



INSTRUCTIONS

GEK-7384 A

Directional Comparison Carrier-Current Pilot Relaying
With MHO-Type Distance Relays

GENERAL  ELECTRIC

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) or 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 that the 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 effect 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 typical 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.

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. In-flowing Current Above G2 Pickup

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/M2 or 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 re-closing 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 | Z31 Z23 Z12 | 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/Z31, 68/Z12 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. |
| | | 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 second 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)

GEK-7384

| | | | | |
|--|--|----|---|---|
| | | 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 $1.25 \times [(\text{Setting of M at opposite end}) + 0.5 - (\text{ohms of protected line section})]$. |
| 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 = $1.25 (\text{Setting of M at opposite end}) + 0.5 - (\text{ohms of line section between the 2 closed terminals})$. |
| 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 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 <u>minimum</u> setting is 125% of the impedance of the protected line section, taking account of the line impedance angle. The <u>maximum</u> 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 permit 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 = $1.25 \left[\text{Settings of M at opposite end} \right] + 0.5 - (\text{ohms of line section between the two closed terminals})$. |
| 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} | 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 = $1.25 [(Setting \text{ of } M \text{ at opposite end}) - (\text{ohms of protection section})]$. 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. |
| | | Z_{2-3} | |
| | | Z_{3-1} | |
| 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 = $1.25 [(Setting \text{ of } M \text{ at opposite end}) + 0.5 - (\text{ohms of line section between the 2 closed terminals})]$ |
| 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 | 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. |
| | | 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 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 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. |

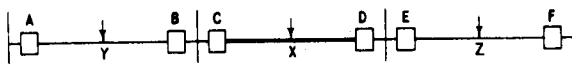


FIG. 1 (K-6400721-2) Sh. 1 Typical Transmission Lines

R-X CHARACTERISTIC OF
CARRIER STARTING UNITS

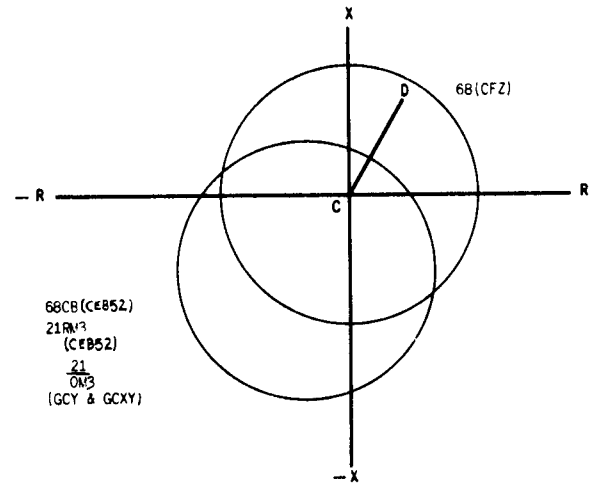


FIG. 2 (K-6400721-4) Sh. 3 Carrier Starting Unit Characteristics

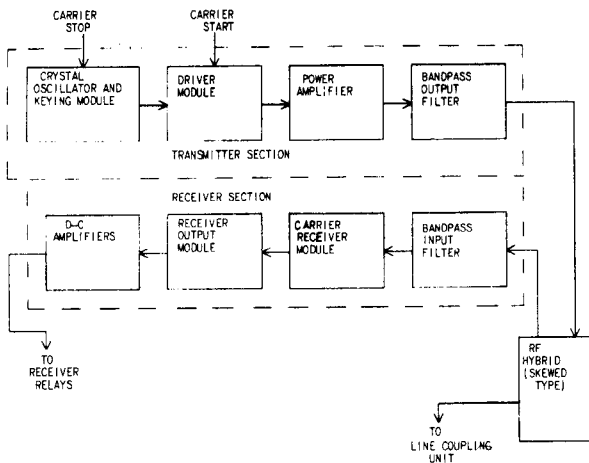


FIG. 3 (0226A6908-0) Sh. 3 Block Diagram Of CS27B Carrier Set

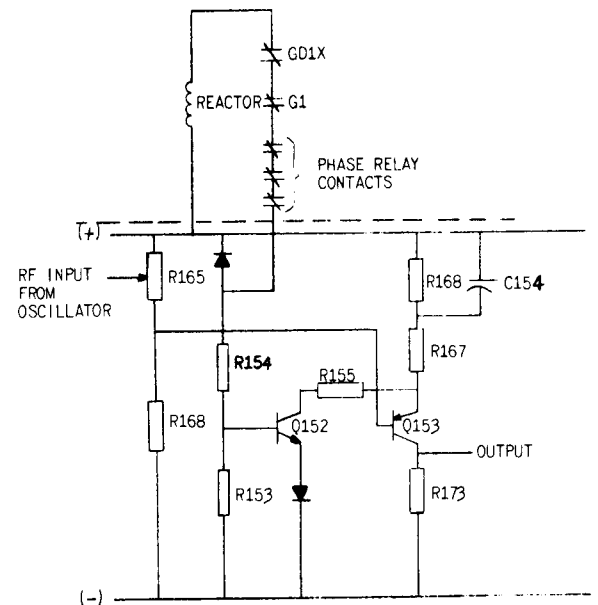


FIG. 4 (0226A6908-0) Sh. 2 Carrier Starting Control Of CS27B

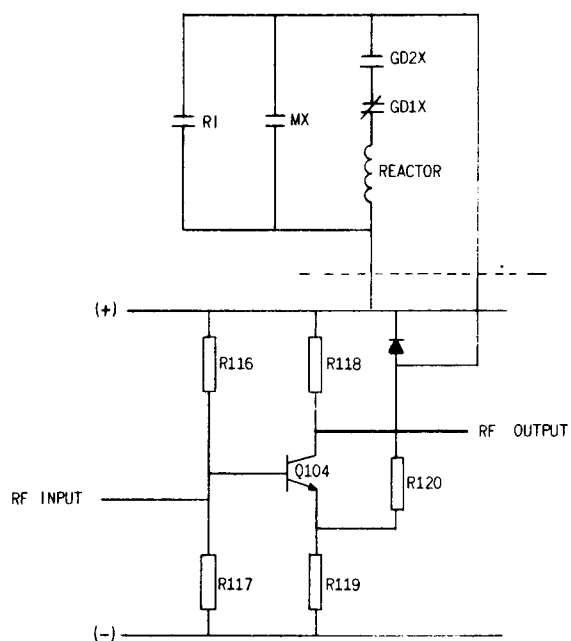


FIG. 5 (0226A6908-0) Sh. 1 Carrier Stopping Control
of CS27B

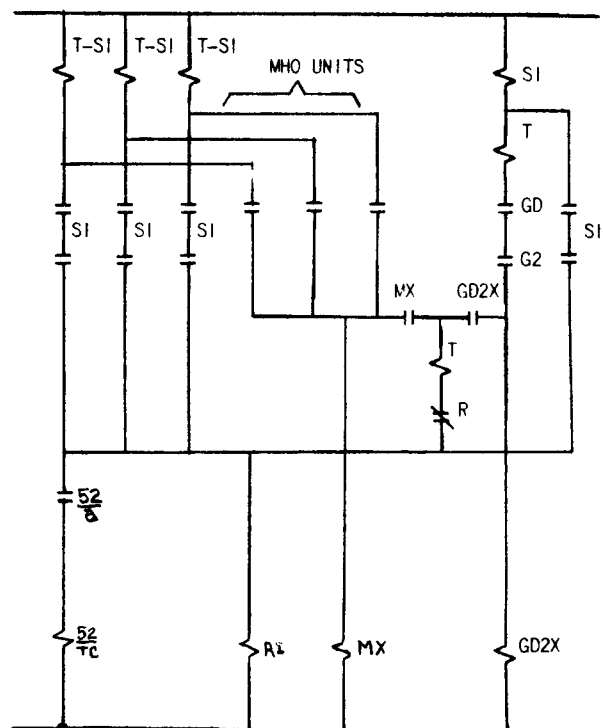


FIG. 6 (0165A6077-2) Sh. 3 Carrier Trip And Auxiliary Circuits

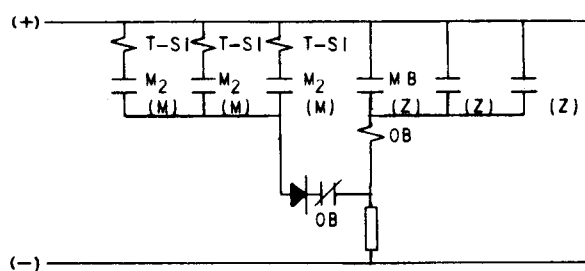


FIG. 7 (K-6400721-4) Sh. 11 Out-of-Step Blocking Control Circuits

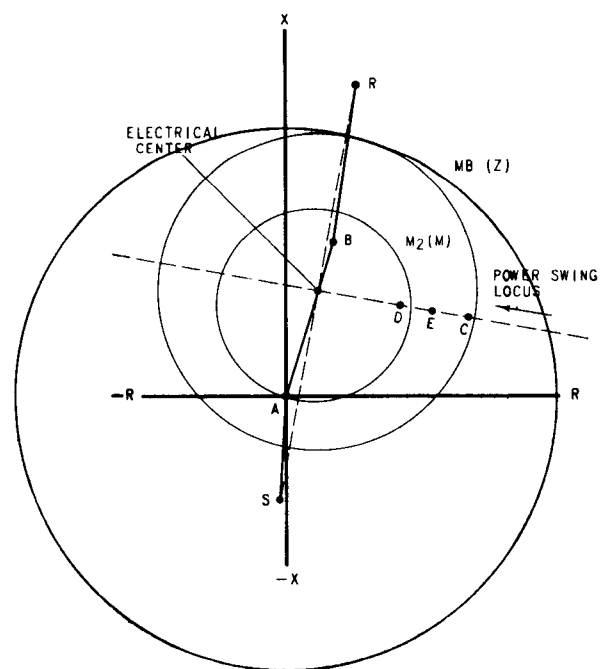


FIG. 8 (K-6400721-2) Sh. 13 Out-of-Step Blocking
Coordination

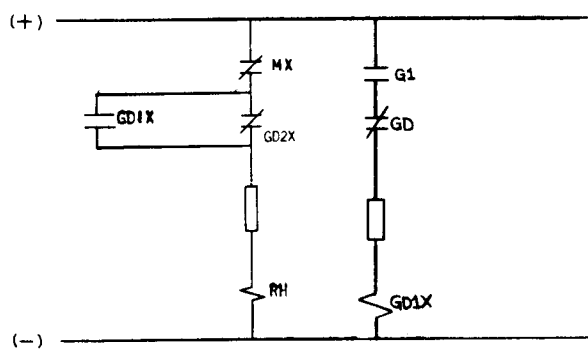


FIG. 9 (K-6400721-4) Sh. 3 Carrier Coordination Control Circuits

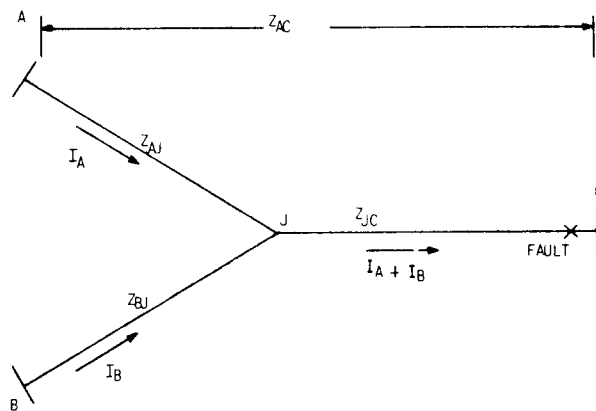


FIG. 10 (0227A2530-0) Three Terminal Line

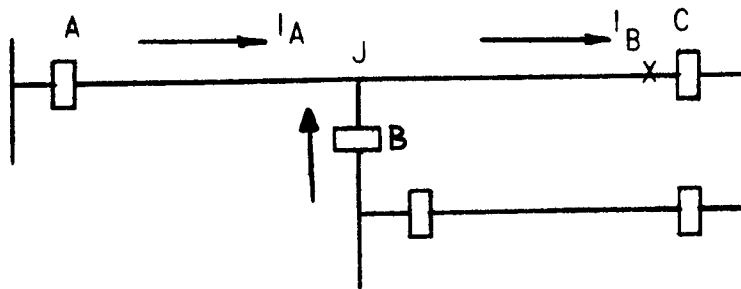


FIG. 11 (0165A6077-2) Sh. 4 Three Terminal Line With External Tie



Journal of Management Education 32(1)

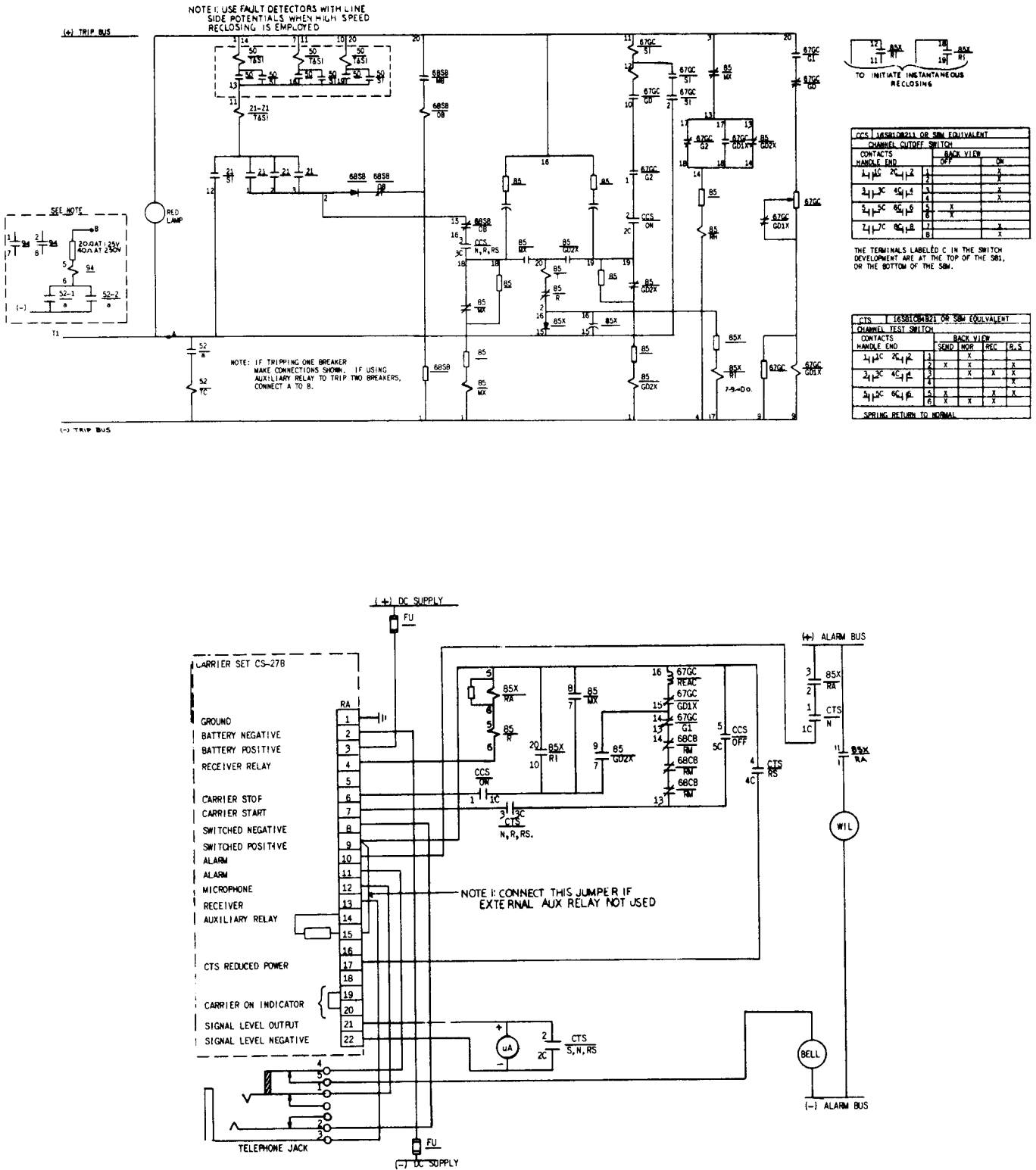
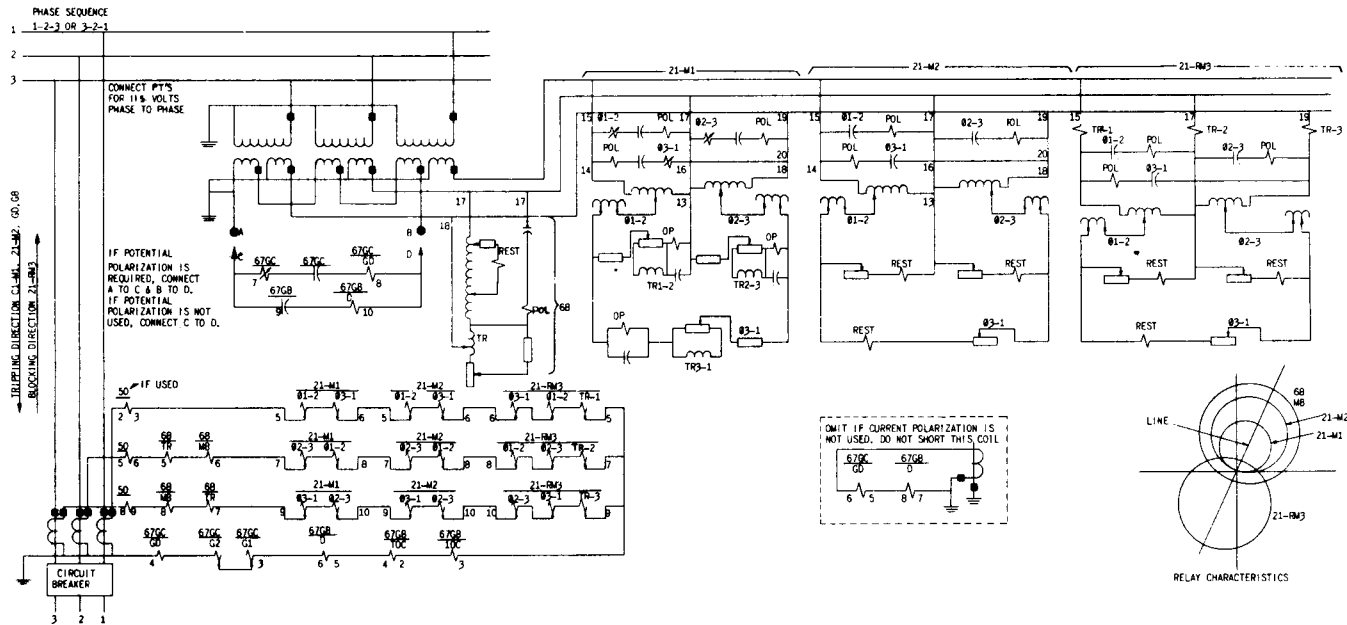


FIG. 12B (0116B9493-3) Sh. 2 Elementary Diagram, Tables II, IX and X



| 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 |
| CLP12C | 0148A3975 | K-6209276 |
| JBCG51K (INVERSE) | 0104A8978 | K-6209276 |
| JBCG53K (VERY INVERSE) | 0104A8978 | K-6209276 |
| NAA22L | 0208A2307 | K-6209272 |
| RPM21D | 0127A9440 | K-6209270 |
| CARRIER SET 4CS27B | | |
| CHANNEL CUTOFF SW. | SB1 16SB10B211 | 116A130 |
| CHANNEL TEST SW. | SB1 16SB1CB4B21 | 116A130 |
| MICROMM DO-91 (SURFACE) | | 0148A3872 |
| MICROMM 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 GAO (48, 125V) | | 104A8523 |
| 102L218 G11 (250V) | | 104A8523 |

| LEGEND | | |
|-----------|-------------|--|
| DEVICE NO | DEVICE TYPE | INCL. ELEM. DESCRIPTION |
| 21-M1 | CEY51A | 3 PHASE - 1ST ZONE WHO RELAY |
| | | 01-2 PHASE 1-2 UNIT, ETC. |
| | | T&S1 TARGET & SEAL-IN |
| 21-M2 | CEY52A | 3 PHASE-2ND ZONE & CARR. TRIPPING RELAY |
| | | 01-2 PHASE 1-2 UNIT, ETC. |
| | | T&S1 TARGET & SEAL-IN |
| 21-M3 | CEB52A | 3 PHASE-3RD ZONE & CARR. START WHO RELAY |
| | | 01-2 PHASE 1-2 UNIT, ETC. |
| | | TR-1 PHASE 1 TRANSACTOR ETC. |
| | | T&S1 TARGET & SEAL-IN |
| 21X | RPM21D | TIMING RELAY |
| | TU | TIMING UNIT |
| | TX | AUXILIARY FOR TIMING UNIT |
| 50 | PJC31C | INSTANTANEOUS PHASE FAULT DETECTOR |
| | | T&S1 TARGET & SEAL-IN |
| 50 | CHC12 | INSTANTANEOUS PHASE FAULT DETECTOR |
| | S1 | 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 |
| | S1 | SEAL-IN |
| | T | TARGET |
| 67GB | JBCG | GROUND DIRECTIONAL OVERCURRENT RELAY |
| | D | DIRECTIONAL UNIT |
| | IOC | INSTANTANEOUS UNIT |
| | TOC | TIME DELAY UNIT |
| | T&S1 | TARGET & SEAL-IN |
| 94 | HGA14AM | AUXILIARY TRIPPING RELAY |
| 68 | CEB51A | OFFSET WHO OUT OF STEP BLOCKING RELAY |
| | MB | WHO BLOCKING UNIT |
| | TR | TRANSACTOR |
| | OB | AUXILIARY TO WHO BLOCKING UNIT |
| 85 | BCA | CARRIER CURRENT AUXILIARY RELAY |
| | R | RECEIVER RELAY PILOT COIL |
| | PH | RECEIVER RELAY HOLDING COIL |
| | GD2X | AUXILIARY TO GD & G2 |
| | MX | AUXILIARY 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

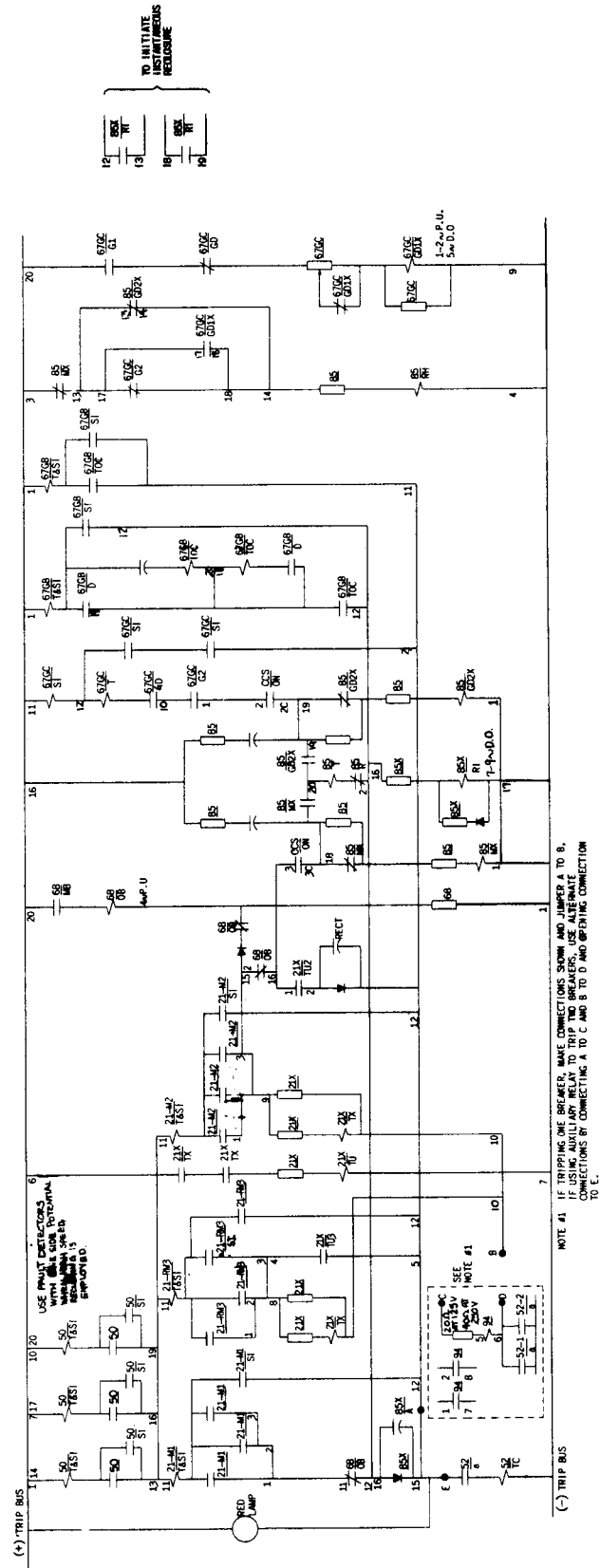
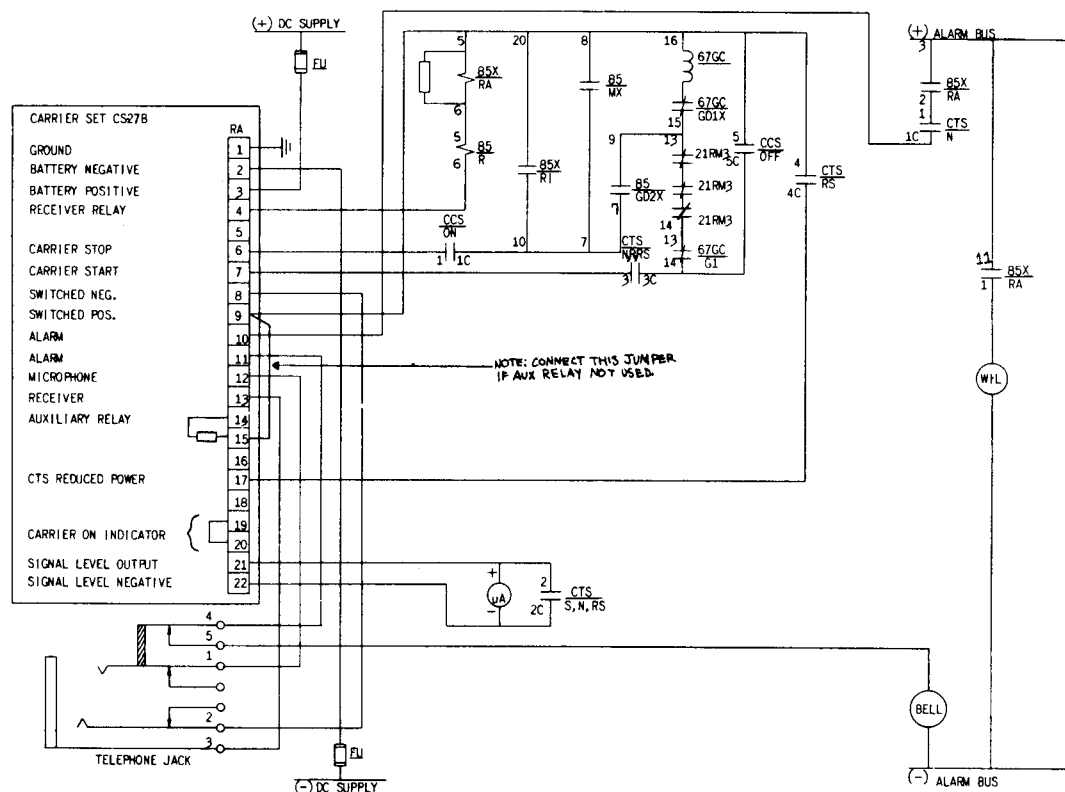


FIG. 13B (0116B9498-2) Sh. 2 Elementary Diagram, Tables III, XI and XII

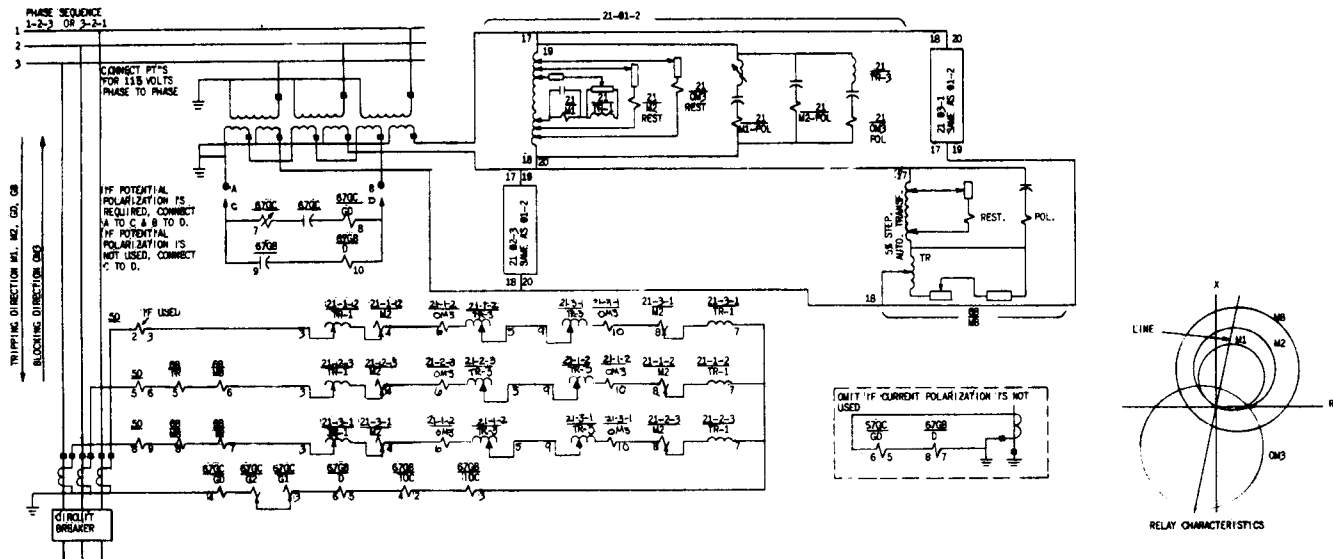


| CCS 16SB1DB211 OR SBM EQUIVALENT | | | | | | | |
|----------------------------------|----|----|---|-----------|---|----|--|
| CHANNEL CUTOFF SWITCH | | | | | | | |
| CONTACTS HANDLE END | | | | BACK VIEW | | | |
| | | | | OFF | | ON | |
| 1 | 1C | 2C | 2 | 1 | | X | |
| | | | | 2 | | X | |
| 3 | 3C | 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



| TYPE OR DESCRIPTION | INT. CONNS. | OUTLINE |
|--------------------------|------------------|-----------|
| BCA11AV | 0148A4083 | K-6209272 |
| CARRIER SET 4CS278 | | |
| CHANNEL CUTOFF SW. | SB-1 16581D8211 | 116A130 |
| CHANNEL TEST SW. | SB-1 16581C84821 | 116A130 |
| CEBS1A | 0178A9134 | K-6209274 |
| CLPG12C | 0148A3675 | K-6209276 |
| CLG51A | 0178A7049 | K-6209276 |
| JB055IX (INVERSE) | 0104A8978 | K-6209276 |
| JB055IX (INVERSE) | 0104A8978 | K-6209276 |
| RUC3AC (IF USED) | K-4375226 | K-6209272 |
| RUC3AC (IF USED) | 0178A7082 | K-6209272 |
| RUC3AC (IF USED) | | K-6209272 |
| TELEPHONE JACK | | K-6400578 |
| WHITE LAMP | | K-6151144 |
| HGA14AM BACK CONN. 11F | K-6400533 | K-6400533 |
| HGA14AM FRONT CONN. USED | 377A139 | 377A139 |
| CLC12A | 0148A3696 | K-6209272 |
| NAA22L | 0208A2307 | K-6209272 |
| RECT. 102L218G10 | 125V | 104A8523 |
| RECT. 102L218G11 | 250V | 104A8523 |

| 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 |
| | | TAS1 | TARGET & SEAL-IN |
| | | TR | TRANSACTOR |
| | | SI | SEAL-IN |
| 21X | RPM | | TIMING RELAY |
| | | T1 | ZONE #1 TARGET |
| | | T2 | ZONE #2 TARGET |
| | | T3 | ZONE #3 TARGET |
| | | T4 | TIMING ELEMENT |
| | | TX | AUX. FOR TIMING ELEMENT |
| 50 | PJC | | INSTANTANEOUS OVERCURRENT RELAY |
| | | TAS1 | TARGET & SEAL-IN |
| 52/8 | JBOG | | AUX. SWITCH ON CIRCUIT BREAKER |
| 67GB | JBOG | | GROUND DIRECTIONAL OVERCURRENT RELAY |
| | | D | DIRECTIONAL UNIT |
| | | IOC | INSTANTANEOUS UNIT |
| | | TOC | TIME OVERCURRENT UNIT |
| | | TAS1 | 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 |
| | | GD2X | 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 |
| | | RM | 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 |
| | | RR | RECLOSURE INITIATING AUXILIARY |
| 94 | HGA | | AUX. FOR TRIPPING TWO CIRCUIT BREAKERS |
| CTS | | | 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

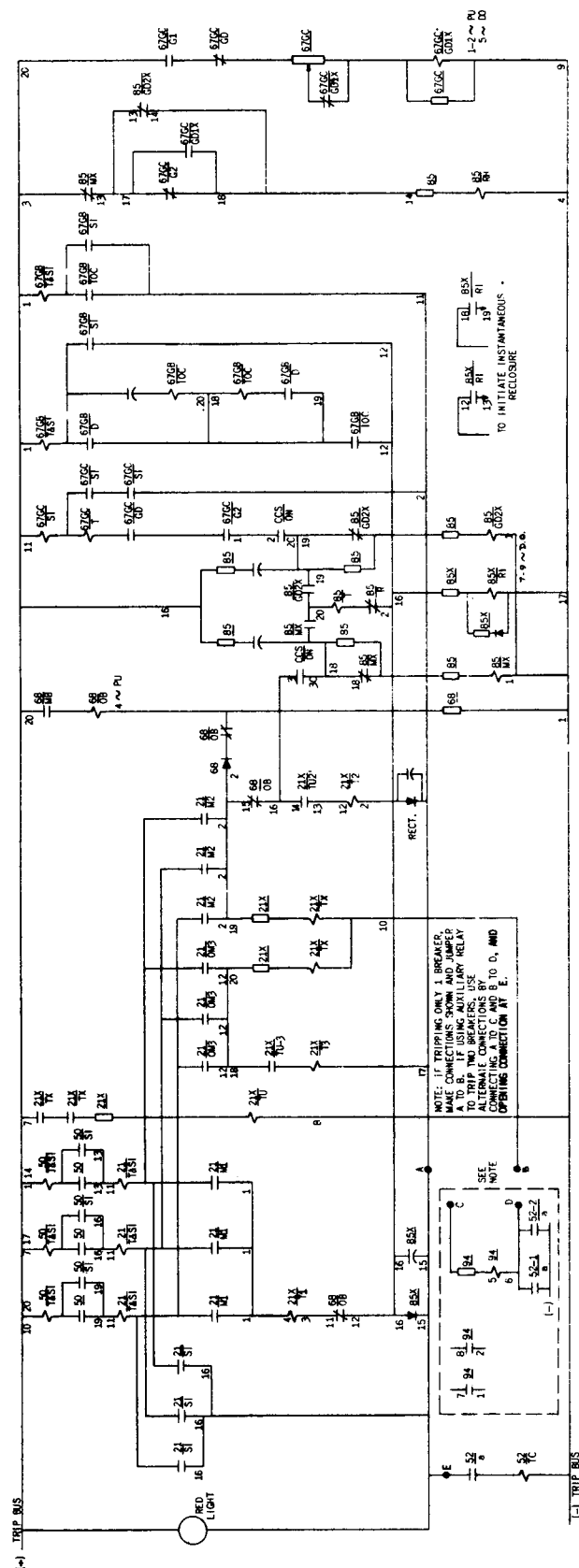
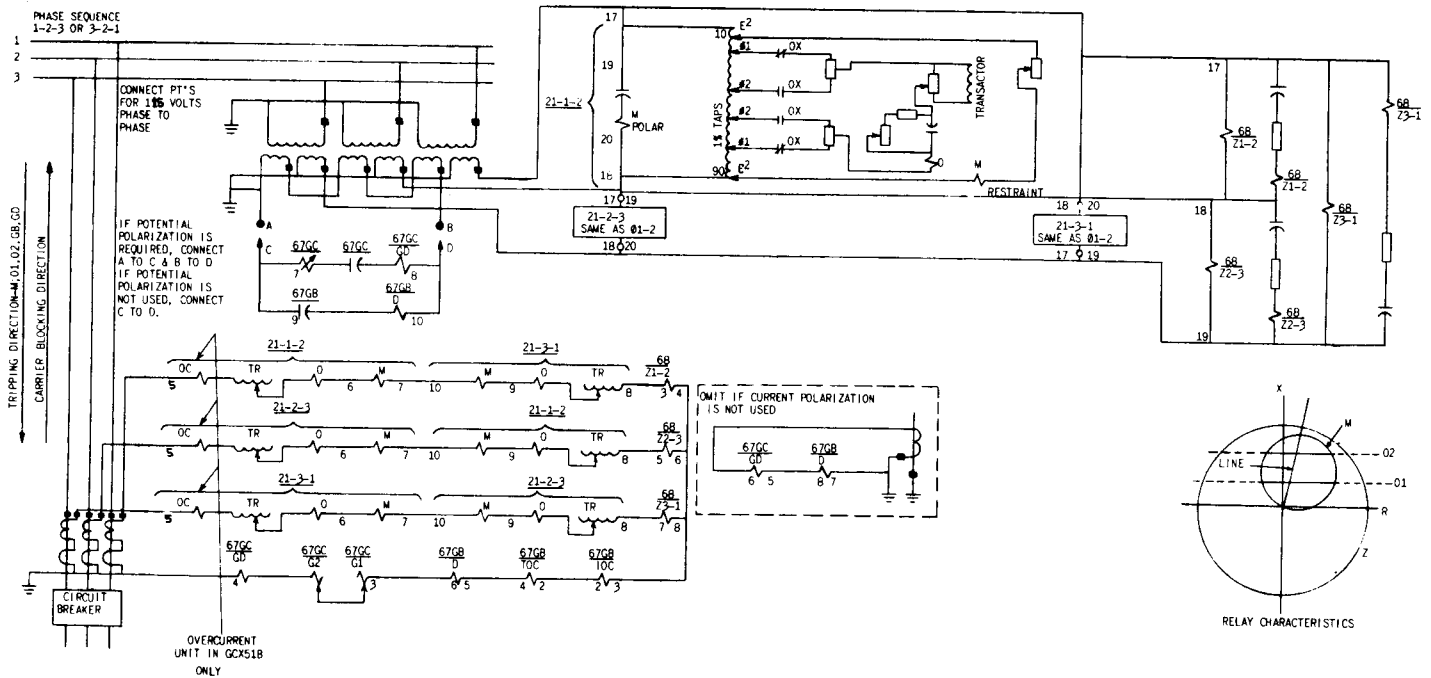


FIG. 14B (0116B9496-2) Sh. 2 Elementary Diagram, Tables IV, X.

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

33



| TABULATION OF DEVICES | | | |
|----------------------------|------------------|-----------|--|
| TYPE OR DESCRIPTION | INT. CONNS. | OUTLINE | |
| BCA11AV | 0148A40B3 | K-6209272 | |
| CHANNEL CUTOFF SWITCH | SB-1 16SB10B211 | 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 | |
| JBCG52K (VERY INVERSE) | 0104A8978 | K-6209276 | |
| MICROHM. DO91 (SDMI-FLUSH) | | K-8946606 | |
| RM110 | 0178A7092 | K-6209272 | |
| TEL. JACK | | K-6400578 | |
| WHITE LAMP | | K-6151144 | |
| CARRIER SET ACS27B | | | |
| MICROHM. DO-92 (SURFACE) | | 0148A8972 | |
| HGA14AM BACK CONN. (IF) | K-6400533 | K-6400533 | |
| HGA14AL FRONT CONN. (USED) | 377A139 | 377A139 | |
| NAA221 | 0208A2307 | K-6209272 | |

| CCS-16SB10B211 OR SBM EQUIVALENT CHANNEL CUTOFF SWITCH | | | |
|---|--------|-----------|----|
| CONTACTS HANDLE END | | BACK VIEW | |
| | | OFF | ON |
| 1 1C | 2C 2 | 1 | X |
| 2 1C | 4C 4 | 2 | X |
| 3 1C | 6C 6 | 3 | X |
| 4 1C | 8C 8 | 4 | X |
| 5 1C | 10C 10 | 5 | X |
| 6 1C | 12C 12 | 6 | X |
| 7 1C | 14C 14 | 7 | X |
| 8 1C | 16C 16 | 8 | X |

| CTS 16SB1CB4B21 OR SBM EQUIVALENT CHANNEL TEST SWITCH | | | |
|--|--------|-----------|-----|
| CONTACTS HANDLE END | | BACK VIEW | |
| | | SEND | REC |
| 1 1C | 2C 2 | 1 | X |
| 2 1C | 4C 4 | 2 | X |
| 3 1C | 6C 6 | 3 | X |
| 4 1C | 8C 8 | 4 | X |
| 5 1C | 10C 10 | 5 | X |
| 6 1C | 12C 12 | 6 | X |
| 7 1C | 14C 14 | 7 | X |
| 8 1C | 16C 16 | 8 | X |

| LEGEND | | |
|---------|---------|--|
| DEVICES | DEVICES | INCL. TYPE ELEM. |
| 21X | RPM | T1 |
| | | T2 |
| | | T3 |
| | | TU |
| | | TX |
| 21 | GCX | AUX. FOR TIMING UNIT |
| | | REACTANCE TYPE STEP DISTANCE RELAY |
| | | M |
| | | O |
| | | OX |
| | | T&S |
| 52/a | JBCG | AUX. SWITCH ON CIRCUIT BREAKER |
| 67GB | JBCG | GROUND DIRECTIONAL OVERCURRENT RELAY |
| | | D |
| | | IOC |
| | | TOC |
| | | T&S |
| 67GC | CLPG | CARRIER GROUND DIRECTIONAL RELAY |
| | | G1 |
| | | G2 |
| | | GD |
| | | GOIX |
| | | SI |
| | | T |
| 68 | CFZ | FAULT DETECTOR & OUT OF STEP RELAY |
| | | OR |
| | | Z1-2 |
| 85 | BCA | CARRIER CURRENT AUXILIARY RELAY |
| | | RH |
| | | GD2X |
| | | MX |
| 85X | NAA | TARGET |
| | | RA |
| 94 | HGA | RECEIVER RELAY INITIATING AUXILIARY |
| CCS | | AUX. FOR TRIPPING TWO CIRCUIT BREAKERS |
| CTS | | CHANNEL CUTOFF SWITCH |
| | | CHANNEL TEST SWITCH |

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

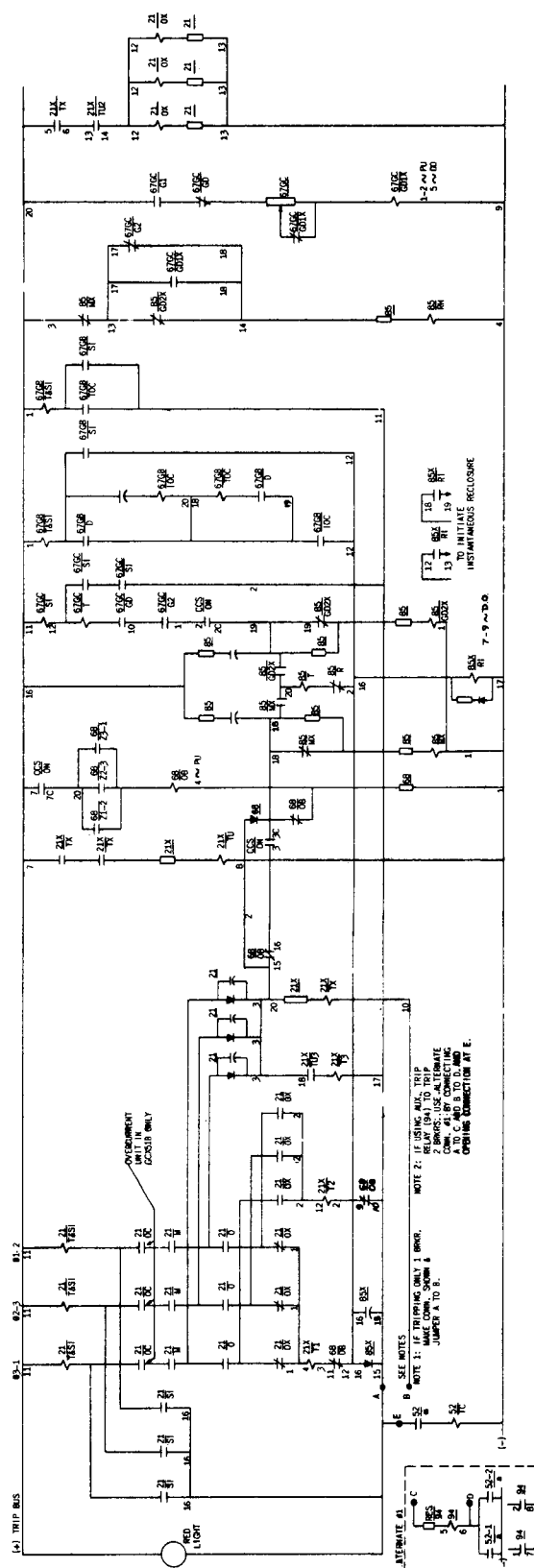
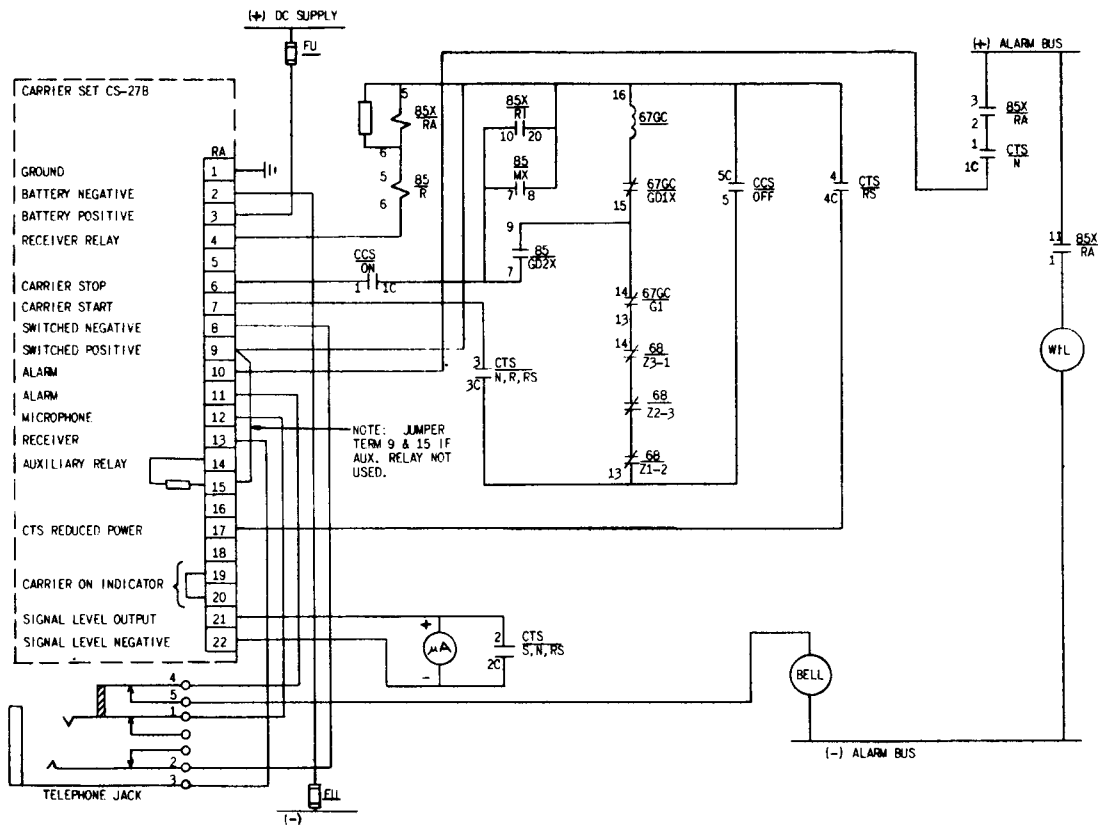


FIG. 15B (0116B9497-1) Sh. 2 Elementary Diagram, Tables V and XIII

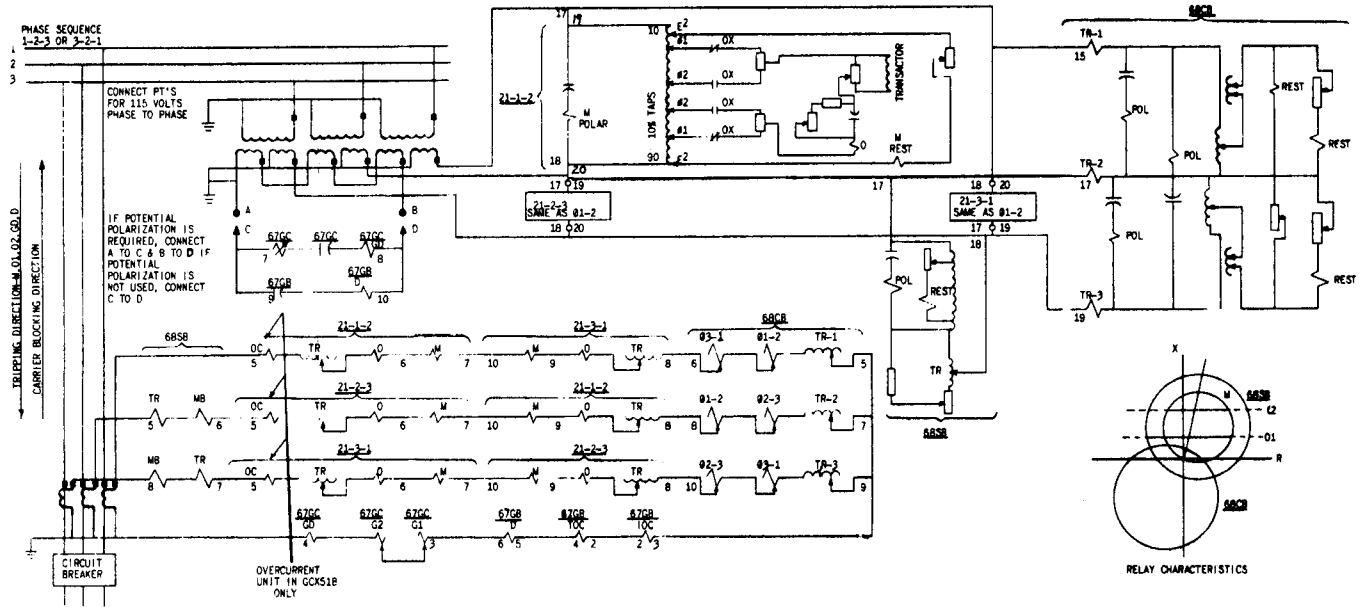


| CCS 16SB1DB211 OR SBM EQUIVALENT | | | | | | | |
|----------------------------------|----|----|---|-----------|---|----|--|
| CHANNEL CUTOFF SWITCH | | | | | | | |
| CONTACTS HANDLE END | | | | BACK VIEW | | | |
| | | | | OFF | | ON | |
| 1 | 1C | 2C | 2 | 1 | | X | |
| | | | | 2 | | X | |
| 3 | 3C | 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 |
| | | | | 4 | | | X |
| 5 | 5C | 6C | 6 | 5 | X | | X |
| | | | | 6 | 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 | |
| BCA114V | 0148A4083 | K-6209272 | |
| CARRIER SET ACSS278 | | | |
| CARRIER CUTOFF SWITCH | SB1 | 165B108211 | 116A0130 |
| CARRIER TEST SWITCH | | 165B108211 | 116A0130 |
| CEB51A | 178A0134 | K-6209274 | |
| CEB52A | 178A0134 | 178A0136 | |
| CLPG12C | 148A3975 | K-6209276 | |
| GR-1A OR B | 203A0583 | K-6209276 | |
| JBC051K (INVERSE) | 104A0978 | K-6209276 | |
| JBC051K (VERY INVERSE) | 104A0978 | K-6209276 | |
| MICROAN DO-01 (SEMI-FLUSH) | | K-8946606 | |
| MICROAN DO-01 (SURFACE) | | 148A3872 | |
| MAA22L | 208A2307 | K-6209272 | |
| RM4110 | 178A0902 | K-6209272 | |
| TELEPHONE JACK | | K-6400578 | |
| WHITE LAMP (12-5) | | K-6400578 | |
| WCA144M BACK CONN. | IF | K-6400533 | |
| WCA144M FRONT CONN. | USED | 377A0139 | |
| RECTIFIER/D (208A3005 BR-1) | 48V | | |
| (DOUBLE UNIT) = GR-2 | 125V | | 208A3716 |
| = GR-3 | 250V | | |
| (RECTIFIER/S (SINGLE UNIT) = GR-4 | 48V | | |
| = GR-5 | 125V | | 208A3717 |
| = GR-6 | 250V | | |

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 SHOWN PROVIDES 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 STUO 18 OF 21X MUST BE REMOVED. IF 68CB IS UNIT NOT USED, ALSO OPEN CONNECTION TO STUO 12 OF 68CB.

NOTE 3: OVERCURRENT UNIT IN GCS18 ONLY. USE OVERCURRENT UNIT WITH LINE SIDE POTENTIAL WHEN HIGH SPEED RECLOSING IS EMPLOYED.

| LEGEND | | | |
|----------|-------------|--------------|--|
| DEV. NO. | DEVICE TYPE | THREL. ELDM. | DESCRIPTION |
| 21 | GDX | | REACTANCE TYPE STEP DISTANCE RELAY |
| | M | | WHD TYPE STARTING UNIT |
| | O | | REACTANCE TYPE OHM UNIT |
| | OX | | OVERCURRENT FAULT DETECTOR |
| | TAS1 | | ZONE TRANSFER AUXILIARY FOR O |
| 21X | RPW | | TARGET AND SEAL-IN |
| | | | TIMING RELAY |
| | | TL 12, 15 | TARGETS FOR ZONES 1, 2, A, 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 |
| | TAS1 | | TARGET AND SEAL-IN |
| 67GC | CLPG | | CARRIER GROUND DIRECTIONAL RELAY |
| | C1 | | CARRIER GROUND BLOCKING UNIT |
| | C2 | | CARRIER GROUND TRIPPING UNIT |
| | GD | | CARRIER GROUND DIRECTIONAL UNIT |
| | GD1X | | AUX. TO CONTINUE GROUND BLOCKING |
| | SI | | SEAL-IN |
| | T | | TARGET |
| 68CB | CEB52A | | 1 PHASE OFFSET WHD CARRIER START DELAY |
| | MB | | WHD BLOCKING UNIT |
| | TRI-2 | | PHASE 2-2 TRANSACTOR, ETC. |
| 68SA | CEB51A | | OUT OF STEP BLOCKING RELAY |
| | MB | | WHD 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 |
| 85A | MAA22L | | CARRIER AUXILIARY RELAY |
| | RA | | RECEIVER ALARM UNIT |
| | RI | | RECLOSURE INITIATING UNIT |
| 94 | RECALLMORAL | | AUX. FOR TRIPPING 2 BREAKERS |
| 95 | SBI | | CHANNEL CUTOFF SWITCH |
| CTS | SBI | | CHANNEL TEST SWITCH |

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

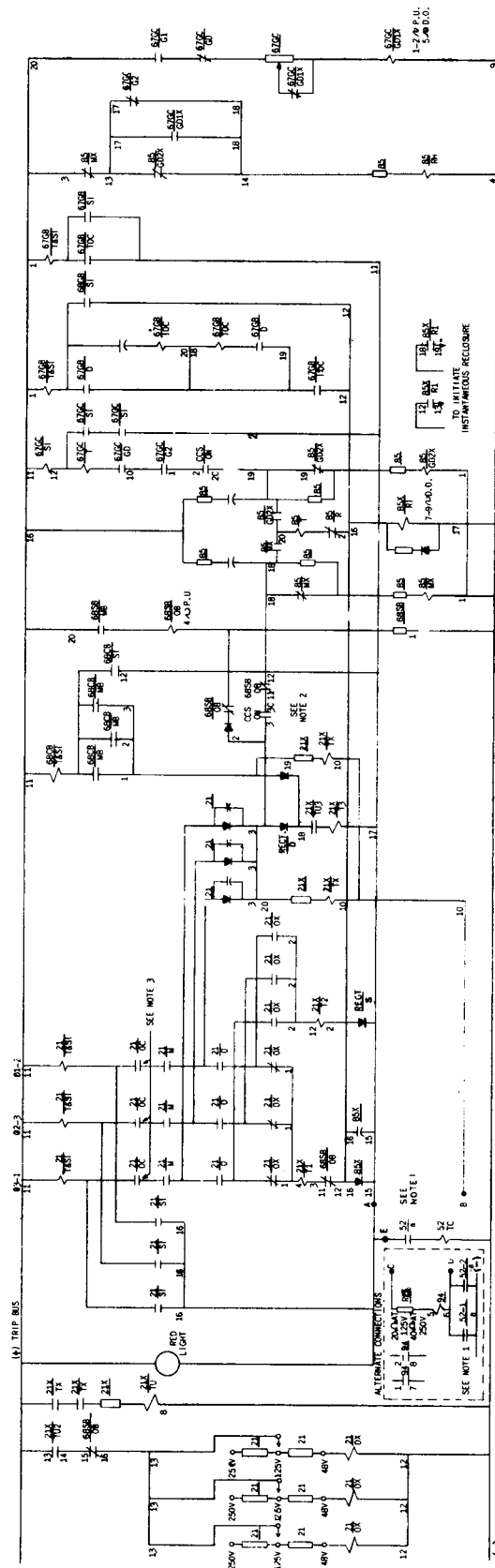
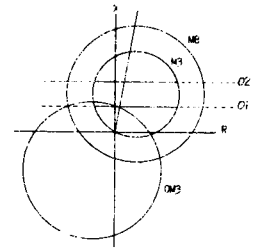


FIG. 16B (0164B9179-3) Sh. 2 Elementary Diagram, Table VI

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

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



| KEY | CODE | UNIT | LEGEND |
|------|------|------|---|
| SYM | TYPE | ELCU | DESCRIPTION |
| 21 | GEY | | REACTANCE TYPE STEP INSTANTANEOUS DELAY |
| | | | REACTANCE TYPE OWN UNIT |
| | MO | | 3RD ZONE AND UNIT |
| | MO | | REVERSED 3RD ZONE AND UNIT |
| | OX | | ZONE TRANSFER AUX. FOR 3 |
| | TASI | | TARGET & SEAL-IN |
| | | 51 | SEAL-IN |
| 21X | SRM | | TIMING DELAY |
| | | 11 | ZONE #1 TARGET |
| | | 12 | ZONE #2 TARGET |
| | | 13 | ZONE #3 TARGET |
| | | 14 | TIMING ELEMENT |
| | | 15 | AUX. FOR TIMING ELEMENT |
| 50 | PIC | | INSTANTANEOUS OVERCURRENT DELAY |
| | TASI | | TARGET & SEAL-IN |
| 52A | | | AUX. SM. ON CIRCUIT BREAKER |
| 57GR | IBCD | | INSTANTANEOUS OVERCURRENT DELAY |
| | D | | DIRECTIONAL UNIT |
| | 10C | | INSTANTANEOUS UNIT |
| | 10K | | TIME OVERCURRENT UNIT |
| | TASI | | TARGET & SEAL-IN |
| | | 51 | SEAL-IN |
| 67OC | CLRS | | CARRIER GROUND DIRECTIONAL RELAY |
| | GL | | CARRIER GROUND BLOCKING UNIT |
| | G2 | | CARRIER GROUND TRIPPING UNIT |
| | GO | | CARRIER GROUND DIRECTIONAL UNIT |
| | GOX | | AUX. TO CONTINUE GROUND BLOCK |
| | S1 | | SEAL-IN UNIT |
| | T | | TARGET |
| 6R | CFR | | OFFSTEP AND BLOCKING DELAY |
| | MR | | OUT-OF-STEP BLOCKING UNIT |
| | TR | | TRANSACTOR |
| 85 | BCA | | AUX. FOR OUT-OF-STEP BLOCKING |
| | R | | CARRIER CURRENT AUXILIARY RELAY |
| | RM | | RECEIVER RELAY PILOT COIL |
| | GOX | | AUX. TO GO & G2 |
| | MX | | AUX. TO MS. |
| | T | | TARGET |
| RSX | AAA | | CARRIER AUXILIARY RELAY |
| | RA | | RECEIVER IN ARM UNIT |
| | RI | | DISCLOSURE INITIATING AUX. |
| 84 | HGA | | AUX. FOR TRIPPING TIME CIRCUIT BREAKER |
| CS | | | CHANNEL OUTSIDE SWITCH |
| CTS | | | CHANNEL TEST SWITCH |



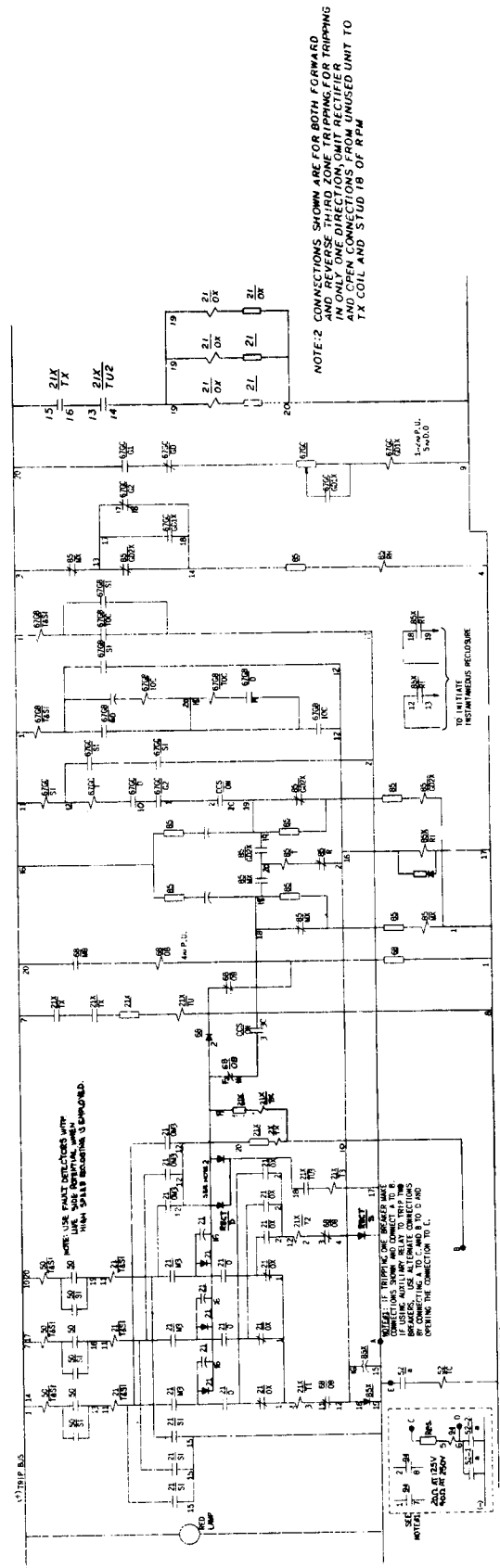
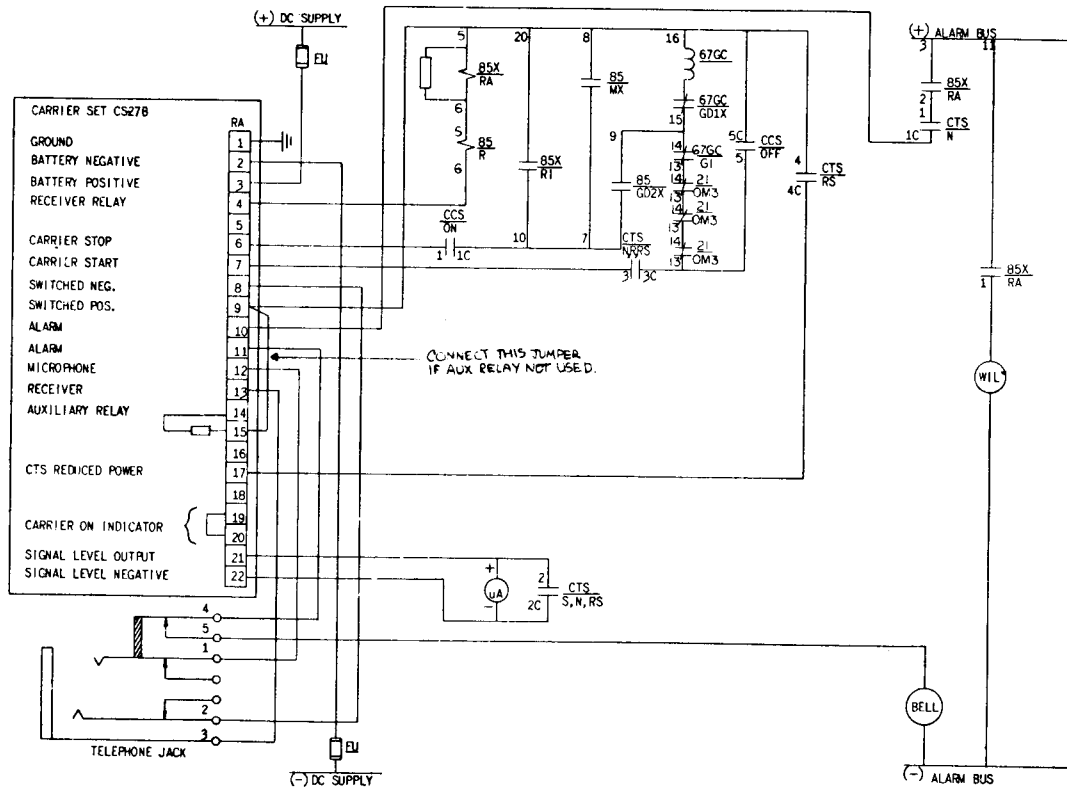


FIG. 17B (0116B9495-3) Sh. 2 Elementary Diagram, Tables VII, XIV, XV and XVI



| CCS 16SB1DB211 OR SBM EQUIVALENT | | | |
|----------------------------------|----|-----------|----|
| CHANNEL CUTOFF SWITCH | | | |
| CONTACTS | | BACK VIEW | |
| HANDLE END | | OFF | ON |
| 1 | 1C | 2C | 2 |
| 1 | 1C | | X |
| 2 | 2C | | X |
| 3 | 3C | 4C | 4 |
| 3 | 3C | | X |
| 4 | 4C | | X |
| 5 | 5C | 6C | 6 |
| 5 | 5C | X | |
| 6 | 6C | X | |
| 7 | 7C | 8C | 8 |
| 7 | 7C | | X |
| 8 | 8C | | 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 | | BACK VIEW | |
| HANDLE END | | SEND | NOR |
| 1 | 1C | 2C | 2 |
| 1 | 1C | X | X |
| 2 | 2C | X | X |
| 3 | 3C | 4C | 4 |
| 3 | 3C | X | X |
| 4 | 4C | X | X |
| 5 | 5C | 6C | 6 |
| 5 | 5C | X | X |
| 6 | 6C | X | X |
| 7 | 7C | 8C | 8 |
| 7 | 7C | X | X |
| 8 | 8C | X | X |

SPRING RETURN TO NORMAL

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

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