ABB Power T&D Company Inc.
Relay Division
Coral Springs, FL 3365

Type KRQ Directional Overcurrent Negative Sequence Relay For Ground Protection

CAUTION

Before putting the relay into service, remove blocking from all the moving parts. Inspect the relay and operate all elements by hand to be sure no damage has occurred during shipment. Also see caution note under "SETTINGS".

APPLICATION

The type KRQ relay is a high-speed directional overcurrent ground relay in which the directional unit operates on negative sequence current and voltage. and the overcurrent unit operates on residual current. The negative sequence current and voltage are obtained by means of self-contained negative current and voltage filters.

The relay is intended for use at locations where the present equipment or system conditions do not permit the use of the conventional types of directional ground relays operating entirely on residual current and voltage.

At undergrounded substation on grounded systems where only two potential transformers are available, or where there is a delta-wye transformer between the potential transformers and the protected line, the type KRQ relay is applicable for ground protection.

The KRQ is also used. without modification to provide directional ground fault protection in the KD carrier relaying scheme. Operation of the relays in connection with the carrier scheme is fully described in I.L. 4 l-9 11.

CONSTRUCTION AND OPERATION

The type KRQ relay consists of a directional cylinder unit operating on negative sequence quantities, negative-sequence current and voltage filters, high-speed overcurrent cylinder unit operating on residual current, and an indicating contractor switch.

DIRECTIONAL UNIT (D)

The directional unit is a product induction cylinder type unit operating on the interaction between the polarizing circuit flux and the operating circuit flux.

Mechanically. the directional unit is composed of four basic components A die-cast aluminum frame. an electromagnet, a moving element assembly, and a molded bridge.

The frame serves as the mounting structure for the magnetic core. The magnetic core which houses the lower pin bearing is secured to the frame by a locking nut. The bearing can be replaced, if necessary. without having to remove the magnetic core from the frame.

The electromagnet has two series-connected polarizing coils mounted diametrically opposite one another; two series-connected operating coils mounted diametrically opposite one another: two magnetic adjusting plugs; upper and lower adjusting plug clips. and two locating pins. The locating pins are used to accurately position the lower pin bearing , which is threaded into the bridge. The electromagnet is secured to the frame by four mounting screws.

All possible contingencies which may arise during installation, operation or *maintenance, and all details and variations of this equipment do not purport to be covered by these instructions. If further information is desired by purchaser regarding this particular installation, operation or maintenance of this equipment, the local ABB Power T&D Company Inc. representative should be contacted.*

SUPERSEDES I.L. 41-164G DATED APRIL 1977
DENOTES CHANGED **SINCE PREVIOUS ISSUE**

EFFECTIVE MAY 1985

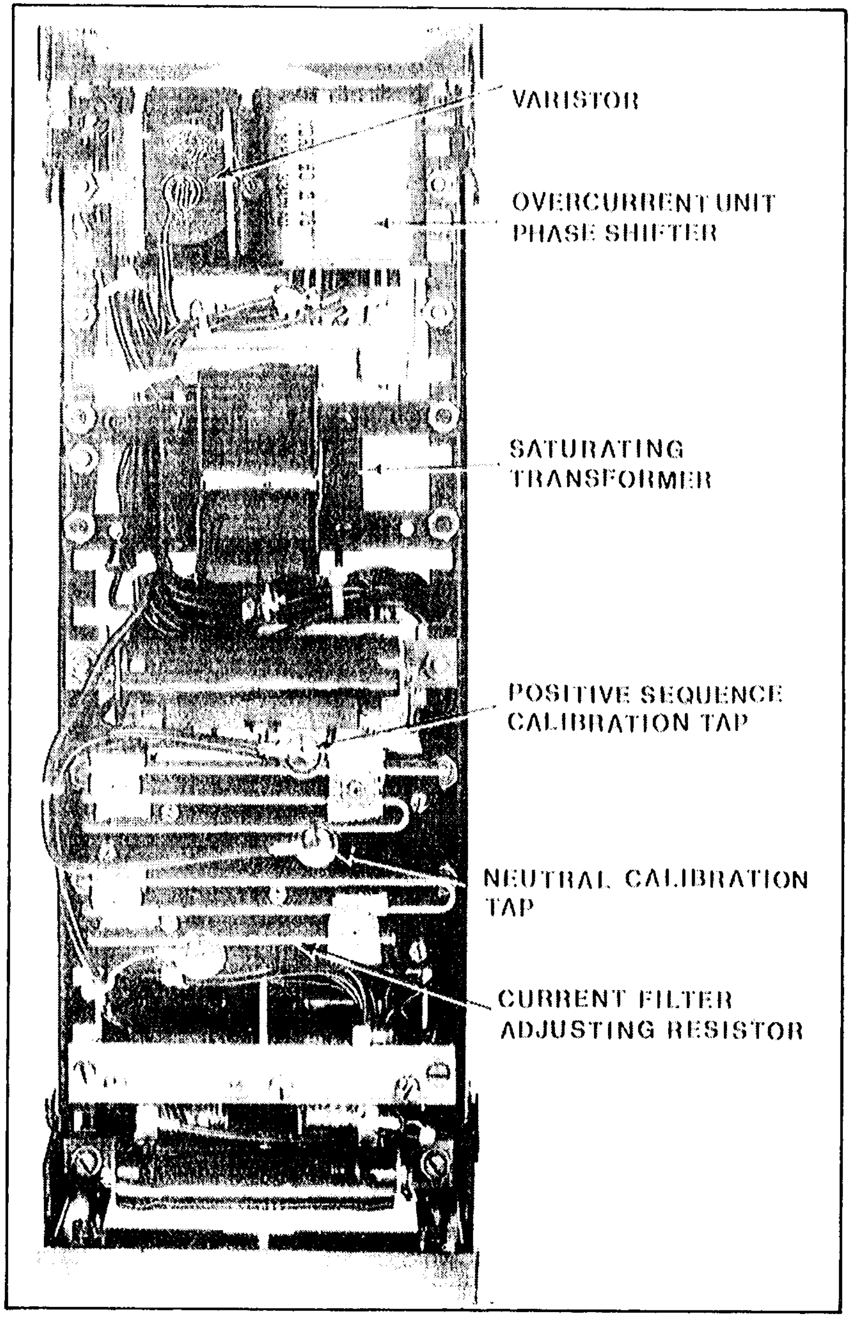

Fig. 1. Type KRQ Relay without case (Rear View).

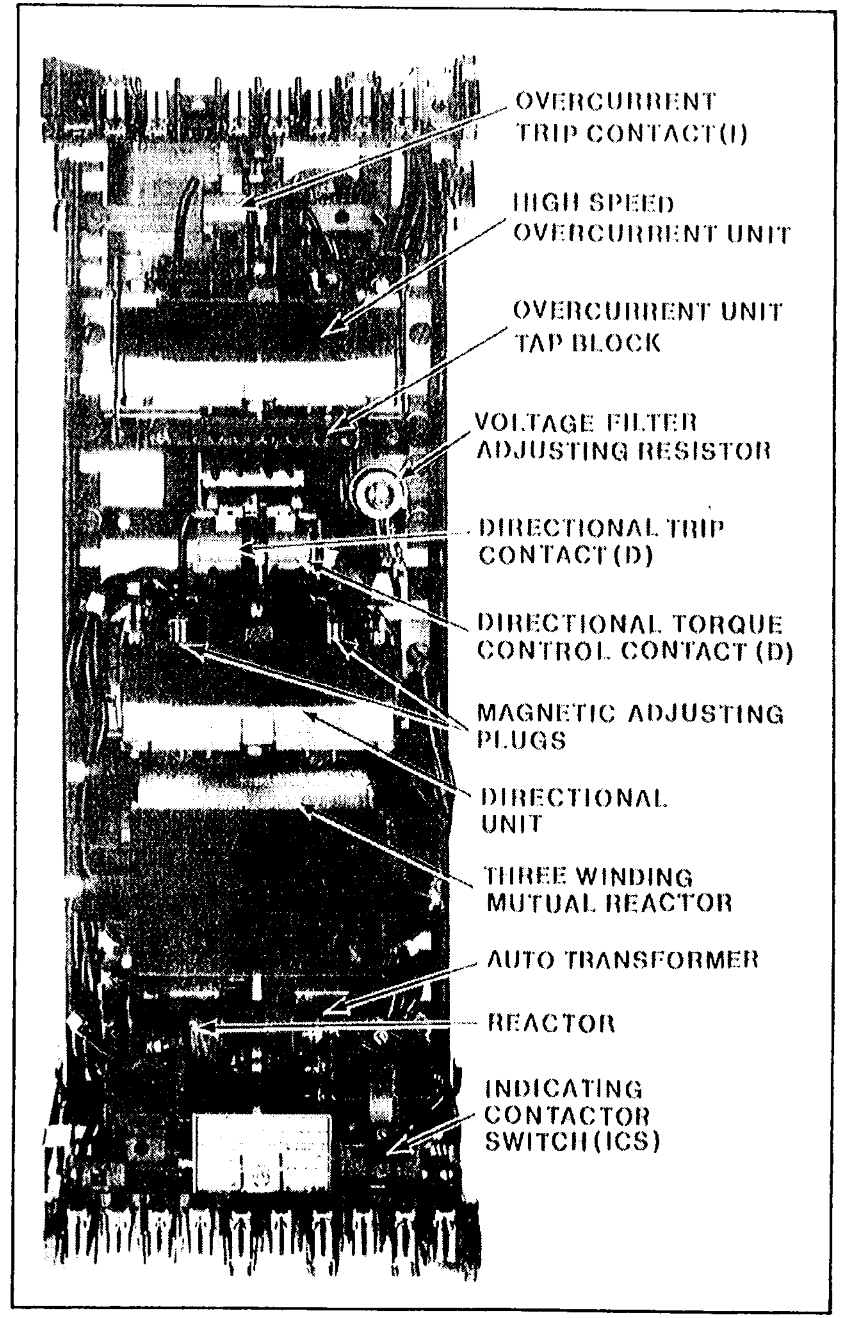

Fig. 2. Type KRQ Relay without case (Front View).

The moving element assembly consists of a spiral spring, contact carrying member, and an aluminum cylinder assembled to a molded hub which holds the shaft. The shaft has removable top and bottom jewel bearings. The shaft rides between the bottom pin bearing and the upper pin bearing with the cylinder rotating in an air gap formed by the electromagnet and the magnetic core.

The bridge is secured to the electromagnet and frame by two mounting screws. In addition to holding the upper pin bearing, the bridge is used for mounting the adjustable stationary contact housing. The stationary contact housing is held in position by a spring type clamp. The spring adjuster is located on the underside of the bridge and is attached to the moving contact arm by a spiral spring. The spring adjuster is also held in place by a spring type clamp.

With the contacts closed, the electrical connection is made through the stationary contact housing clamp, to the moving contact, through the spiral spring out to the spring adjuster clamp.

NEGATIVE SEQUENCE FILTER

The current and voltage filters consist of reactors and resistors connected together as shown in the internal schematic (Fig. 3).

OVERCURRENT UNIT (I)

The overcurrent unit is similar in construction to the directional unit. The time phase relationship of the two air-gap fluxes necessary for the development of torque is achieved by means of a capacitor connected in series with one pair of pole windings.

The normally-closed contact of the directional unit is connected across one pair of pole windings of the overcurrent unit as shown in the internal schematics. This arrangement short-circuits the operating current around the pole windings, preventing the overcurrent unit from developing torque. If the directional unit should pickup for a fault, this short-circuit is removed allowing the overcurrent contact to commence closing almost simultaneously with the directional contact for high-speed operation.

OVERCURRENT UNIT TRANSFORMER

This transformer is of the saturating type for limiting the energy to the overcurrent unit at higher values of fault current and to reduce C.T. burden. The primary winding is tapped and these taps are brought out to a tap block for ease in changing the pickup of the overcurrent unit. The use of a tapped transformer provides approximately the same energy level at a given multiple of pickup current for any tap setting, resulting in one time curve throughout the range of the relay.

Across the secondary is connected a non-linear resistor known as a varistor. The effect of the varistor is to reduce the voltage peaks applied to the overcurrent unit and phase shifting capacitor.

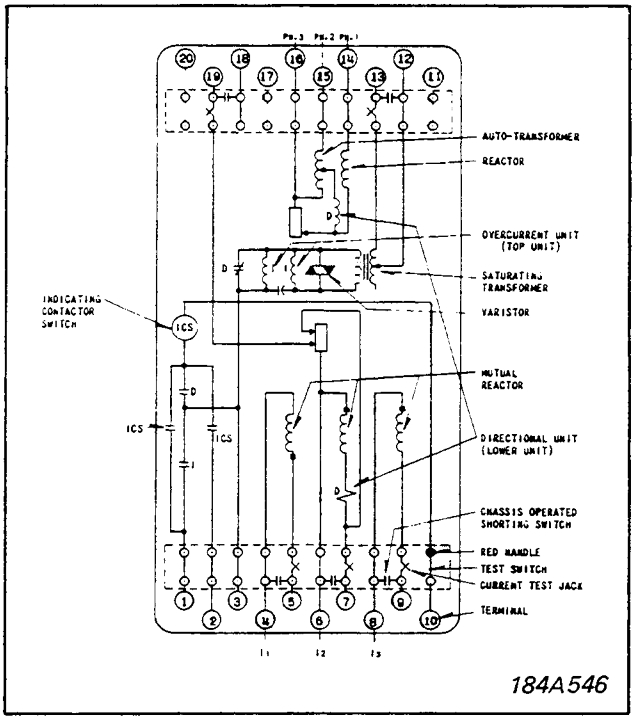

Fig. 3. Internal Schematic of the Type KRQ Relay in the Type FT42 Case.

INDICATING CONTACTOR SWITCH UNIT (ICS)

The indicating contactor switch is a small d-c 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 con-

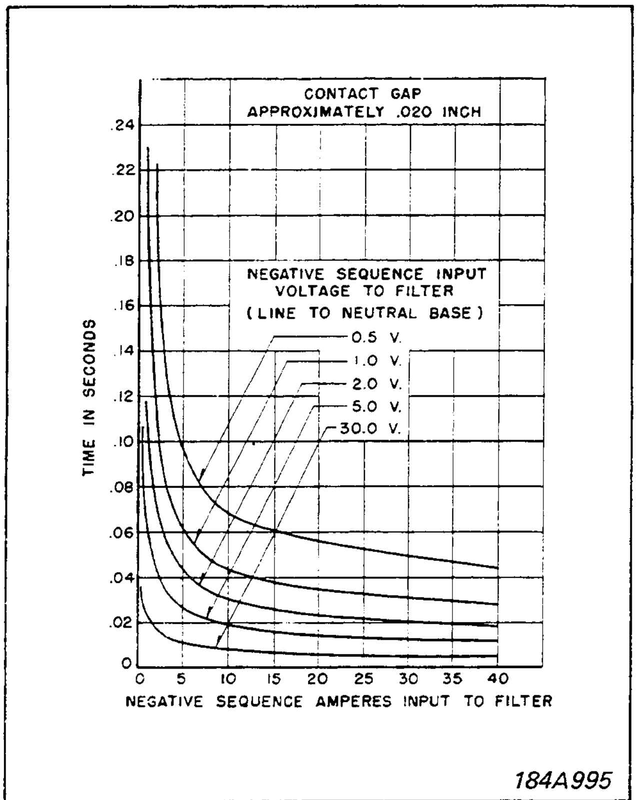

Fig. 4. Time Curves of the Directional Unit (D).

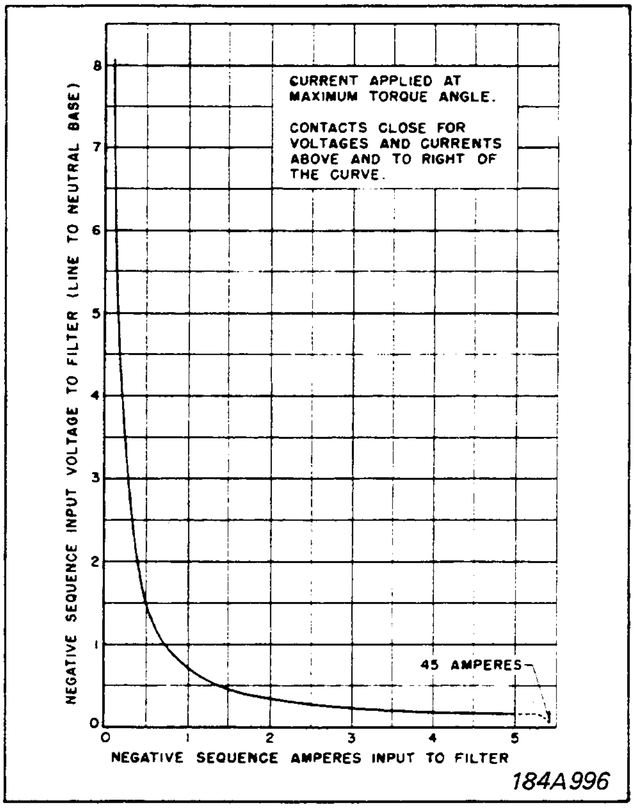

Fig. 5. Sensitivity Curve of the Directional Unit (D).

tacts. 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 the outside of the case by 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 value of the switch.

CHARACTERISTICS

INSTANTANEOUS OVERCURRENT UNIT (I)

The relays are available in the following current ranges:

Range	Taps					
0.5-2 Amps	0.5	0.75	1.0	1.25	1.5	2
1-4	1.0	1.5	2.0	2.5	3.0	4.0
2-8	2	3	4	5	6	8
4-16	4	6	8	9	12	16
10-40	10	15	20	24	30	40

The tap value is the minimum current required to just close the overcurrent relay contacts. For pickup settings in between taps, refer to the section under Adjustments.

DIRECTIONAL UNIT (D)

The directional unit minimum pickup is approximately 0.76 volt-amperes (e.g. 0.19 volt and 4 amperes) in terms of negative sequence quantities applied at the relay terminals at the maximum torque angle of approximately 98^{o} (current leading voltage). See Fig. 5.

TRIP CIRCUIT

The main contacts will safely close 30 amperes at 250 volts d-c and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has a pickup of approximately 1 ampere.

The trip circuit resistance is 0.1 ohm d-c.

SETTINGS

OVERCURRENT UNIT (I)

The only setting required is the pickup current setting which is made by means of the connector screw located on the tap plate. By placing the connector screw in the desired tap, the relay will just close its contacts at the tap value current.

For carrier relaying, the carrier-trip overcurrent unit located in the type KRQ relay should be set on a higher tap than the carrier-stat overcurrent unit located at the opposite end of the line.

CAUTION: Since the tap block connector screw carries operating current, be sure that the screw is turned tight.

In order to avoid opening the current transformer circuits when changing taps under load, connect a spare tap screw in the desired tap position before removing the other tap screw from the original tap position.

DIRECTIONAL UNIT (D)

No setting is required.

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 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. 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.

For detailed FT case information, refer to I.L. 41-076.

The external connections of the directional overcurrent relay are shown in Fig. 6.

External connections may be checked by using the relay as specified in either Fig. 9 or 10 depending upon whether or not the 15/5A auxiliary CT is used. About 0.3 of an ampere load current at a known power-factor angle should be flowing in the main CT secondaries. This check is appropriate prior to commissioning the relay or when troubleshooting.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory. Upon receipt of the relay, no customer adjustments, other than those covered under "SETTINGS", should be required.

CONTACTS

The moving contact assembly has been factory adjusted for low contact bounce performance and should not be changed.

The set screw in each stationary contact has been adjusted for optimum follow and this adjustment should not be disturbed.

Acceptance Check

The following check is recommended to insure that the relay is in proper working order:

OVERCURRENT UNIT (I)

1. **Contact Gap**

The gap between the stationary and moving contacts with the relay in the de-energized position should be approximately .020".

2. **Minimum Trip Current**

The normally-closed contact of the directional unit should be blocked open when checking the pickup of the overcurrent unit.

The pickup of the overcurrent unit can be checked by inserting the tap screw in the desired tap hole and applying rated tap value current. The contact should close within ±5% of tap value current.

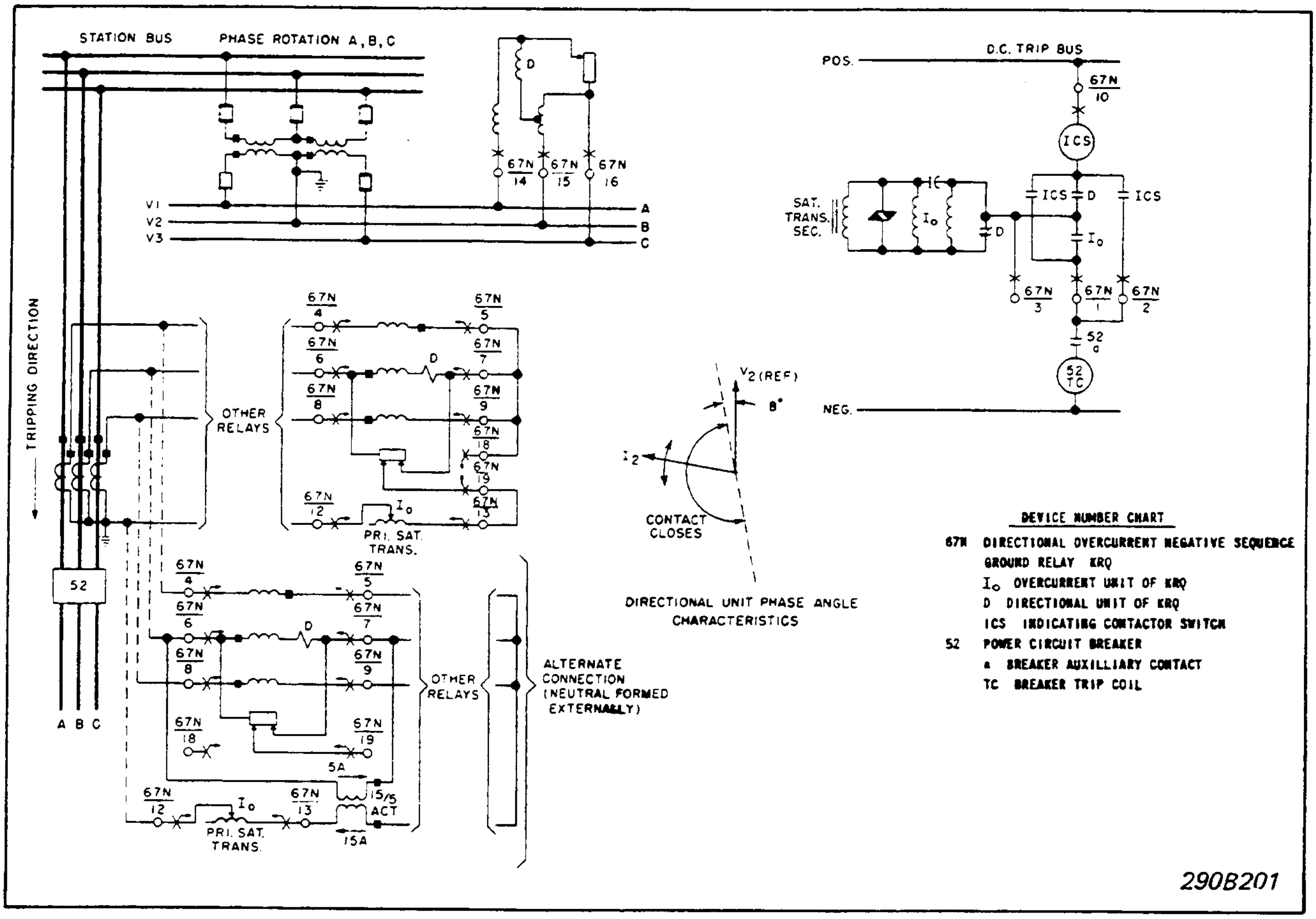

Fig. 6. External Schematic for Type KRQ Relay.

NEGATIVE SEQUENCE FILTER

The filters are adjusted for balance in the factory and no further adjustments or maintenances should be required. The nominal voltage and current output of the filters on positive sequence is approximately zero. This serves as a convenient check on the balance of the filters. If any two input leads to the potential filter should be interchanged, a high voltage occurs across the output terminals of the filter. Similarly, if any two of the phase leads to the input terminals of the current filter are interchanged, an output current will be obtained.

DIRECTIONAL UNIT (D)

1. Contact Gap

The gap between the stationary contact and moving contact with the relay in the de-energized position should be approximately .020''.

2. Sensitivity

Refer to the test diagram in Fig. 7. Apply a single-phase voltage V_{AB} equal to 0.57 volts (corresponds to a negative-sequence input voltage of .19 volts) and a single-phase current equal to

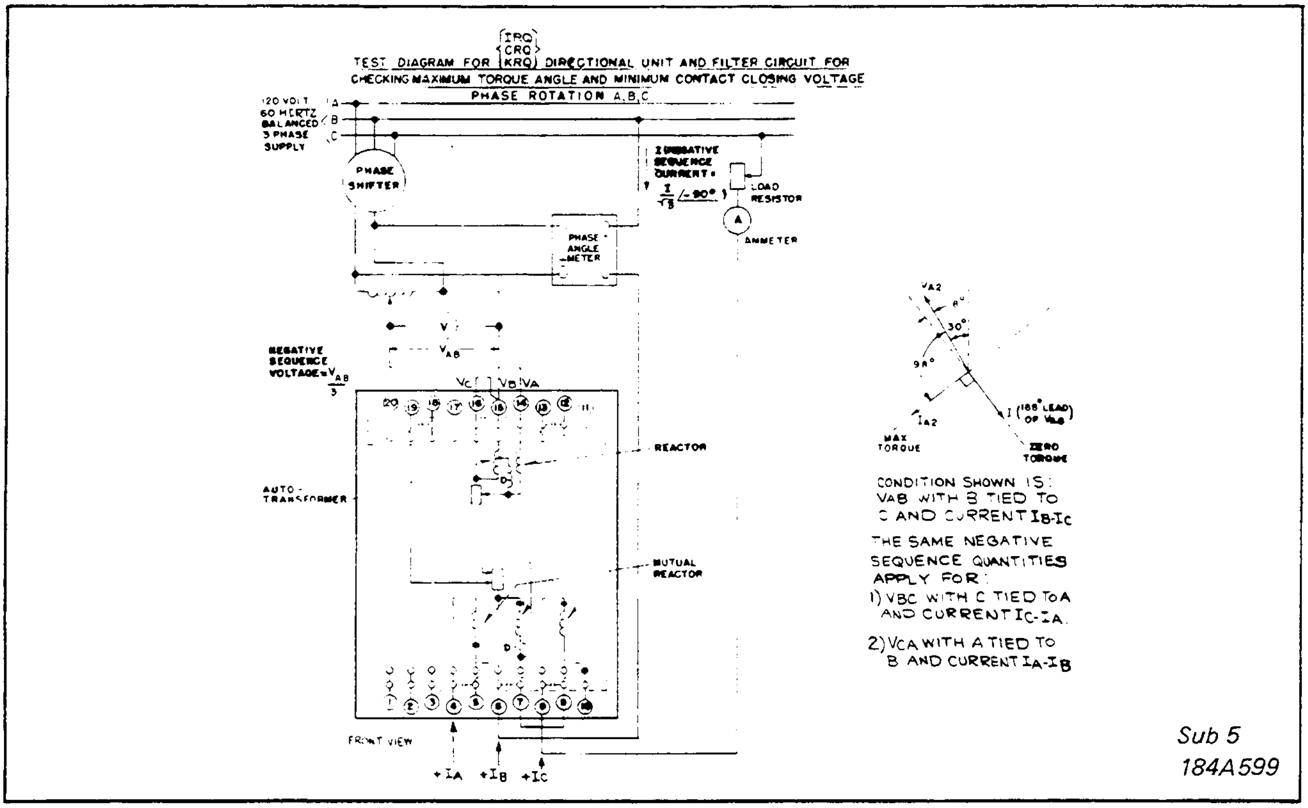

Fig. 7. Test Diagram for Checking Maximum-Torque Angle and Minimum Voltage for Contact Closure of Directional Unit.

6.93 amperes as shown (corresponds to a negative sequence input current of 4 amperes). With a angle meter connected as shown, rotate the phase shifter until the current leads the voltage by 188°.

This corresponds to the negative sequence component of current leading the negative sequence component of voltage by 98°. The directional unit contact should pickup within ±10% of the above input voltage to the relay. The above quantities are determined as follows:

V_{A2} = Neg. Sequence Voltage

$$V_{A2} = \frac{1}{3}(V_{AN} + a^2 V_{BN} + a V_{CN})$$

$$V_{A2} = \frac{1}{3}(\frac{2}{3} V_{AB} - \frac{1}{3} a^2 V_{AB} - \frac{1}{3} a V_{AB})$$

$$V_{A2} = \frac{V_{AB}}{3}(\frac{2}{3} - \frac{1}{3} a^2 - \frac{1}{3} a)$$

$$V_{A2} = \frac{V_{AB}}{3}$$

for V_{AB} = 0.57 volts

$$V_{A2} = 0.19 \text{ volts}$$

$$I_{A2} = \frac{1}{3}(I_A + a^2 I_B + aI_C)$$

$$I_{A2} = \frac{1}{3}(O + a^2 I - aI)$$

$$I_{A2} = \frac{I}{\sqrt{3}} \angle -90^\circ$$

for I = 6.93 amps.

$$I_{A2} = 4 \angle -90^\circ \text{ amps.}$$

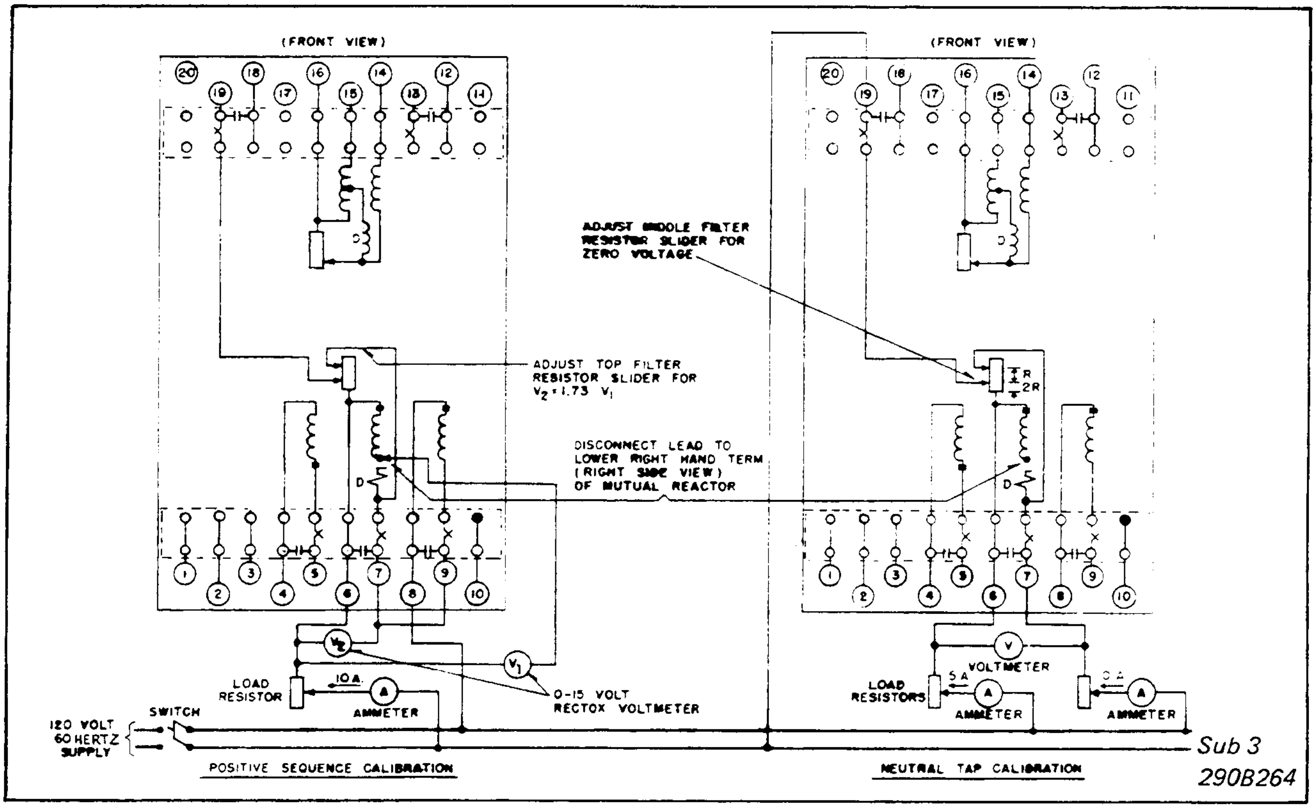

Fig. 8. *Test Diagram for Calibration of Negative Sequence Current Filter in KRQ Relay.*

3. **Spurious Torque**

With the relay connected in the test diagram as above, remove the input voltage and connect terminals 14, 15, and 16 together. Remove the phase-angle meter. With 80 amperes single-phase current applied, there should be no spurious closing torque.

4. **Core Adjustment**

a. Apply 40 volts balanced 3-phase voltage, 60 Hz. to terminals 14, 15 and 16 of the relay. Do not apply current. No trip should be observed for this condition. Reverse the voltage to terminals 14 and 15. No trip should be observed.

b. If trip is observed for either condition in "a" proceed as follows: With balanced 40 V. 3-phase 60 Hz voltage applied to terminals 14, 15 and 16 adjust core until the contact arm just restrains. The core can be adjusted by the use of an insulated screwdriver in the slots at the bottom of the cylinder unit. Recheck on balanced 3-phase, 40 V positive sequence voltage. Relay must not operate.

5. **Refer to Fig. 8.**

Do not apply voltage. Pass 5 Amps. in terminal 6 and out terminal 8. There should be no trip. Reverse the current: no trip.

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 be between 1 and 1.2 amperes. The indicator target should drop freely.

The contact gap should be approximately 5/64" between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously. The third moving contact should make at approximately the same time.

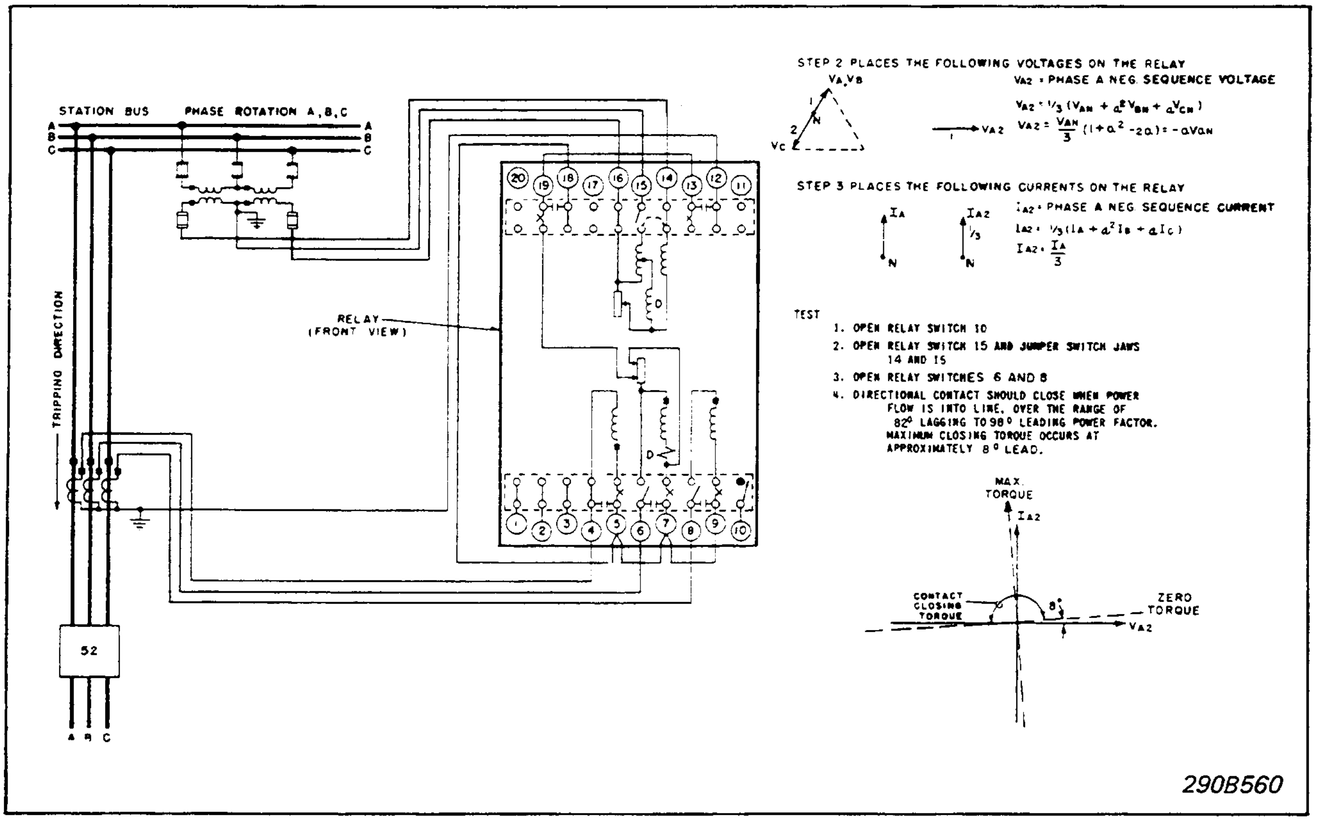

Fig. 9. In-Service Test Procedure for Verifying Proper External Connections where CT Neutral is Formed Within Relay.

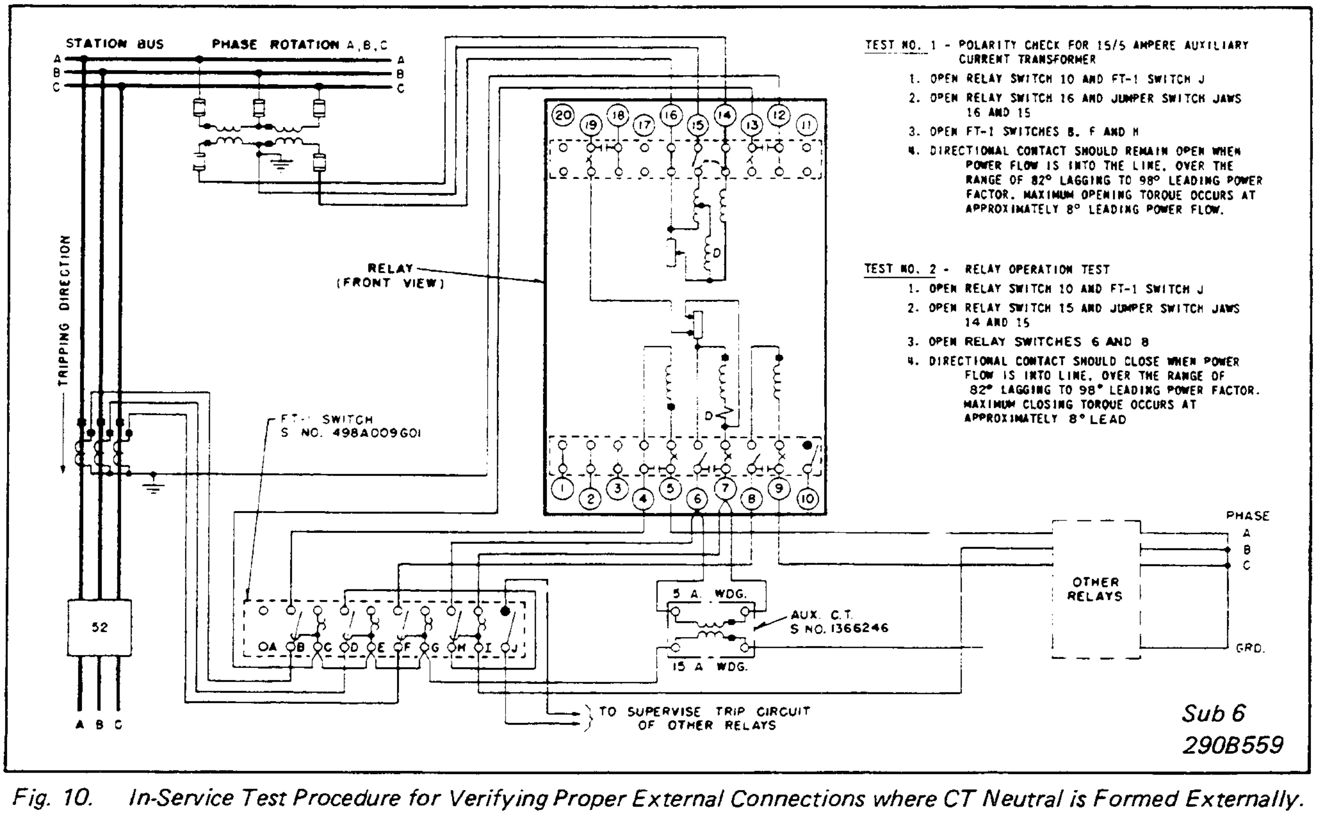

Fig. 10. In-Service Test Procedure for Verifying Proper External Connections where CT Neutral is Formed Externally.

ROUTINE MAINTENANCE

All relays should be inspected periodically and the operation should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

All contacts should be periodically cleaned. 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.

CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments have been disturbed. This procedure should not be used unless it is apparent that the relay is not in proper working order. (See "Acceptance Check").

OVERCURRENT UNIT (I)

1. The upper pin bearing should be screwed down until there is approximately .025" clearance between it and the top of shaft bearing. The upper pin bearing should then be securely locked in position with the lock nut. The lower bearing position is fixed and cannot be adjusted.

2. The contact gap adjustment for the overcurrent unit is made with the moving contact in the reset position, i.e. against the right side of the bridge. Move in the left-hand stationary contact until it just touches the moving contact. Then back off the stationary contact 2/3 of one turn for a gap of approximately .020". The clamp holding the stationary contact housing need not be loosened for the adjustment since the clamp utilizes a spring-type action in holding the stationary contact in position.

3. The sensitivity adjustment is made by varying the tension of the spiral spring attached to the moving element assembly. The spring is adjusted by placing a screwdriver or similar tool into one of the notches located on the periphery of the spring adjuster and rotating it. The spring adjuster is located on the underside of the bridge and is held in place by a spring type clamp that does not have to be loosened prior to making the necessary adjustments.

Before applying current, block open the normally-closed contact of the directional unit. Insert the tap screw in the minimum value tap setting and adjust the spring such that the contacts will close as indicated by a neon lamp in the contact circuit when energized with the required current. The pickup of the overcurrent unit with the tap screw in any other tap should be within ±5% of tap value.

If adjustment of pickup current in between tap settings is desired, insert the tap screw in the next lowest tap setting and adjust the spring as described. It should be noted that this adjustment results in a slightly different time characteristic curve and burden.

NEGATIVE SEQUENCE VOLTAGE FILTER

A. Apply 120 volts balanced 3-phase voltage 60 cycles to terminals 14, 15, and 16 of the relay, making sure that phase 1, 2 and 3 of the applied voltage is connected to terminals 14, 15, and 16 respectively.

B. Using a calibrated high resistance rectox voltmeter, measure the voltage between the tap on the auto-transformer (middle terminal, lower right hand reactor, front view) and the tap on the adjustable 2" resistor. If the voltage is high (40 to 50 volts) the filter is probably improperly connected. If properly connected, the voltage will be low. Using a low range (approximately 5 volts) move the adjustable tap until the voltage reads a minimum. This value should be less than 1.5 volts.

NEGATIVE SEQUENCE CURRENT FILTER

Refer to Fig. 8 for positive sequence calibration.

A. Connect relay terminals 7 and 9 together. Remove lead to lower right hand terminal of mutual reactor (right side view) to disconnect the directional unit.

B. Pass 10 amperes in terminal 6 and out terminal 8.

C. With a 0-15 volts, rectox type voltmeter, measure and record voltage between terminals 6 and the lower right hand terminal of mutual reactor. This voltage should be between 1.85 and 1.95 volts.

D. Now measure the voltage from terminal 6 to terminal 7. Adjust the top filter resistor tap until this voltage is 1.73 times the reading of part C.

Refer to Fig. 8 for neutral tap calibration.

Using the test connections as shown and a low range voltmeter connected between terminal 6 and 7, adjust the middle filter resistor tap connection until the measured voltage is zero. Reconnect lead to mutual reactor at end of this test.

DIRECTIONAL UNIT (D)

1. The upper bearing screw should be screwed down until there is approximately .025" clearance between it and the top of the shaft bearing. The upper pin bearing should then be securely locked in position with the lock nut.

2. Contact gap adjustment for the directional unit is made with the moving contact in the reset position, i.e., against the right side of the bridge. Advance the right hand stationary contact until the contacts just close. Then advance the stationary contact an additional one-quarter turn.

   Now move in the left-hand stationary contact until it just touches the moving contact. Then back off the stationary contact 3/4 of one turn for a contact gap of .020" to .024". The clamp holding the stationary contact housing need not be loosened for the adjustment since the clamp utilizes a spring-type action in holding the stationary contact in position.

3. The sensitivity adjustment is made by varying the tension of the spiral spring attached to the moving element assembly. The spring is adjusted by placing a screwdriver or similar tool into one of the notches located on the periphery of the spring adjuster and rotating it. The spring adjuster is located on the underside of the bridge and is held in place by a spring type clamp that does not have to be loosened prior to making the necessary adjustments.

   The spring is to be adjusted such that the contacts will close when the relay is energized with 0.57 volts and 6.93 amps at 188° (current leading voltage), considering the relay connected to the test circuit in Fig. 7.

4. The magnetic plugs are used to reverse any unwanted spurious torques that may be present when the relay is energized on current alone.

   The reversing of the spurious torques is accomplished by using the adjusting plugs in the following manner:

   a) Connect the relay voltage circuit terminals (phase 1, 2, and 3) together.

   b) Apply 80 amperes single-phase current (momentarily) in phase 2 terminal and out phase 3 terminal.

Plug adjustment is then made per Table I such that any contact closing spurious torques are reversed. The plugs are held in position by upper and lower plug clips. These clips need not be disturbed in any manner when making the necessary adjustments.

The magnetic plug adjustment may be utilized to positively close the contacts on current alone. This may be desired on some installations in order to insure that the relay will always trip the breaker on zero potential.

INDICATING CONTACTOR SWITCH (ICS)

First adjust the two main contacts (left and right hand side, front view), for a contact gap of 5/64" (-1/64", +0).

Close the main relay contacts and check to see that the relay picks up between 1 and 1.2 amperes d-c.

Make sure that all three contacts make and the target drops freely when the above current is applied.

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.

TABLE I
DIRECTIONAL UNIT CALIBRATION

RELAY RATING	CURRENT AMPERES	BOTH PLUGS IN CONDITION	ADJUSTMENT
All Ranges	40	Spurious Torque in Contact Closing Direction (Left Front View)	Right (Front-View) Plug Screwed Out Until Spurious Torque is Reversed.
All Ranges	40	Spurious Torque in Contact Opening Direction (Right Front View) (Contacts remain open)	Left (Front View) Plug Screwed Out Until Spurious Torque is in Contact Closing Direction. Then the plug is screwed in Until Spurious Torque is Reversed.

ENERGY REQUIREMENTS
INSTANTANEOUS OVERCURRENT UNIT OPERATING CURRENT CIRCUIT – 60 HERTZ

AMPERE RANGE	TAP	VA AT TAP VALUE	P.F. ANGLE	VA AT 5 AMPS.	P.F. ANGLE
.5-2	.5	.37	39	24	46
	.75	.38	36	13	37
	1	.39	35	8.5	34
	1.25	.41	34	6.0	32
	1.5	.43	32	4.6	31
	2	.45	30	2.9	28
1-4	1	.41	36	9.0	36
	1.5	.44	32	5.0	32
	2	.47	30	3.0	29
	2.5	.50	28	2.1	27
	3	.53	26	1.5	26
	4	.59	24	0.93	24
2-8	2	1.1	49	6.5	48
	3	1.2	43	3.3	42
	4	1.3	38	2.1	37
	5	1.4	35	1.4	35
	6	1.5	33	1.1	33
	8	1.8	29	0.7	29
4-16	4	1.5	51	2.4	51
	6	1.7	45	1.2	45
	8	1.8	40	0.7	40
	9	1.9	38	0.6	38
	12	2.2	34	0.37	34
	16	2.5	30	0.24	31
10-40	10	1.7	28	0.43	28
	15	2.4	21	0.27	21
	20	3.1	16	0.20	17
	24	3.6	15	0.15	15
	30	4.2	12	0.11	13
	40	4.9	11	0.08	12

ENERGY REQUIREMENTS
FOR THE DIRECTIONAL UNIT AND THE FILTER
(All Burdens at 60 Hertz)

The current burden of the relay with positive sequence currents applied (no output current to the directional unit) is as follows:

Phase	Continuous Rating-Amps.	One Second Rating-Amps.	Watts at 5 Amps.	Volt-Amps. at 5 Amps.	Power Factor Angle
1	10	150	5.4	7.5	44° Lag
2	10	150	5.5	5.5	0°
3	10	150	.35	1.28	74° Lag

The current burden of the relay with zero sequence currents applied is as follows:

Phase	Watts At 5 Amps.	Volt – Amps. At 5 Amps.	Power Factor Angle
1	4.66	5.5	32°
2	4.92	5.0	10°
3	3.30	3.7	27°

The voltage burden of the relay with positive sequence voltage applied (no output voltage to the directional unit) is as follows:

Pot. Transf. Across Phase	Volts	Watts	Volt-Amps.	Power Factor Angle
Burden values on three star connected potential transformers. Values at the star voltage of 66.4 volts (115 volts delta).				
1	115	0	26.8	90° Lag
2	115	0.2	0.3	48° Lag
3	115	23.2	27.0	30° Lag
Burden values on two open-delta potential transformers. Values at 115 volts.				
12	115	–23.2	46.5	120° Lag
23	115	46.6	46.6	0°
23	115	.10	.48	58° Lag
31	115	23.2	46.5	60° Lag
31	115	23.2	46.6	60° Lag
12	115	0.50	0.52	2° Lead
Burden values on three delta connected potential transformers. Values at 115 volts.				
31	115	15.4	31.0	60° Lag
12	115	–7.8	15.6	120° Lag
23	115	15.6	15.6	0°

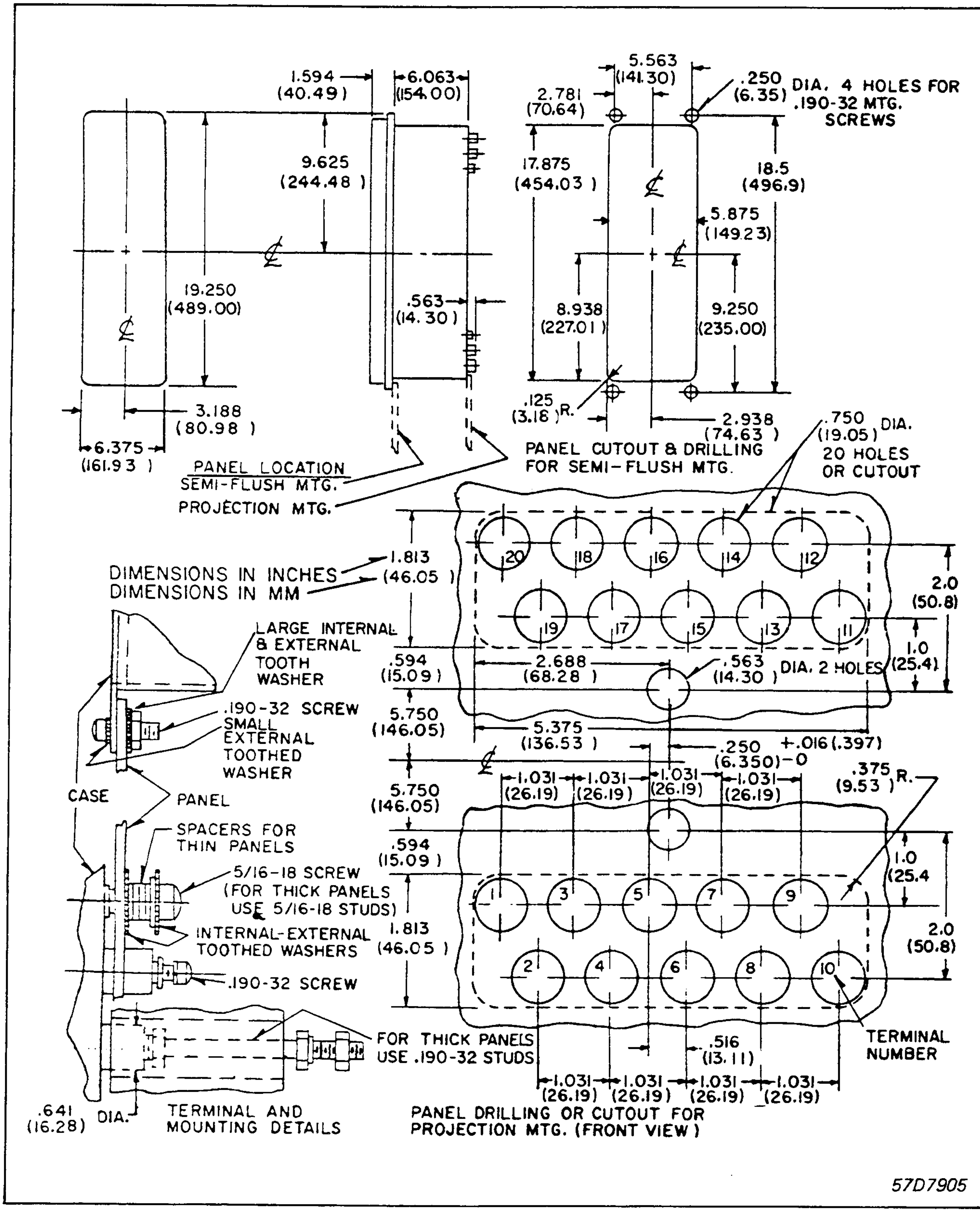

Fig. 11. Outline and Drilling Plan for the Type KRQ Relay in the Type FT42 Case.

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ABB

ABB Power T&D Company Inc.
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Addendum to
I.L. 41-164H

Type KRQ Directional Overcurrent Negative Sequence Relay For Ground Protection

Effective: August 1990
This Addendum Supersedes
All Previous Addenda

A - Add New Information • C - Change Existing Information • D - Delete Information

D

Page 5

SETTINGS;

Delete the third paragraph begining "CAUTION"

Delete the fourth paragraph begining "In order to avoid opening".

A

Page 5

SETTINGS;

Add the following:

CAUTION

Since the tap block screw carries operating current, be sure that the screws are turned tight.

In order to avoid opening current transformer circuits when changing taps under load, the relay must be first removed from the case. Chassis operating shorting switches on the case will short the secondary of the current transformer. The taps should then be changed with the relay outside of the case and then reinserted into the case.

All possible contingencies which may arise during installation, operation or maintenance, and all details and variations of this equipment do not purport to be covered by these instructions. If further information is desired by purchaser regarding this particular installation, operation or maintenance of this equipment, the local ABB Power T&D Company Inc. representative should be contacted.

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