INSTRUCTIONS

GEK-7384 A

Directional Comparison Carrier-Current Pilot Relaying

With MHO-Type Distance Relays

GENERAL ELECTRIC

Contents

DIRECTIONAL COMPARISON
CARRIER-CURRENT PILOT RELAYING
WITH MHO-TYPE DISTANCE RELAYS

INTRODUCTION

The load carrying ability of a transmission line depends on the stability limit of the line, beyond which limit power cannot be transmitted and still have the generation behind the two terminals of the line in synchronism. There are two types of stability limits; the steady-state limit, and the transient limit. In reaching the steady-state limit the power transmitted over the line is increased gradually so that the generation is able to take up the increases in load with no tendency to overshoot due to mechanical inertia of moving parts in generator or governing equipment. The transient stability limit can be reached by a disturbance to the system which brings inertia reactions into play.

Continuity of service depends on keeping all parts of a transmission system in operation or at least in an operable condition for a maximum percentage of the time. Conversely, the amount of time a transmission line is out of service for maintenance or due to a short circuit must be held to a minimum.

The longer the transmission system is subjected to the disturbance of a fault, the greater is the possibility of transient instability, and the greater is the damage to the electrical equipment. Thus, it is important from both the standpoints of stability and continuity of service that faults be cleared as quickly as possible. It is equally important that the fault be cleared by taking a minimum of the system out of service, or in other terms, that the protective relay be selective to the highest possible degree.

For non-persistent faults, high-speed reclosing in an invaluable aid to both system stability and continuity of service, but this subject deserves more emphasis than can be given here and consequently will only be mentioned briefly.

CARRIER-CURRENT RELAYING

Pilot relaying is characterized by an intercommunication system between two or more terminals of a transmission line, over which information is transferred from terminal to terminal. The information obtained from any one terminal is in itself inadequate for high-speed selectivity, but the total information received from all terminals is sufficient to produce a relaying system of maximum selectivity and speed.

By using a channel of high-frequency current (30 to 250 Kilohertz) the power conductors themselves can be used to carry efficiently the required relaying information. Coupling capacitors with safe insulation to high voltage can be used to lead to and draw from the power conductors the high-frequency current with low impedance to this current and high impedance to the power frequency current. Parallel resonant circuits called traps tuned to the carrier frequency confine this high-frequency current to the section of the power line between the relaying terminals without introducing any appreciable impedance to the power line current. These traps prevent the carrier signal from being drained off by an external fault, which would render the carrier current relaying ineffective at the time when it is most needed.

Thus, the use of high-frequency carrier current to convey the necessary relaying information allows the power conductors themselves to be used to effectively transmit this information.

FAULT LOCATION

As described in the subsection "Carrier-Current Relaying" it is necessary for the relays at the terminals of a protected line to compare via the carrier-current channel what each terminal of relays "sees" under fault conditions. It is obviously necessary that any relay which is used to determine in what direction a fault occurs must have a sense of direction, that is, it must be a directional relay. Therefore, directional relays are used at each terminal to determine whether the fault is internal (in the protected section) of external (outside the protected section). When an internal fault occurs, the line should be de-energized completely and quickly by tripping the line circuit breakers at each terminal. When the fault is external the circuit breakers should not be tripped immediately but should allow time for the breakers on the faulted external line section to trip.

Considering the directional relays at each end of the protected section, let us examine their basic operation in a directional comparison carrier-current relaying scheme. Please refer to Fig. 1.

Fig. 1 represents three adjacent transmission line sections, with circuit breakers A, B, C, D, E, and F, and faults shown in locations X, Y, and Z. Let us consider the section between the breakers C and D as the section to be protected by carrier-current relays. The directional relays at breaker C operate only for faults to the right of breaker C, and directional relays at breaker D operate only for faults to the left of breaker D. This means that the only faults that can operate both the directional relays at C and D are those faults that occur between C and D (internal faults). Faults such as Y and Z will operate only one of the directional relays, e.g., fault Y operates only the directional relays at D; fault Z operates only the directional relays at C.

Thus, we have a distinguishing characteristic between internal and external faults. Internal faults cause the directional relays at both terminal C and D to operate, external faults operate the directional relays at only one terminal. It is the function of the carrier channel to indicate instantaneously to both terminals whether or not the directional relays at both terminals C and D have operated.

METHOD OF COMMUNICATION

Briefly, if the fault is external, carrier-current is transmitted for the duration of the fault from one terminal to block tripping at the other terminal. If the fault is internal, carrier-current transmission is stopped instantaneously at both terminals, and both breakers are tripped. Also, if there is no fault carrier-current is not transmitted from either terminal. Speaking in terms of the directional units, the directional tripping unit causes carrier-current transmission from the local transmitter to stop whenever the directional tripping unit operates.

If carrier-current transmission is off under normal unfaulted conditions, and the directional tripping units operate to stop carrier-current transmission, it is obvious that something is needed to start transmission. This function is performed by additional elements which must be sensitive to faults and very fast, but need not be directional. It is vital to start carrier and block tripping for every external fault, Therefore the carrier-starting fault detectors must operate faster and be more sensitive than the directional units. More will be said about this co-ordination later.

This type of scheme is termed "Directional Comparison" since each terminal determines the direction of the fault and then compares its information with the other terminals via the carrier equipment before attempting to trip. Summarized below are the basic characteristics of a directional comparison scheme and its associated carrier equipment.

1. The transmission of carrier-current from any terminal prevents tripping of the opposite terminal of the protected section.
2. Carrier-current is transmitted for external faults by the operation of fault detectors.
3. Carrier-current transmission is stopped at each terminal for internal faults by the operation of the directional relays at each terminal, thereby allowing tripping at each terminal.
4. The carrier-current transmission is off under normal, unfaulted conditions.

Referring back to Fig. 1 let us examine the relay operations for an internal and an external fault noting the approximate accumulative times in the sequence in cycles on a 60 cycle per second basis.

For an internal fault:

1. (0 cycles) Fault occurs at X.

2. (1/2 cycle) Fault detectors at C and D operate, starting carrier current at C and D.

3. (1 cycle) Directional relays at C and D operate, stopping carrier current at C and D.

4. (2 cycles) Trip coils of breakers at C and D are energized.

5. (5 to 10 cycles) Breakers at C and D open, de-energizing faulted line section.

For an external fault:

1. (0 cycles) Fault occurs at Y.

2. (1/2 cycle) Fault detectors at C and D operate, starting carrier current at C and D.

3. (1 cycle) Directional Relay at D operates, stopping carrier current at D. Carrier current at C is not stopped, it is received at D and blocks tripping.

4. (Some time after 5 cycles) Breakers A and B open,due to the operation of the relays at A and B, de-energizing faulted line section.

EQUIPMENT

PHASE RELAYS

The phase relays used here to start and stop carrier are electromechanical, induction cup distance relays. These relays have current and voltage inputs and measure the impedance of a fault to determine whether to trip. The major advantage of using this type of relay is that it can be set to trip only when a fault is within a certain distance from the relay terminal. How this is accomplished is explained in the individual relay instruction books and will not be discussed here.

Separate sets of phase relays, one set to start carrier and a second to stop carrier and attempt tripping are necessary at each terminal. As an example, the characteristics of two types of carrier start relays are plotted on an R-X diagram in Figure 2. Here CD is the protected section of the line and the characteristics are for relays located at C.

The circular characteristic with its center at the origin is that of the impedance unit in the CFZ relay. This relay is used as a carrier starting unit and out-of-step blocking unit with a two-terminal GCX scheme. The other characteristic shown is often called a reverse offset-mho characteristic, and performs the same carrier start function. It is important to note that both characteristics include the origin which insures that for a zero voltage fault near the relay terminals carrier will be started and maintained to block tripping.

Although not shown, the carrier stop and tripping relays have characteristics which can also be plotted on an R-X diagram. These relays must detect faults anywhere in the protected section of the line, and are normally set to overlap the end of the line to insure detection of faults at the remote terminal.

GROUND RELAYS

Under normal conditions little ground, or zero-sequence, current flows in a line. Thus, the presence of such current is a good-indication a fault has occurred, and the main relaying problem is determining whether the fault is internal. For this reason ground relays can normally be much simpler than the phase relays they complement.

The ground relays used here are of induction-cup construction for high-speed operation. However, they are not distance-type relays, although such relays are used occasionally for ground fault detection. Instead, carrier starting is performed by a low-set zero-sequence over-current unit, while tripping and carrier stop are done by a higher-set zero sequence overcurrent fault detection unit with directional supervision. This scheme provides high speed carrier starting and also high speed tripping for phase to ground faults.

CARRIER SET CS-27B

The CS27B is a high speed, solid state transmitter-receiver unit used for electromechanical relay directional comparison schemes. A block diagram of the CS27B is given in Fig. 3. This diagram shows thatthe unit consists of a transmitter, a receiver, and a hybrid coupling section. The transmitter is composed of four stages. First is the crystal oscillator and keying module where the carrier frequency is generated by a dual-crystal oscillator circuit. Depending on the status of the carrier stop circuit discussed subsequently, the output of this stage feeds the driver module. There the signal is preamplified and voice modulation, if present, added. Also included is the carrier start circuitry used to start carrier for blocking purposes, for voice communication, or for transmitting a reduced power signal for testing. The output of this stage goes to the power amplifier. This circuit uses a design that features very little power drain when no carrier input is present. The amplifier output is passed through a band-pass filter to eliminate harmonics and then is fed to the hybrid module. The purpose of the RF hybrid is to isolate the local transmitter output from the receiver. This avoids saturating the receiver circuits and reduces the channel release time. However, unlike previous carrier sets, the CS27B receiver may not receive its own carrier signal and the associated relay logic scheme must include this possibility.

The function of the receiver circuit is to energize the receiver relays when a carrier signal is received. The input to the receiver section coming from the hybrid unit is first filtered to remove any stray signals. The filter output drives the carrier receiver module which detects the presence of carrier. This stage feeds the receiver output module where the signal is amplified. One output of this module is fed to the signal level output meter, while second feeds the D-C amplifier stage. The amplifier here provides current for the external carrier relays used to block tripping and energize the alarm bus.

OPERATION OF THE SCHEME

CARRIER STARTING AND BLOCKING

Carrier starting in the CS27B is controlled in the driver module of the transmitter section. Figure 4 shows the part of the circuit involved, and also above the dashed line shows the carrier start contacts located in the relays. Under unfaulted conditions the nature of the scheme requires that no carrier be transmitted. In the circuit shown, transistor Q153 acts effectively as a switch, which when off feeds nothing to the amplifier, but when switched on passes the carrier signal to the amplifier to start carrier.

The switching of Q153 is controlled by Q152 and the carrier start contacts. For help in coordinating carrier stop and carrier start, the start contacts in the relay are made to be normally closed, while the carrier stop contacts are normally open. Since the carrier start contacts open before the stop contacts close, this helps ensure blocking of tripping for external faults. Normally, the starting contacts will be closed, allowing current to flow through resistors R154 and R153. This biases Q152 on, drawing current through R155. This current flows through R167 and R168, and the resulting voltage drop across these two resistors keeps Q153 cut off.

To start carrier, a carrier start contact opens, interrupting the flow of current through R154 and R153. Q152 will then be cut off, so that the current through R155 goes to zero. This will allow Q153 to turn on and feed the carrier signal to the amplifier stage, thus starting carrier.

At the remote terminals, the received carrier signal will operate two relays. One, the R relay, when energized opens a contact in the trip circuit and blocks tripping. A second unit, relay RA, is a telephone-type receiver alarm relay with its coil connected in series with the R relay coil. It picks up to operate a bell and a lamp for test or signalling purposes. Its pickup is higher than that of the R relay so that if a regular carrier signal or a test signal picks up RA the carrier receiver output will be great enough to reliably operate the R relay.

CARRIER STOPPING AND TRIPPING

Carrier stopping in the CS27B is accomplished in the oscillator and keying module of the transmitter. When the directional tripping relays operate, carrier is stopped by blocking transmission of the oscillator circuit output. Since this prevents the carrier signal from passing to the amplifier sections, the status of the carrier start circuit has no affect on carrier transmission once carrier has been stopped. This gives the preference of carrier stop over carrier start or any carrier test signal which is necessary for a directional comparison carrier-current scheme.

Figure 5 shows the carrier stop circuit in the crystal oscillator and keying module, and above the dashed line are shown the associated carrier stop contacts located in the relays. The operation of the circuit is as follows. Under normal conditions transistor Q104 is biased into its operating range by resistors R116 and R117. Thus, Q104 passes the carrier signal to the driver module. When one of the carrier stop contacts close, however, the following will occur. Current will flow through resistors R120 and R119, and the resulting voltage drop across R119 will raise the emitter voltage level above that of the base and cut off Q104, thus stopping carrier.

The relay coils (MX, GD2X, RI) that close the carrier stop contacts are shown in Figure 6, which shows the tripping circuit. 52/TC is the trip coil, and in series with it is a 52/a contact from the breaker auxiliary switch which is inserted to interrupt the trip coil current. This is connected to the trip bus. The normally closed R contact connected in series with the target is opened by the R coil and is used to block tripping when carrier is received. This contact is discussed in the section on contact coordination.

Either the MX or GD2X contacts when closed can energize the trip bus as long as the R contact is closed

MX will be energized by any of the mho units operating, and contacts of this relay will also stop carrier as shown in Figure 5. GD2X will be energized when both the ground current directional unit and the ground overcurrent unit close their contacts. GD2X will also stop carrier as long as GD1X, a transient blocking relay, has not been picked up.

The RI unit shown connected to the trip bus has two functions. First, there is an RI contact in the carrier stop circuit, so that when an instantaneous trip occurs carrier will be stopped for the duration of the drop out time delay of RI after the phase or ground relays drop out. This prevents carrier from being restarted to block tripping at a remote terminal that is slow to trip.

A second function of the RI relay is to initiate instantaneous reclosing after a high speed trip operation. In such an application an RI contact would energize a reclosing relay such as the NSR. In a scheme combining high speed and time delayed tripping, however, a blocking rectifier is necessary to prevent the RI relay from being energized after a time-delay trip and thereby initiating an undesirable reclosure.

OUT-OF-STEP BLOCKING

These carrier-current relaying schemes recognize out-of-step and power swing conditions by using more sensitive relays which will operate earlier on these conditions, but which will be by-passed under fault conditions. The MB unit in Fig. 7 is an offset mho unit in a Type CEB relay and is connected to operate in the direction of the protected section. This unit is placed in only one phase of the line since it is probable that a power swing or out-of-step condition will appear the same in all phases. The Z units in Fig. 7 used in the GCX scheme are impedance units in a Type CFZ relay and they perform the function of fault detection in addition to out-of-step blocking; consequently, they are present in all three phases.

The OB element shown in Fig. 7 is a time-delay telephone-type auxiliary relay. It is adjusted for a 4-cycle delay on pickup. This auxiliary is usually used either to prevent a breaker from tripping on an out-of-step or power swing condition or to prevent a breaker reclosing after it has tripped on an out-of-step condition. With relays other than the GCX51 it is more commonly used to prevent the breaker reclosing operation because the mho characteristics are the smallest characteristics available for enclosing the fault area and are thus unlikely to cause tripping on any system disturbance from which the system will normally recover. Even for a complete loss of synchronism, tripping will not occur unless the impedance locus happens to fall within the relay characteristic i.e., in the immediate neighborhood of the protected section.

When an out-of-step condition begins, the apparent system impedance moves along a locus passing through the electrical center of the system at a speed dependent upon the rate of progress of the swing. Fig. 8 shows such a locus on a typcial R and X diagram. As the system impedance moves to a point C just inside the MB (or Z) unit characteristic, this more sensitive unit will close its contacts energizing the OB relay. If, within the next four cycles, the system impedance moves to a point D on the locus, just inside the M2 (or M) unit characteristic, this unit will close its contacts shorting out the OB relay coil through the OB "b" contact and tripping the breaker either instantaneously as a carrier trip, or as a time delay trip if a carrier signal is being received from the remote terminal. If on the other hand the system impedance only moves from point C to point E in four cycle time, the OB relay will pick up and block tripping in zone 1 and zone 2, and the carrier trip circuits, or prevent reclosing under these conditions. These conditions are, therefore, recognized as an out-of-step or power swing condition by the speed with which the system impedance moves along its locus.

When a fault occurs the MB (or Z) and M2 (or M, etc.) units operate simultaneously, so that the OB relay coil is by-passed through its own "b" contact by the M2 (or M) contacts before OB can pick up to prevent such shorting. Thus, out-of-step blocking quite correctly does not occur.

CARRIER TRIP TARGETS

The carrier trip circuits are those which energize the trip coil of the circuit breaker if carrier-current is off during the fault, and do not trip the breaker if carrier current is received for the duration of a fault. Other protective relays may trip the same breaker, but tripping by these relays is not primarily dependent on the reception or absence of carrier current.

In these carrier-current relay schemes, targets are provided to indicate all possibilities of fault tripping. These target locations and functions are as below:

1. A target in the receiver relay indicates when a carrier trip occurs.
2. A target in the ground relay indicates when ground is involved.
3. A target in the phase relay(s) indicate(s) the operation of a phase relay.

4. In the case of distance relays used also for backup, targets in the RPM timer indicate the time zone involved.

5. Targets in the ground backup relay indicate a ground backup trip.

CONTACT COORDINATION

Several relays have been added to the basic scheme to increase overall security. The time that these relays add to tripping for an internal fault is normally negligible, while for certain types of external faults they help prevent false trips.

RH Coil

One requirement of a directional comparison scheme is to block tripping for an external fault. At a remote terminal a race may develop between the relays attempting to trip and the carrier signal opening the receiver relay R contact to block tripping. To avoid this, relay R has two windings. One, the R winding, is energized by a received carrier signal and so under normal conditions, is de-energized. However, there is a second winding, termed the receiver holding coil RH, which is connected as shown in Figure 9. Since under normal conditions both MX and GD2X are not picked up, the RH winding will be energized and will hold the R contact in the trip circuit open.

For an external fault, either MX or GD2X may be picked up and so de-energize coil RH. However, there will be sufficient time delay so that the received carrier signal will energize the R winding soon enough to keep the R contact open and block tripping. For an internal fault, however, RH will drop out after MX or GD2X is energized, and the R contact will close to allow tripping since no carrier signal will be received to hold R open.

GD1X Relay

Shown in Figure 9 is the GD1X coil. The purpose of this unit is to prevent false tripping under transient conditions following the clearing of an external fault. Before such a fault is cleared, G1 may very well pick up and this will pick up GD1X after a two cycle delay. When external breakers open to clear the fault, a transient power reversal may occur, picking up GD and G2 and attempting a trip.

However, the GD1X contacts will keep the RH coil energized; holding open the R contact and, thus, blocking tripping. In addition, GD1X will have started carrier and the GD1X contact in the carrier stop circuit will prevent the ground relays from stopping carrier. This condition will persist for five cycles after GD1X is de-energized by either GD picking up or G1 dropping out.

MANUAL FEATURES

CARRIER TEST SWITCH

The carrier test switch, CTS, performs the following functions:

(a) It shunts the reserve signal microammeter except when it is in the REC position to receive a test signal.

(b) It starts the transmitter for testing, SEND.

(c) It inserts the microammeter for measuring a signal from the remote transmitter, REC.

(d) It introduces an attenuating resistor into the transmitter supply so that the receiver output current at the other terminal(s) is made to vary with the received signal voltage. Since the received signal voltage depends on the attenuation over the power conductors, this is often used to detect and roughly measure the amount of sleet on the power conductors.

CARRIER CUTOFF SWITCH

This switch, designated as CCS, is used to open the carrier trip circuits in case an essential part of the carrier-current relaying equipment is out of service for maintenance or other reasons. Under such conditions protection is provided by the distance relays with their zones of protection, and by the time delay ground backup relays.

This switch should be turned to the "OFF" position whenever the carrier-starting relays at another station are out of service for any reason, as otherwise a fault external to the other terminal may cause false tripping of this terminal.

TABLE A

SCHEME	ELEM. DIAG.	TERMINALS	TABLES FUNCTIONS	TABLES SETTINGS
CEY-CEB	116B9493	2	I, II	VIII, IX
		3		VIII, X
CEY-CEY-CEB	116B9498	2	I, III	VIII, XI
		3		VIII, XII
GCY	116B9496	2	I, IV	VIII, XI
		3		VIII, XII
GCX	116B9497	2	I, V	VIII, XIII
	164B9129	3	I, VI	VIII, XIV
GCXY	116B9495	2	I, VII	VIII, XV
		3		VIII, XVI

FUNCTIONS AND SETTINGS

Table A lists the tables showing the functions and settings of devices used in the several schemes. Tables I and VII cover the devices common to all the schemes.

It is improtant to note that protective relay settings depend on system conditions and the circuit to be protected. For this reason, the information supplied in the attached tables can only be qualitative and not quantitive. The user must calculate his own relay settings and these must be applied to the relays by the user before the relays are put into service.

BASIC RULES FOR SETTINGS

In order to insure proper operation of the protective schemes covered by these instructions the following general rules must be followed with regard to relay settings. They are stated here for better understanding.

A. GENERAL

1. Under no conditions should the settings of any of the phase relays, including the out-of-step blocking relay, be such that load can cause them to operate.

2. All phase relays employed in these schemes are supplied with phase-to-phase potentials and the currents of the same 2 phases. Thus, they reach the same distance for all types of multi-phase faults.

3. In no case should any relay be set outside of the rated ranges as given in the instruction book.

4. All values of ohms, amperes and volts used in these tables are in terms of secondary quantities; ohms are phase-to-neutral values.

B. CARRIER PHASE RELAYS

1. In most of the schemes under consideration, the same phase relays that provide carrier protection also provide back-up protection. Thus, these relays must be set to provide for both functions. In general, the requirements do not conflict. However, it is well to remember that the carrier portions of this scheme provide the best part of the overall line protection and this should greatly influence the relay settings.

2. Since high-speed carrier stopping and tripping depend on the operation of the carrier-stopping and tripping units, these units at all terminals must be set to pick up for all multi-phase faults in the protected line section for all practical system conditions. It should be noted that on three-terminal lines, an internal fault near one terminal will appear to be farther away, impedance-wise from the relay terminal than it actually is because of the current infeed from the second remote terminal. This must be considered when setting the reach of the carrier stop and trip units.

   For example, the apparent impedance to the relays at A for the fault at C is:

$$Z_{(app)} = Z_{AC} + \frac{IB}{IA} Z_{JC}$$

where A, B, C are the three terminals, and J is the junction of the three branches as shown in Fig. 10.

3. Because successful carrier blocking for external phase faults is essential to prevent false tripping, the carrier starting units for external faults must reach farther than the reach of the carrier-stopping and tripping units at the remote terminals. An offset setting is required on all mho-type carrier-starting units to insure that these units will pick up and stay picked up to maintain carrier transmission on nearby, zero-voltage external faults.

4. Out-of-step blocking is obtained by virtue of the sequence of operation between the measuring unit of the out-of-step blocking relay and the carrier tripping unit. This sequence of operation is measured by the time-delay auxiliary OB unit in the out-of-step blocking relay. The OB unit has a four-cycle time delay on pickup. The measuring unit of the out-of-step blocking relay must be set so that its characteristic is larger than, and encircles, that of the carrier tripping unit at the same terminal. Its characteristic must be sufficiently large so that the apparent impedance resulting from a system swing or out-of-step condition will require more than four cycles (on a 60-cycle base) to traverse the distance from the periphery of the blocking relay characteristic to that of the tripping unit characteristic. This will permit out-of-step blocking to get set up. It is important to note that the proper setting for the measuring unit of the out-of-step blocking relay will depend on the rate of the fastest swing and the setting of the corresponding tripping unit.

5. The PJC overcurrent fault detectors that are recommended when line-side potentials are employed, are not mechanically capable of being operated in the picked-up position continuously. For this reason they should be set above maximum full load current. However, the setting should be as low as possible to insure fast operation during fault conditions. Note, CHC fault detector relays are available that are suitable for operation continuously picked up. These may be set below full load current.

C. BACK-UP PHASE RELAYS

1. The high-speed,first-zone units must be set short enough so that they do not reach beyond any of the remote terminals, even under conditions of minimum infeed.

2. The second-zone, time-delay units should be set with a reach that is long enough to insure that they will operate for phase faults anywhere in the protected line section. On three-terminal lines the effects of infeed must be considered. See section B-2 above. The second-zone time setting of the RPM relay should be as short as possible but long enough to insure time coordination for faults in adjacent line sections as far away as the reach of their second-zone units.

3. The third-zone time-delay units of the GCX51A and B relays control the RPM timer. For this reason, the reach should be at least somewhat longer than the associated second-zone units. In GCXY and GCY51A and CEB52 relay applications, the third-zone units "look" in the reverse direction; and while they control the associated RPM timing relay, so do the second-zone units. For this reason, the reach setting is based on the requirements to start carrier. See section B-3 above. The third-zone time setting of the RPM relay should be set to insure time coordination with relays on the adjacent line sections, with due regard to the reach settings of those relays.

D. CARRIER GROUND RELAYS

1. Since high-speed carrier stopping and tripping depends on the operation of the directional units of the carrier ground relays, these directional units (GD) at all terminals must pick up for all single-phase-to-ground faults in the protected line section for all practical system operating conditions. Dual polarization provides for maximum sensitivity and should be used where facilities are available.

2. Since high-speed carrier tripping also depends on the operation of the overcurrent units (G2), these units at all terminals must pick up for all single-phase-to-ground faults in the protected line section for all practical system operating conditions.

3. Since proper carrier blocking for external ground faults is necessary for blocking false tripping, the overcurrent units (G1), which start carrier, must be set more sensitive than the overcurrent units (G2) at the remote terminals of the protected line section. In general, the magnitudes of zero-sequence currents flowing in all three terminals of a three-terminal line for an external ground fault are different. Because of this, the ratio of G1 setting to G2 setting will depend

on the number of terminals that the protected line has. This has been reflected in the suggested settings for G1 and G2 in the Table VII.

E. BACK-UP GROUND RELAYS

1. The pickup setting of the high speed units must be high enough to insure that these units do not pick up for any ground fault external to the protected line section.

2. The pickup setting of the time delay units must be low enough to insure positive operation for all single-phase-to-ground faults on the protected line for all practical system operating conditions. Unless local backup is provided at the terminal(s) leading out of theopposite station(s) the setting should be low enough to provide backup for all adjacent line sections in the forward direction, at least sequentially. The time-dial setting must provide for time coordination with similar relays on all adjacent lines in the forward direction.

F. CARRIER GROUND RELAYS ON 3-TERMINAL LINES WITH EXTERNAL TIES

With an external tie between two terminals of a 3-terminal line as shown in Fig.11, it is possible to have a considerable magnitude of ground current flowing out of terminal B for an internal fault near terminal C. Depending on the system configuration and the fault location, the current magnitudes and direction may vary from this situation, all the way to the normal situation of current flowing into the faulted line at all terminals, in four stages as outlined below. The same type of situation can exist on phase faults, but it is a little easier to deal with because the voltage restraint in the distance relays used as phase fault detectors compensates them for changes in source impedance, and therefore, their reach changes less than that of the ground relays, with system conditions.

1. <u>Out-flowing Current Above G1-Pickup</u>

For this case (as mentioned above) G1 will start carrier at B, thus blocking A and C. The primary relaying cannot operate, so the clearing depends intially on the back-up relaying at C. Since the minimum clearing time at C is about four cycles, and the pickup time of GD1X at B is the pickup time of G1 plus two cycles, GD1X will probably be set up, and therefore, the carrier relaying at A and B still cannot respond until the five cycle dropout time of GD1X at B has expired.

This is delayed sequential tripping, and as far as a blocking system of relaying is concerned, there is no remedy for this situation if the setting of G1 is already the highest that can be used with sufficient margin for blocking A in case of an external fault beyond C. (For the margin necessary for this latter situation, see Case 4, below.)

2. <u>Out-flowing or In-flowing Current Below G1 Pickup</u>

Note that for any system configuration where Case 1 can arise, Case 2 will arise instead, if the fault location is further away from C.

For this case, G1 does not operate, so carrier is not started at B, GD1X does not pick up, and tripping at A and C is normal. B will trip as soon as C has cleared.

This is instantaneous sequential tripping, and as far as a blocking system of relaying is concerned, there is no remedy for this situation if the setting of GD is already the lowest that can be obtained.

3. <u>In-flowing Current Above G1 Pickup But Below G2 Pickup</u>

Note that for any system configuration where Case 1 and 2 can arise, Case 3 can arise instead, if the fault location is still further away from C.

For this case, G1 starts carrier at B, thus blocking A and C. As in Case 1, the primary relaying cannot operate, so the clearing depends initially on the back-up relaying at C. However, unlike Case 1, GD picks up, so GD1X does not pick up, and therefore, the primary relaying will trip A and B as soon as C trips by back-up relaying.

This is instantaneous sequential tripping of terminals A and B. For the narrow range of ground fault currents, or of ground fault locations, represented in Case 3, it is possible to have an auxiliary relay at B which will respond to the operation of GD and will bypass G1 contact in the carrier starting circuit, thus making the primary relaying again effective at A and C, and eliminating the instantaneous sequential tripping of A. However, terminal B will still have only instantaneous sequential tripping, and this must be taken into account in choosing the dead time of the breakers at A and C in case of instantaneous reclosing. Therefore the only practical advantage obtained by the added auxiliary relay at B is that in the current range between G1 and G2 it keeps the primary protection at A and C effective rather than having to depend on the back-up relaying to trip C. It does not improve the performance for Case 1 or 2, if either of these cases can exist for any fault location on the protected line.

4. <u>In-flowing Current Above G2 Pickup</u>

For this case, operation is normal at all terminals if the proper margin has been taken in choosing the settings. An internal fault will be cleared correctly, and the only concern necessary is the result of an external fault. Considering Fig. 11, an external fault at the right may draw equal currents out of terminals B and C, but the sum of these currents will flow in through A if there is no ground current supplied from any other line or grounded bank at B. In order to insure blocking at A for a fault which would draw currents just below G1 pickup at B and C, it is necessary to set the pickup of G2 at A for at least 2.5 times the pickup of G1 at B or C, rather than only 1.25 times. Unless fault data are available to prove it unnecessary, the usual meshed system (with external interconnections possible among each pair of terminals) requires a similar 2.5:1 ratio of G2 pickup at any terminal to the G1 pickup at each of the other two terminals.

TABLE I

FUNCTIONS THAT ARE COMMON TO ALL SCHEMES

DEVICE	DEV. NO.	UNIT	FUNCTION
BCA11AV	85	GD2X	Controlled by 67GC/GD. In turn it de-energizes 85/RH coils and stops local carrier. It is picked up only for ground faults in the tripping direction. Has 6-9 ms pickup and fast dropout.
		MX	Controlled by 21/M2or 21/M depending on scheme used. In turn it provides the same functions as GD2X except for multi-phase faults.
		R	Picks up on receipt of a carrier signal to block local tripping. Has fast pickup and dropout times.
		RH	Drops out for faults in tripping direction. RH & R are wound on same core. The normally closed contacts labelled R are closed when both R & RH are de-energized, and they are open when either R or RH or both are energized.
		T	Provides target indication for carrier trip.
NGA15B	85Y	GDY	Purchased only for a terminal, on a 3-terminal line, where current flowing in toward an internal fault is above G1 pickup but below G2 pickup. Controlled by 67GD. In turn it by-passes G1 contact to remove carrier started by G1, thus permitting tripping of other terminals if current is flowing in at both of them.
NAA22L	85X	RA	Picks up on receipt of a carrier to give an alarm.
		RI	Initiates Automatic Reclosing. Holds off carrier for approximately 8 cycles after a trip. Has fast pickup and 7-9 cycle dropout times.
16SB1CB4B21	CTS		Switch for testing the carrier channel.
Microammeter			Reads strength of received signal in REC position of switch, during RS test.
White Lamp			Identifies source of carrier signal if more than 1 carrier terminal is connected to same alarm bell.
Tel Jack			For voice communication.
16SB1DB211	CCS		Channel cutout switch for removing directional comparison and instantaneous reclosing from service. Backup relaying remains in service.
JBCG51K or JBCG53K or JBCG77K	67GB	D	Directional unit. Provides directional control for IOC & TOC listed directly below.
		IOC	Directional Instantaneous Overcurrent Unit. Provides high-speed back-up protection on ground faults.
		TOC	Directional Time Overcurrent Unit. Provides time delay back-up protection on ground faults.
CLPG12C	67GC	GD	Ground Directional Unit in Carrier Scheme. With G2 it operates on ground faults in the tripping direction to control GD2X and initiate carrier tripping. Also operates in conjunction with 67GC/G1 for ground faults in the non-tripping direction to control 67GC/GD1X.
		G1	Non-directional overcurrent unit that starts carrier on ground faults. It also operates in conjunction with 67GC/GD1X.
		G2	Non-directional overcurrent unit. It operates in conjunction with 67GC/GD to provide carrier stopping and tripping for ground faults in the tripping direction.
		GD1X	Auxiliary relay with 1-2 cycle pickup and 5 cycle dropout time. Controlled by 67GC/GD and 67GC/G1 to prolong carrier transmission and hold the carrier trip circuit open on single-phase-to-ground faults in the non-tripping direction.
		T	Target to indicate ground fault carrier trip.
CHC12A	50		Non-directional Instantaneous Overcurrent Relay. Fault detector to supervise all tripping by 21. May safely be set below load current and picked up continuously. With line-side potential, use this or PJC.
PJC31C	50		Non-directional Instantaneous Overcurrent Relay. Fault detector to supervise all tripping by 21. Should not be set below maximum load current. With line-side potential, use this or CHC. Not needed when GCX51B used.

TABLE II

APPLIES TO CEY52A CEB52A,2-OR 3-TERMINAL LINE APPLICATIONS DRAWING 116B9493

CEY52A	21	M	Directional Mho Distance Relay. Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping.
CEB52A	68	RM	Offset Mho Distance Relay. Operates to start carrier transmission.
CEB51A	68	MB	Operates in conjunction with 68/OB to provide out-of-step blocking of tripping.
		OB	Auxiliary Unit for out-of-step blocking. Has 4 cycle time delay pickup. Operates in conjunction with 68/MB to block zone 1, zone 2, and carrier tripping by phase relays on system swings and out-of-step conditions. This blocking is prevented in the event that 21/M contacts close and short down 68/OB before 68/OB gets picked up, as in case of an internal fault.

TABLE III

APPLIES TO CEY-CEY-CEB PHASE RELAYS IN 2- OR 3-TERMINAL LINE APPLICATIONS DRAWING 116B9498

DEVICE	DEV. NO.	UNIT	FUNCTION
CEY51A	21-M1		Directional Mho Distance Relay - Operates to provide first zone back-up protection for multi-phase faults.
CEY52A	21-M2		Directional Mho Distance Relay - Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping. Controls 21X/TU-2 to provide second zone back-up protection of multi-phase faults.
CEB52A	21-M3		Offset Mho Distance Relay - Operates to start carrier transmission. Controls 21X/TX to initiate operation of RPM Timing Relay. Operates in conjunction with 21X/TU-3 to provide reversed third zone back-up protection for multi-phase faults.
RPM21D	21X	TX TU	Auxiliary Unit with energizes the timing unit 21X/TU. Operated from phase-distance relays 21-M2 or 21-M3. Timing unit operated from 21X/TX. Has contacts TU-2 and TU-3 for second and third zone time delay tripping in conjunction with phase-distance relays.
CEB51A	68	MB	Operates in conjunction with 68/OB to provide out-of-step blocking of tripping.
		OB	Auxiliary Unit for out-of-step blocking. Has 4 cycle time delay pickup. Operates in conjunction with 68/MB to block zone 1, zone 2, and carrier tripping by phase relays on system swings and out-of-step conditions. This blocking is prevented in the event that 21/M2 contacts close and short down 68/OB before 68/OB gets picked up, as in case of an internal fault.

TABLE IV

APPLIES TO GCY51A 2- OR 3-TERMINAL LINE APPLICATIONS DRAWING 116B9496

GCY51A	21	M1	Directional Mho Distance Unit - Operates to provide first zone back-up protection for multi-phase faults.
		M2	Directional Mho Distance Unit - Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-2 to provide second zone backup protection for multi-phase faults.
		OM3	Offset Mho Distance Unit - Operates to start carrier transmission. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-3 to provide reversed third zone back-up protection for multi-phase faults.
RPM11D	21X	TX	Auxiliary Unit which energized the timing unit 21X/TU. Operated from phase-distance relays.
		TU	Solenoid Timing Unit operated from 21X/TX. Has contacts TU-2 and TU-3 for second and third zone time delay tripping in conjunction with phase-distance relays.
		T1, T2 T3	Targets used in conjunction with zones 1, 2 and 3 of the phase-distance relays.
CEB51A	68	MB	Operates in conjunction with 68/OB to provide out-of-step blocking of tripping.
		OB	Auxiliary Unit for out-of-step blocking. Has 4 cycle time delay pickup. Operates in conjunction with 68/MB to block zone 1, zone 2, and carrier tripping by phase relays on system swings and out-of-step conditions. This blocking is prevented in the event that 21/M2 contacts close and short down 68/OB before 68/OB gets picked up, as in case of an internal fault.

TABLE V

APPLIES TO GCX51A OR -B 2-TERMINAL LINE APPLICATIONS - DRAWING 116B9497

DEVICE	DEV. NO.	UNIT	FUNCTION
GCX51A	21	M	Directional Mho Distance Unit. Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-3 to provide third zone back-up protection for multi-phase faults. Operates in conjunction with 21/O to provide first zone back-up protection for multi-phase faults. Operates in conjunction with 21X/TU-2 to energize 21/OX which in turn switches the reach of 21/O from zone 1 to zone 2.
		O	Non-directional Reactance Distance Unit. Operates in conjunction with 21/M to provide first-zone back-up protection for multi-phase faults. Also operates in conjunction with 21/M, 21/OX and 21X/TU-2 to provide second zone back-up protection for multi-phase faults.
		OX	Auxiliary Transfer Unit. Operates in conjunction with 21M and 21X/TU-2 to switch the reach of 21/O from first to second zone.
		OC	Non-directional Overcurrent Unit. Present only in GCX51B. Performs same function as PJC31C. Acts as a fault detector to supervise operation of all multi-phase fault tripping. Should not be set below maximum load current.
RPM11D	21X	TX	Auxiliary Unit which energizes the timing unit 21X/TU. Operated from Phase-distance relays.
		TU	Timing Unit operate from 21X/TX. Has contacts TU-2 and TU-3 from second and third zone time delay tripping in conjunction with phase-distance relays.
		T1,T2,T3	Targets used in conjunction with zones 1, 2 and 3 of the phase-distance relays.
CFZ17A	68	Z_{31} Z_{23} Z_{12}	Non-directional Impedance Distance Units. Start carrier on multi-phase faults. Also operate in conjunction with 68/OB to provide out-of-step blocking of tripping.
		OB	Auxiliary Unit for out-of-step blocking. Has 4 cycle time delay pickup. Operates in conjunction with 68/Z_{31}, 68/Z_{12} to block zone 1, zone 2 and carrier tripping by phase relays on system swings and out-of-step. This blocking is prevented in the event that 21/M contacts close and short down 68/OB before 68/OB gets picked up, as in case of an internal fault.

TABLE VI

APPLIES TO GCX51A OR -B 3-TERMINAL LINE APPLICATIONS - DRAWING 164B9179

GCX51A	21	M	Directional Mho Distance Unit. Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-3 to provide third zone back-up protection for multi-phase faults. Operates in conjunction with 21/O to provide first zone back-up protection for multi-phase faults. Operates in conjunction with 21X/TU-2 to energize 21/OX which in turn switches the reach of 21/O from zone 1 to zone 2.
		O	Non-directional Reactance Distance Unit. Operates in conjunction with 21/M to provide first-zone back-up protection for multi-phase faults. Also operates in conjunction with 21/M, 21/OX and 21X/TU-2 to provide second zone back-up protection for multi-phase faults.
		OX	Auxiliary Transfer Unit. Operates in conjunction with 21M and 21X/TU-2 to switch the reach of 21/O from first to second zone.
		OC	Non-directional Overcurrent Unit. Present only in GCX51B. Performs same function as PJC31C. Acts as a fault detector to supervise operation of all multi-phase fault tripping. Should not be set below maximum load current.
CEB52A	68CB	RM	Offset Mho Distance Relay - Operates to start carrier transmission. Controls 21X/TX to initiate operation of RPM Timing Relay. Operates in conjunction with 21X/TU-3 to provide reversed third zone back-up protection for multi-phase faults.
RPM11D	21X	TX	Auxiliary Unit which energizes the timing unit 21X/TU. Operated from Phase-distance relays.
		TU	Timing Unit operated from 21X/TX. Has contacts TU-2 and TU-3 for second and third zone time delay tripping in conjunction with phase-distance relays.
		T1,T2,T3	Targets used in conjunction with zones 1, 2 and 3 of the phase-distance relays.
CEB51A	68	MB	Operates in conjunction with 68SB/OB to provide out-of-step blocking of tripping.
		OB	Auxiliary Unit for out-of-step blocking. Has 4 cycle time delay pickup. Operates in conjunction with 68SB/MB to block zone 1, zone 2 and carrier tripping by phase relays on system swings and out-of-step conditions. This blocking is prevented in the event that 21/M contacts close and short down 68SB/OB before 68SB/OB gets picked up, as in case of internal fault.

TABLE VII

APPLIES TO GCXY ON 2- OR 3-TERMINAL LINE APPLICATIONS - DRAWING 116B9495

DEVICE	DEV. NO.	UNIT	FUNCTION
GCXY51A	21	OM3	Offset Mho Distance Unit - Operates to start carrier transmission. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-3 to provide reversed third zone back-up protection for multi-phase faults faults.
		M3	Directional Mho Distance Unit. Operates in conjunction with 85/MX to stop carrier transmission and provide for carrier tripping. Controls 21X/TX to initiate operation of RPM timing relay. Operates in conjunction with 21X/TU-3 to provide third zone back-up protection for multi-phase faults. Operates in conjunction with 21/O to provide first zone back-up protection for multi-phase faults. Operates in conjunction with 21X/TU-2 to energize 21/OX which in turn switches the reach of 21/O from zone 1 to zone 2.
		O	Non-directional Reactance Distance Unit. Operates in conjunction with 21/M to provide first zone back-up protection for multi-phase faults. Also operates in conjunction with 21/M, 21/OX and 21X/TU-2 to provide second zone back-up protection for multi-phase faults.
		OX	Auxiliary Transfer Unit. Operates in conjunction with 21/M3 and 21X/TU-2 to switch the reach of 21/O from first to second zone.
RPM11D	21X	TX	Auxiliary Unit which energizes the timing unit 21X/TU. Operated from phase-distance relays.
		TU	Solenoid Timing Unit operated from 21X/TX. Has contacts TU-2 and TU-3 for second and third zone time delay tripping in conjunction with phase-distance relays.
		T1,T2,T3	Targets used in conjunction with zones 1, 2 and 3 of the phase-distance relays.
CEB51A	68	MB	Operates in conjunction with 68/OB to provide out-of-step blocking of tripping.
		OB	Auxiliary Unit for out-of-step blocking. Has 4 cycle time delay pickup. Operates in conjunction with 68/MB to block zone 1, zone 2 and carrier tripping by phase relays on system swings and out-of-step conditions. This blocking is prevented in the event that 21/M contacts close and short down 68/OB before 68/OB gets picked up, as in case of an internal fault.

TABLE VIII

GROUND RELAY SETTINGS - ALL SCHEMES

DEVICE	DEV. NO.	UNIT	TWO TERMINAL LINES	THREE TERMINAL LINES
JBCG51K or JBCG53K or JBCG77K	67GB	D	No adjustment available	No adjustment available.
		IOC	Set pickup no lower than 125% of the maximum current in the relay for a ground fault at the remote terminal with the remote breaker closed.	Assume one of the remote terminal breakers open and determine the maximum current in the relay for a ground fault at the second remote terminal. assume only the seond remote terminal breaker to be open and determine the maximum current in the relay for a ground fault at the first remote terminal. Set the pickup no lower than 125% of the greater of the two values obtained.
		TOC	Set pickup no higher than 67% of the minimum single phase-to-ground-fault current in the relay with the remote breaker closed. Unless local backup is provided at the terminal (s) leading out of the opposite station (s), the settings should be low enough to provide backup for all adjacent line sections in the forward direction, at least sequentially. Set time dial to coordinate with other ground relays on the system.	
CLPG12C	67GC	GD	Set for minimum pickup (maximum sensitivity). Check to insure pickup for all single-phase-to-ground faults on the protected line with line breakers closed on both terminals. Use dual polarization.	Set for minimum pickup (maximum sensitivity). Check to insure pickup for all single-phase-to-ground faults on the protected line with the line breakers closed at all three terminals. Use dual polarization.
		G2	Set pickup no higher than 67% of the minimum single-phase-to-ground fault current in the relay with the remote breaker closed. Lower pickup settings are permissible and in most cases desirable for increased speed of operation. However, do not set pickup lower than 125% of the G1 pickup setting at the remote end of the line.	Set pickup no higher than 67% of the minimum single-phase-to-ground fault current in the relay with both remote line breakers closed. Lower pickup settings are permissible and in most cases desirable for increased speed of operation. However, do not set pickup lower than 250% of the G1 pickup settings at the two remote terminals.

TABLE VIII (continued)

		G1	Set pickup no higher than 80% of the pickup of the opposite terminal's G2 unit.	Set pickup no higher than 40% of the lower of settings of the two opposite terminal's G2 units.

TABLE IX

PHASE RELAY SETTINGS -- CEY52A - CEB52A RELAYS -- 2-TERMINAL LINES -- DRAWING 116B9493

DEVICE	DEV. NO.	UNIT	SETTINGS
CEY52A	21	M	Set to reach 125-150% of the ohms to the opposite terminal, taking the line impedance angle into consideration. 125% tends to give slow operation for end-zone faults, so it would be used only to avoid false operation on swings, or operation of 68SB on maximum load with the setting which results from the setting chosen for 21-M.
CEB52A	68CB	RM	Set for 0.5 ohm offset. Set the reach for not less than 1.25 x [(Setting of M at opposite end) + 0.5- (ohms of protected line section)] .
CEB51A	68SB	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68SB should exceed the reach of 21 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load, mentioned below. The offset tap of 68SB should be the available value nearest to half the difference between the ohmic settings of 68SB and 21. The reach of 68SB must not be great enough to cause operation by maximum load current.
CHC12A	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should not be more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABLE X

PHASE RELAY SETTINGS -- CEY52A - CEB52A RELAYS -- 3-TERMINAL LINES -- DRAWING 116B9493

DEVICE	DEV. NO.	UNIT	SETTINGS
CEY52A	21	M	Set to reach 125-150% of the maximum apparent impedance to either of the other terminals, including the effect of infeed and line-impedance angle. 125% tends to give slow operation for end-zone faults, so it would be used only to avoid false operation on swings. 150% is the preferred settings. However, the setting should not be long enough to require a setting on 68SB so high that it will be picked up by maximum load.
CEB52A	68CB	RM	For each terminal, make the following calculation of desired reach for each of the other terminals with the opposite one of the other terminals open, and use the greater of the 2 values of desired reach. Minimum reach = 1.25 (Setting of M at opposite end) + 0.5-(ohms of line section between the 2 closed terminals) .
CEB51A	68SB	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68SB should exceed the reach of 21 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load current, mentioned below. The offset tap of 68SB should be the available value nearest to half the difference between the ohmic settings of 68SB and 21. The reach of 68SB must not be great enough to cause operation by maximum load current. If this requirement cannot be met, the setting of 21 must be reduced (which will result in sequential tripping), and the CEB14 should be substituted to prevent 68SB/OB getting set up for a particular range of fault locations.
CHC12A	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABLE XI

PHASE RELAY SETTINGS -- CEY51A-CEY52A-CEB52A RELAYS -- 2-TERMINAL LINES -- DWG. 116B9498
OR GCY51 RELAYS -- 2-TERMINAL LINES -- DWG..116B9496

CEY51A OR GCY51	21-M1 21	M1	Set for 80-90% of the impedance to the remote end of the line, taking account of the impedance angle of the line.
CEY52A OR GCY51	21-M2 21	M2	The minimum setting is 125% of the impedance of the protected line section, taking account of the line impedance angle. The maximum setting is the least of 3 maximums, determined as follows: The first maximum is 80% of the total impedance (not reactance) ohms to the end of the shortest zone-1 reach on any other line out of the opposite station, taking account of the line-impedance angle. The second maximum is a setting such that the unit will not trip on the maximum swing from which the system might recover (usually considered 120°). The third maximum is a setting which will permit choosing a setting of MB such that MB will not operate due to maximum load. The best setting is (approximately) the square root of the product of the (greater) minimum and the least maximum.
CEB52A OR GCY51	21RM3 21	OM3	The setting of this unit depends on the setting of the M2 unit at the other terminal. Set for 0.5 ohm offset. Set the reach for not less than 1.25 [(Setting of M2 at opposite end) + (offset ohms) - (ohms of protected line section)] .
RPM21D OR RPM11D	21X	TU2	Set for a long enough delay to premit clearing of any fault on any other line out of the opposite station, within reach of this 21-M2, plus the desired margin.
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of the station where relays are, within reach of 21/RM3 or 21/OM3, plus the desired margin (margin usually 10 cycles).
CEB51A	68	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing(for each system condition) progresses. The reach of 68 should exceed the reach of 21-M2 or 21/M2 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M subject to the limitation due to load current, mentioned below. The offset tap of 68 should be the available value nearest to half the difference between the ohmic settings of 68 and 21. The reach of 68 must not be great enough to cause operation by maximum load current.
CHC12A	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferably 58% of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABLE XII

PHASE RELAY SETTINGS -- CEY51A-CEY52A-CEB52A RELAYS -- 3-TERMINAL LINES -- DWG. 116B9498
OR GCY51A RELAYS -- 3-TERMINAL LINES -- DWG. 116B9496

DEVICE	DEV. NO.	UNIT	SETTINGS
CEY51A OR GCY51	21-M1 21	M1	Set for 80-90% of the impedance to the nearer remote terminal, taking the line impedance angle into consideration. Do not include the effects of infeed.
CEY52A OR GCY51	21-M2 21	M2	Set to reach 110-150% of the maximum apparent impedance to either of the other terminals including the effects of the infeed and line-impedance angle. 110% gives slow operation for end-zone faults, so it would be used only to prevent false operation on swings or to avoid excessive reach from the standpoint of coordination with relays on other lines out of the other stations. 150% is the preferred setting. However, the setting should not be long enough to require a setting on 68 so high that it will be picked up by maximum load.
CEB52A OR GCY51	21RM3		For each terminal, make the following calculation of desired reach for each of the other terminals with the opposite one of the other terminals open, and use the greater of the two values of desired reach. Minimum reach = 1.25 [(Settings of M at opposite end) + 0.5 - (ohms of line section between the two closed terminals)] .
RPM21D OR RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of either of the other two stations, within reach of M2 (omitting the effect of infeed), plus the desired margin (margin usually 10 cycles).
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of this station, within reach of OM3 (omitting the effect of infeed), plus the desired margin (margin usually 10 cycles).
CEB51A	68	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68 should exceed the reach of 21-M2 or 21/M2 by an amount sufficient to allow at least 4 cycle (.067 sec.) along the swing line intersecting the two characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load, mentioned below. The offset tap of 68 should be the available value nearest to half the difference between the ohmic settings of 68 and 21. The reach of 68 must not be great enough to cause operation by maximum load. If this requirement cannot be met, the setting of 21 must be reduced (which will result in sequential tripping), and the CEB14 should be substituted to prevent 68/OB getting set up for a particular range of fault locations.
CHC12	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferable 58% of the minimum 3-phase fault current but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABLE XIII
PHASE RELAY SETTINGS -- GCX51-CFZ17 RELAYS -- 2-TERMINAL LINES -- DWG. 116B9497

GCX51	21	M	Set for at least 125% of the impedance to the opposite terminal, taking account of the line impedance angle. However, 125% tends to give slow operation for end-zone faults, so at least 150% is preferred. The setting must not be large enough to permit operation by maximum load, or to permit response to a severe fault on an adjacent phase. The setting is also influenced by the fact that if there is no local back-up relaying on other lines out of the opposite terminal, it is desirable to have M provide zone-3 protection out to 80% of the shortest zone-2 reach on any of those lines, taking account of only the minimum reliable infeed at the opposite station.
		0_1	Set for 80-90% of the reactance to the opposite terminal, for zone-1 protection.
		0_2	Set for 80% of the total reactance to the end of the shortest zone-1 reach on any other line out of the opposite station, taking account of only the minimum reliable infeed at the opposite station.
		OC	The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.
CFZ17	68	Z_{1-2} Z_{2-3} Z_{3-1}	The maximum setting is one which will permit the relay to reset at maximum load, following a swing therefore the maximum suggested setting is 80% of the impedance corresponding to maximum load. If out-of-step blocking is not used, the minimum setting = 1.25 [(Setting of M at opposite end) - (ohms of protection section)]. If out-of-step blocking is used, the minimum setting for that purpose should be determined by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system conditions) progresses. The reach of 68 should exceed the reach of 21/M by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of 21/M Then use the higher of the minimums found for the carrier starting function and for the out-of-step blocking function, subject to the maximum determined by the load, mentioned above.
RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of the opposite station, within reach of this 21/02, plus the desired margin.
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of the opposite station, within reach of this 21/M, plus the desired margin (margin usually 10 cycles).

TABLE XIV
PHASE RELAY SETTINGS -- GCX51A-CEB52A -- 3-TERMINAL LINES -- DWG. 0116B9495

GCX 51A	21	01	Set for 80-90% of the reactance to the nearest other terminal. Do not include the effects of infeed.
		02	Set to reach 110% of the maximum apparent impedance to either of the other two terminals including the effects of infeed and line-impedance angle.
		M	Set to reach 125-150% of the maximum apparent impedance to either of the other two terminals including the effects of infeed and line-impedance angle. 150% is the preferred setting. However, the setting should not be long enough to require a setting on 68SB so high that it will be picked up by maximum load.
		OC	The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.
CEB52A	68CB	RM	For each terminal, make the following calculation of desired reach for each of the other terminals with the opposite one of the other terminals open, and use the greater of the 2 values of desired reach. Minimum reach = 1.25 [(Setting of M at opposite end) + 0.5 - (ohms of line section between the 2 closed terminals)]
RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of either of the other 2 stations, within reach of 02 (omitting the effect of infeed), plus the desired margin, (margin usually 10 cycles).
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of this station, within reach of M or RM (omitting the effect of infeed), plus the desired margin (margin usually 10 cycles).
CEB51A	68SB	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing(for each system condition) progresses. The reach of 68SB should exceed the reach of 21 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the

TABLE XIV (continued)

			swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load, mentioned below. The offset tap of 68SB should be the available value nearest to half the difference between the ohmic settings of 68SB and 21. The reach of 68SB must not be great enough to cause operation by maximum load.

TABLE XV

PHASE RELAY SETTINGS -- GCXY -- 2-TERMINAL LINES -- DWG. 116B9495

DEVICE	DEV. NO.	UNIT	SETTINGS
GCXY51A	21	M3	Set for at least 125% of the impedance to the opposite terminal, taking account of the line impedance angle. However, 125% tends to give slow operation for end-zone faults, so at least 150% is preferred. The setting must not be large enough to permit operation by maximum load, or to permit response to a severe fault on an adjacent phase. The setting is also influenced by the fact that if there is no local back-up relaying on other lines out of the opposite terminal, it is desirable to have M provide zone-3 protection out to 80% of the shortest zone-2 reach on any of those lines, taking account of only the minimum reliable infeed at the opposite station.
		0_1	Set for 80-90% of the reactance to the opposite terminal, for zone-1 protection.
		0_2	Set for 80% of the total reactance to the end of the shortest zone-1 reach on any other line out of the opposite station, taking account of only the minimum reliable infeed at the opposite station.
		OM3	The setting of these units depends on the line impedance and the M2 setting at the opposite terminal. Set for not less than 1.25 [(Setting of M2 at opposite end) + (OM3 offset ohms) - (ohms of protected line section)].
RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of the opposite station, within reach of 21/M2; plus the desired margin(margin usually 10 cycles).
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of the station where these relays are, with reach of this 21/OM3, plus the desired margin (margin usually 10 cycles).
CEB51A	68	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68 should exceed the reach of 21 by an amount sufficient to allow at least 4 cycles (.067 sec.) along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitation due to load, mentioned below. The offset tap of 68 should be the available value nearest to half the difference between the ohmic settings of 68 and 21. The reach of 68 must not be great enough to cause operation by maximum load.
CHC12A	50		The setting with a phase-to-phase test connection should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

TABLE XVI

PHASE RELAY SETTINGS -- GCXY -- 3-TERMINAL LINES -- DWG. 0116B9495

GCXY	21	O1	Set for 80-90% of the reactance to the nearest other terminal. Do not include the effects of infeed.
		O2	Set to reach 110% of the maximum apparent impedance to either of the other two terminals including the effects of infeed and line-impedance angle.
		M3	Set to reach 125-150% of the maximum apparent impedance to either of the other two terminals including the effects of infeed and line-impedance angle. 150% is the preferred setting. However, the setting should not be long enough to require a setting on 68 so high that it will be picked up by maximum load.
		OM3	For each terminal, make the following calculation of desired reach for each of the other terminals with the opposite one of the other terminals open, and use the greater of the 2 values of desired reach. Minimum reach = 1.25 [(Setting of M at opposite end) + 0.5 - (ohms of line section between the 2 closed terminals)].
RPM11D	21X	TU2	Set for a long enough delay to permit clearing of any fault on any other line out of either of the other 2 stations, within reach of M2 (omitting the effect of infeed), plus the desired margin (margin usually 10 cycles).
		TU3	Set for a long enough delay to permit clearing of any fault on any other line out of this station, within reach of OM3 (omitting the effect of infeed), plus the desired margin (margin usually 10 cycles).
CEB51A	68	MB	This setting should be chosen by means of a graphic solution on an R-X diagram, including swing lines for different system conditions, showing the successive values of apparent impedance at known intervals of time as the fastest swing (for each system condition) progresses. The reach of 68 should exceed the reach of 21 by an amount sufficient to allow at least 4 cycles (.067 sec.)along the swing line intersecting the 2 characteristics. If no swing study is available as a basis for these settings, the setting should be at least 150% of the setting of M, subject to the limitiation due to load, mentioned below. The offset tap of 68 should be the available value nearest to half the difference between the ohmic settings of 68 and 21. The reach of 68 must not be great enough to cause operation by maximum load.
CHC12A	50		The setting with a phase-to-phase test connections should be not more than 58% of the minimum 3-phase fault current. This insures at least 150% of pickup for phase-to-phase faults, or more for 3-phase faults.
PJC31C	50		The setting should be not more than 69%, or preferably 58%, of the minimum 3-phase fault current; but not less than 110% of the maximum load current. The 69% value insures at least 125% of pickup for phase-to-phase faults.

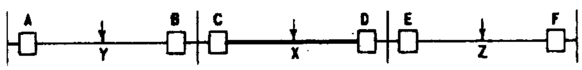


FIG. 1 (K-6400721-2) Sh. 1 Typical Transmission Lines

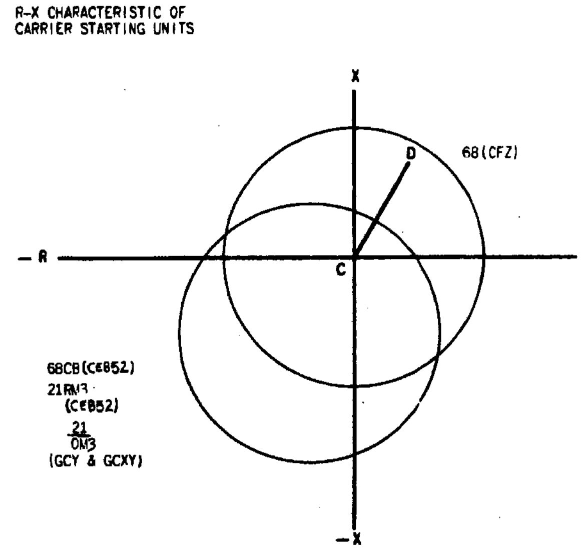


FIG. 2 (K-6400721-4) Sh. 3 Carrier Starting Unit Characteristics

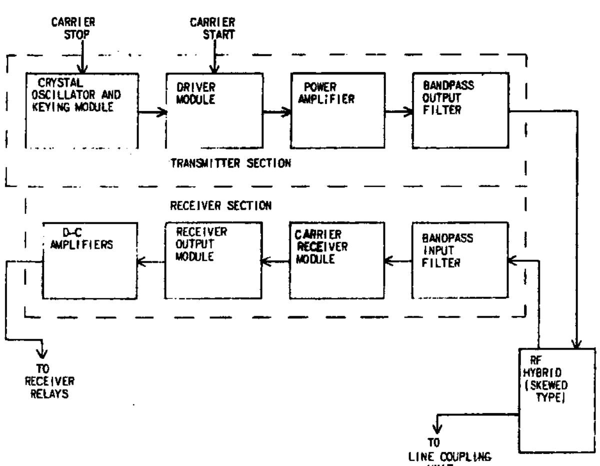


FIG. 3 (0226A6908-0) Sh. 3 Block Diagram Of CS27B Carrier Set

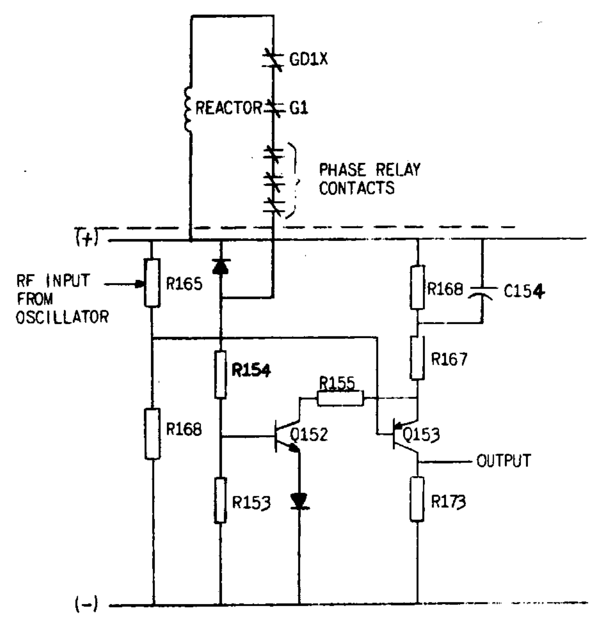


FIG. 4 (0226A6908-0) Sh. 2 Carrier Starting Control Of CS27B

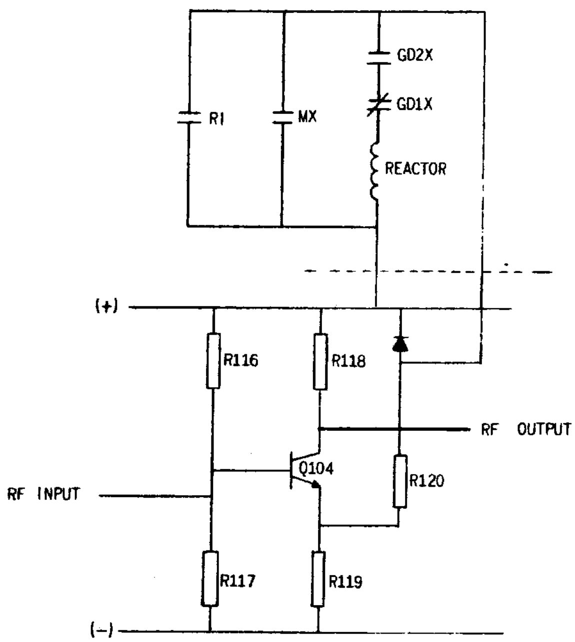


FIG. 5 (0226A6908-0) Sh. 1 Carrier Stopping Control of CS27B

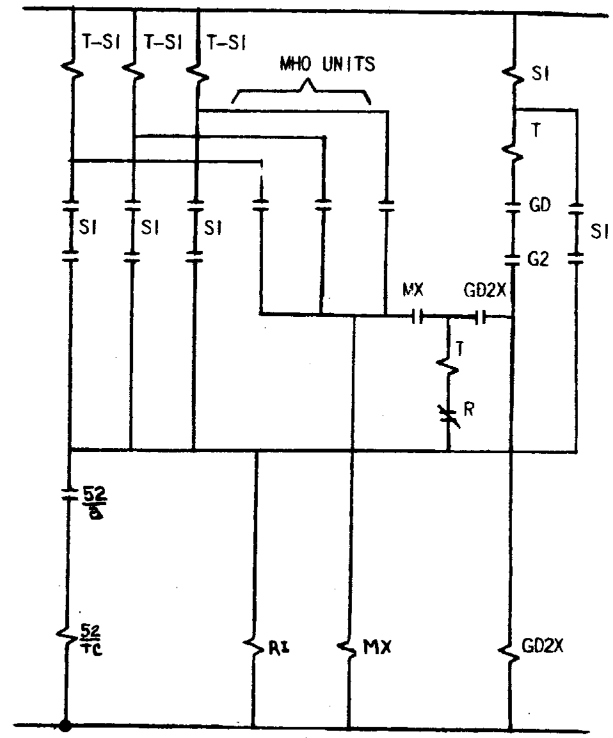


FIG. 6 (0165A6077-2) Sh. 3 Carrier Trip And Auxiliary Circuits

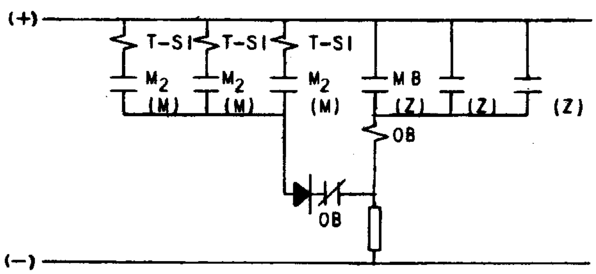


FIG. 7 (K-6400721-4) Sh. 11 Out-of-Step Blocking Control Circuits

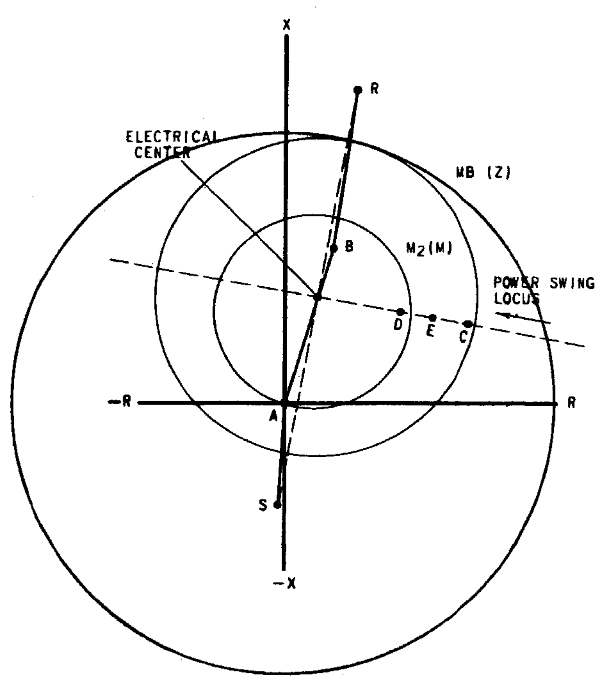


FIG. 8 (K-6400721-2) Sh. 13 Out-of-Step Blocking Coordination

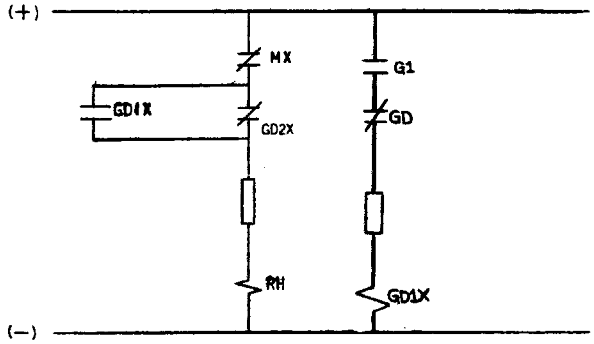


FIG. 9 (K-6400721-4) Sh. 8 Carrier Coordination Control Circuits

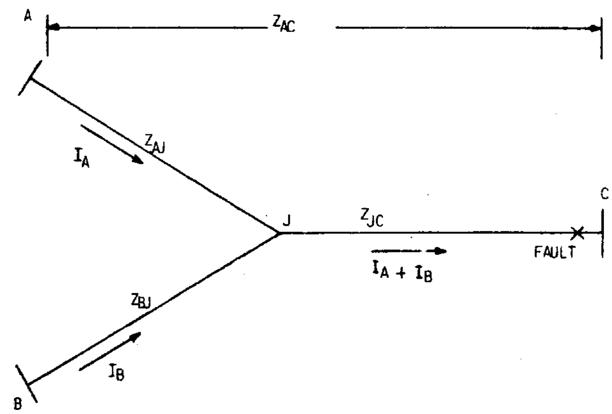


FIG. 10 (0227A2530-0) Three Terminal Line

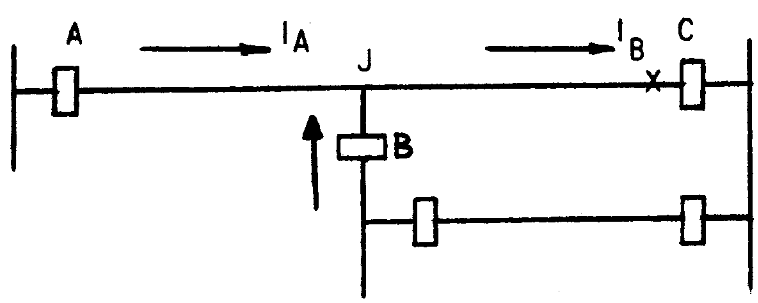
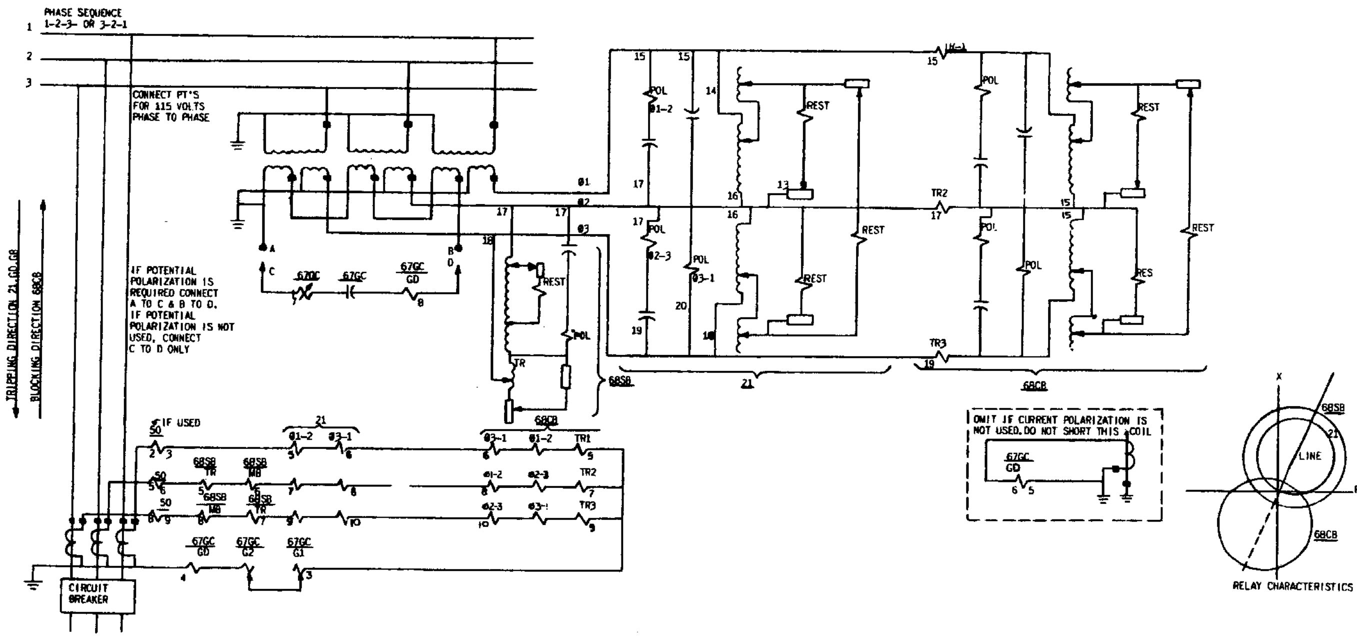


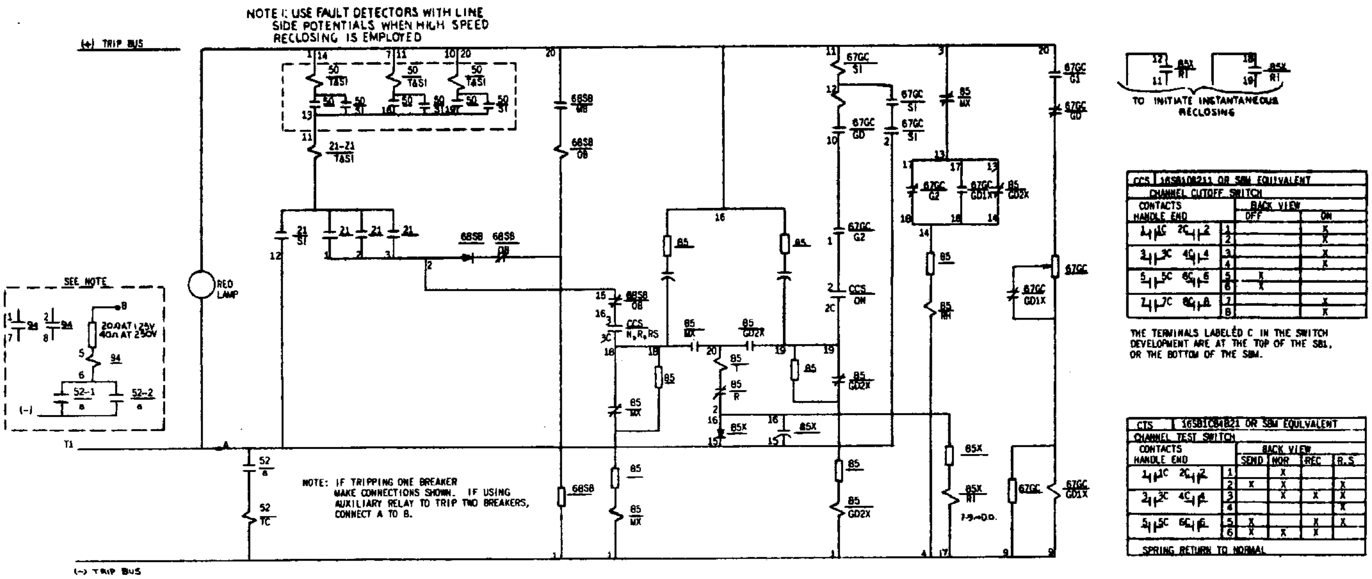
FIG. 11 (0165A6077-2) Sh. 4 Three Terminal Line With External Tie



DEVICE NO	DEVICE TYPE	INCL ELEM	LEGEND
21	CEY52A		3 PHASE MHO TYPE CARRIER TRIP RELAY
		φ1-2	PHASE 1-2 UNIT ETC.
		T&SI	TARGET & SEAL-IN UNIT
50	CHC12		INSTANTANEOUS FAULT DETECTOR
		SI	SEAL-IN
		T	TARGET
50	PJC31C		INSTANTANEOUS OVERCURRENT RELAY
		T&SI	TARGET & SEAL-IN UNIT
67GC	CLPG12C		CARRIER GROUND RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GD1X	AUX. TO CONTINUE GROUND BLOCKING
		T&SI	TARGET & SEAL-IN UNIT
68CB	CEB52A		3 PHASE OFFSET MHO CARRIER START RELAY
		φ1-2	PHASE 1-2 UNIT ETC.
		TR1-2	PHASE 1-2 TRANSACTOR ETC.
68SB	CEB51A		OUT OF STEP BLOCKING RELAY
		MB	MHO BLOCKING UNIT
		OB	AUXILIARY UNIT TO MB
		TR	TRANSACTOR
85	BCA11AV		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER UNIT OPERATING COIL
		RH	RECEIVER UNIT HOLDING COIL
		GD2X	AUXILIARY TO GD AND G2
		MX	AUXILIARY TO M
		T	TARGET
85X	NAA22L		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING UNIT
94	HGA14AM	OR AL	AUX. FOR TRIPPING 2 BREAKERS
CCS	SB1		CHANNEL CUTOFF SWITCH
CTS	SB1		CHANNEL TEST SWITCH

TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INT. CONNS.	OUTLINE
BCA11AV		0148A4083	K-6209272
CEB51A		0178A9134	K-6209274
CEB52A		0178A7134	0178A7336
CEY52A		0178A7133	0178A7336
CHC12A		0148A3956	K-6209272
CLPG12C		0148A3975	K-6209276
PJC31C		K-6375726	K-6209272
NAA22L		0208A2307	K-6209272
CHANNEL CUTOFF SW.	SB1	16SB1DB211	116A130
CHANNEL TEST SW.	SB1	16SB1CB4B21	116A130
LAMPS	ET-6		362A612 P-1
TELEPHONE JACK			K-6400578
MICROAM DO-91 (FLUSH)			A5481699
MICROAM DO-91 (SURFACE)			0148A3372
CARRIER SET 4CS27B			
HGA14AM (BACK CONN)		K-6400533	K-6400533
HGA14AL (FRONT CONN)		377A139	377A139

FIG. 12A (0116B9493-1) Sh. 1 Elementary Diagram, Table II, IX and X



CCS	16SB1OB211 OR SBM EQUIVALENT		
CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW OFF	BACK VIEW ON
1-1C 2C-2	1		X
	2		X
3-3C 4C-4	3		X
	4		X
5-5C 6C-6	5	X	
	6	X	
7-7C 8C-8	7		X
	8		X

CTS	16SB1CB4B21 OR SBM EQUIVALENT				
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW SEND	NOR	REC	R.S
1-1C 2C-2	1		X		
	2	X	X		X
3-3C 4C-4	3		X	X	X
	4				X
5-5C 6C-6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					

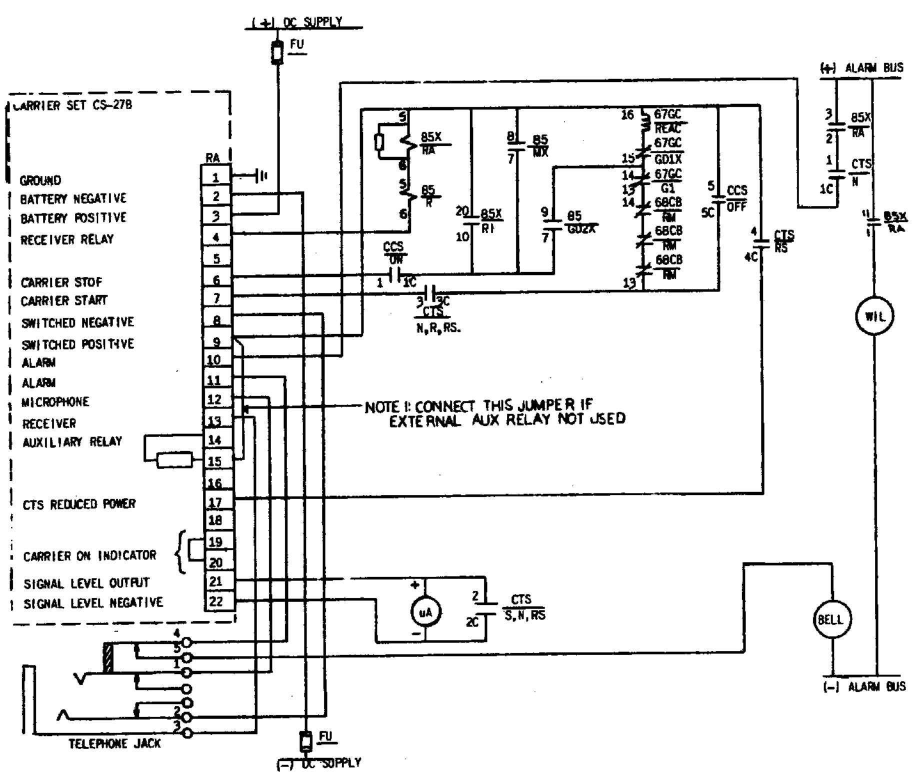
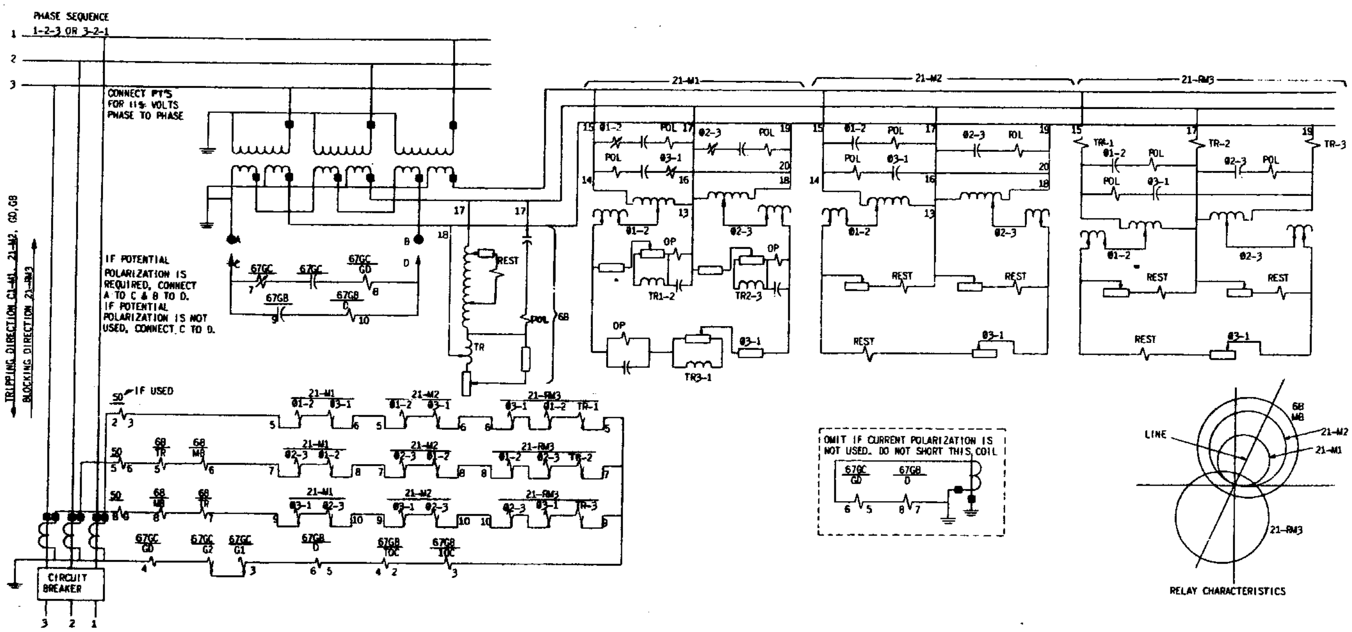


FIG. 12B (0116B9493-3) Sh. 2 Elementary Diagram, Tables II, IX and X



TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INTERNAL CONNS	OUTLINE
BCA11AV		C148A4083	K-6209272
CEB51A		0178A9134	K-6209274
CEB52A		0178A7134	0178A7336
CEY51A		0178A7132	0178A7336
CEY52A		0178A7133	0178A7336
CHC12A		0148A3956	K-6209272
CLPG12C		0148A3975	K-6209276
JBCG51K(INVERSE)		0104A8978	K-6209276
JBCG53K(VERY INVERSE)		C104A8978	K-6209276
NAA22L		0208A2307	K-6209272
RPM21D		0127A9440	K-6209270
CARRIER SET 4CS27B			
CHANNEL CUTOFF SW.	SB1	16SB1DB211	116A130
CHANNEL TEST SW.	SB1	16SB1CB4B21	116A130
MICROAM DO-91(SURFACE)			0148A3872
MICROAM DO-91(FLUSH			A-5481699
TELEPHONE JACK			K-6400578
WHITE LAMP			K-6151144
HGA14AL (FRONT CONN)		377A139	377A139
HGA14AM (BACK CONN)		K-6400533	K-6400533
PJC31C		K-6375726	K-6209272
RECTIFIER			
102L218 G10 (48,125V)			104A8523
102L218 G11 (250V)			104A8523

LEGEND			
DEVICE NO	DEVICE TYPE	INCL. ELEM	DESCRIPTION
21-M1	CEY51A		3 PHASE - 1ST ZONE MHO RELAY
		Ø1-2	PHASE 1-2 UNIT, ETC.
		T&SI	TARGET & SEAL-IN
21-M2	CEY52A		3 PHASE-2ND ZONE & CARR. TRIPING RELAY
		Ø1-2	PHASE 1-2 UNIT, ETC.
		T&SI	TARGET & SEAL-IN
21-RM3	CEB52A		3 PHASE-3RD ZONE & CARR. START MHO RELAY
		Ø1-2	PHASE 1-2 UNIT, ETC.
		TR-1	PHASE 1 TRANSACTOR ETC.
		T&SI	TARGET & SEAL-IN
21X	RPM21D		TIMING RELAY
		TU	TIMING UNIT
		TX	AUXILIARY FOR TIMING UNIT
50	PJC31C		INSTANTANEOUS PHASE FAULT DETECTOR
		T&SI	TARGET & SEAL-IN
50	CHC12		INSTANTANEOUS PHASE FAULT DETECTOR
		SI	SEAL-IN
		T	TARGET
67GC	CLPG		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GDIX	AUXILIARY TO CONTINUE BLOCKING
		SI	SEAL-IN
		T	TARGET
67GB	JBCG		GROUND DIRECTIONAL OVERCURRENT RELAY
		D	DIRECTIONAL UNIT
		IOC	INSTANTANEOUS UNIT
		TOC	TIME DELAY UNIT
		T&SI	TARGET & SEAL-IN
94	HGA14AM	OR AL	AUXILIARY TRIPPING RELAY
68	CEB51A		OFFSET MHO OUT OF STEP BLOCKING RELAY
		MB	MHO BLOCKING UNIT
		TR	TRANSACTOR
		OB	AUXILIARY TO MHO BLOCKING UNIT
85	BCA		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER RELAY PILOT COIL
		RH	RECEIVER RELAY HOLDING COIL
		GD2X	AUXILLIARY TO GD & G2
		MX	AUXILLIARY TO 21-M2
85X	NAA22L		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING UNIT
CCS	SB1		CHANNEL CUTOFF SWITCH
CTS	SB1		CHANNEL TEST SWITCH

FIG. 13A (0116B9498-1) Sh. 1 Elementary Diagram, Tables III, XI and XII

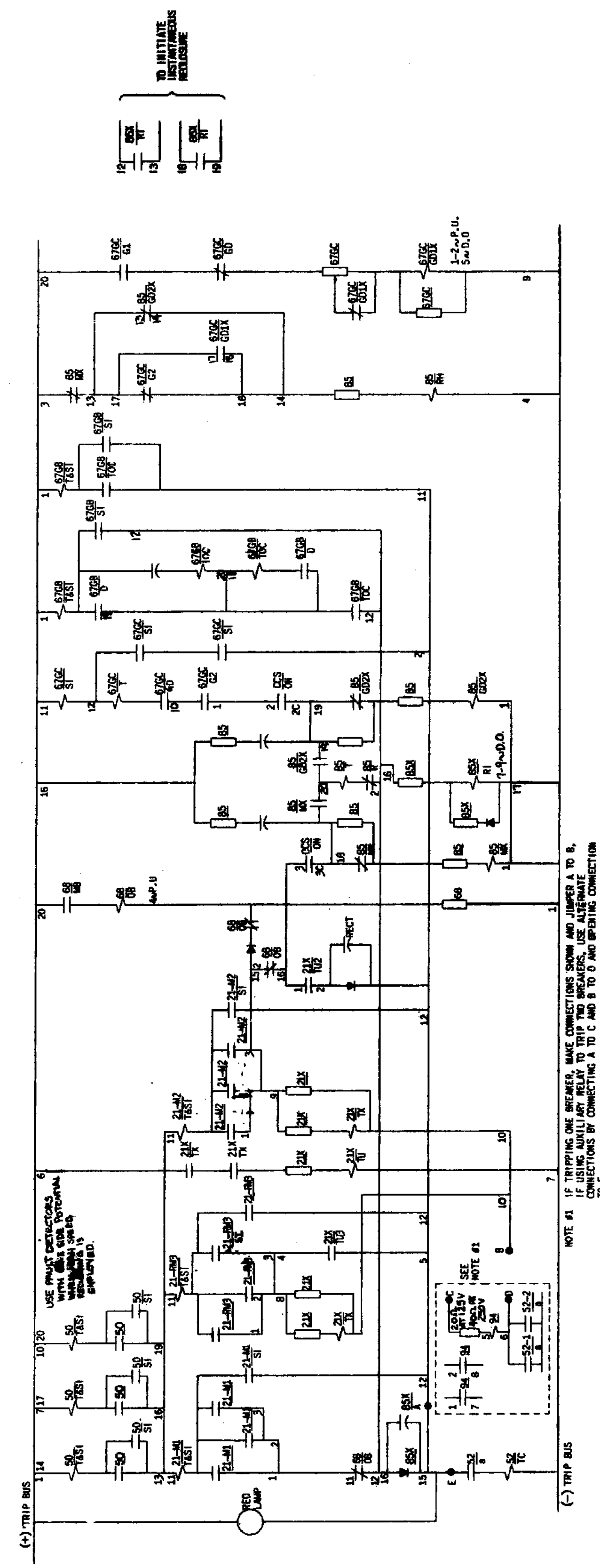
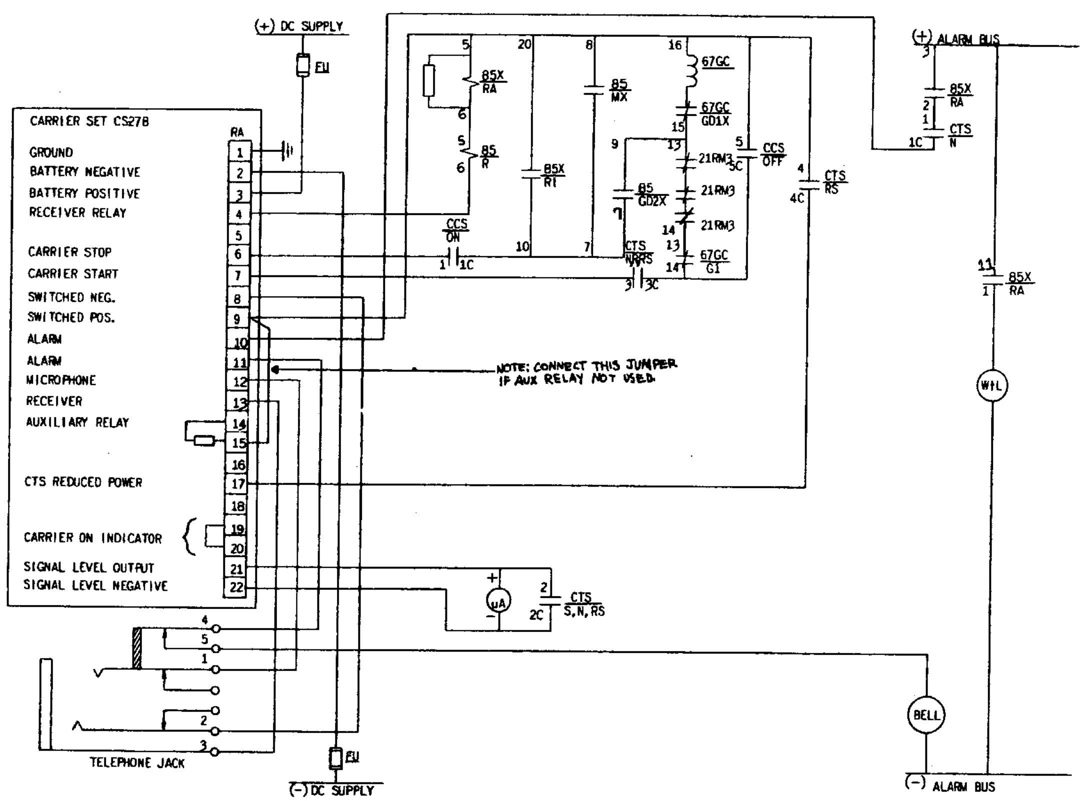


FIG. 13B (0116B9498-2) Sh. 2 Elementary Diagram, Tables III, XI and XII

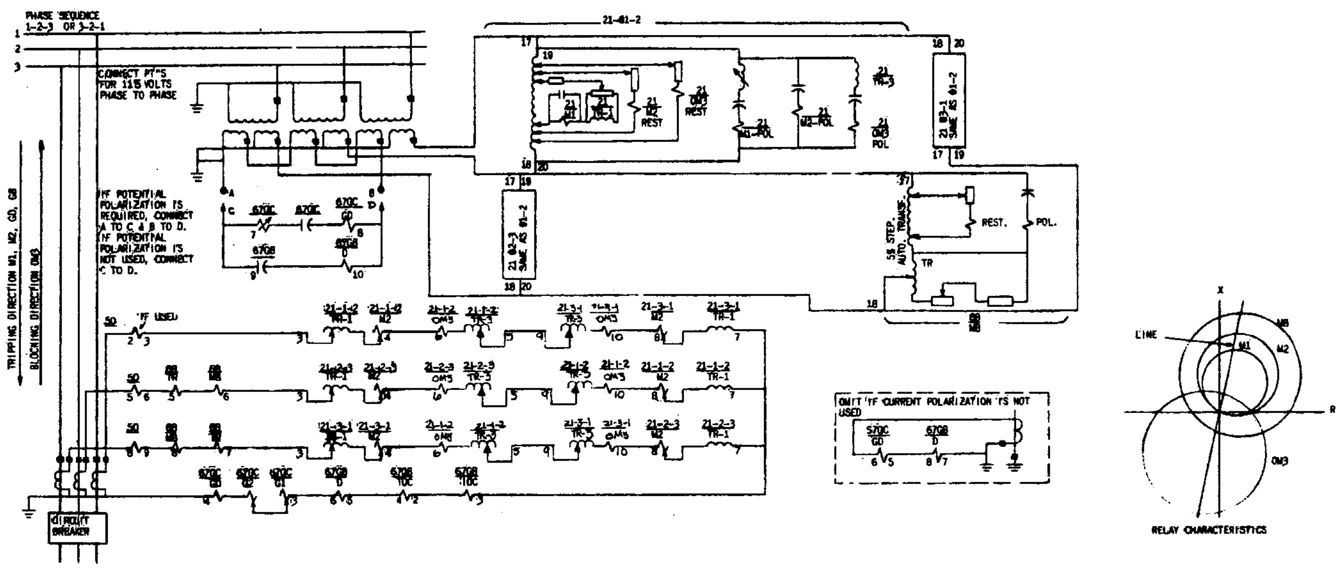


CCS 16SB1DB211 OR SBM EQUIVALENT			
CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW	
		OFF	ON
1 1C 2C 2	1		X
	2		X
3 3C 4C 4	3		X
	4		X
5 5C 6C 6	5	X	
	6	X	
7 7C 8C 8	7		X
	8		X

THE TERMINALS LABELED C IN THE SWITCH DEVELOPMENT ARE AT THE TOP OF THE SB1, OR THE BOTTOM OF THE SBM.

CTS 16SB1CB4B21 OR SBM EQUIVALENT					
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW			
		SEND	NOR	REC.	R. S.
1 1C 2C 2	1		X		
	2	X	X		X
3 3C 4C 4	3		X	X	X
	4				X
5 5C 6C 6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					

FIG. 13C (0116B9498-3) Sh. 3 Elementary Diagram, Tables III, XI and XII



TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INT. CONNS.	OUTLINE
BCA11AV		0148A4083	K-6209272
CARRIER SET 4C5278			
CHANNEL CUTOFF SW.	SB-1	16SB1DB211	116A130
CHANNEL TEST SW.	SB-1	16SB1CB4B21	116A130
CEB51A		0178A9134	K-6209274
CLPG12C		0148A3975	K-6209276
GCY51A		0178A7049	K-6209276
JBCG51K (INVERSE)		0104A8978	K-6209276
JBCG53K (VERY INVERSE)		0104A8978	K-6209276
PJC31C (IF USED)		K-6375726	K-6209272
RPM11D		0178A7092	K-6209272
MICROAM DO-91 (SEMI-FLUSH)			K-8946606
MICROAM DO-91 (SURFACE)			0148A3872
TELEPHONE JACK			K-6400578
WHITE LAMP			K-6151144
HGA14AM BACK CONN. } IF		K-6400533	K-6400533
HGA14AL FRONT CONN. } USED		377A139	377A139
CHC12A		0148A3956	K-6209272
NAA22L		0208A2307	K-6209272
RECT. 102L218G10	125V		104A8523
RECT. 102L218G11	250V		104A8523

LEGEND			
DEVICE NO	DEVICE TYPE	INCL ELEM	DESCRIPTION
21	GCY		MHO TYPE STEP DISTANCE RELAY
		M1	1ST ZONE MHO UNIT
		M2	2ND ZONE MHO UNIT
		OM3	3RD ZONE MHO UNIT
		T&SI	TARGET & SEAL-IN
		TR	TRANSACTOR
		SI	SEAL-IN
21X	RPM		TIMING RELAY
		T1	ZONE #1 TARGET
		T2	ZONE #2 TARGET
		T3	ZONE #3 TARGET
		TU	TIMING ELEMENT
		TX	AUX. FOR TIMING ELEMENT
50	PJC		INSTANTANEOUS OVERCURRENT RELAY
		T&SI	TARGET & SEAL-IN
52/a			AUX. SWITCH ON CIRCUIT BREAKER
67GB	JBCG		GROUND DIRECTIONAL OVERCURRENT RELAY
		D	DIRECTIONAL UNIT
		IOC	INSTANTANEOUS UNIT
		TOC	TIME OVERCURRENT UNIT
		T&SI	TARGET & SEAL-IN
		SI	SEAL-IN
67GC	CLPG		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GD1X	AUX. TO CONTINUE GROUND BLOCKING
		SI	SEAL-IN UNIT (GROUND)
		T	TARGET
68	CEB		OFFSET MHO BLOCKING RELAY
		MB	OUT-OF-STEP BLOCKING UNIT
		TR	TRANSACTOR
		OB	AUX. FOR OUT-OF-STEP BLOCKING
85	BCA		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER RELAY PILOT COIL
		RH	RECEIVER RELAY HOLDING COIL
		GD2X	AUX. TO GD AND G2
		MX	AUX. TO M2
		T	TARGET
85X	NAA		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING AUXILIARY
94	HGA		AUX. FOR TRIPPING TWO CIRCUIT BREAKERS
CCS			CHANNEL CUTOFF SWITCH
CTS			CHANNEL TEST SWITCH
50	CHC		INSTANTANEOUS PHASE FAULT DETECTOR
		SI	SEAL-IN
		T	TARGET

FIG. 14A (0116B9496-2) Sh. 1 Elementary Diagram, Tables IV, XI and XII

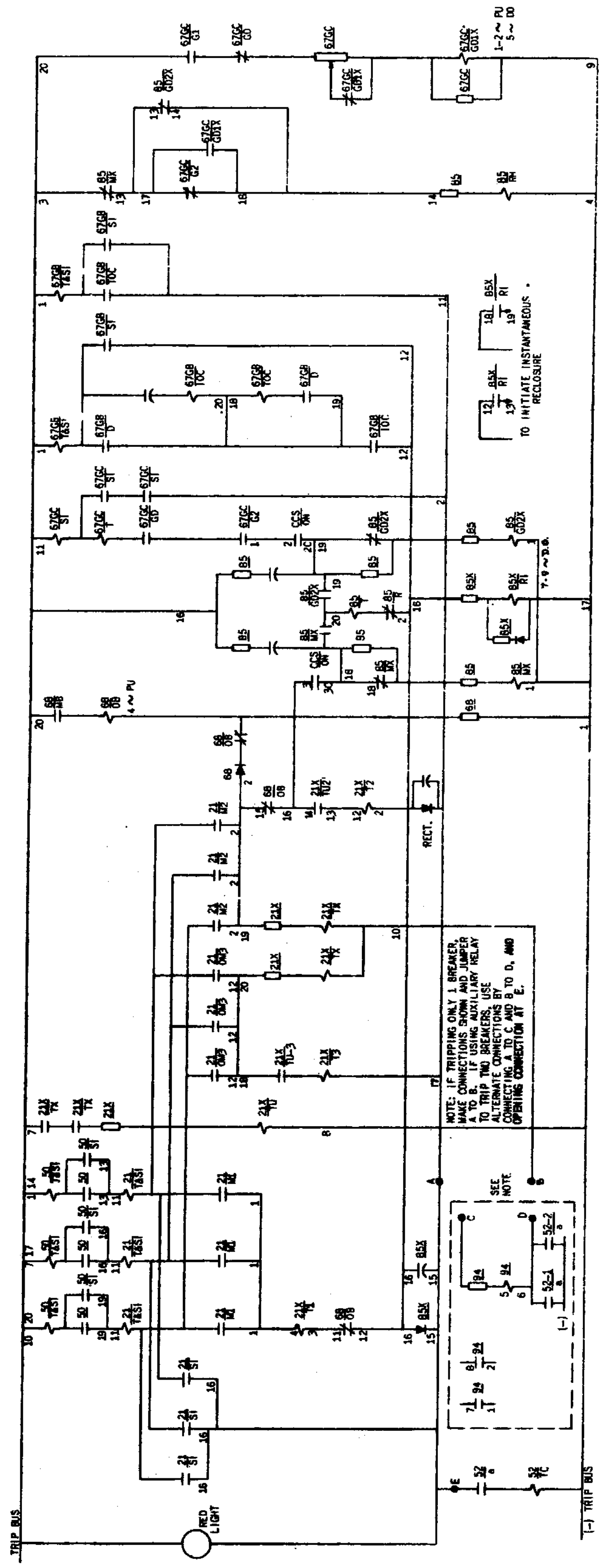
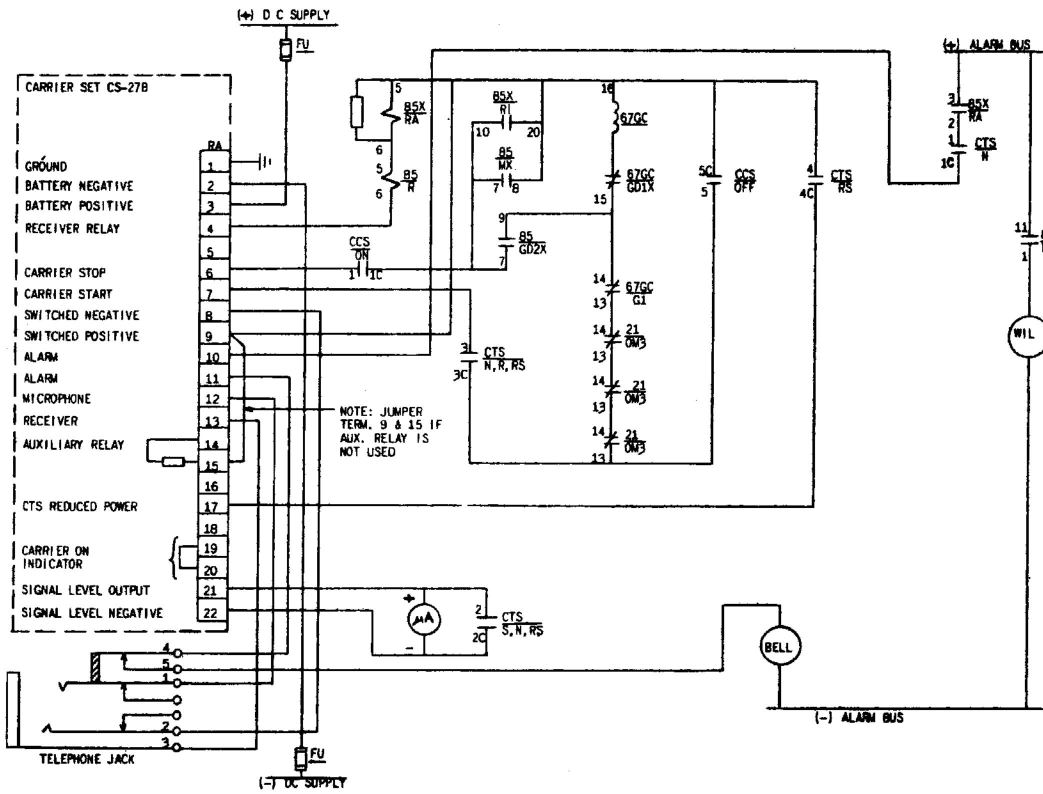


FIG. 14B (0116B9496-2) Sh. 2 Elementary Diagram, Tables IV, X

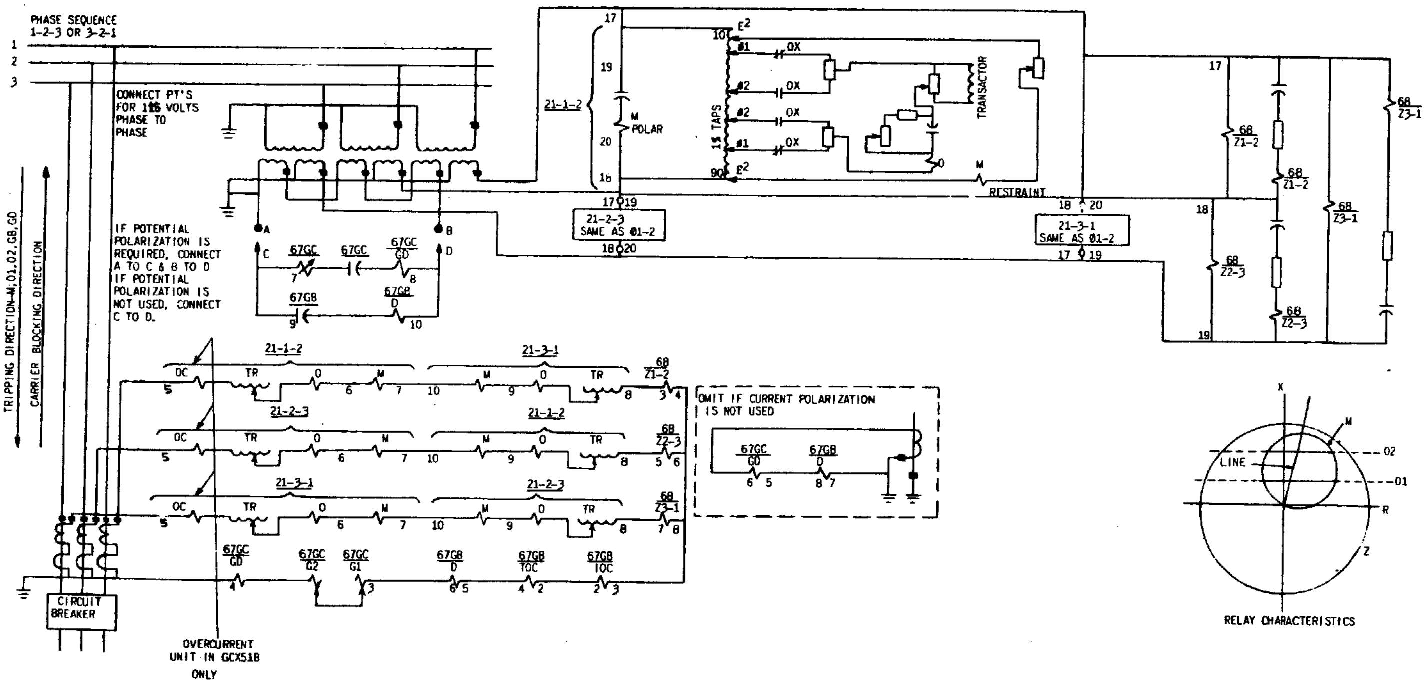


CCS 16SB1DB211 OR SBM EQUIVALENT			
CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW	
		OFF	ON
1 – 1C 2C – 2	1		X
	2		X
3 – 3C 4C – 4	3		X
	4		X
5 – 5C 6C – 6	5	X	
	6	X	
7 – 7C 8C – 8	7		X
	8		X

THE TERMINALS LABELED C IN THE SWITCH DEVELOPMENT ARE AT THE TOP OF THE SB1 OR THE BOTTOM OF THE SBM.

CTS 16SB1CB4B21 OR SBM EQUIVALENT					
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW			
		SEND	NOR	REC.	R.S.
1 – 1C 2C – 2	1		X		
	2	X	X		X
3 – 3C 4C – 4	3		X	X	X
	4				X
5 – 5C 6C – 6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					

FIG. 14C (0116B9496-1) Sh. 3 Elementary Diagram, Tables IV, XI and XII



TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INT. CONNS.	OUTLINE
BCA11AV		0148A4083	K-6209272
CHANNEL CUTOFF SWITCH	SB-1	16SB1DB211	116A130
CHANNEL TEST SWITCH	SB-1	16SB1CB4B21	116A130
CFZ17A		418A767	K-6209276
CLPG12C		0148A3975	K-6209276
GCX51A OR GCX51B		0203A8583	K-6209276
JBCG51K (INVERSE)		0104A8978	K-6209276
JBCG53K (VERY INVERSE)		0104A8978	K-6209276
MICROAM. DO91 (SEMI-FLUSH)			K-8946606
RPM11D		0178A7092	K-6209272
TEL. JACK			K-6400578
WHITE LAMP			K-6151144
CARRIER SET 4CS27B			
MICROAM. DO-91 (SURFACE)			0148A3872
HGA14AM BACK CONN. (IF USED)		K-6400533	K-6400533
HGA14AL FRONT CONN. (IF USED)		377A139	377A139
NAA22L		0208A2307	K-6209272

CCS-16SB1DB211 OR SBM EQUIVALENT CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW OFF	BACK VIEW ON
1 1C 2C 2	1		X
	2		X
3 3C 4C 4	3		X
	4		X
5 5C 6C 6	5	X	
	6	X	
7 7C 8C 8	7		X
	8		X

CTS 16SB1CB4B21 OR SBM EQUIVALENT CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW SEND	NOR	REC	R.S.
1 1C 2C 2	1		X		
	2	X	X		X
3 3C 4C 4	3		X	X	X
	4				X
5 5C 6C 6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					

LEGEND			
DEVICE NO.	DEVICE TYPE	INCL. ELEM.	DESCRIPTION
21X	RPM		TIMING RELAY
		T1	ZONE #1 TARGET
		T2	ZONE #2 TARGET
		T3	ZONE #3 TARGET
		TU	TIMING UNIT
		TX	AUX. FOR TIMING UNIT
21	GCX		REACTANCE TYPE STEP DISTANCE RELAY
		M	MHO-TYPE STARTING UNIT
		O	REACTANCE-TYPE OHM UNIT
		OX	ZONE-TRANSFER AUXILIARY FOR O
		T&SI	TARGET & SEAL-IN
52/a			AUX. SWITCH ON CIRCUIT BREAKER
67GB	JBCG		GROUND DIRECTIONAL OVERCURRENT RELAY
		D	DIRECTIONAL UNIT
		IOC	INSTANTANEOUS OVERCURRENT UNIT
		TOC	TIME OVERCURRENT UNIT
		T&SI	TARGET & SEAL-IN
67GC	CLPG		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GD1X	AUX. TO CONTINUE GROUND BLOCKING
		SI	SEAL-IN UNIT (GROUND)
		T	TARGET
68	CFZ		FAULT DETECTOR & OUT OF STEP RELAY
		OB	OUT-OF-STEP BLOCKING AUXILIARY
		Z1-2, Z2-3, Z3-1	IMPEDANCE UNITS (1 PER PHASE)
85	BCA		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER RELAY PILOT COIL
		RH	RECEIVER RELAY HOLDING COIL
		GD2X	AUX. TO GD AND G2
		MX	AUX. TO M
		T	TARGET
85X	NAA		CARRIER AUX. RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING AUXILIARY
94	HGA		AUX. FOR TRIPPING TWO CIRCUIT BREAKERS
CCS			CHANNEL CUTOFF SWITCH
CTS			CHANNEL TEST SWITCH

FIG. 15A (0116B9497-0) Sh. 1 Elementary Diagram, Tables V and XIII

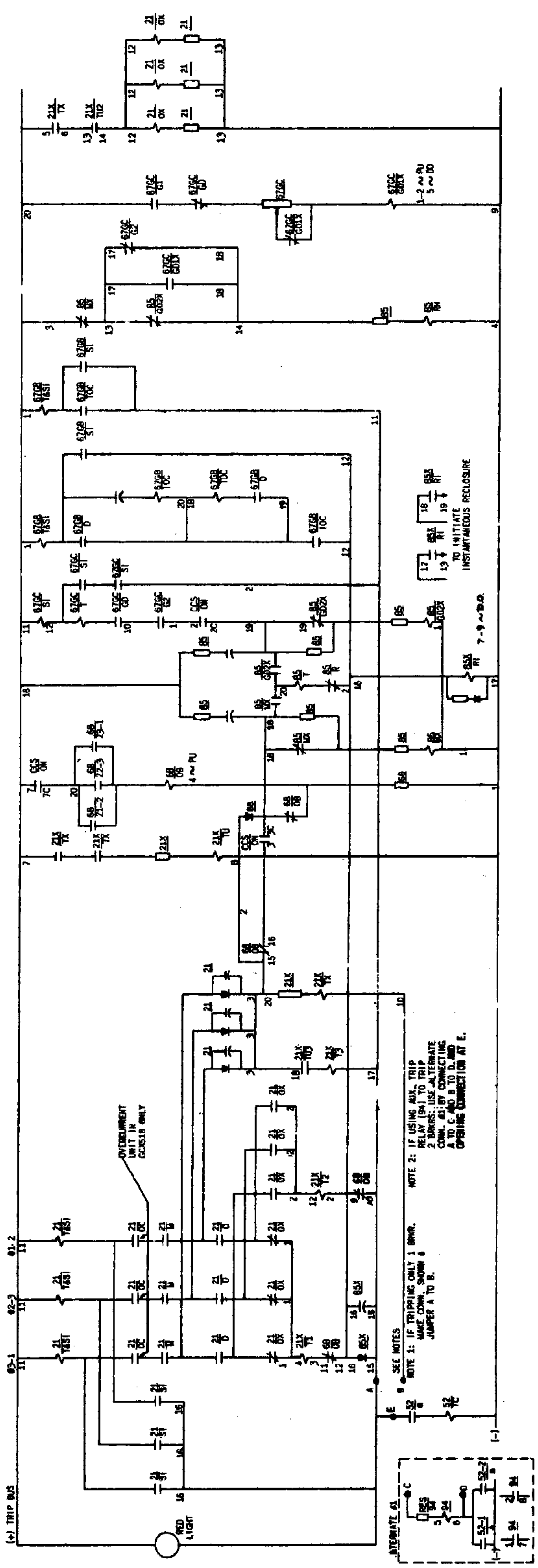
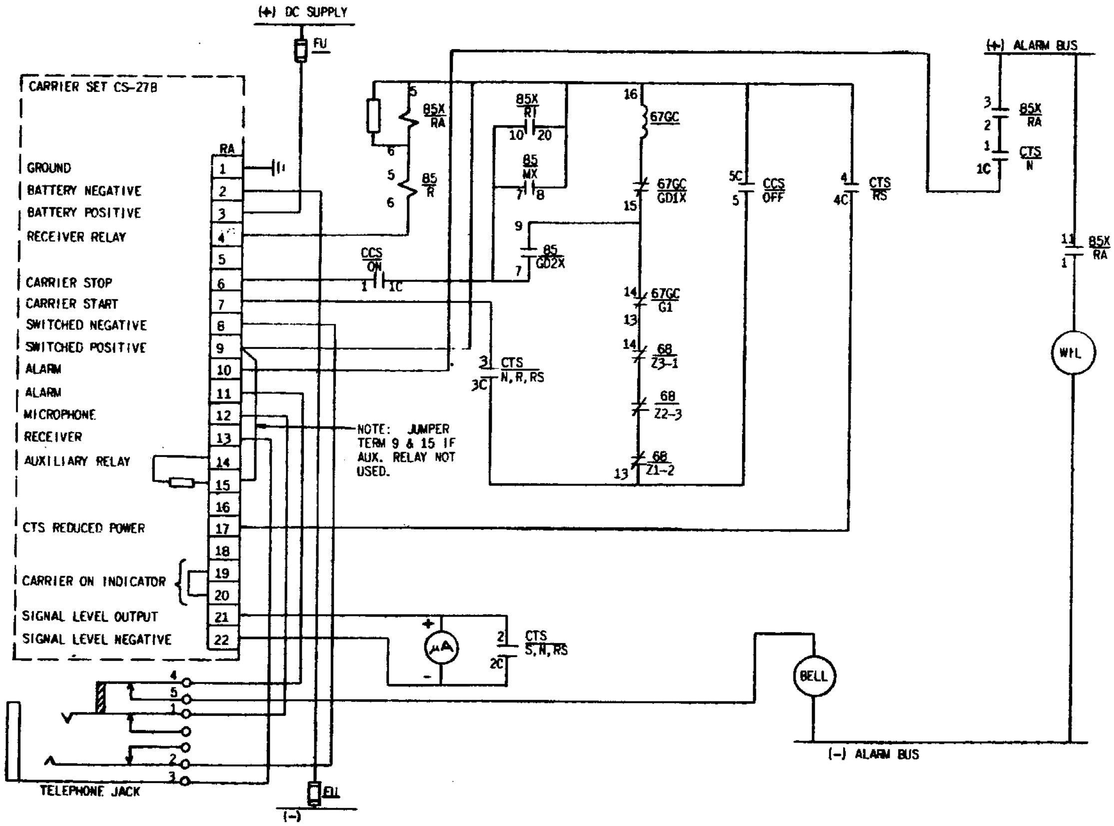


FIG. 15B (0116B9497-1) Sh. 2 Elementary Diagram, Tables V and XIII

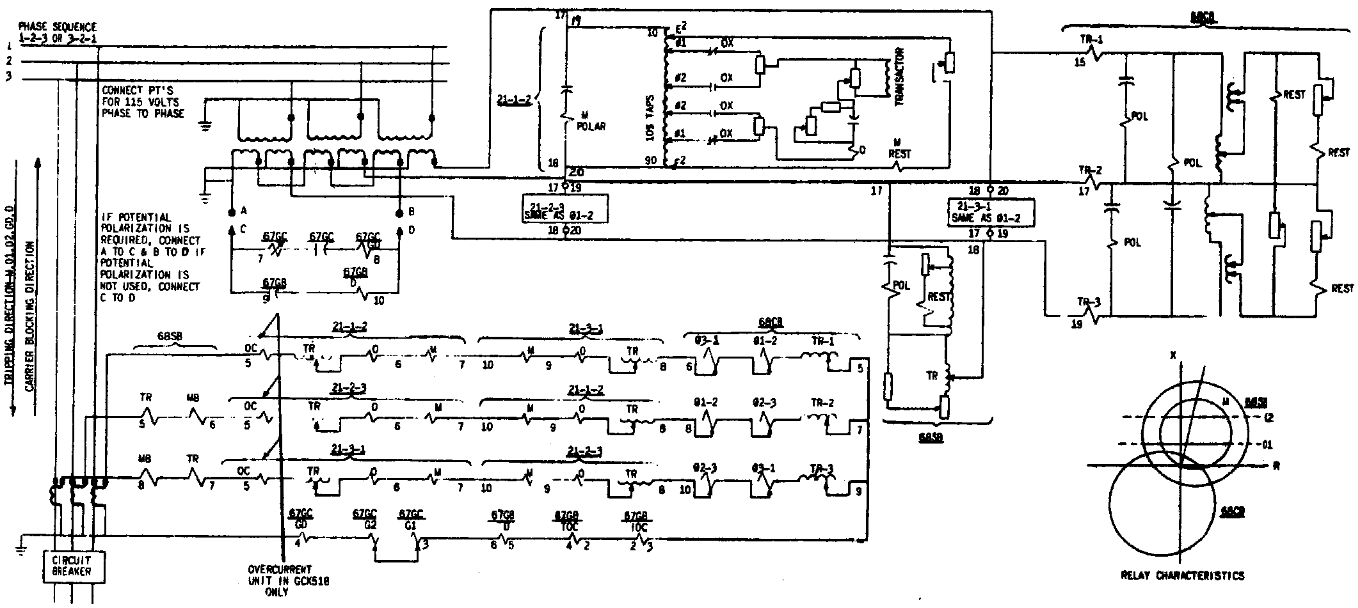


CCS 16SB1DB211 OR SBM EQUIVALENT			
CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW	
		OFF	ON
1 1C 2C 2	1		X
	2		X
3 3C 4C 4	3		X
	4		X
5 5C 6C 6	5	X	
	6	X	
7 7C 8C 8	7		X
	8		X

THE TERMINALS LABELED C IN THE SWITCH DEVELOPMENT ARE AT THE TOP OF THE SB1 OR THE BOTTOM OF THE SBM.

CTS 16SB1CB4B21 OR SBM EQUIVALENT					
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW			
		SEND	NOR	REC	R.S.
1 1C 2C 2	1		X		
	2	X	X		X
3 3C 4C 4	3		X	X	X
	4				X
5 5C 6C 6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					

FIG. 15C (0116B9497-0) Sh. 3 Elementary Diagram, Tables V and XIII



TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INT. CONNS.	OUTLINE
BCA11AV		0148A4083	K-6209272
CARRIER SET 4CS278			
CARRIER CUTOFF SWITCH	SB1	16SB1DB211	116A0130
CARRIER TEST SWITCH		16SB1CB4B21	116A0130
CEB51A		178A9134	K-6209274
CEB52A		178A7134	178A7336
CLPG12C		148A3975	K-6209276
GCX51A OR B		203A8583	K-6209276
JBCG51K (INVERSE)		104A8978	K-6209276
JBCG53K (VERY INVERSE)		104A8978	K-6209276
MICROAM DO-91 (SEMI-FLUSH)			K-8946606
MICROAM DO-91 (SURFACE)			148A3872
NAA22L		208A2307	K-6209272
RPM11D		178A7092	K-6209272
TELEPHONE JACK			K-6400578
WHITE LAMP (ET-5)			K-6151144
HGA14AM BACK CONN. IF USED		K-6400533	K-6400533
HGA14AL FRONT CONN		377A0139	377A0139
RECTIFIER/D 208A3666 [?] GR-1 (DOUBLE UNIT)	48V		208A3716
" GR-2	125V		208A3716
" GR-3	250V		208A3716
RECTIFIER/S " GR-4 (SINGLE UNIT)	48V		208A3717
" GR-5	125V		208A3717
" GR-6	250V		208A3717

NOTE 1: IF TRIPPING ONE BREAKER, MAKE CONNECTIONS SHOWN AND JUMPER A TO B. IF USING AUXILIARY RELAY (94) TO TRIP TWO BREAKERS USE ALTERNATE CONNECTIONS BY CONNECTING A TO C AND B TO D. AND OPEN CONNECTION AT E.

NOTE 2: CIRCUIT SHOWNPROVIDES THIRD ZONE PROTECTION IN BOTH FORWARD AND REVERSE DIRECTIONS. IF PROTECTION IN ONLY ONE DIRECTION IS DESIRED, RECTIFIER IS NOT REQUIRED, AND CONNECTIONS FROM UNUSED UNIT TO TX COIL AND STUD 18 OF 21X MUST BE REMOVED, IF 68CB IS UNIT NOT USED, ALSO OPEN CONNECTION TO STUD 12 OF 68CB.

NOTE 3: OVERCURRENT UNIT IN GCX51B ONLY. USE OVERCURRENT UNIT WITH LINE SIDE POTENTIAL WHEN HIGH SPEED RECLOSING IS EMPLOYED.

LEGEND			
DEV. NO.	DEVICE TYPE	INCL. ELEM.	DESCRIPTION
21	GCX		REACTANCE TYPE STEP DISTANCE RELAY
		M	MHO TYPE STARTING UNIT
		O	REACTANCE TYPE OHM UNIT
		OC	OVERCURRENT FAULT DETECTOR
		OX	ZONE TRANSFER AUXILIARY FOR O
		T&SI	TARGET AND SEAL-IN
21X	RPM		TIMING RELAY
		T1,T2,T3	TARGETS FOR ZONES 1, 2, & 3
		TU	TIMING UNIT
		TX	AUX. FOR TIMING UNIT
67GB	JBCG		GROUND DIRECTIONAL OVERCURRENT RELAY
		D	DIRECTIONAL UNIT
		IOC	INSTANTANEOUS OVERCURRENT UNIT
		TOC	TIME OVERCURRENT UNIT
		T&SI	TARGET AND SEAL-IN
67GC	CLPG		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GD1X	AUX. TO CONTINUE GROUND BLOCKING
		SI	SEAL-IN
		T	TARGET
68CB	CEB52A		3 PHASE OFFSET MHO CARRIER START RELAY
		MB	MHO BLOCKING UNIT
		TR1-2	PHASE 1-2 TRANSACTOR, ETC.
68SA	CEB51A		OUT OF STEP BLOCKING RELAY
		MB	MHO BLOCKING UNIT
		OB	AUX. UNIT TO MB
		TR	TRANSACTOR
85	BCA		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER UNIT OPERATING COIL
		RH	RECEIVER UNIT HOLDING COIL
		GD2X	AUX. TO GD AND G2
		MX	AUX. TO M
		T	TARGET
85X	NAA22L		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING UNIT
94	HGA11AM OR AL		AUX. FOR TRIPPING 2 BREAKERS
CCS	SB1		CHANNEL CUTOFF SWITCH
CTS	SB1		CHANNEL TEST SWITCH

FIG. 16A (0164B9179-2) Sh. 1 Elementary Diagram, Table VI

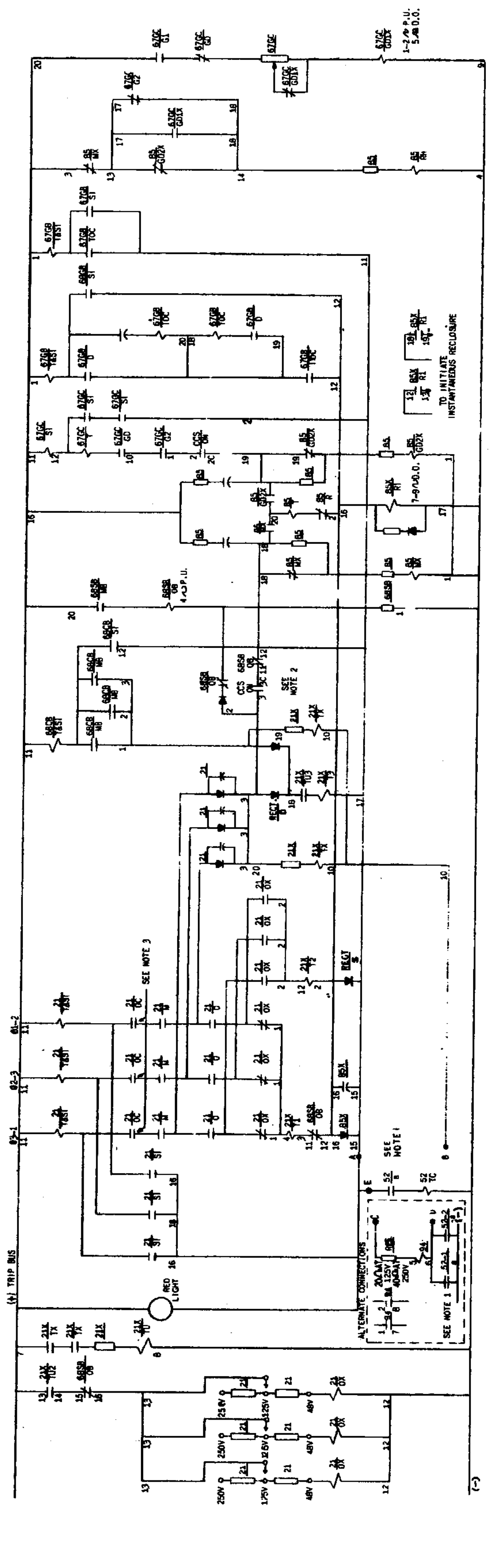
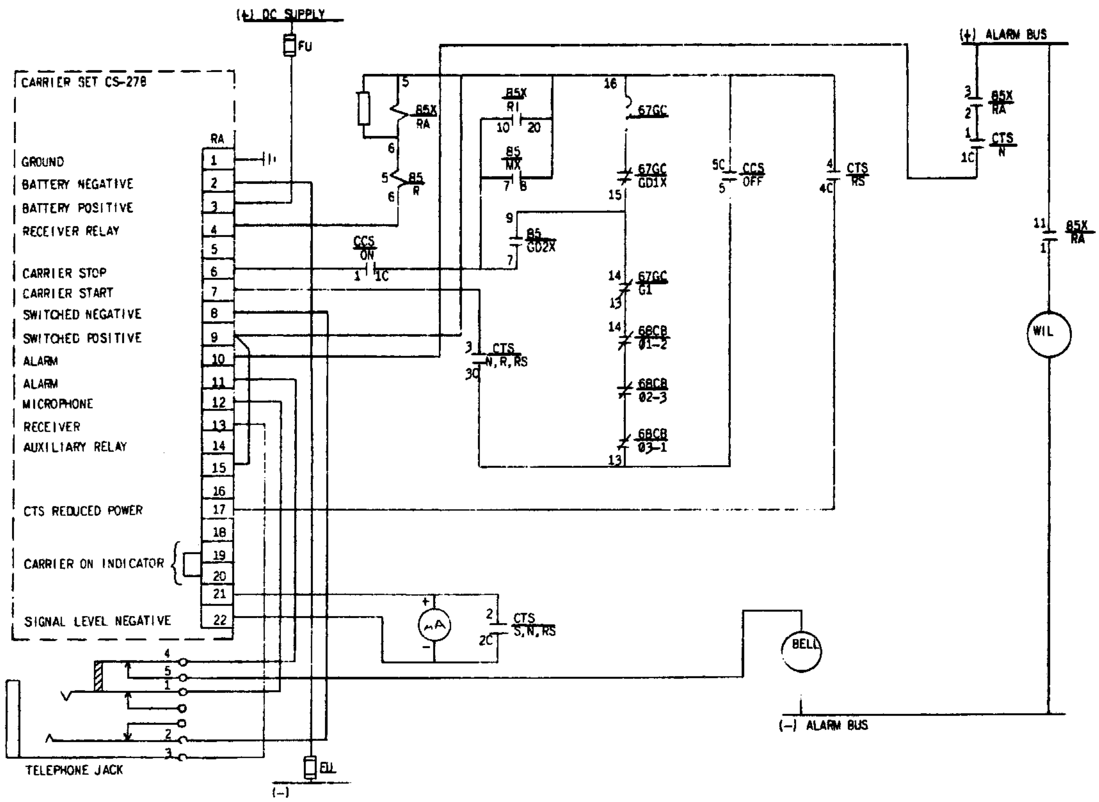


FIG. 16B (0164B9179-3) Sh. 2 Elementary Diagram, Table VI

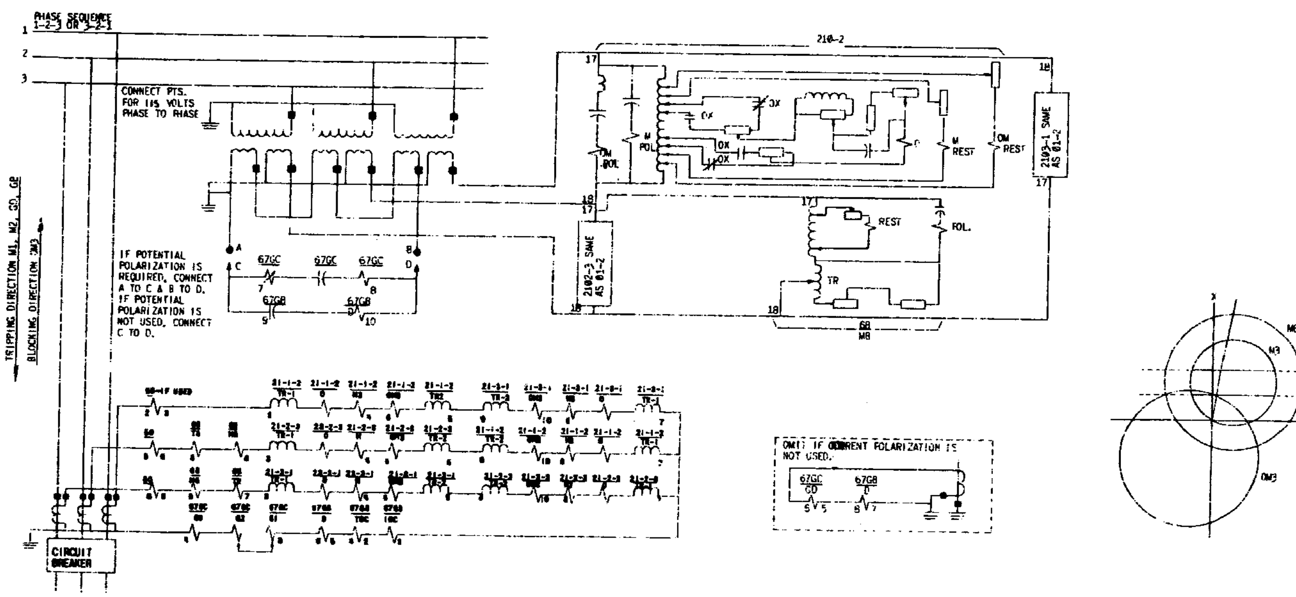


CCS 16SB1DB211 OR SBM EQUIVALENT			
CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW	
		OFF	ON
1 1C 2C 2	1		X
	2		X
3 3C 4C 4	3		X
	4		X
5 5C 6C 6	5	X	
	6	X	
7 7C 8C 8	7		X
	8		X

THE TERMINALS LABELED C IN THE SWITCH DEVELOPMENT ARE AT THE TOP OF THE SB1 OR THE BOTTOM OF THE SBM.

CTS 16SB1CB4B21 OR SBM EQUIVALENT					
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW			
		SEND	NOR	REC	R.S.
1 1C 2C 2	1		X		
	2	X	X		X
3 3C 4C 4	3		X	X	X
	4				X
5 5C 6C 6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					

FIG. 16C (0164B9179-0) Sh. 3 Elementary Diagram, Table VI



TABULATION OF DEVICES

TYPE OF DESCRIPTION		INTERNAL CONNS.	OUTLINE
BCA11AV		0148A4083	K-6209272
CARRIER SET 4CS27B			
CHANNEL CUTOFF SW.	SB-1	16SB1DB211	116A[illegible]
CHANNEL TEST SW.	SB-1	16SB1CB4B21	116A[illegible]
CEB51A		178A9134	K-6209274
CLPG12C		0148A3975	K-6209276
GCXY51A		0178A9162	0178A7336
JBCG51K(INVERSE)		0104A8978	K-6209276
JBCG53K(VERY INVERSE)		[illegible]	K-6209276
NAA22L		0208A2307	K-6209272
PJC31C (IF USED)		K-6375726	K-6209272
RPM11D		0178A7092	K-6209272
MICROAM. DO-91(SEMI-FLUSH)			A5481699
MICROAM. DO-91(SURFACE)			0148A3872
TELEPHONE JACK			K-6400578
WHITE LAMP (ET-5)			K-6151144 F-3
WHITE LAMP(ET-6)			362A612 P-1
HGA14AM BACK CONN — IF USED		K-6400533	K-6400533
HGA14AL FRONT CONN — IF USED		377A139	377A139
CHC12A		0148A3956	K-6209272
RECTIFIER/D208A3666-G1	48 V		0208A3716
(DOUBLE UNIT) " G2	125V		0208A3716
" G3	250V		0208A3716
RECTIFIER/S " G4	48V		0208A3717
(SINGLE UNIT) " G5	125V		0208A3717
" G6	250V		0208A3717

LEGEND

DEVICE FUNCTION	DEVICE TYPE	INCL. ELEM.	DESCRIPTION
21	GCXY		REACTANCE TYPE STEP DISTANCE RELAY
		O	REACTANCE TYPE OHM UNIT
		M3	3RD ZONE MHO UNIT
		OM3	REVERSED 3RD ZONE MHO UNIT
		OX	ZONE TRANSFER AUX. FOR O
		TASI	TARGET & SEAL-IN
		SI	SEAL-IN
21X	RPM		TIMING RELAY
		T1	ZONE #1 TARGET
		T2	ZONE #2 TARGET
		T3	ZONE #3 TARGET
		TU	TIMING ELEMENT
		TX	AUX FOR TIMING ELEMENT
50	PJC		INSTANTANEOUS OVERCURRENT RELAY
		T&SI	TARGET & SEAL-IN
52/a			AUX. SW. ON CIRCUIT BREAKER
67GB	JBCG		GROUND DIRECTIONAL OVERCURRENT RELAY
		D	DIRECTIONAL UNIT
		IOC	INSTANTANEOUS UNIT
		TOC	TIME OVERCURRENT UNIT
		TASI	TARGET & SEAL-IN
		SI	SEAL-IN
67GC	CLPG		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GD1X	AUX. TO CONTINUE GROUND BLOCK
		SI	SEAL-IN UNIT
		T	TARGET
68	CEB		OFFSET MHO BLOCKING RELAY
		MB	OUT-OF-STEP BLOCKING UNIT
		TR	TRANSACTOR
		OB	AUX. FOR OUT-OF-STEP BLOCKING
85	BCA		CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER RELAY PILOT COIL
		RH	RECEIVER RELAY HOLDING COIL
		GD2X	AUX. TO GD & G2
		MX	AUX. TO M3.
		T	TARGET
85X	NAA		CARRIER AUXILIARY RELAY
		RA	RECEIVER ALARM UNIT
		RI	RECLOSURE INITIATING AUX.
94	HGA		AUX. FOR TRIPPING TWO CIRCUIT BREAKERS
CCS			CHANNEL CUTOFF SWITCH
CTS			CHANNEL TEST SWITCH

FIG. 17A (0116B9495-4) Sh. 1 Elementary Diagram, Tables VII, XIV, XV and XVI

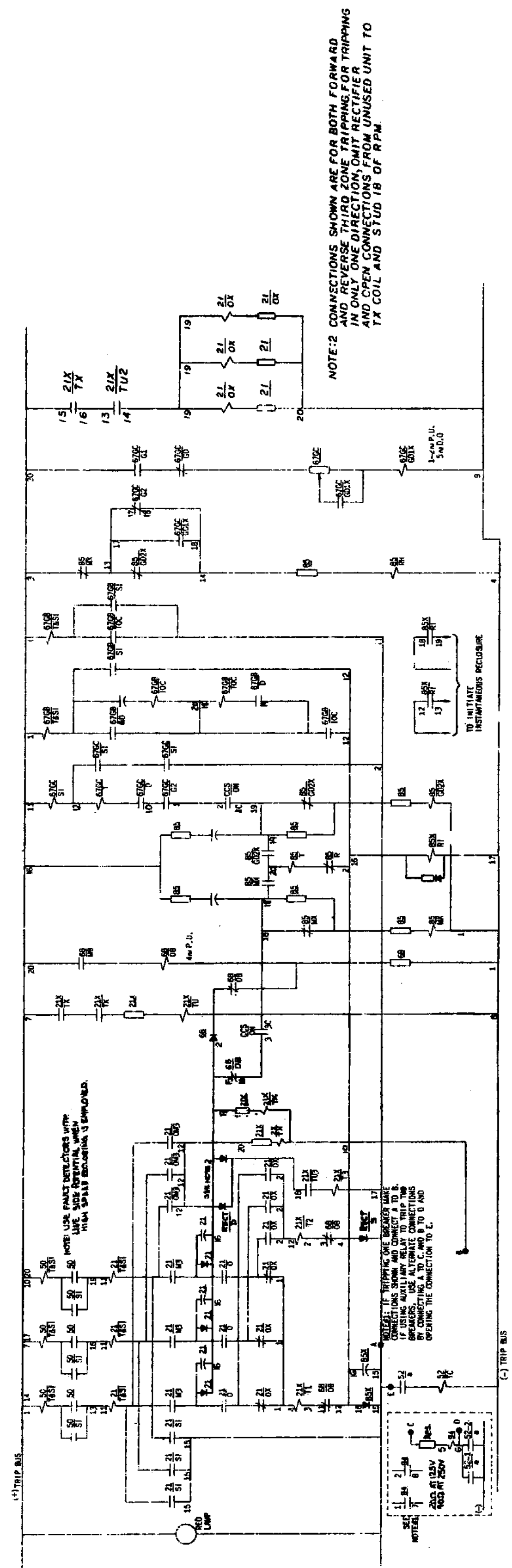
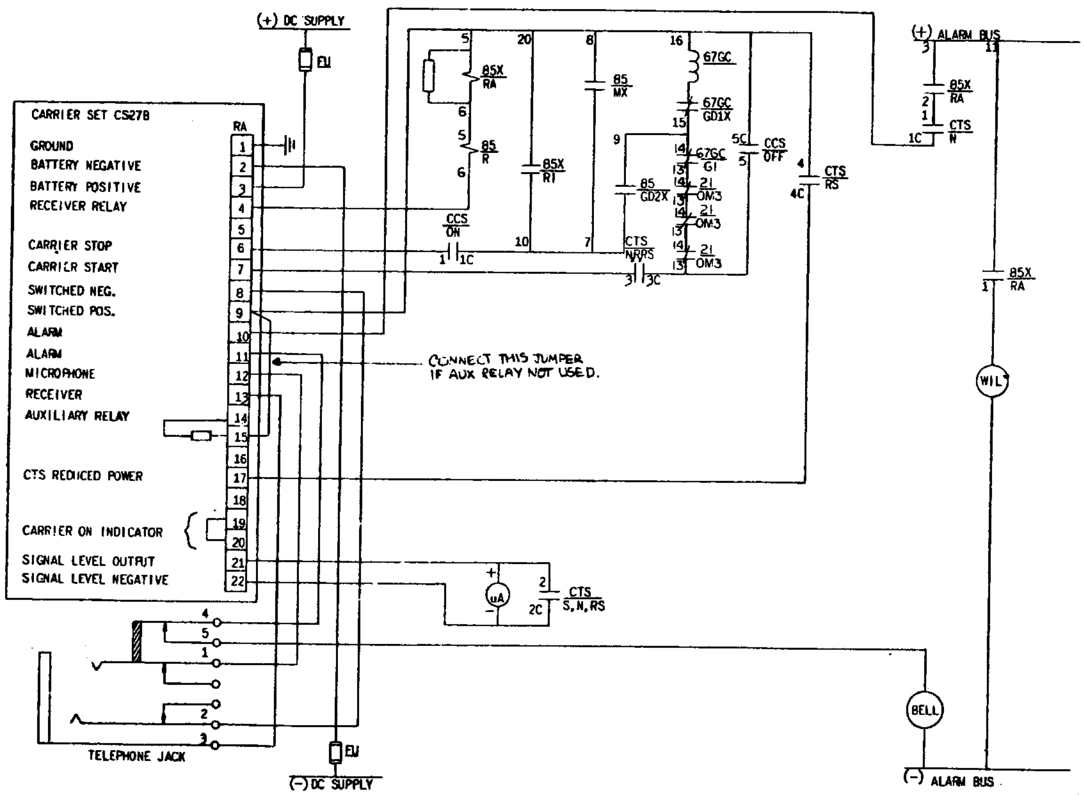


FIG. 17B (0116B9495-3) Sh. 2 Elementary Diagram, Tables VII, XIV, XV and XVI



CCS 16SB1DB211 OR SBM EQUIVALENT			
CHANNEL CUTOFF SWITCH			
CONTACTS HANDLE END		BACK VIEW	
		OFF	ON
1 1C 2C 2	1		X
	2		X
3 3C 4C 4	3		X
	4		X
5 5C 6C 6	5	X	
	6	X	
7 7C 8C 8	7		X
	8		X

THE TERMINALS LABELED C IN THE SWITCH DEVELOPMENT ARE AT THE TOP OF THE SB1, OR THE BOTTOM OF THE SBM.

CTS 16SB1CB4B21 OR SBM EQUIVALENT					
CHANNEL TEST SWITCH					
CONTACTS HANDLE END		BACK VIEW			
		SEND	NOR	REC.	R. S.
1 1C 2C 2	1		X		
	2	X	X		X
3 3C 4C 4	3		X	X	X
	4				X
5 5C 6C 6	5	X		X	X
	6	X	X	X	
SPRING RETURN TO NORMAL					

FIG. 17C (0116B9495-3) Sh. 3 Elementary Diagram, Tables VII, XIV, XV and XVI

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