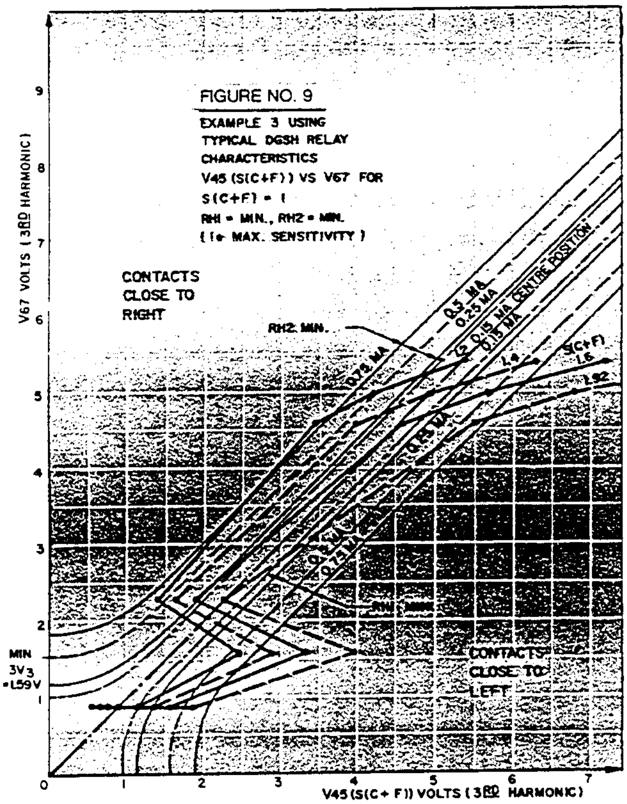


Figure 9

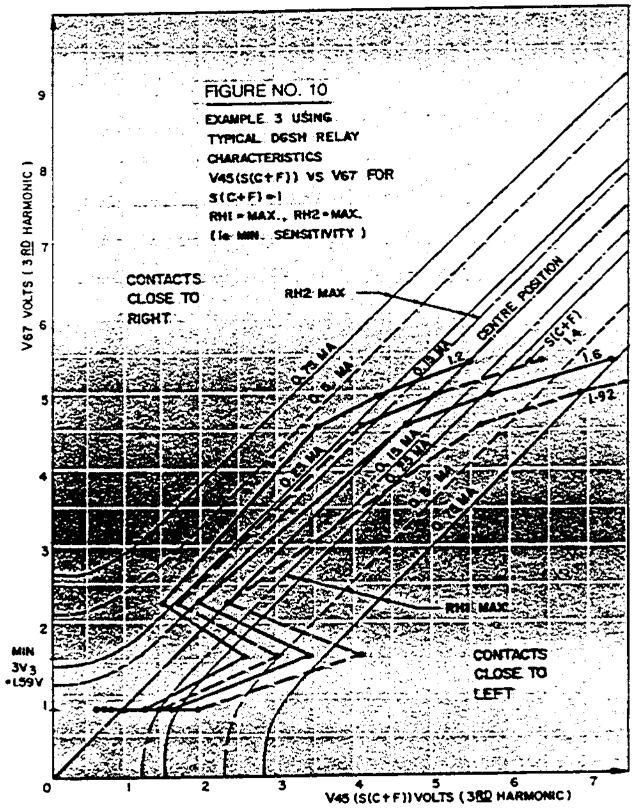


Figure 10

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the DGSH relay vertically by means of the two mounting studs for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Mount the DGSU relay horizontally by means of the four mounting slots in the flanges. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

If the relays are to be transported on rack panels the use of shipping braces is recommended.

ACCEPTANCE

The following tests should be performed prior to commissioning the relay to insure that it is in good operating condition and that no damage has occurred while in transit.

Mechanical — A visual inspection of the relay to make sure that there are no loose connections, and that the D-3 element moves freely.

Electrical — the relay may be checked electrically by performing the folowing tests.

Note that surge capacitors C3 & C4 are not connected during testing. When the relay is connected as in Fig. 5 open FT switch blades 8 and 9 to disconnect C3 and C4.

A. *Third Harmonic Unit*
   i) Balance — check per part C4 and 5 of the Calibration and Adjustment section of this leaflet applying third harmonic voltages to both inputs simultaneously (4 & 5) (6 & 7).
   ii) Sensitivity — check per part D1 and 2 of the Calibration and Adjustment section of this leaflet.

B. *Indicating Contactor Switch — (ICS)*
   Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

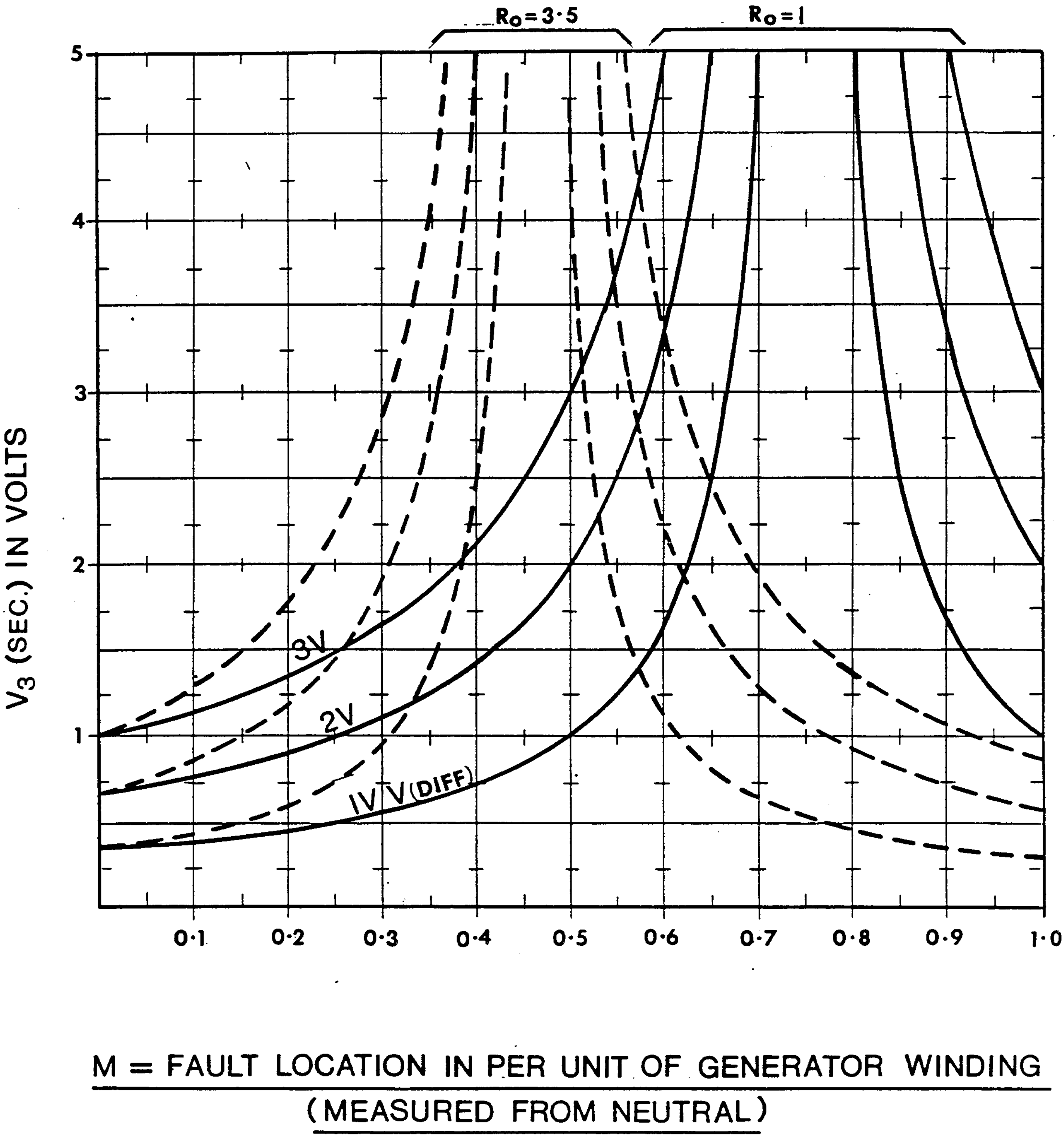

Ro = 3·5
Ro = 1
5
4
3
2
1
V3 (SEC.) IN VOLTS
3V
2V
1V
V(DIFF)
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
M = FAULT LOCATION IN PER UNIT OF GENERATOR WINDING
(MEASURED FROM NEUTRAL)

Figure 11

CALIBRATION AND ADJUSTMENT

The proper adjustments to insure correct operation of the relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

NOTE: The following sections refer to reactor L1 and L2 adjustments. The reactors have been factory set and sealed and are not readily re-adjustable. Calibration should proceed omitting the adjustments to L1 and L2.

A. *Adjustment of the Moving Element*

If the moving element should be removed, the bearing end-play should be checked when replacing it.

This should be from .020 inch to .025 inch, and can be measured by inserting a feeler gauge between the upper bearing screw and the shoulder on the moving element shaft.

The core and moving coil assembly should not be removed from the frame casting of the D-3 element unless a keeper having the same radius on the core is placed on the core in such manner as to bridge the iron pole pieces as the core is withdrawn from the bore of the casting. It is necessary also to insert spacers in the air gap so that the core will remain approximately centered when the mounting screws are removed, to prevent damaging the coil winding when sliding the assembly out of the casting.

B. *Series Resonant Tuned Circuit, Third Harmonic Adjustment*

1. i) Set potentiometers RH-1 and RH-2 to 500 ohms.
   ii) Set the isolating/matching transformer taps for a 1:1 ratio as follows: S = 1, C = 1, F = 00 and resistor taps to 16 + 64 + 128 = 208 ohms.
2. i) Connect the test circuit as shown in figure 12.
   ii) Trigger the scope on line and adjust the voltage source frequency to obtain a stable pattern (i.e. exactly 3rd harmonic of the line frequency).
3. Adjust reactors L_1 and L_2 until V and I are in phase ± 50 microseconds with 10V third harmonic applied.
4. Lock both reactors.
5. It should be noted that in order to provide equal outputs from each of comparator circuit over the frequency range fundamental to third harmonic + 10 hz it is necessary to match the Q's of the two tuned circuits. This is accomplished by matching the effective series capacitance of $C_1 + C_{1X}$ and $C_2 + C_{2X}$ to within approximately 1%. In some units a trim capacitor is used to provide this equalization.

C. *Balancing*

1. Apply 10V ≤ third harmonic to both inputs simultaneously (4 & 5) (6 & 7).
2. Adjust potentiometer RH-2 until the D-3 element deflection is zero and tighten the locking nut.
3. Connect the scope to the output of one of the bridges (i.e. across the D-3 element coil).
   Carefully adjust L2 until the output voltage is zero as indicated by a flat (d-c) trace on the oscilloscope.
4. Vary the input voltage from 0 to 10V at third harmonic. The D-3 element must not deflect more than ± 0.075 ma as read on the D-3 element scale.
5. Slowly vary the input frequency from fundamental to third harmonic + 10 hz at 10V. The D-3 element must not deflect more than ± 0.075 ma as read on the D-3 element scale.

D. *Sensitivity Check*

1. Apply 2V at third harmonic to terminals 4 & 5 and check that the D-3 element deflection is 0.3 ma or more at RH-1 max. and 0.5 ma or more at RH-1 minimum.
2. Repeat above for terminals 6 and 7 except use RH-2.

ROUTINE MAINTENANCE

The relays should be inspected periodically, at such time intervals as may be dictated by experience, to insure that the relays have retained their calibration and are in proper operating condition.

All contacts should be cleaned periodically. A contact burnisher S# 182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

GLOSSARY OF SYMBOLS

- M — Fault location in per unit of generator winding measured from the neutral.
- N_N — Neutral end voltage transformer turns ratio.
- N_T — Terminal end voltage transformer turns ratio.
- R_O — Ratio of 3 V_{OT}/V_N or $(V_{67} \times N_T)/V_{45} \times N_N)$ under non-fault conditions.
- V_3 — Generator third harmonic voltage per phase.
- V_N — Neutral end zero sequence voltage.
- V_{OT} — Terminal end zero sequence voltage per phase.
- V_{DIFF} — Voltage difference is secondary volts applied to the relay operating element.

  $(3\overline{V}_{OT}/\overline{N}_T - (\overline{V}_N \times S(C + F)/N_N)$

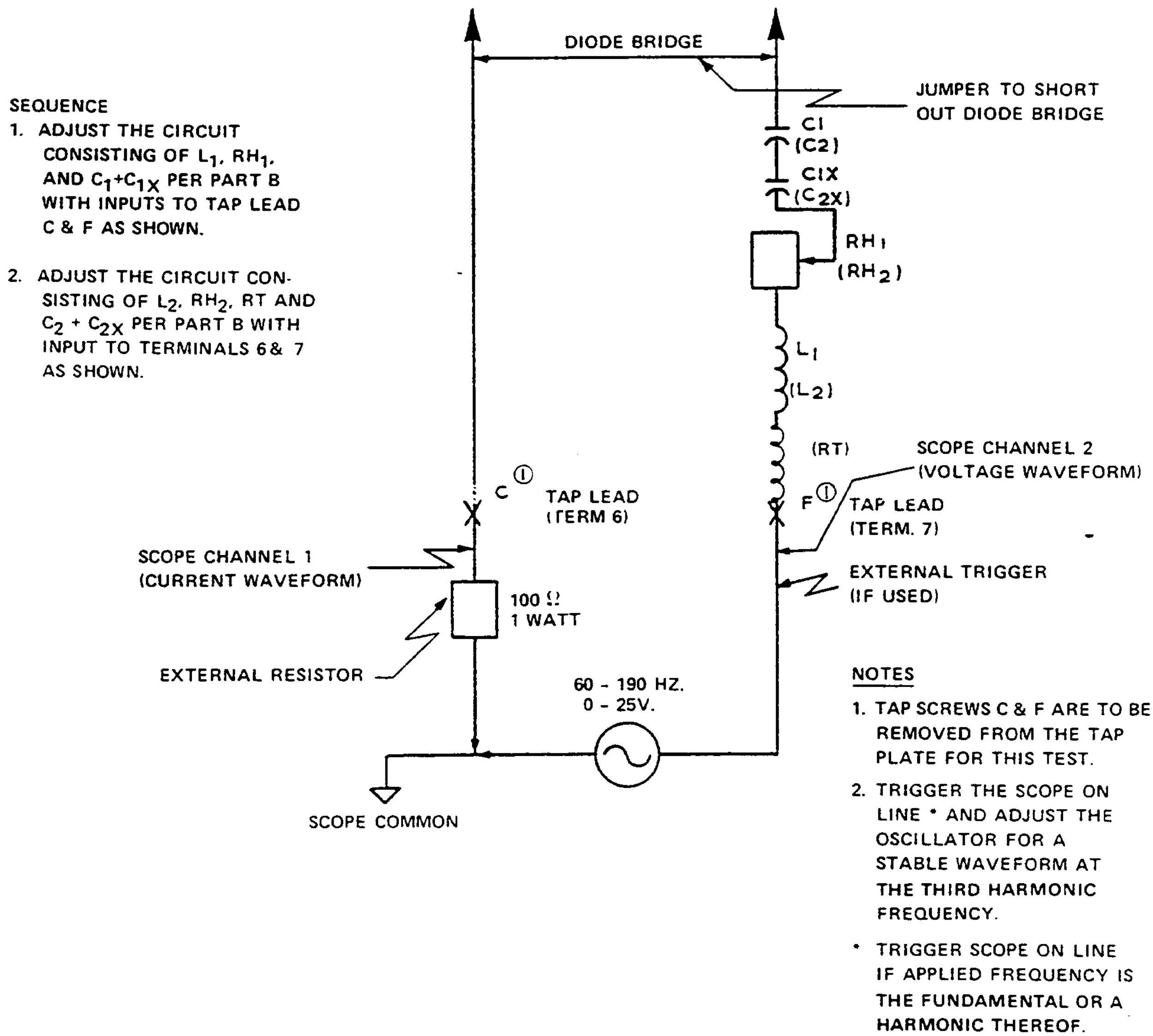


Figure 12 — Test Diagram for adjusting DGSH/DGSU Relay Harmonic Pass Filters.

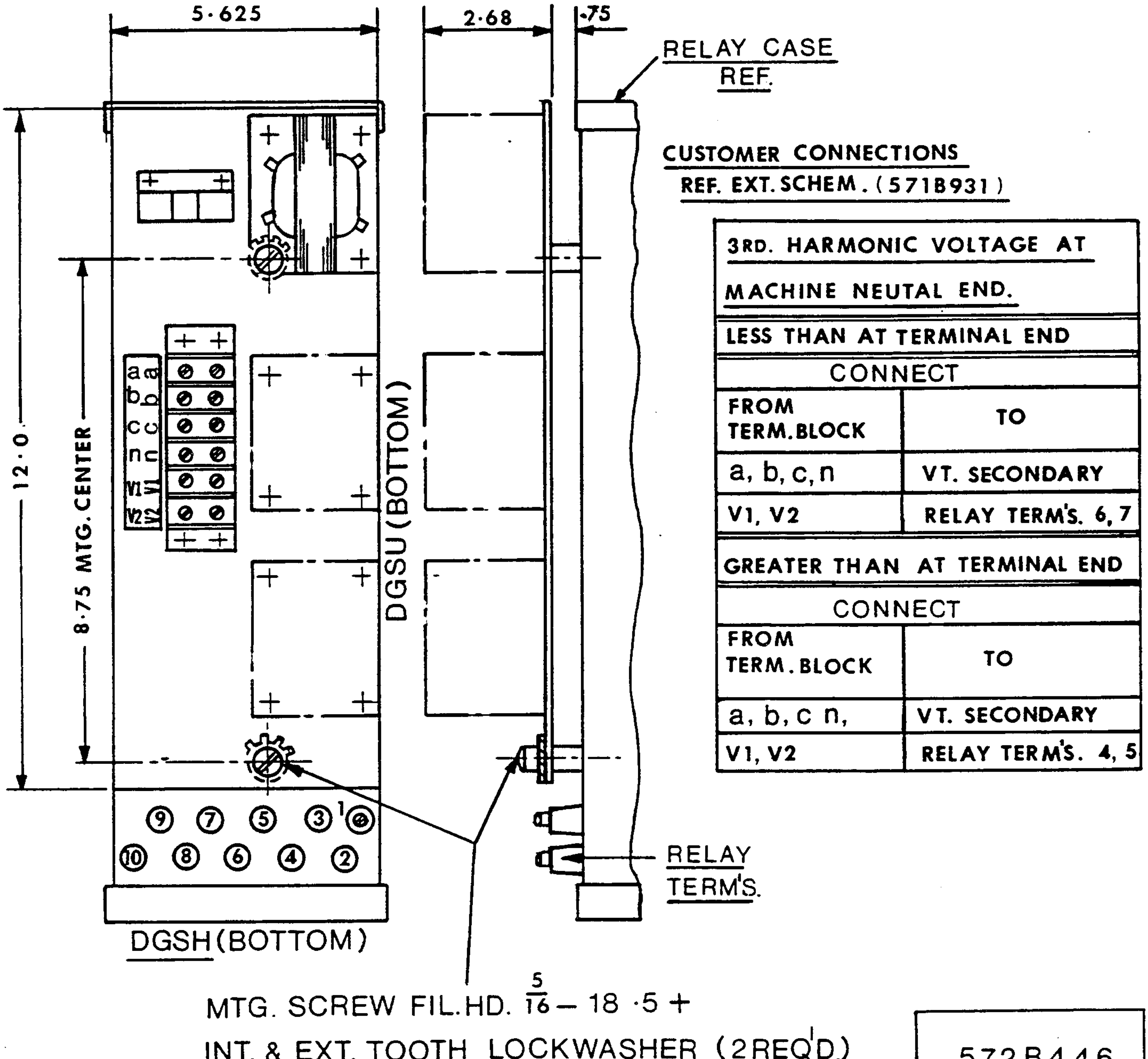
TABLE 1: RESISTOR TAP SELECTION TABLE

ISOLATING/MATCHING TRANSFORMER					COPPER RESISTOR (RT) TAPS						
Ratio 1:S (C+F)	S	C	F	Nom. Res. Ohms	Windings Used = X (Ohms) 16	32	64	128	256	512	Nom. Res. Ohms
.1:1	1	1	.00	207	X		X	X			208
1:1.03	1	1	.03	216	X		X	X			208
1:1.06	1	1	.06	225		X	X	X			224
1:1.09	1	1	.09	234	X	X	X	X			240
1:1.12	1	1	.12	243	X	X	X	X			240
1:1.15	1	1	.15	253					X		256
1:1.18	1	1.18	.00	263					X		256
1:1.21	1	1.18	.03	273	X				X		272
1:1.24	1	1.18	.06	283		X			X		288
1:1.27	1	1.18	.09	293		X			X		288
1:1.30	1	1.18	.12	303	X	X			X		304
1:1.33	1	1.18	.15	313			X		X		320
1:1.36	1	1.36	.00	324			X		X		320
1:1.39	1	1.36	.03	335	X		X		X		336
1:1.42	1	1.36	.06	346		X	X		X		352
1:1.45	1	1.36	.09	357		X	X		X		352
1:1.48	1	1.36	.12	368	X	X	X		X		368
1:1.51	1	1.36	.15	380				X	X		384
1:1.54	1	1.54	.00	391				X	X		384
1:1.57	1	1.54	.03	403	X			X	X		400
1:1.6	1	1.54	.06	415		X		X	X		416
1:1.63	1	1.54	.09	427	X	X		X	X		432
1:1.66	1	1.54	.12	439	X	X		X	X		432
1:1.69	1	1.54	.15	451			X	X	X		448
1:1.72	1	1.72	.00	464	X		X	X	X		464
1:1.75	1	1.72	.03	476		X	X	- X	X		480
1:1.78	1	1.72	.06	489	X	X	X	X	X		496
1:1.81	1	1.72	.09	502	X	X	X	X	X		496
1:1.84	1	1.72	.12	515						X	512
1:187	1	1.72	.15	529	X					X	528
1:1.9	1	1.90	.00	542		X				X	544
1:1.93	1	1.90	.03	556	X	X				X	560
1:1.96	1	1.90	.06	569			X			X	576

TABLE 1: RESISTOR TAP SELECTION TABLE (CONTINUED)

ISOLATING MATCHING TRANSFORMER					COPPER RESISTOR (RT) TAPS						
Ratio 1:S (C+F)	S	C	F	Nom. Res. (Ohms)	Windings Used = X (Ohms) 16	32	64	128	256	512	Nom. Res. (Ohms)
1:2	2	1	.00	290		X			X		288
1:2.06	2	1	.03	304	X	X			X		304
1:2.12	2	1	.06	318			X		X		320
1:2.18	2	1	.09	333	X		X		X		336
1:2.24	2	1	.12	348		X	X		X		352
1:2.3	2	1	.15	363	X	X	X		X		368
1:2.36	2	1.18	.00	378				X	X		384
1:2.42	2	1.18	.03	394	X			X	X		400
1:2.48	2	1.18	.06	410		X		X	X		416
1:2.54	2	1.18	.09	426	X	X		X	X		432
1:2.6	2	1.18	.12	443			X	X	X		448
1:2.66	2	1.18	.15	460	X		X	X	X		464
1:2.72	2	1.36	.00	478		X	X	X	X		480
1:2.78	2	1.36	.03	495	X	X	X	X	X		496
1:2.84	2	1.36	.06	513						X	512
1:2.90	2	1.36	.09	531						X	528
1:2.96	2	1.36	.12	550		X				X	544
1:3.02	2	1.36	.15	569			X			X	576
1:3.08	2	1.54	.00	588	X		X			X	592
1:3.14	2	1.54	.03	607		X	X			X	608
1:3.2	2	1.54	.06	627	X	X	X			X	624
1:3.26	2	1.54	.09	647				X		X	640
1:3.32	2	1.54	.12	668	X	X		X		X	672
1:3.38	2	1.54	.15	709			X	X		X	688
1:3.44	2	1.72	.00	709			X	X		X	704
1:3.5	2	1.72	.03	731		X	X	X		X	736
1:3.56	2	1.72	.06	752	X	X	X	X		X	752
1:3.62	2	1.72	.09	774					X	X	768
1:3.68	2	1.72	.12	796		X			X	X	800
1:3.74	2	1.72	.15	819	X	X			X	X	816
1:3.8	2	1.90	.00	842	X		X		X	X	848
1:3.86	2	1.90	.03	865		X	X		X	X	864
1:3.92	2	1.90	.06	888	X	X	X		X	X	880
1:3.98	2	1.90	.09	912	X			X	X	X	912
1:4.04	2	1.90	.12	936		X		X	X	X	928
1:4.1	2	1.90	.15	960			X	X	X	X	960

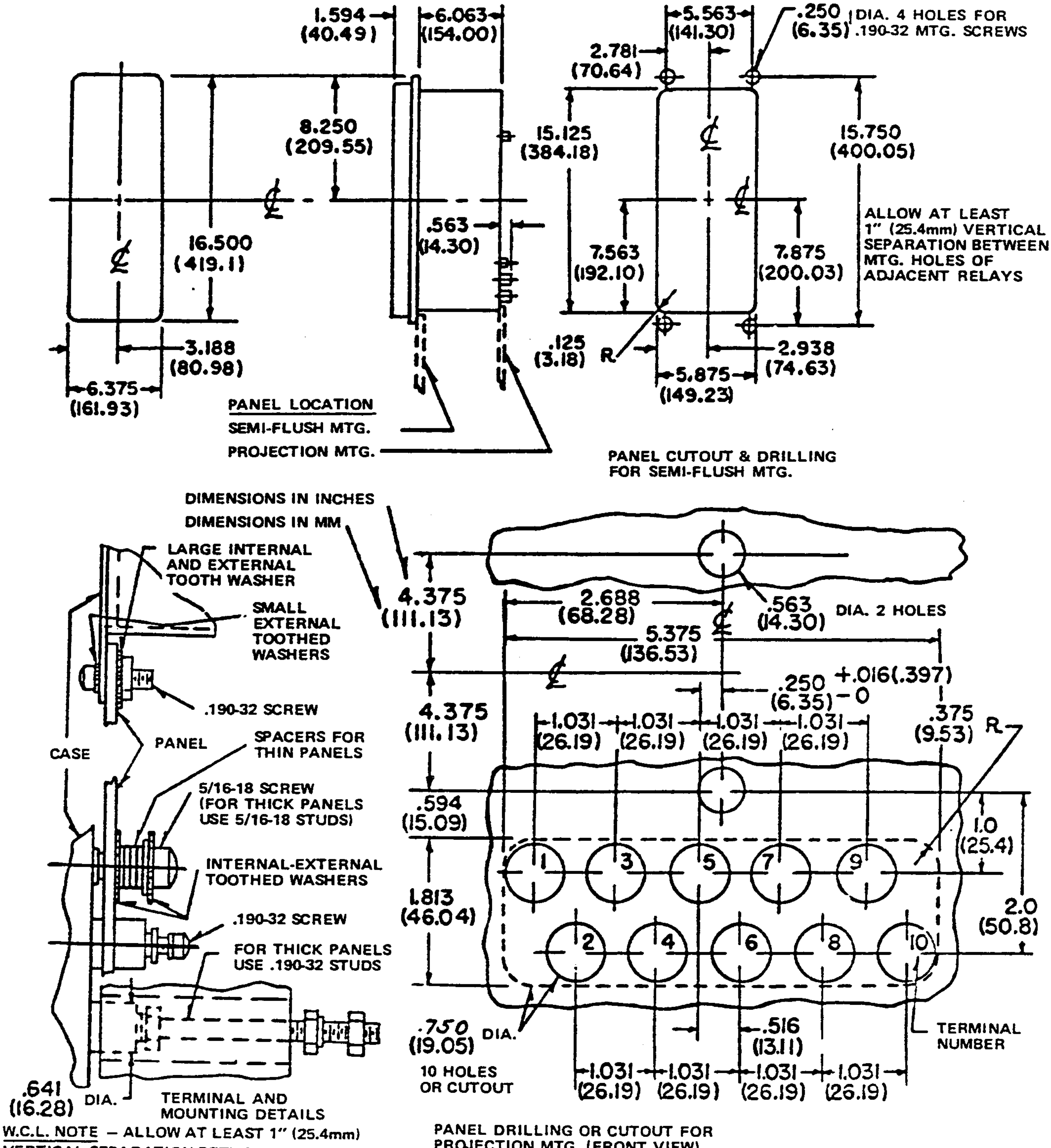
NOTE: DGSH IS MOUNTED VERTICAL (AS SHOWN)
DGSU IS MOUNTED HORIZONTAL
(4 RACK UNITS.)



3RD. HARMONIC VOLTAGE AT MACHINE NEUTAL END.	
LESS THAN AT TERMINAL END	
CONNECT	
FROM TERM. BLOCK	TO
a, b, c, n	VT. SECONDARY
V1, V2	RELAY TERM'S. 6, 7
GREATER THAN AT TERMINAL END	
CONNECT	
FROM TERM. BLOCK	TO
a, b, c n,	VT. SECONDARY
V1, V2	RELAY TERM'S. 4, 5

572B446
sub 2

Figure 13 — External Transformer Assembly — Outline



W.C.L. NOTE – ALLOW AT LEAST 1" (25.4mm) VERTICAL SEPARATION BETWEEN MTG. HOLES OF ADJACENT RELAYS

Figure 14 — Outline and Drilling for Relay Case Type FT-31

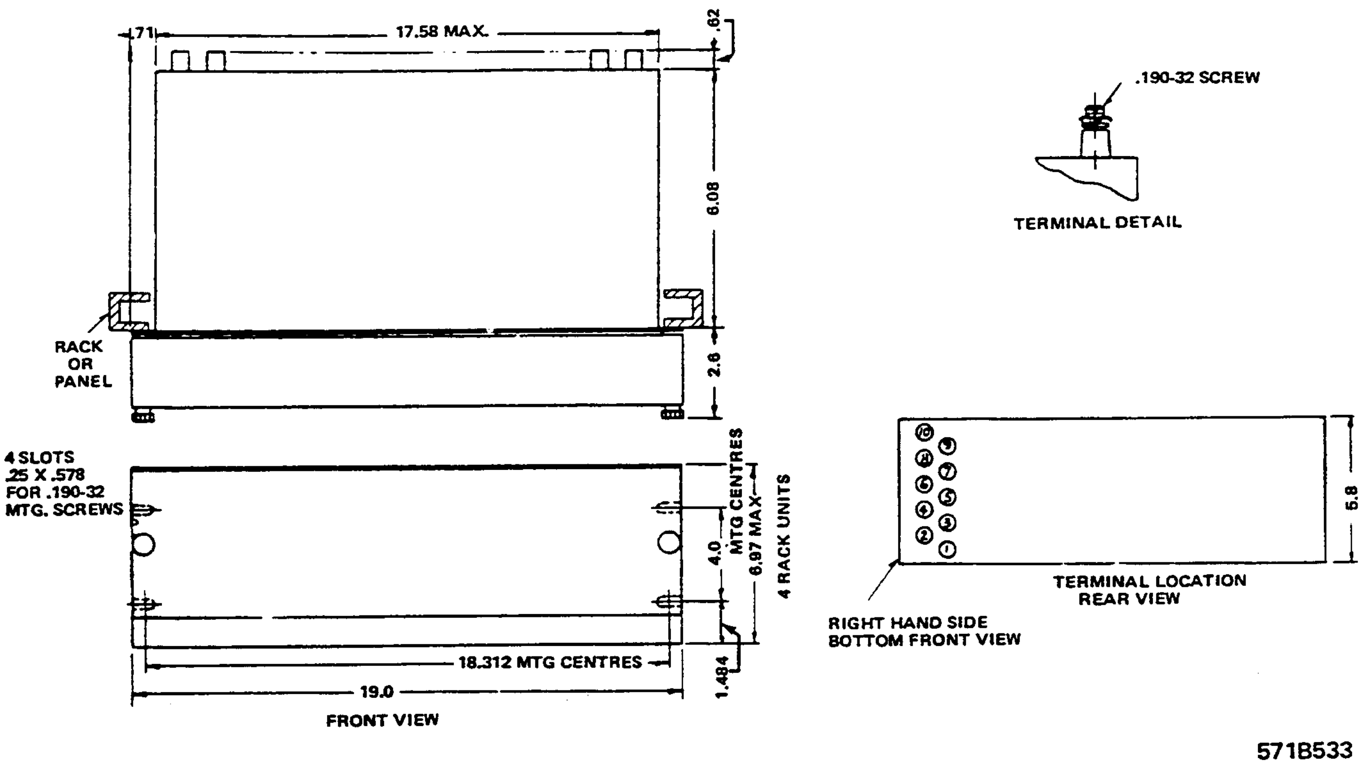


Figure 15 — Outline Drawing for FTU-41D6 Case (4RU)

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