Doc. no. 61-10 AG
Rev. ind.
Date

APPLICATION GUIDE

Type RADHL
Wire Pilot Differential Relay

High Speed Protection for Short to Medium Length Circuits
Short to medium Length Circuits

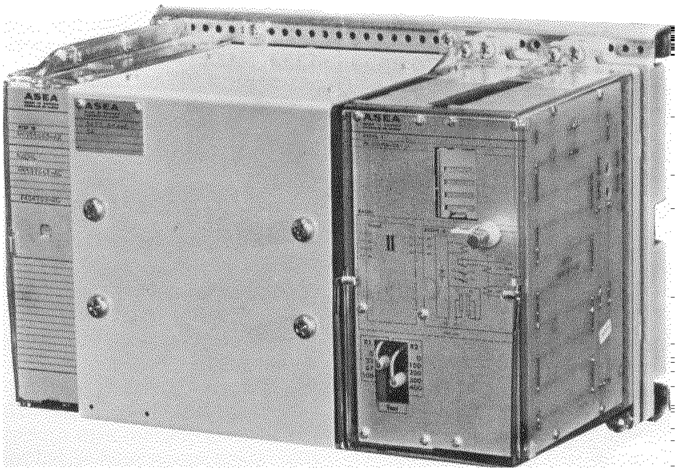


Fig. 1. Relay type RADHL, basic version.

General

The DHL is a high speed relay system designed for use with a dedicated pair of metallic pilot wires to provide protection for short to medium length circuits. It is not designed for use with audio tone equipment as the signal medium. The system requires no isolating transformers in the pilot circuit in most cases, but they may be used at the customer's convenience with no reduction in the quality of the protection

The system consists of a sensing relay at each of the two terminals, used in a bridge configuration to develop the needed sense for internal and external faults. The three phase currents are converted to a single phase quantity in a summation type current transformer. A center tap on the output of this CT provides the needed point of reference for the resistance bridge type measuring system. The pilot wire resistance serves as one arm of this bridge.

Within the relays, this pilot circuit resistance is padded out to 1000 ohms, regardless of the actual resistance of the pilot wires. This is the only setting adjustment of the DHL system. Thus, all installations will have substantially identical operating characteristics. For pilot circuits over 1000 ohms resistance a ratio matching transformer is used at each terminal. This extends the permissible resistance to 2000 ohms. This is about 24 miles, 40 km, of No. 19 gage wire. The capacitance of the pilot wires must also be kept within a maximum limit of 2 uF when the isolating transformer is not used and 0.7 uF when it is used. This transformer may also be used when desired as an isolating transformer to extend the 5 kV insulation rating to 15 kV at each terminal.

Changes from February 1977 issue: Text and pictures changed to reflect revised physical arrangements. No significant change in technical specifications.

ABB Automation Products AB

Postal address	Telephone	Telefax
ABB Automation Products AB	+46 (0)21 34 20 00	+46 (0)21 14 69 18
Substation Automation Division		
SE-721 59 Västerås / Sweden		

Doc. no. 61-10AG
Rev. ind.
Date April 1978

List of contents **Page**

List of illustrations **Page**

Reference Publications

A	Sales Information	61-10 SI
B	Application Guide (This publication)	61-10 AG
C	Test Instruction (Includes commissioning and servicing)	61-10 TI
D	COMBIFLEX system	
	Sales Information	92-10 SI
	Application Guide	92-10 AG
E	COMBITEST system	
	Sales Information	92-11 SI
	Application Guide	92-11 AG
F	Accessories	
	Auxiliary relays MS 1	21-16 SI
	Auxiliary relays MA 1	21-10 SI
	Auxiliary relay with target with SF 1	21-10 SI
	Polarized relay CLA 2	-
	Voltage supply unit TUB 2	RK 73-13 E
	Current relay IL 2	RK 41-11 E
F	Price lists	

Application

The DHL is applicable to the protection of all two terminal circuits where a metallic pilot pair of no more than 2000 ohms series resistance or 2uF shunt capacitance is available. These include:

1 Cable circuits of high voltage

The length or voltage of the power cable being protected generally causes no application problems. The cable charging currents, which reflects into any pilot system as a very weak internal fault will not exceed a safe margin below the relay pickup sensitivity. Nor will these currents cause undue heating in any relay component. Normally inrush currents when energizing a cable are largely balanced out in the bridge type measuring network and hence need no special attention when applying the relay. The ratio matching/isolating transformers are generally not needed on cable circuits. The usual metallic sheath and other cable bonding assure that the system will usually be within the 5 kV rating of the DHL at each terminal. Should the distance between the power circuit terminals result in the pilot wire resistance exceeding the allowable 1000 ohms without the ratio matching transformers, they should, of course, be used.

2 Cable circuits of high voltage

High voltage cables are generally longer than moderate and low voltage cables. Also their charging kVA is higher for a given length. The DHL is applicable for the protection of such circuits providing relay application parameters are not exceeded, i.e.

1) The difference in ground potential during a fault must be within the 5 kV (or 15 kV when isolating transformers are used) or suitable surge protection must be added.

2) The fundamental frequency charging current must be well below the pickup value of the relay for a single infeed three-phase fault.

The energizing transient may be above the normal frequency pickup value of the relay. However, its short duration and high frequency will generally preclude any false relay operation.

3 Overhead circuits

There are no unique restrictions on the use of the DHL for overhead circuits. Generally, two factors need careful review.

a) The location of the pilot wire should avoid direct exposure to the circuit being protected. It is preferable to route the pilot as remote from the protected circuit as feasible. When the pilot circuit is to be on the same right of way, or even on the same pole or tower as the power circuit, a twisted, shielded pair should be used for the pilot circuit.

b) The difference in ground potential rise at the two terminals may justify use of the ratio matching/isolating transformers even though they may not be needed for pilot wire resistance reasons. In general, there is a greater difference in ground potential rise between overhead connected stations than between cable connected because of the lack of cable sheaths, etc., which tend to maintain a lower resistance between these latter type stations.

4 Tie circuits

The DHL will not trip incorrectly on severe system power surges, including out-of-step conditions. Thus, the full capability of any circuit, can be utilized in emergencies without concern for inadvertent trip out.

5 Combination transformer circuits

Circuits that include transformers at one, or both, ends are generally protected with individual zones of protection, i.e., DHL around the circuit proper, and transformer differential relay type RADSE around the transformers. The DHL is not recommended to form a protective zone around both the transformer and circuit. When a single zone is desired, the DSE transformer differential relay may be used since it has been designed to specifically reject possible resonances between the circuit capacitance and transformer inductances.

6 Tapped loads

The DHL generally cannot be used on circuits with tapped loads. Only when the tap terminates in a transformer or comparable impedance of high enough value, is such a tap acceptable. This impedance must be sufficient to prevent any inrush condition or any fault external to the tap from creating current conditions above the minimum settings of the DHL since such a condition will appear to the DHL as a minor internal fault.

7 Transfer trip application

Remote tripping can be provided over the DHL channel by application of a voltage to the pilot wires. This will result in a tripping condition occurring at both terminals regardless of any load (or fault) currents on the main circuit. This feature is valuable in the above system configuration of a circuit and transformer unit in which transformer faults must be cleared by a transfer trip signal to the remote terminal.

The DHL can also frequently be used to advantage when the main requirement is for transfer tripping. In this application the DHL system is used in place of other types of transfer trip relays. This has the advantage of one channel being capable of transfer tripping in two directions. And, once selected for transfer tripping, the DHL may then be used in place of some of the other primary protective relays.

8 Supervisory simplifications

When supervision of the pilot wires is desired, both the transmitter and receiver for the DHL supervising equipment locate at the same station. When there are several pilot circuits at one station this equipment may all be located at this one station, thus facilitating observing the conditions on the various pilot wires.

9 Current transformer flexibility

The DHL system can be used with different type CT's at the two terminals so long as the turns ratios are the same and they are each adequate for the service.

Long secondary leads between the relay location and the current transformers are not a limitation. When lead burdens approach limiting values with the 5 ampere model, the I A or 2 A version of the DHL is recommended with the corresponding lower secondary current rated CT's.

10 Fault detector considerations

The DHL will trip at both ends for internal faults regardless of a possible weak or no infeed from one end. When fault detectors are used they establish a minimum amount of fault current from either end in order for that end to trip.

11 Open pilot wire

An open pilot wire will result in correct DHL tripping for internal faults and incorrect tripping for external faults. Also with open pilot wires, undesired tripping will occur on load currents if they exceed the three-phase fault sensitivity. When fault detectors are used to prevent this possibility the resulting settings may limit minimum fault current sensitivity.

12 Short pilot wire

A shorted pilot wire will generally result in no operation regardless of fault location. With pilot wire resistance approaching the maximum value, a short circuit near to a terminal may result in trip out for either internal or external faults, but at reduced sensitivity.

13 Limiting pilot wire

The pilot wire resistance should not exceed 1000 ohms (2000 ohms when the isolating transformer is used). The pilot wire shunt capacitance should not exceed 2.0 uF (0.7 uF when the isolating transformer is used).

The pilot wire dielectric rating should be capable of safely withstanding the 5 kV design level of the relay, or the 15 kV rating of the primary of the isolating transformer.

Description

General

The basic version of the DHL consists of:

1- type RTXP 18 test
1- type RXDHL 4 measuring unit
1- type SLCE 8 three-phase summation transformer

The relay is available with the SLCE 8 mounted on apparatus bars with the RXDHL 4 module, or furnished loose for separate mounting. When IL 2 fault detector are specified, they are mounted on the same apparatus bars as the RXDHL 4 module and summation CT. There are also other versions with extra output relays type MS I or ME 1.

Fig. 1. shows the DHL with the summation CT mounted as a unit. Fig. 2 shows the arrangement when the summation CT is furnished loose for mounting in any convenient location.

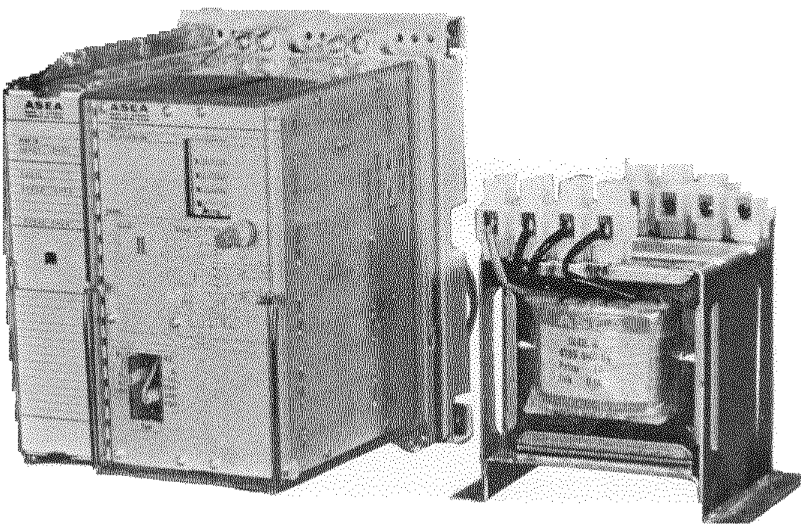


Fig. 2. Type DHL, basic version with summation CT furnished loose.

The pilot-wire-supervision equipment consists of one master station unit and one remote station unit as shown in Fig. 3. The master station unit is available in two different versions. One with separate signals for short-circuited and open or reversed pilot wires and one with a common signal for all types of faults.

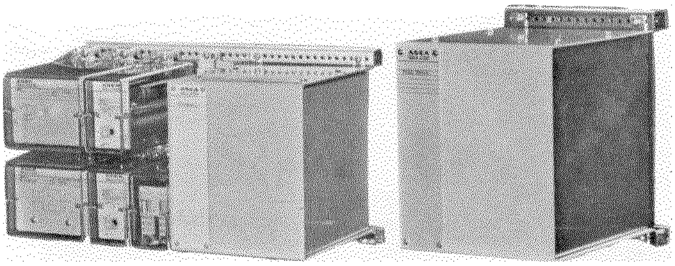


Fig. 3. Pilot wire supervision equipment Master station unit with separate signals for different type of faults to the left and remote station unit to the right.

Both the DHL and the pilot-wire-supervision equipment are designed in the COMBIFLEX modular system. They mount on apparatus bars for installation in equipment frames for mounting on a 19" equipment rack. They may also be installed in a relay case type RHGX, which is sized for the specific relay model, ordered.

Test switch

The relay includes a test switch for testing all relay components. When the test-plug handle type RTXH 18 is inserted in the test switch this test facility permits complete testing of the relay from this one location without additional or coordinated actions. However, if the circuit loading is above the single end feed pickup value of the relay, it will be necessary to insert the trip-block plug at the far end, before inserting the test handle at the near end under test. Also, should it ever be necessary to block the tripping of the relay, trip block plug RTXB inserts into the RTXP 18 without otherwise disturbing the relay. Figure 8 shows the details of the test switch and the various test plugs. Figures 9 to 14 show how the external wiring connects to this test switch for the several variations noted herein.

Relay module, RXDHL 4

The DHL 4 module includes an instantaneous dc measuring relay with a 4-diode rectifier. A 500 ohm fixed resistor and a 0-500 ohm adjustable resistor are also included in the DHL 4. Taps located at the lower left of the relay faceplate makes the resistor adjustment. These resistors make up the arms of a bridge that includes the pilot wire itself. The function of the bridge is to develop an output voltage only when a fault is internal to the protected section. This voltage is then applied to the measuring relay. Details are in section on THEORY OF OPERATION.

The residual voltage across the bridge is brought out to a pair of test terminals on the faceplate of the relay. These are located at the bottom of the resistor tap plate and are marked "Test" Do not confuse these with the resistor taps which are located directly above these test points. The points marked "Test" are not resistor test points.

The measuring relay has three output contacts, each capable of tripping a circuit breaker. One of these is wired to an RSP target. The target is provided with electrical reset, as well as the manual reset lever. The relay faceplate also includes a wiring diagram showing the relationship of the relay terminals to the internal components.

A set of regulating diodes which holds the voltage on the pilot wire to approximately 60 V maximum value are also contained in the DHL 4 module.

Doc. no. 61-10AG
Rev. ind.
Date April 1978

Summation transformer, SLCE 8

The summation current transformer, type SLCE 8, has a center tapped output winding for connection into the mentioned pilot-wire bridge network.

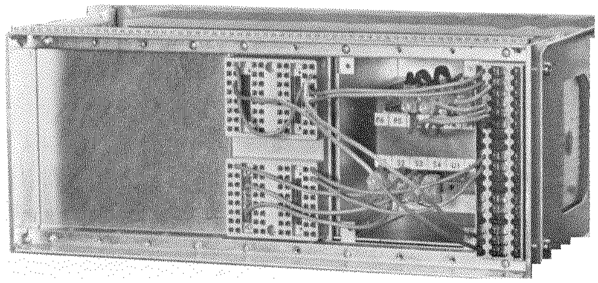


Fig. 4. Rear view of DHL and SLCE 8 summation transformer in a 4S-equipment frame showing the factory installed interconnected wiring between the modules.

Supervisory equipment

When pilot wire supervisory equipment is specified it may also be mounted at the user's convenience. One option of mounting is shown in Figure 5. In this case, the equipment is mounted in a separate 19" equipment frame. This equipment may also be specified in a separate RHGX relay case.

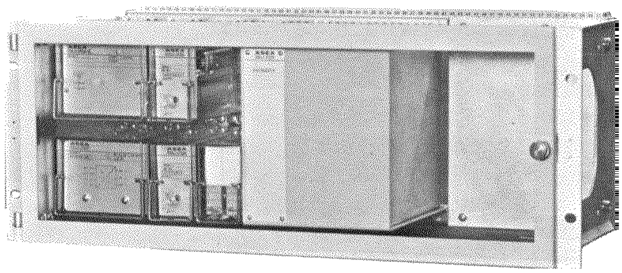


Fig. 5a. Master station unit with separate signals for short-circuited and open or reversed pilot wires.

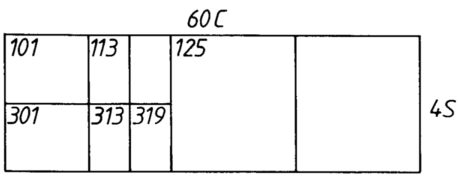


Fig. 5b. Reference numbers of the seat location of the master station unit modules. Front view.

101	Polarized sensing relay RXCLA 2
301	Voltage supply unit RXTUB 2
113, 313	Auxiliary relays RXMA 1
319	Target relay RXSF 1
125	Capacitor unit

The supervisory equipment at the remote station consists only of a capacitor unit, which also includes the diode for detection of interchanged pilot wires. The size of the capacitor unit is 4S 18C equal to unit 125 at the master station.

Monitoring equipment

In addition to supervising the pilot wires, some users wish to routinely check the status of the internal components in the DHL system. This is accomplished with a voltmeter and a selector switch. When ordered, these instruments, shown in Figure 6, are furnished loose for mounting at the user's convenience.

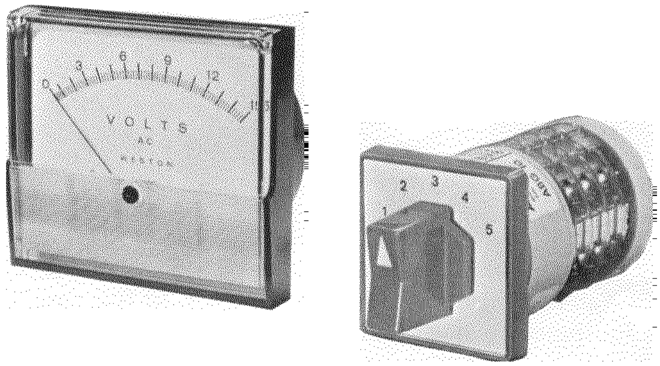


Fig. 6. Meter and selector switch for monitoring internal relay conditions.

Isolating transformers

When ratio matching/isolating transformers, type SLCE 8, are required, they are provided loose for mounting at the user's convenience. These are shown in Figure 7. They have a turns ratio of I to 1.7. They increase the allowable pilot-wire resistance from 1000 ohms to 2000 ohms and reduce the allowable pilot-wire capacitance from 2uF to 0.7uF. They have no other effect on the performance of the relay. When it is desired to isolate the pilot wires from the terminal equipment, the isolating transformers are used, even though the 1000 ohms limit is not being exceeded.

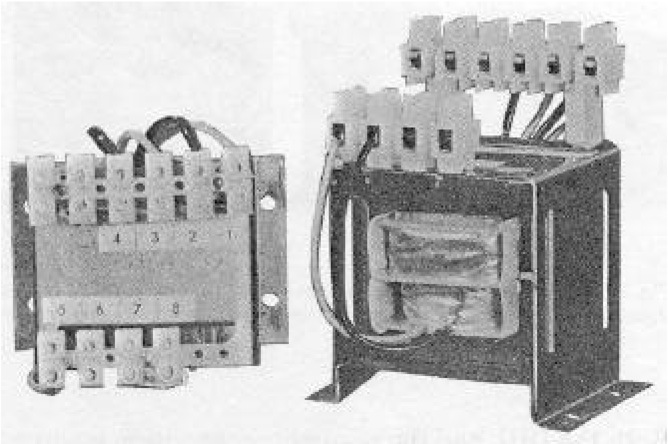
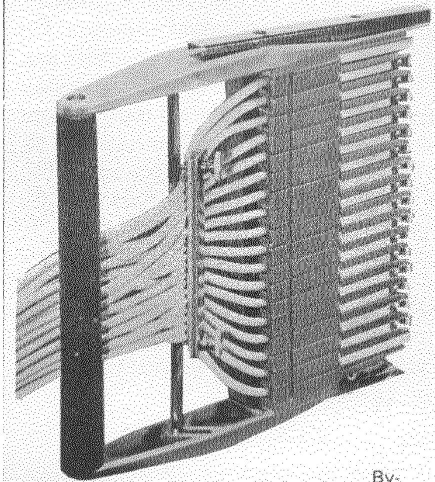
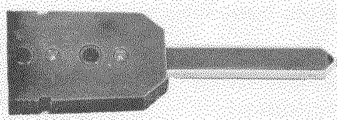


Fig. 7. Impedance matching/isolating transformer.

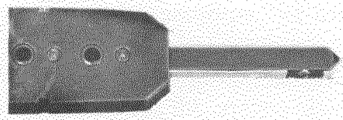
Test plug handle RTXH 18



Test plug handle includes

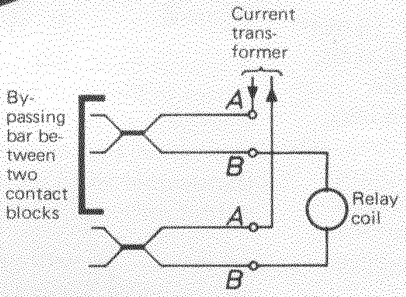


2 plug pins for + and – located at the top and bottom of the test plug handle. Used for supply of dc voltage to the test equipment. This pin does not open any contacts.

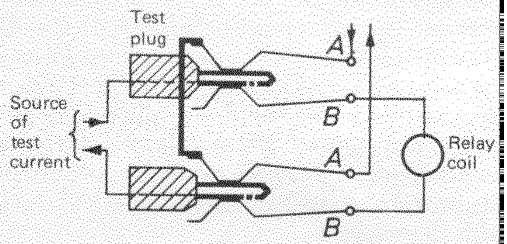


16 test plugs fitted in all remaining spaces in the test plug handle. These isolate both types of contacts i.e., those having a contact tip near the front of the test switch, intended for trip circuits, and those with a contact tip further inside, intended for current and voltage circuits.

NORMAL POSITIONS

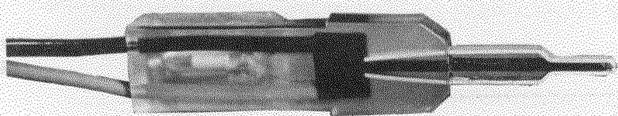


TEST POSITIONS

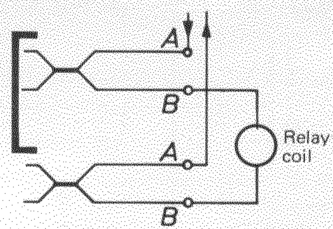


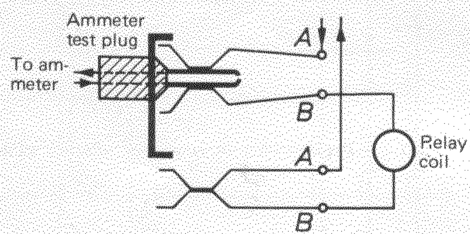
Current testing of relay.
(positions 3 to 6, 9 to 10)

Loose plugs



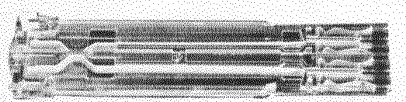
The ammeter test plug RTXM is used separately for service current measurement. It incorporates an overvoltage protection consisting of a gas tube. An arc occurs at approx. 300 V and short circuits the current if this is opened by mistake or if the plug is inserted in the test switch without an ammeter connected to the plug. A bimetal contact is heated up by the arc and takes over the short circuiting.

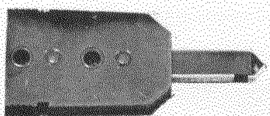




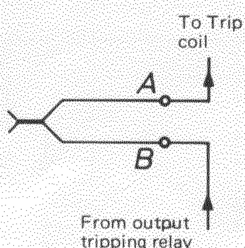
Load current measurement.
(positions 3-6, 9-10)

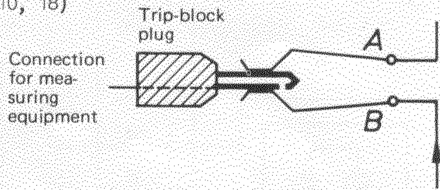
Test switch contact for current circuits (positions 1, 3-6, 9-10, 18)





The trip-block plug RTXB is short and is used separately for blocking trip circuits. It can also be used for measurement purposes in trip circuits. The plug is red to draw attention to the fact that blocking has been carried out. The door of the COMBIFLEX equipment frame can be closed while the plug remains inserted in the test switch.





Interruption or blocking of a dc circuit or for time measurement of trip pulses etc.

Test switch contact for trip circuits (positions 2, 13-17)

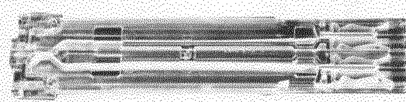


Fig. 8. Details of test-plug handle, various test plugs, test switch contacts and method of use.

Installation Requirements

The DHL relay has only nominal physical requirements for a successful installation. It is designed to mount in a standard 19" equipment frame. The complete basic version occupies 7" of rack space.

Securely fitted clear plastic covers protect the individual modules. All terminals and connections of the COMBIFLEX system are silver plated, contact pressures are substantial, leads terminate in connectors which directly mate with the module terminals to which the interconnected wiring or the switchboard leads have been crimped. Corrosive atmosphere and high humidity should be avoided as a matter of general prudence.

Field wiring

Field wiring is mostly terminated in the RXTP 18 test switch. Position No. 1 is at the top, position 18 at the bottom. The wires must be fitted With the ASEA COMBIFLEX terminal connectors for insertion into the respective positions. These connectors are designed electrically for a secure, low resistance (5 milliohms maximum) contact. The mechanical design provides a secure capture. They are not removable without using the provided tool. This extractor, RTXD, is shipped with the relay.

Depending on the application, some external wiring may need to be connected directly to the relay terminals without going through the test switch as shown in Figure 9. The same ASEA wire terminal connectors are used in all cases. The larger, 20A, connector should be used for all current circuits and for all connections to the RTXP 18 test switch. It can accommodate up to No. 12 wire. The smaller, 10A, connector should be used for all other connections. It can take up to No. 14 wire.

The location of each relay wire terminal can be determined from its number on the wiring diagram, Figure 9 to 15. The test system is described in more detail in Figure 8.

A typical basic DHL installation-wiring diagram is shown in Figure 9. In all installations, all field wiring is brought to the »A» side of the test switch RTXP 18 in position 101, including the ratio matching/isolating transformer when used. Exceptions are with certain output options.

An installation with pilot-wire supervisory equipment also included is wired, as shown in Figure 10.

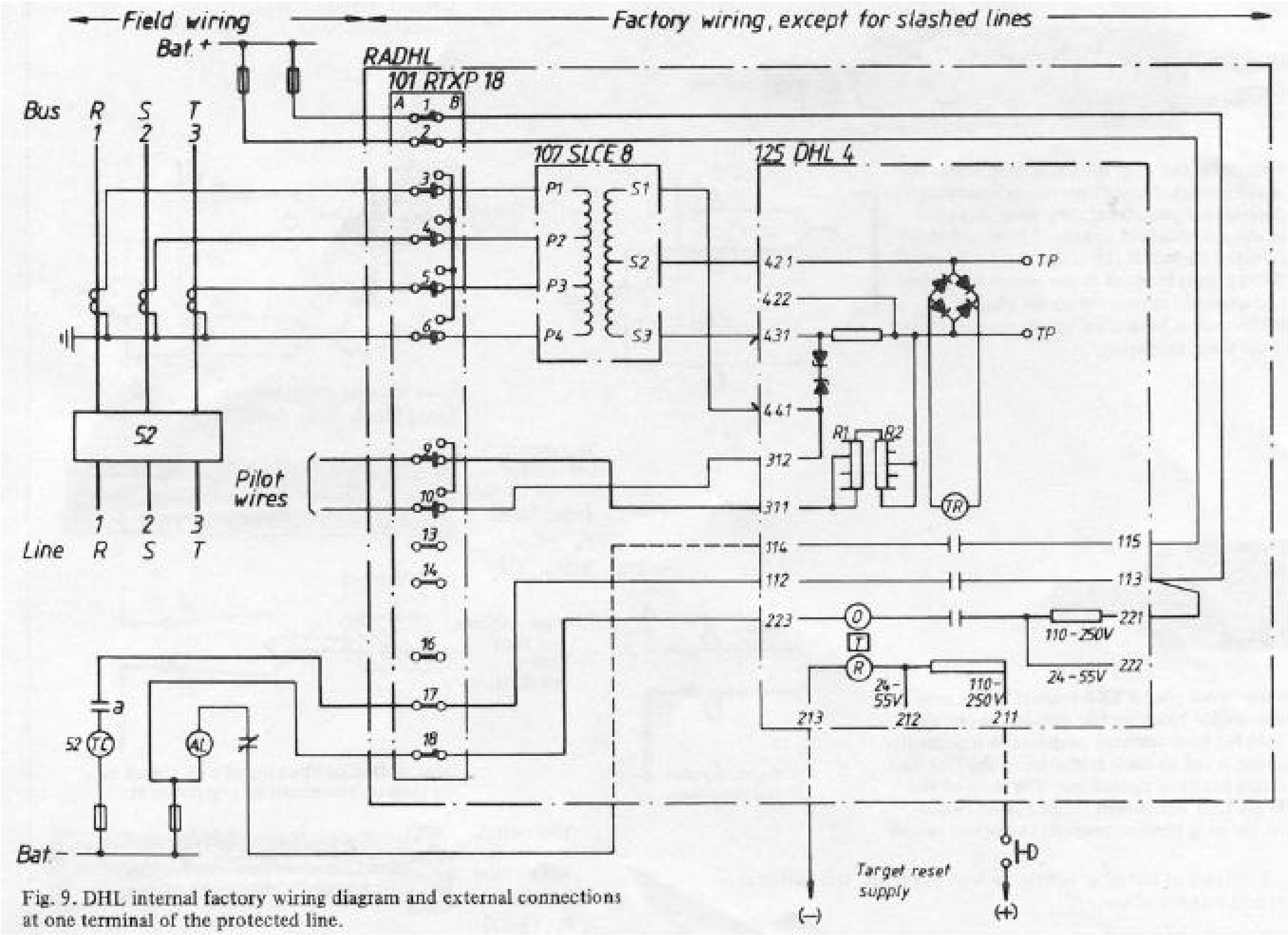


Fig. 9. DHL internal factory wiring diagram and external connections at one terminal of the protected line.

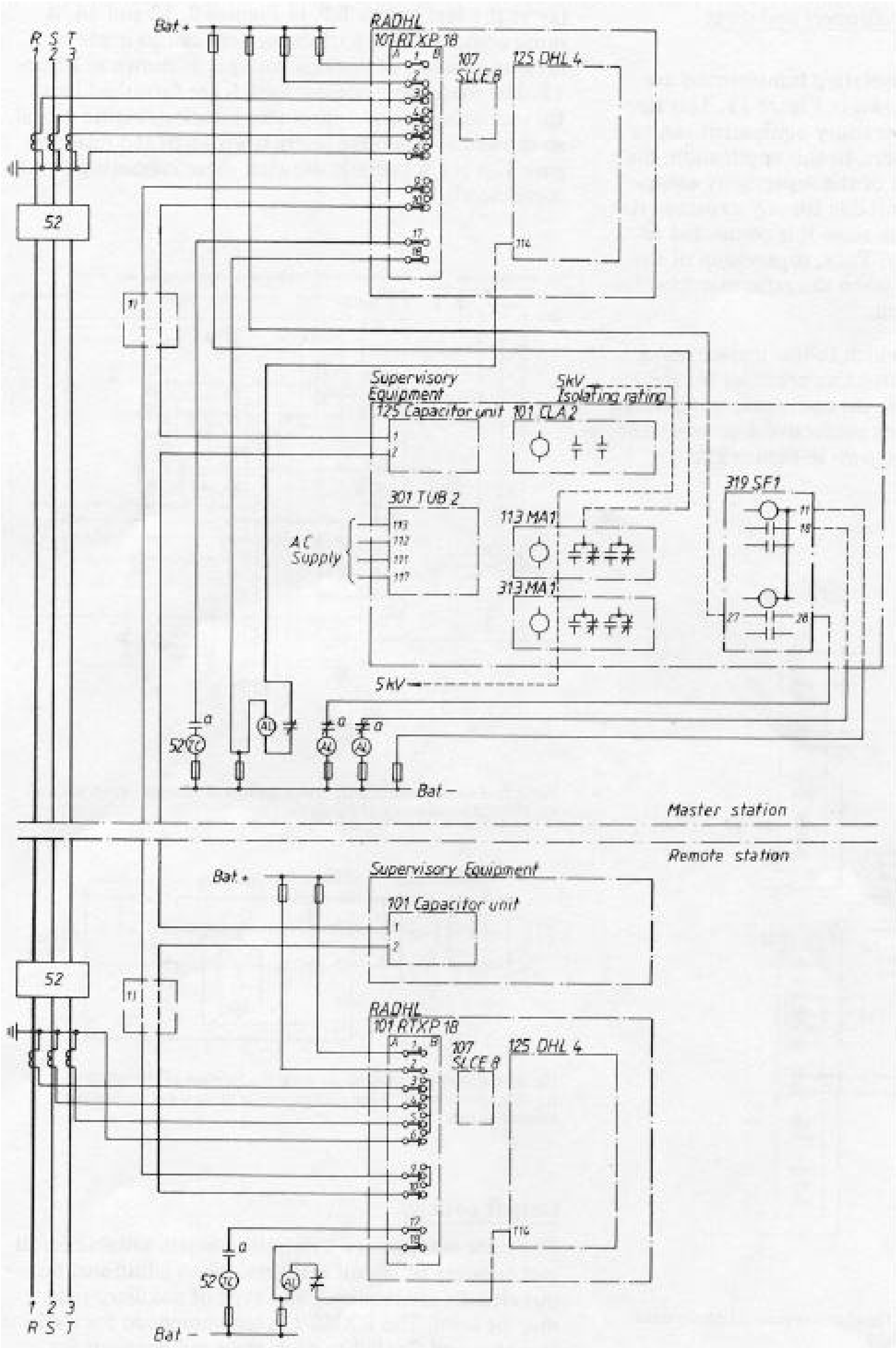


Fig. 10. Wiring diagram showing external connections between DHL and supervisory equipment at the master station and remote station. For additional field wiring within the DHL see Figure 9 and within the supervisory equipment see Figure 19.

Note 1) See Figure 11 for external connections of ratio matching/isolating transformers when used.

<u>Use of ratio matching transformers and surge suppressors</u>

When the ratio matching/isolating transformers are used, they are wired as shown in Figure 11. This figure also shows how the supervisory equipment can be used with these transformers. In this application, the basic 5 kV insulation level of the supervisory equipment at each terminal is suitable for any expected rise in station ground potential, since it is connected to the local ground internally. Thus, supervision of the pilot wires is also feasible when the ratio matching/isolating transformers are used.

Protective arrangements, which follow conventional communication circuit protective practices for this type of service, are acceptable for containing possible surges. One method for adding protective gaps when excess voltage are anticipated is shown in Figure 19b

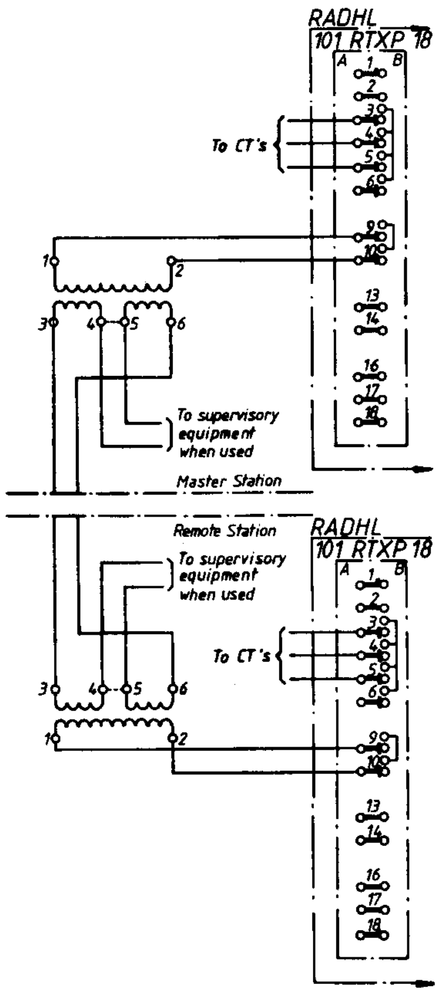


Fig. 11. Ratio matching/isolating transformers external connections.

Use of ac: monitoring equipment

Monitoring the relay system is done by measuring the ac voltage across the rectifier input to the measuring relay at the test points T.P. in Figures 9, 12 and 14. A more complete check of the system can be made by measuring selected internal voltages as shown in Figure 12. The meter and selector switch are furnished loose for mounting in any convenient location. Figure 12a also shows the complete internal wiring of the relay. Figure 12b is a schematic showing these measuring points more clearly.

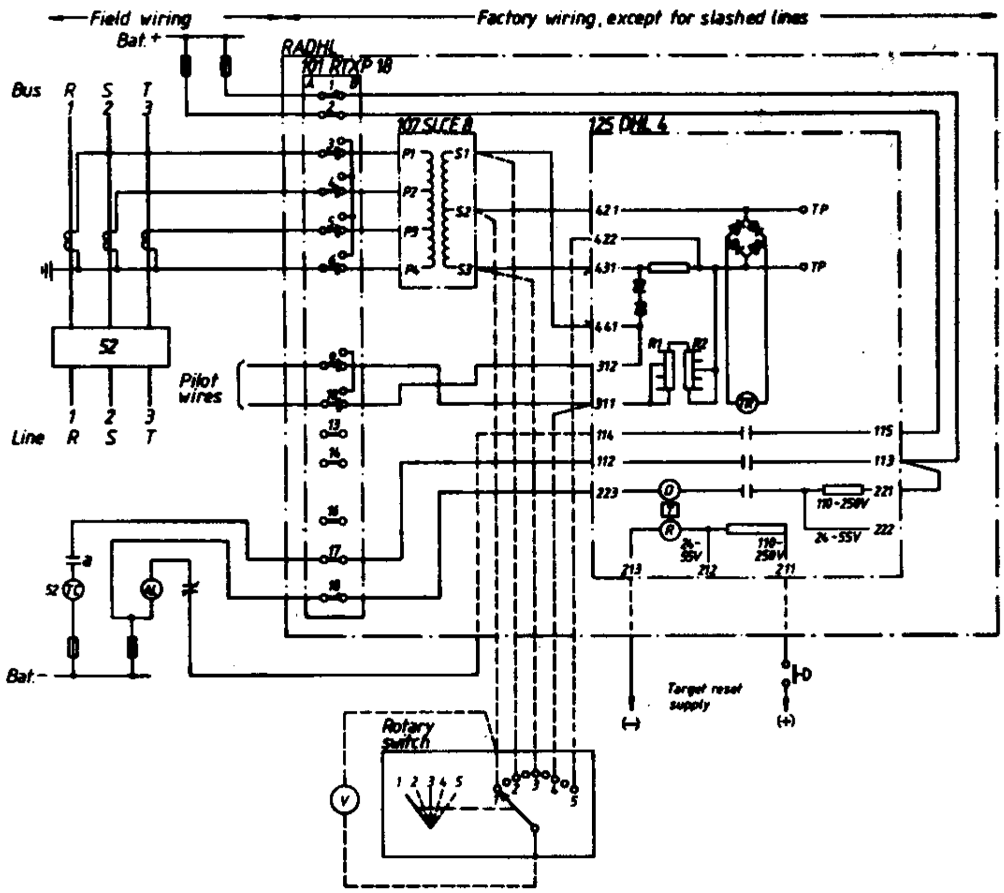


Fig. 12a. Connections to DHL when meter and selector switch are used for internal monitoring of the relay.

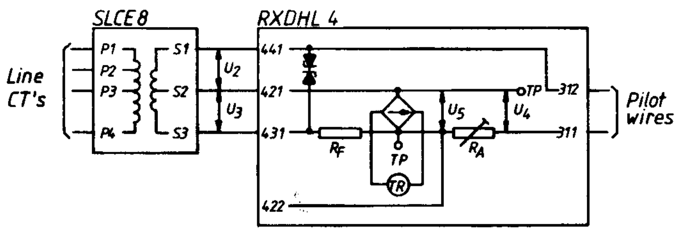


Fig. 12b. Schematic diagram showing the location of the voltage, U_2-U_5, measured with the meter monitor at each position of the selector switch.

Output options

The basic relay has two output contacts suitable for direct tripping of circuit breakers. When additional output circuits are required, any type of auxiliary relay may be used. The RXMS 1 is recommended for its 3 ms response and flexibility of contact arrangement for either N.O. or N.C. contacts. It can be provided with up to six contacts. Its coil has a continuous rating that permits it to be sealed-in. Thus, it can also be used to provide a lockout function. A representative wiring diagram of such a system is shown in Figure 13.

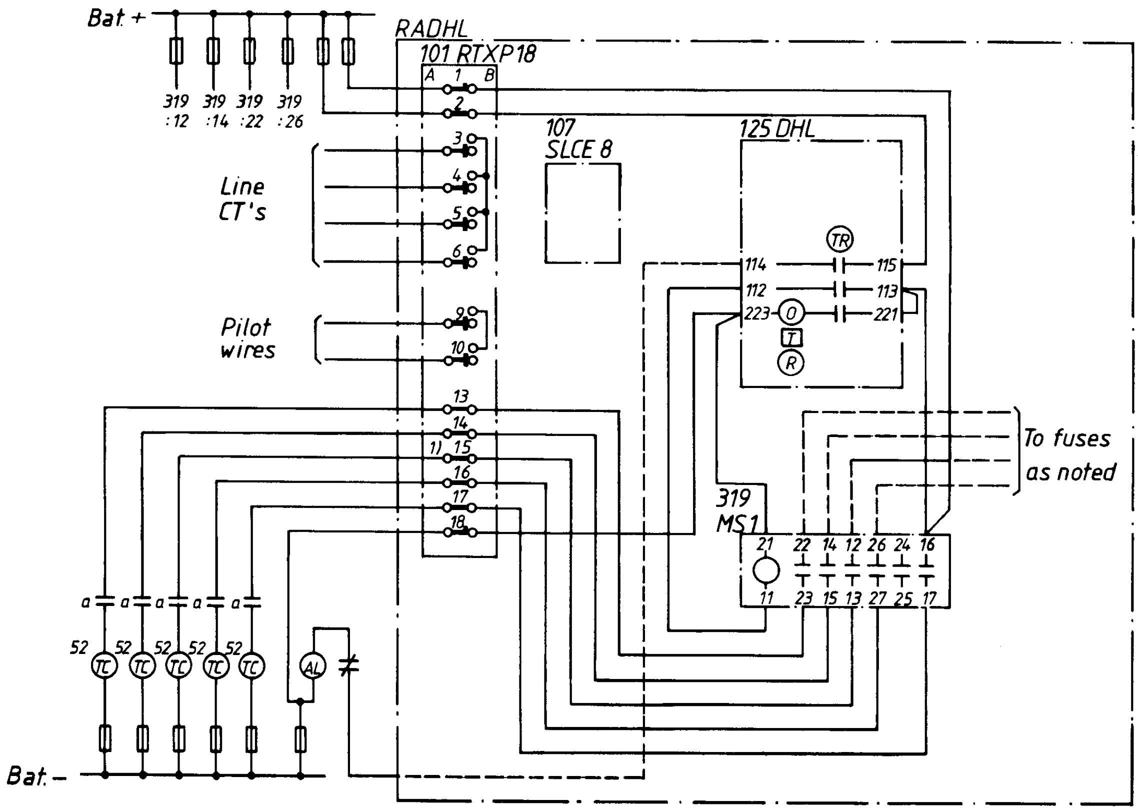


Fig. 13. Internal wiring of MS 1 to test switch and interconnections to DHL 4. Typical wiring for tripping of up to five breakers.

Note 1) Contact 15 in the test switch is normally not included.

Doc. no. 61-10AG
Rev. ind.
Date April 1978

Fault detector

When fault detectors are desired, the basic relay may be expanded to utilize RXIL 2 (two seat relays). Figure 14 shows one wiring option for this equipment. When used in conjunction with the supervisory equipment, any type of pilot channel failure will decommission the DHL relay and set up a suitable alarm. The fault detectors are needed in this arrangement because an open pilot wire could otherwise cause an immediate trip output before the supervisory relay could function.

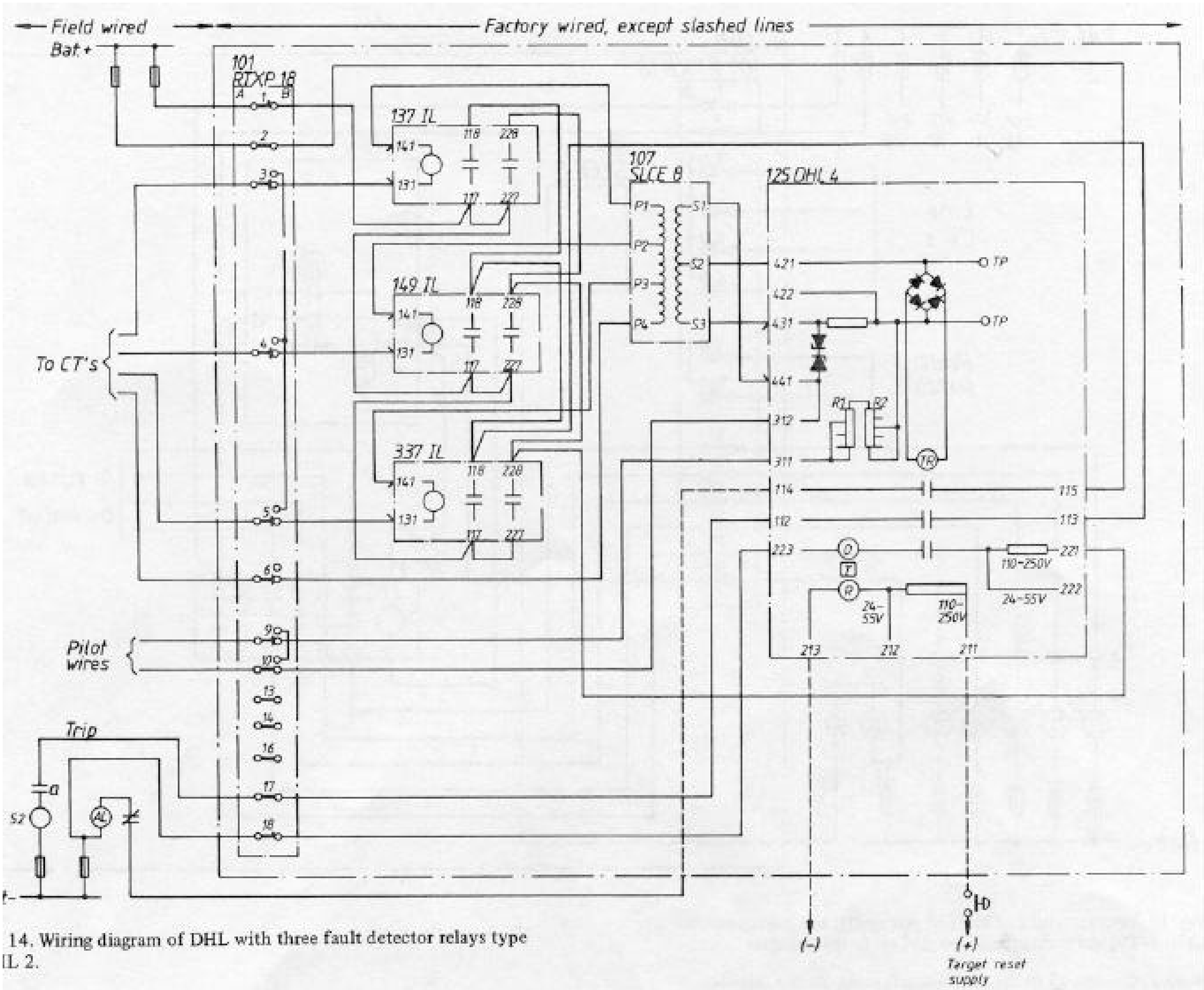


Fig. 14. Wiring diagram of DHL with three fault detector relays type RXIL 2.

Other installation requirements

The operation indicator is provided with 24-55 V dc operate and reset coils. Either coil may be connected for this voltage or through the provided internal dropping resistor for 24 V to 55 V dc supply or 110 V to 250 V dc supply. Figure 15 shows the terminals at the rear of the relay module to be connected for applying the correct auxiliary voltage for the target.

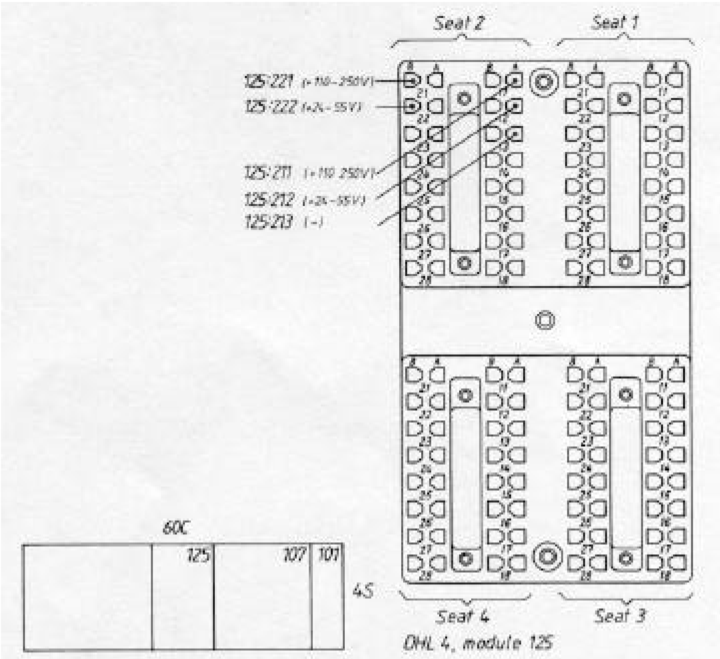


Fig. 15. Physical location of the relay terminals to which internal and field wiring connects for target auxiliary voltage.

The supervisory equipment, when used, requires 120 V or 240 V ac supply. Any additional auxiliary relays or the static fault detectors can be furnished in any of the six standard dc voltages. The DHL measuring relay requires no auxiliary voltage except for target and output tripping power.

Any unused positions in the RTXP 18 test switch may be utilized for any other desired function within the 20 A rating of these test positions.

Current transformer requirements

The turns ratios of the CT's at the two terminals should be the same. The CT's need not be matched, nor of the same manufacture. Different taps on the two sets of CT's to provide the proper ratio are acceptable. In general, auxiliary CT's to bring these ratios into agreement are not recommended, but they may be used if additional calculations confirm their suitability.

The CT ratio should be selected to deliver about 80 % of the DHL rating of 1, 2 or 5 A during full load conditions on the circuit being protected. Overload conditions usually need not be considered since the system can operate continuously at 200 % rating. (Main CT permit- Fault sensitivity will be 25 % to 75 % of relay rating for all types of faults and conditions.

The CT accuracy requirements are based on the severest external fault under symmetrical current conditions. Under this condition and with the CT burden composed of the CT secondary and lead resistance plus an allowance of 5 VA (0.2 ohms on 5 A basis) for the largest single phase burden of the DHL summation CT, the CT should not exceed its 10 % accuracy rated voltage, i.e:

$$I_P/N = \frac{U_{CT} - U_Z}{R_L + R_{CT} + R_{SCT}}$$

where I_P = maximum primary fault

N = turns ratio of main CT

U_{CT} = main CT rated secondary 10% accuracy voltage.

U_Z = main CT rated to the primary side of the summation CT = $\frac{75 x N_P}{2 N_2}$ volts.

N_P = turns of the primary winding affected by the fault i.e.
N_P = N1 for an R-S fault. (See Fig. 18 for values of N_1 and N_2).

R_{CT} = main CT secondary winding resistance

R_L = main CT secondary lead resistance (multiply by 2 for L-G faults).

R_{SCT} = summation CT resistance reflected to the primary side of the summation CT (approx. 0.2 ohms).

When so selected, any CT saturation due to the dc component in asymmetrical fault currents will not cause misoperation. Nor will any CT which saturates during an internal fault, due to ac or dc causes, prevent operation. General prudence suggests limiting maximum fault currents to 100 times normal or 250 A secondary which ever is the smaller.

Burdens

At rated current, three-phase	Total 0.8 VA
At rated current single-phase	R-phase 5 VA S-phase 3.5 VA T-phase 2 VA
Self consumption of summation CT	0.2 VA
DC measuring relay (with rectifier) at pickup current	Approx. 13 mA, 0.15 VA
RXIL 2 as fault detector	See specific relay literature Catalogue RK 41-11E
Impedance matching/isolating transformers SLCE 8	
Winding resistance	65 ohms primary 210 ohms secondary
Magnetizing VA at 60 volts input	0.4 VA

Ratings

Frequency	50 or 60 Hz
Current, I_n (normal)	1.2 or 5 A
Overload	100 % continuous
DC measuring relay with rectifier	
Diodes	1 A, 800 V
Relay	approx. 13 mA RMS
Voltage regulating diodes, each	
Continuous	75 V, 75 W, for diode equipment with standard heat sink
For 5 seconds	2 A
Impedance matching/isolating transformer	
1000/2000 ohms matching	60/100 V
Primary (relay side) kneepoint voltage	$\geq$ 300 V RMS
Dielectric withstand test	
DHL 4, summation CT	5 kV, 50 Hz, 1 min.
Isolation transformer	15 kV, 50 Hz, 5 seconds
Ambient temperature	-25 ^{o}C to +54 ^{o}C (-13 ^{o}F to +131 ^{o}F)
DC auxiliary voltage	
for RSP shunt target	24-45 or 110-250 V dc
for auxiliary relays, as specified	250 V dc, +10 %, -20 %
AC auxiliary voltage	
For pilot wire supervising equipment only	110 or 220 V ac 50 Hz or 120 or 240 V ac 60 Hz
Contacts	
DHL 4, terminals 112-113	
Continuous	15 A
Making	40 A
Breaking 125 V dc L/R $\leq$ 40 ms	0.4 A
DHL 4, terminals 114-115 and IL 2 fault detectors, 17-18 and 26-27	
Continuous	5 A
Make and carry 200 ms	30 A
Breaking 125 V dc, L/R $\leq$ 40 ms	0.4 A

For auxiliary relay ratings, refer to specific relay information, such as 21-16 SI for the RXMS 1 auxiliary relay.

Operating Specifications

Table 1

Internal fault sensitivity - % of rated relay current.

Type of fault	Sensitivity	
	Single end feed	Dual end feed equal from each end
R - Gnd	25 %	12.5 %
S - Gnd	32 %	16 %
T - Gnd	42 %	21 %
R - S	126 %	53 %
S - T	126 %	63 %
T - R	64 %	32 %
R – S - T	72 %	36 %

The above is based on no capacitance between pilot wires. The operating value is to some extent dependent on the pilot-wire capacitance. At a capacitance value of 1.0 uF the operating value increases to 1. 1 times the above stated value; and at 1.5 uF, to 1.4 times the above. Maximum recommended capacitance value is 2 uF that gives operating values of approximately twice the above numbers.

External fault capability 100 times rated current up to 250 A secondary with full offset

Operating time

At 1.1 times pickup	25 ms
At 1.5 times pickup	20 ms
At 2.0 times pickup	15 ms

Table 2

Requirements	Pilot wire requirements	
	Without impedance matching transformers	With transformers
Maximum signal voltage	60 V ac square wave	100 V ac
Maximum signal current	60 mA	36 mA
Permissible elevation of station ground potential	5 kV	15 kV
Pilot channel resistance max.	1000 ohms	2000 ohms
Pilot channel capacitance, max.	2 uF	0.7 uF
Maximum permissible signal mode induced voltage, 60 Hz	10 V	15 V

Energizing surge capability

The relay will not misoperate due to a high frequency energizing surge of a cable of 10 times relay rating which lasts for no more than 10 ms. Note: When energizing surges are of concern the pilot wire capacitance should be padded out to the recommended maximum value of 2.0 uF (0.7 uF with the isolating transformers). One-half should be placed at each end of the pilot wire. The capacitor should have a suitable dielectric rating for this service.

Theory of operation

The DHL wire pilot differential protection system is based on the principle of developing opposing voltages at the two terminals for external faults and in-phase voltages for internal faults. Thus, for external faults a current is circulated between the two terminals over the pilot wires, the internal voltage drops consume the driving voltages and no tripping occurs. For an internal fault, with in-phase voltages, there is no circulating current, a voltage appears across the relay at each terminal and tripping result.

This voltage is measured with a rugged dc relay. To facilitate the measurement, a simple bridge circuit is established by means of a pair of resistors and a center tap on the summation CT. This results in zero voltage across the measuring relay for an external fault and max. 30 V for an internal fault. The relay is calibrated to operate at 10 volts, thus assuring reliable performance under all conditions.

Figure 16 shows how this is accomplished schematically. A summation transformer, S converts the three-phase input currents to a single-phase current. The voltage 2 EA across the summation CT secondaries is held to 75 V peak by means of voltage regulating diodes, Z I and Z2. The output of the summation CT has the mentioned center tap to which one terminal of the measuring relay connects. The resistor RF is fixed at 500 ohms and the resistor RA is adjustable between 0 and 500 ohms. The sum of 2 RA (one at each terminal) plus the pilot wires resistance RpW is always made equal to 1000 ohms.

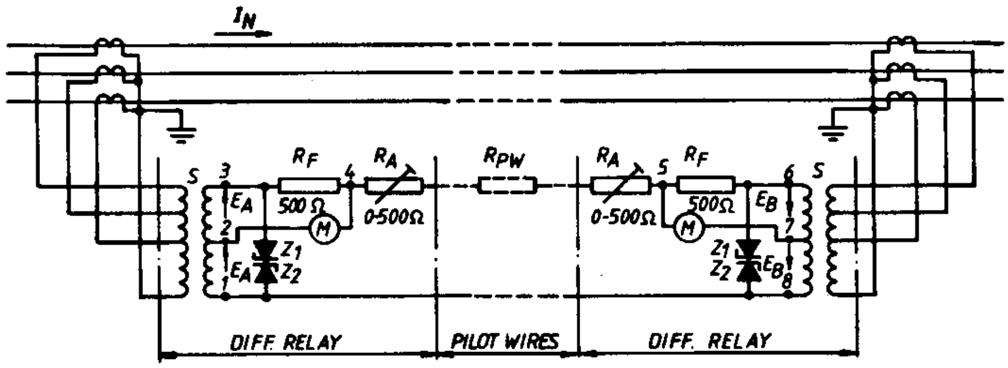


Fig. 16. DHL principle schematic.

For normal load conditions, Figure 17a, it is seen that 1/4 of the total voltage (the sum of the voltages across the two summation CT secondaries) will appear across each RF resistor. Also 1/4 of the total voltage will appear across each half of the summation CT secondary. Thus, no significant voltage will be developed across the measuring relay, M.

For external faults the same general conditions will prevail. The summation CT secondary voltage will increase and the voltage regulating diodes will cause some clipping of this voltage, but the respective 1/4 of the total voltages will exist as before and no voltage will develop across the measuring relay. Note that the voltage regulating diodes regulate the two voltages at the terminals to approximate equal values even if the CT's deviate from their true ratio. This contributes to the relays stability to external faults.

For internal faults equally energized from both terminals, Figure l7b, the voltage from the summation CT's will be in phase and no current will circulate between the two terminals. Thus, the full one half of the summation CT secondary voltage EA will appear across RF and the measuring relay. With the measuring relay requiring 10 volts to operate, EA = 17 volts will need be developed across each half of the summation CT to cause a trip out. This will occur with less than rated current for most type faults, as shown in the sensitivity table above. For more severe faults the measuring relay will receive several times its pickup requirement before the voltage regulating diodes cause any clipping action.

When the fault is energized from only one terminal, both relays will operate at no reduction in sensitivity. It is obvious that the near terminal should trip. Figure 17c shows why the far relay will also operate. Because of the autotransformer action of the idle summation CT of the far end, the same current will flow in the measuring relays at the two ends of the circuit. This aspect of the DHL system is of significance as it adds to the reliability of the system in case of a weak infeed from one terminal. It can also be utilized for a transfer tripping function, by injecting a suitable ac voltage at one terminal.

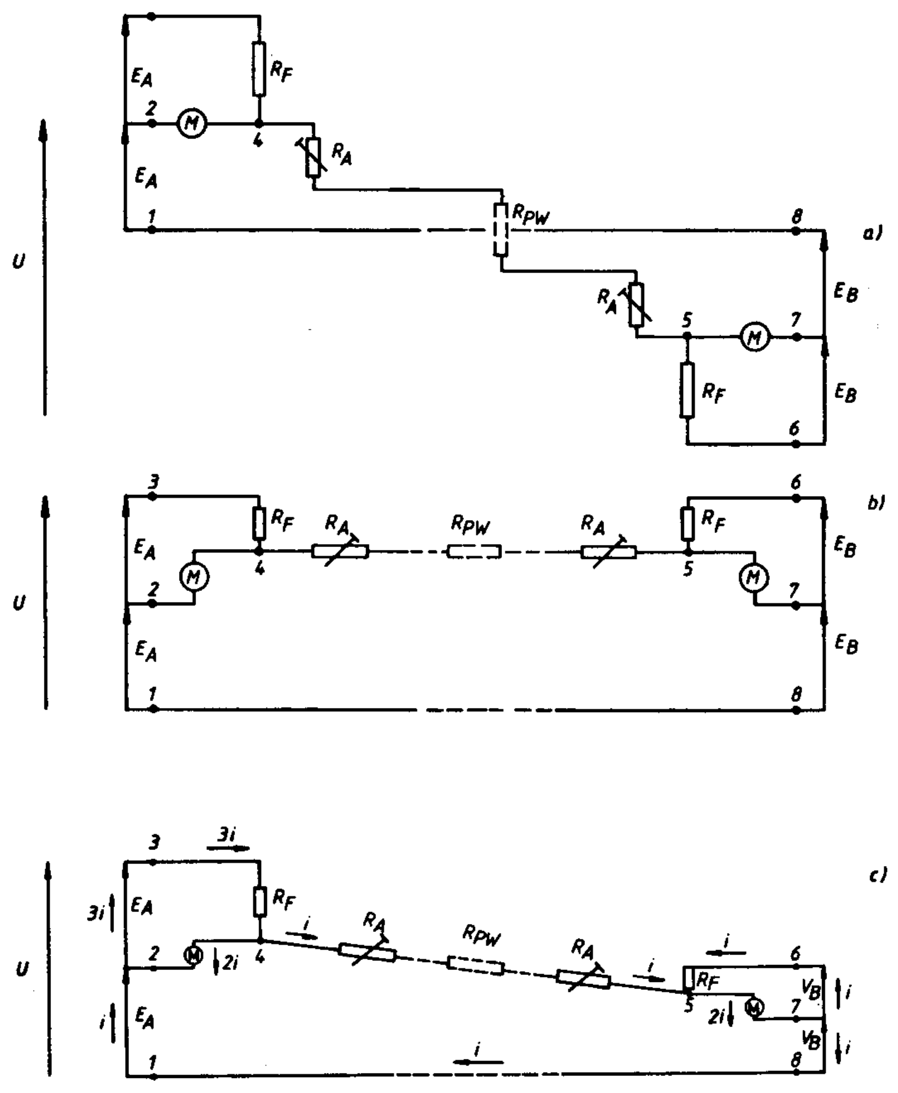


Fig. 17. DHL system voltage distribution.
a) Normal service and external fault.
b) Internal fault equal infeed from both ends.
c) Internal fault, infeed from one end only.

The summation transformer windings are developed as shown in Figure 18. This results in some variations in sensitivity to different types of faults as shown under OPERATING SPECIFICATIONS, page 14, but since both CT's are phased identically, it has no other effect on the relay performance.

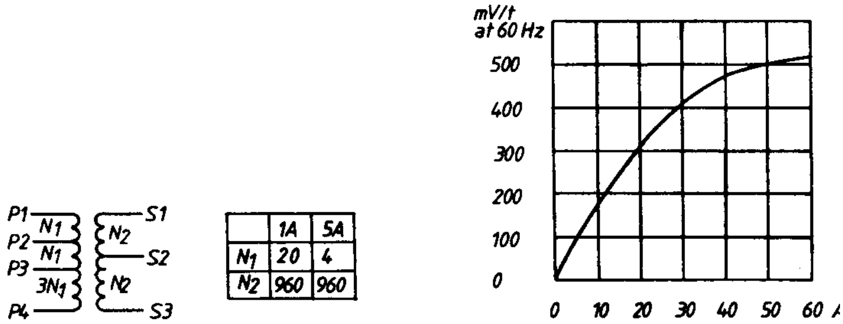


Fig. 18. Summation CT, type SLCE 8, typical magnetizing characteristic and winding development.

When the pilot wire impedance matching transformers are used, the operative principles are identical. The pilot wire effective resistance is reduced by the square of the turns ratio in these transformers. This is chosen to provide a 2/1 resistance change. The actual turns ratio is 1 to 1.7 and not I to 1.41 - so as to compensate for the winding resistances in the two transformers and to also yield a whole integer conversion factor.

The effective shunt capacitance of the pilot wires as seen by the relay is increased when the isolating transformers are used.

The performance of the DHL wire-pilot system during abnormal pilot wire conditions is:

1 For shorted pilot wires the sensitivity is reduced and tripping may not occur for an internal fault.

2 For shorted pilot wires, the system may tend to trip on external faults.

3 For an open pilot wire circuit the relay will operate for internal and external faults.

4 For an open pilot wire circuit the relay will operate on load current above the single ended three-phase fault sensitivity.

The degree to which a shorted pilot wire will result in a malfunction will depend to some extent on the proportion of resistance in RA, the padding resistors, and in the pilot wires, as well as on the location of the pilot wire fault. For short lines with most of the 1000 ohms largely in RA, a pilot wire short circuit at any point on the wires will result in a symmetrical set of resistance values and tripping will be blocked on both internal and external faults. On the other hand, if all of the 1000 ohms is in the pilot wires then a fault at one end of the pilot will create an unbalanced bridge condition and at least one end will trip for both internal and external faults. The principles laid down in Figure 18 can be used to determine the performance under any specific set of conditions.

Monitoring accessory

The relay monitoring meter is connected as shown in Figures 12a and b. Its purpose is to check the near end and far end signals and to observe that the system resistances are still in balance. With the selector switch in position 2 and 3, the voltage on the two halves of the summation CT secondary are read. They should of course be equal. The value should be approximately 8 volts for rated three-phase load current into the summation CT. In position 4, the reflection of the far end voltage into the near end relay is observed. This voltage will depend on the value of resistor RA. It should be than the voltage at position 3 approximately by the ratio of RA to RF, i.e.:

$$U4 = U3 \quad \frac{2R_F - R_A}{2R_F}$$

In position 5, the net operating voltage is read. This should never exceed 2 V with full load at the circuit.

Once established for a given installation, all of the readings should stay in proportion to the amount of load on the system.

Supervisory equipment

The pilot wire supervisory equipment injects a small, I mA dc signal into the pilot wires at one terminal, as shown in Figure 19a and schematically in Figure 20. At the far end terminal an additional 4000 ohms is added together with a 60 Hz bypass capacitor. If a short occurs on the pilot wires, the far end 4000 ohms is effectively shorted out, the monitoring current increases to 2 mA and the polarized relay moves on position to annunciate a shorted pilot wire. If an open circuit develops in the pilot wires the monitoring current goes to zero and the polarized monitoring relay moves in the other direction an open circuit alarm is indicated. Similarly if the pilot wires are inadvertently crossed (as after opening for a megger reading) the supervisory equipment will indicate an open circuit because of the diode in series with the far end 4000 ohms.

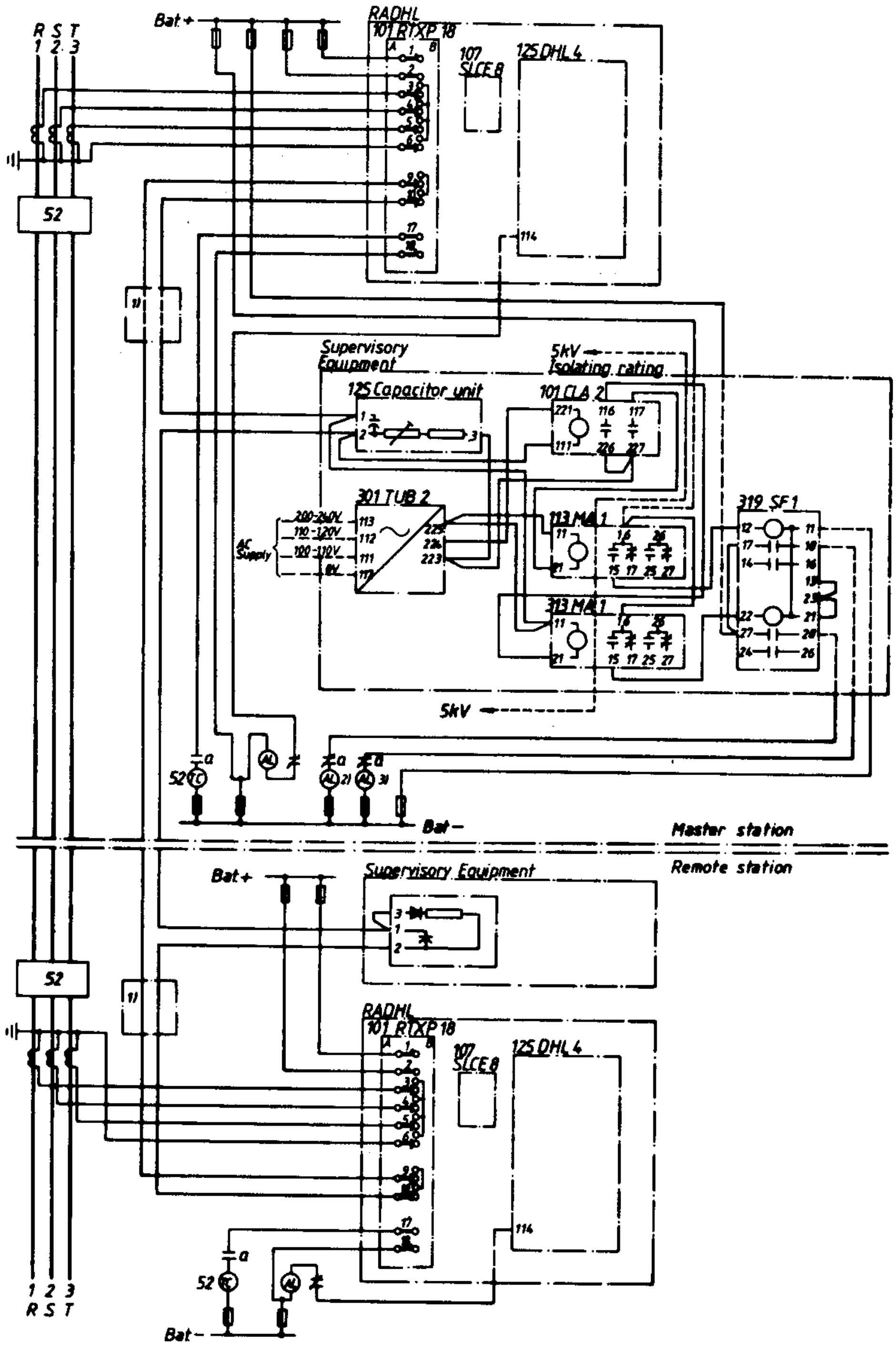


Fig. 19a. Pilot-wire supervisory equipment external and internal connections. The additional field wiring within the supervisory equipment is shown with slashed lines.

Note 1) See Figure 11 for external connections of ratio matching/isolating transformers when used.

Note 2) Alarm for open circuited or interchanged pilot wires.

Note 3) Alarm for short-circuited pilot wires.

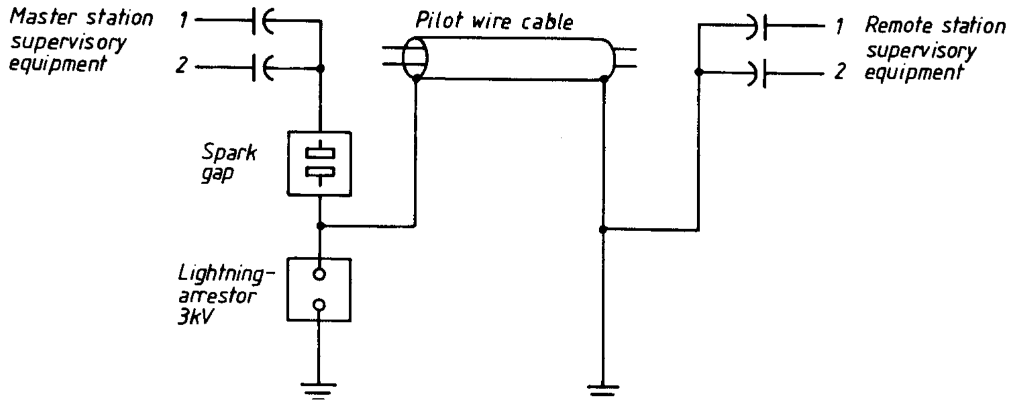


Fig. 19b. Surge suppression added to supervisory equipment.

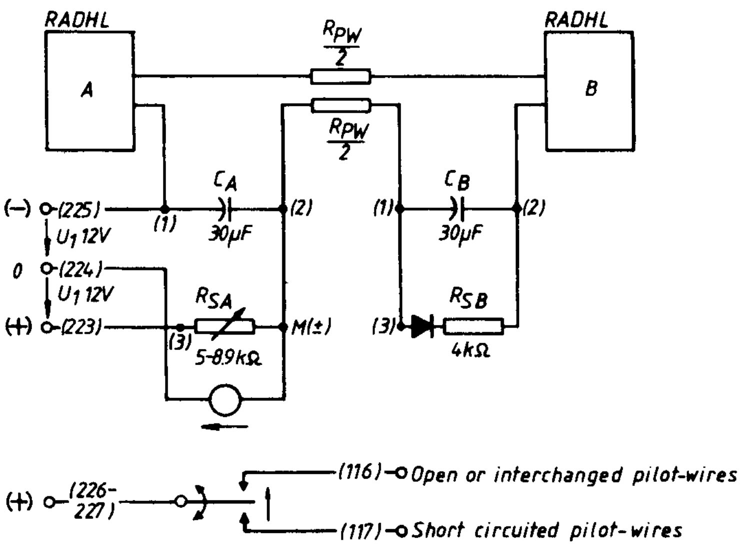


Fig. 20a. Schematic.

Doc. no. 61-10AG
Rev. ind.
Date April 1978

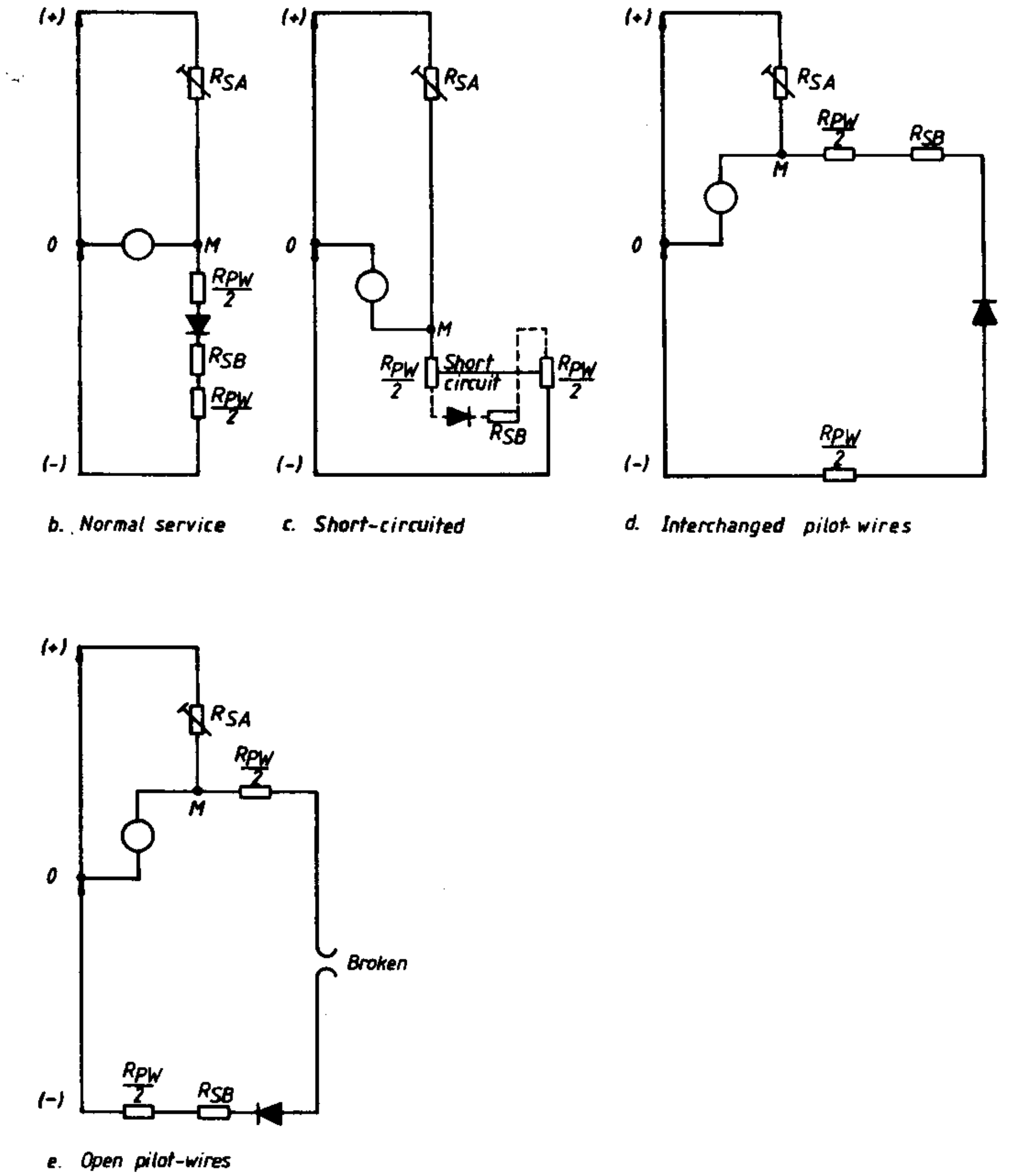


Fig. 20b-e.
b) Normal service.
c) Short-circuited pilot wires.
d) Interchanged pilot wires.
e) Open pilot wires.

Fig. 20. Supervisory equipment principles and voltage distribution.

Setting determinations

The one adjustment in the DHL system is the resistance to pad out the pilot wire to 1000 ohms. It is generally preferable to put 1/2 of this in each relay terminal.

$$R_A = 1/2\ (1000 - R_{PW})$$

R_{PW}, the pilot wire resistance should preferably be measured with a bridge type ohmmeter. The near end should be open circuited and the far end should be short circuited, so as to eliminate the effects of the relay resistances in the measurement.

When the impedance matching/isolating transformers are used, the pilot wire resistance should be measured in the same manner. Also measure the, dc resistance of each winding of the isolation transformer. The above formula must be modified to account for both the isolating transformer turns ratio and the windings resistances curve viz.

$$R_A = 1/2\ [\ 1000 - 2\ R_{TP} - n^2\ (R_{TS} + R_{PW})]$$

where

R_{TP} and R_{TS} are transformer winding resistances, relay and pilot wire sides respectively

R_{TP} is normally 65 ohms and R_{TS} is normally 210 ohms

R_{PW} is pilot-wire resistance

n is turns ratio (not the voltage ratio) of the impedance matching/isolating transformer.
The standard ratio is 1/1.7, in which case $n^2 = 0.346$

There are no other adjustments required for through fault stability.

The internal fault sensitivity is determined by the turns ratio of the main CT's supplying the DHL summation transformer. See Table 1 for internal fault sensitivities on page under Operating Specifications.

Testing

Acceptance tests

Check the nameplates to assure that the relay model numbers and ratings are as specified in the requisition. Visually inspect the components to assure that there has been no mechanical damage in shipment or storage. Confirm that any specified auxiliary relays have the proper coil voltage for the available dc supply and that other auxiliary voltages are connected to the proper terminals for the available voltages.

The operating characteristic of the relay can be checked with the test set up of Figure 2 1. With the test-plug handle RTXH 18 inserted into the test switch RTXP 18, the relay is isolated from the CT's, trip circuits and the pilot wire. With these circuits removed, the measured operating values should be as given in Table 3. These are about one-half of the single end fed fault values listed in Table I under OPERATING SPECIFICATIONS, page 14 as will be evident from analysis of Figure 17c. Contact operation can be confirmed by use of the shown ammeter and resistor or by any other conveniently used procedure.

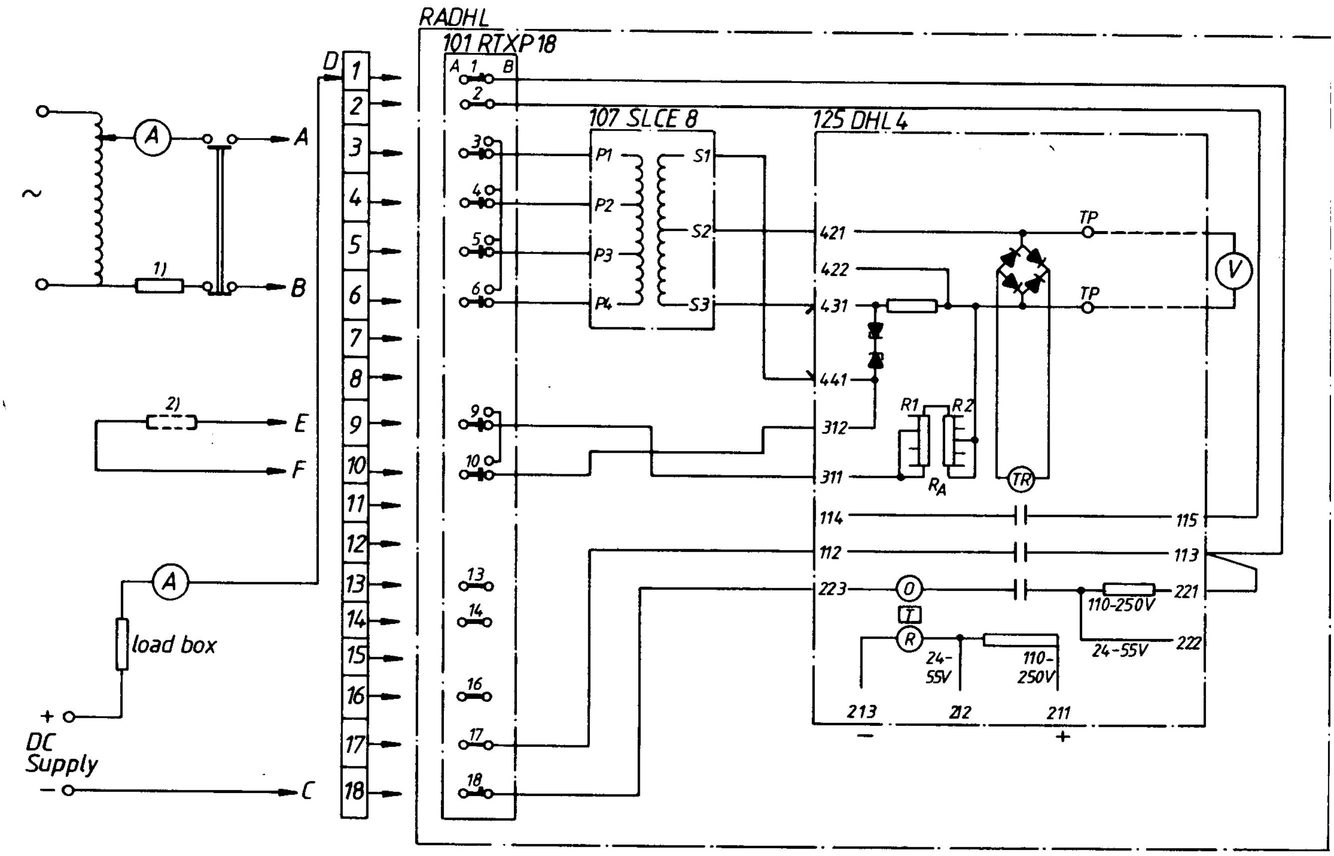


Fig. 21. Acceptance test set up for DHL relay.

Note 1) Current limiting resistor to minimize dissipation in voltage limiting diodes across S, and S3.

Note 2) Set value equal to one-half of pilot-wire equivalent resistance.

Table 3

Relay test values when isolated from pilot wires.

Test current connection A-B	Relay pickup Amperes On 1 A base	(± 10 %) On 5 A base	Voltages *) across rectifier TP's or 125: 421-422	Voltages *) across summation CT full secondary 125: 421-422
3-6 (R-Ground)	0.125	0.625 A	10 V	34 V
4-6 (S-Ground)	0.15	0.75 A	10 V	34 V
5-6 (T-Ground)	0.20	1.0 A	10 V	34 V
3-4 (R-S)	0.625	3.12 A	10 V	34 V
4-5 (S-T)	0.625	3.12 A	10 V	34 V
5-3 (T-R)	0.3125	1.6 A	10 V	34 V

(R-S-T) three-phase test. Generally not feasible, or necessary.
*) These values may be high or low by 15 %.

The relay operating time may be checked in a conventional manner. However, if currents above twice pickup are applied, the voltage limiting diodes will start to clip. To avoid damage, do not keep such currents on longer than necessary. It is also desirable to test the relay with a relatively high impedance current source so as to reduce the work of the voltage limiting diodes at the higher currents.

Note: This test is a measure of the sensitivity of the measuring relay and is not an indication of the overall effective balance of the system, which is entirely a matter of adjustment of R_A

The stability of the relay to en external fault can be simulated as follows. Short-circuit the pilot wire output terminals by connecting a jumper between test positions 9-10 on the test-plug handle. Temporarily increase RA to the maximum 500 ohms of (R I + R2). ac test current while observing no operation of the relay and no significant voltage across test points TP. Reset R I + R2 to the calculated value. Add a resistor in series with the short-circuiting jumper equal to the equivalent pilot wire resistance i.e.:

(500 - RA) ohms

Reapply test current and observe that relay is stable and the voltage reading across the test points TP agree with initial reading

After any high current test the regulating diodes should be checked. Connect an oscilloscope and a voltmeter across the summation CT secondary, terminals 43 1, 441 on the rear of the DHL 4 relay module. Apply an ac test current through a high resistance and increase it until clipping is just apparent. This should occur at 50 V rms, 150 V peak-to-peak on the oscilloscope. DC may also be used to confirm the status of these regula ting diodes, but only after completely isolating from all other components.

The pilot wire supervisory equipment should be connected to the proper source of ac voltage. It should develop 12 V, plus and minus respectively across terminals 301:223 to 301:224 and 301:224 to 301:225. To confirm the overall operation of this equipment, disconnect the pilot wires and connect an external 20 kohm potentiometer to the 30,uF bypass capacitor terminals 125:1 and 125:2. See Figure 19 for connections and Figure 20 for the involved principles.

Adjust the slide wire resistor circuit in module 125 to approximately 6 kohms. This setting can be done with an ohmmeter connected to the terminals 125:2 and 125:3. Connect a dc voltmeter with high internal resistance (> 10000 ohms/volt, preferably a digital) across the polar sensing relay RXCLA 2 terminals 101:221 (+) and 101:111 (-). Adjust the 20 kohm external potentiometer so the voltmeter reading is zero. The CLA 2 relay should be in neutral position.

Reduce the resistance of the external potentiometer until the CLA 2 switches, the pilot-wire short-circuit alarm relay should operate. Restore the external potentiometer value to where the polar sensing relay CLA 2 returns to neutral. Disconnect the external potentiometer and leave the pilot wire circuit open. The CLA 2 relay should switch and the open pilot-wire alarm relay should operate.

At the far end confirm the value of the 30 ~F capacitor and 4000 ohms resistor and the correct polarity of the diode.

Functional in-service checkout

Measure the pilot wire resistance as described above under Setting Determinations and set the resistance, R_A, accordingly to the nearest available value:

$$R_A = ½ (1000 - R_{PW})$$

Available resistance values are given in Figure 22 together with terminal connections.

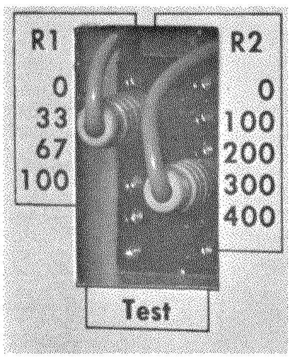


Fig. 22. Details of adjustable padding resistor on front of relay unit RXDHL 4.

Note 1) Test terminals are not resistor test points.

To confirm that the pilot wire capacitance is not excessive it is necessary to recheck the pickup value of the relay with the pilot wire in service, but with the circuit out of service. At both ends, the relays should be normal (test handle removed). At the near end inject test current into each phase of the CT secondaries between the test switch terminals 6 and in turn 3, 4 and 5 on the test switch. The relays should operate at each end with the same input current ± 10 % according to the Operating Specifications, page 25, for an R, S and T to ground single end fed fault. The precise values will depend on the pilot wire capacitance.

Ratio checking of the current transformers and their proper phasing is conventional, as are the circuit breaker trips and lockout checks. In service load checks are facilitated by using the red trip-block plug RTXB at both terminals to prevent inadvertent trip-outs.

Load checks are made to confirm the proper phasing and polarities of the various transformers. With load on the circuit measure the voltage across the TP's for the sensing relay, (or across terminals 125:42-422 according to Figure 9 or at position 5 if external voltmeter and switch is used). It should be less than 2 V with full load on the circuit. If it approaches 10 V, reversed pilot wires are a likely cause, or incorrect CT polarities at one terminal. Either cause can be corrected by reversing either the pilot wires or the CT's.

If the voltage is between 2 V and 10 V, incorrect phasing of one or more of the CT's is likely. A reversed polarity of one CT can be spotted by measuring the voltages across the secondaries of the two summation CT's. They should be equal and with a magnitude of about 4 volts per ampere load current (5 A base). If one is significantly more than this, one or two reversed CT's at that terminal should be suspected.

If these two summation voltages are about equal and moderately excessive voltage exists across the sensing relay, a roll in the phases at one end is most likely.

If none of the above resolve the problem, an incorrectly set padding resistor or a faulty pilot channel is likely.
A faulty pilot channel could include:

1 High resistance connection not identified when the resistance was measured

2 Low leakage resistance

3 Excessive capacitance

4 Voltage induced into pilot wire

5 »Hot» cross of pilot wire from a low voltage circuit.

If pilot wire isolating transformers are used, confirm that they are not wired in backwards and that all windings are properly connected. Confirm their ratio by application of no more than 120 V to the higher voltage winding. Exciting current should not exceed 10 mA at this voltage. Knee point voltage should be about 400 V on the relay side.

If supervisory equipment is used, temporarily disconnect it to remove that possible source of malfunction.

Supervisory functional in-service checkout

With both terminals normal, pilot wires in place, and test switch handles removed, confirm that the CLA 2 polar relay is in mid position and no alarms are on. If not, adjust the slide wire resistor in unit 125 until a dc voltmeter connected across RXCLA terminals 101:221 (+) and 101:111 shows zero reading. Use a digital voltmeter internal resistance > 10000 ohms/volt. Open the pilot wire and confirm that an open alarm is received. Short circuit the pilot wires (at the far end for most severe test) and confirm that a short circuit pilot alarm is received.

Routine testing

Under normal conditions type DHL needs no special testing or maintenance. The covers of the plug-in modules should be fitted properly. Contacts in the output tripping relay or in the test switch which are burnt due to abuse should be carefully dressed with a diamond file or a very fine file. Emery cloth or similar abrasive materials are unsuitable for dressing relay contacts, as insulating grains from the abrasive material may be deposited on the contact surfaces, thereby causing malfunction and failures.

Routine electrical tests can conform in frequency to the user's established practice. Checking the pickup setting of the relays individually at each terminal and timing them at a moderate multiple of pickup is usually adequate. This time should be about 20-30 ms.

The condition of the pilot wires and all other components in the communication channel can be checked for over-all performance by injecting current into the summation CT primary at one end and observing that the relays operate at both ends at comparable values and within a few percent of the values determined on the start-up testing. The condition of the pilot wire proper should also be confirmed with megger readings periodically. The resistance of the pilot wires can be confirmed from correlations of the routine readings of the residual voltage across the sensing relay, TP points on face of relay or terminals 125:421-422, and the circuit loading. Any change in pilot-wire resistance will result in an increased reading from a given load condition.

Spare parts

There are no requirements for stocking spare parts. It is normally more economical to replace a complete plug-in module if defective. This procedure also assures that a replaced component is up to the original factory quality and calibration standards.

Receiving, Handling and Storage

These relays are shipped in cartons designed to protect them from damage when not included as part of a cubicle or control panel. Upon receipt the relay should be inspected for physical damage.

It is recommended that the relay be replaced in its shipping carton after inspection for delivery to jobsite. Also the relay should preferably be left in its shipping carton until time for actual installation.

The relay is not critical as to humidity. But general prudence suggests that it be stored in a dry, moderate temperature environment.

Dimensions

(The dimensions for type DHL and Pilot-wire-supervision equipment are given in the Ordering Information in 61-10 SI).

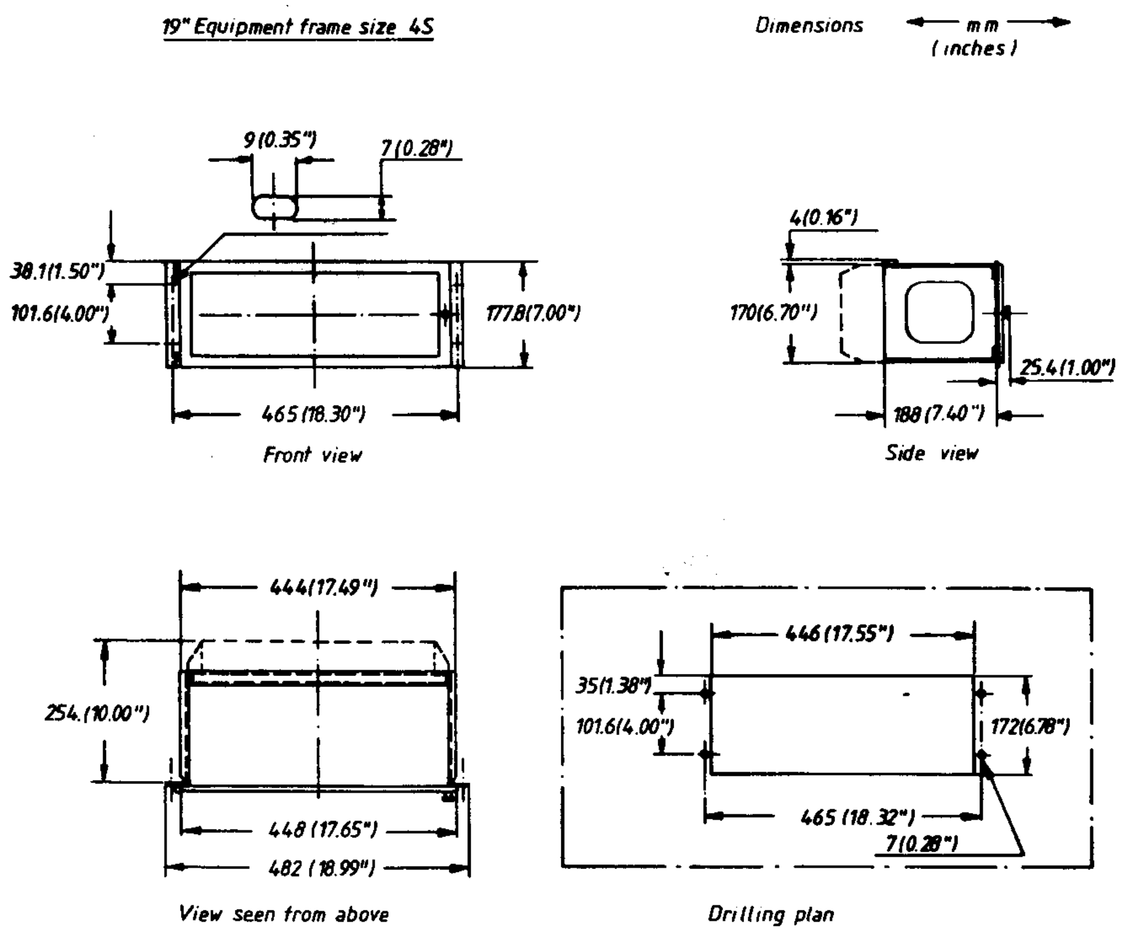


Fig. 23. Physical dimensions of 4S 60C equipment, panel drilling and cutout.

Doc. no. 61-10AG
Rev. ind.
Date April 1978

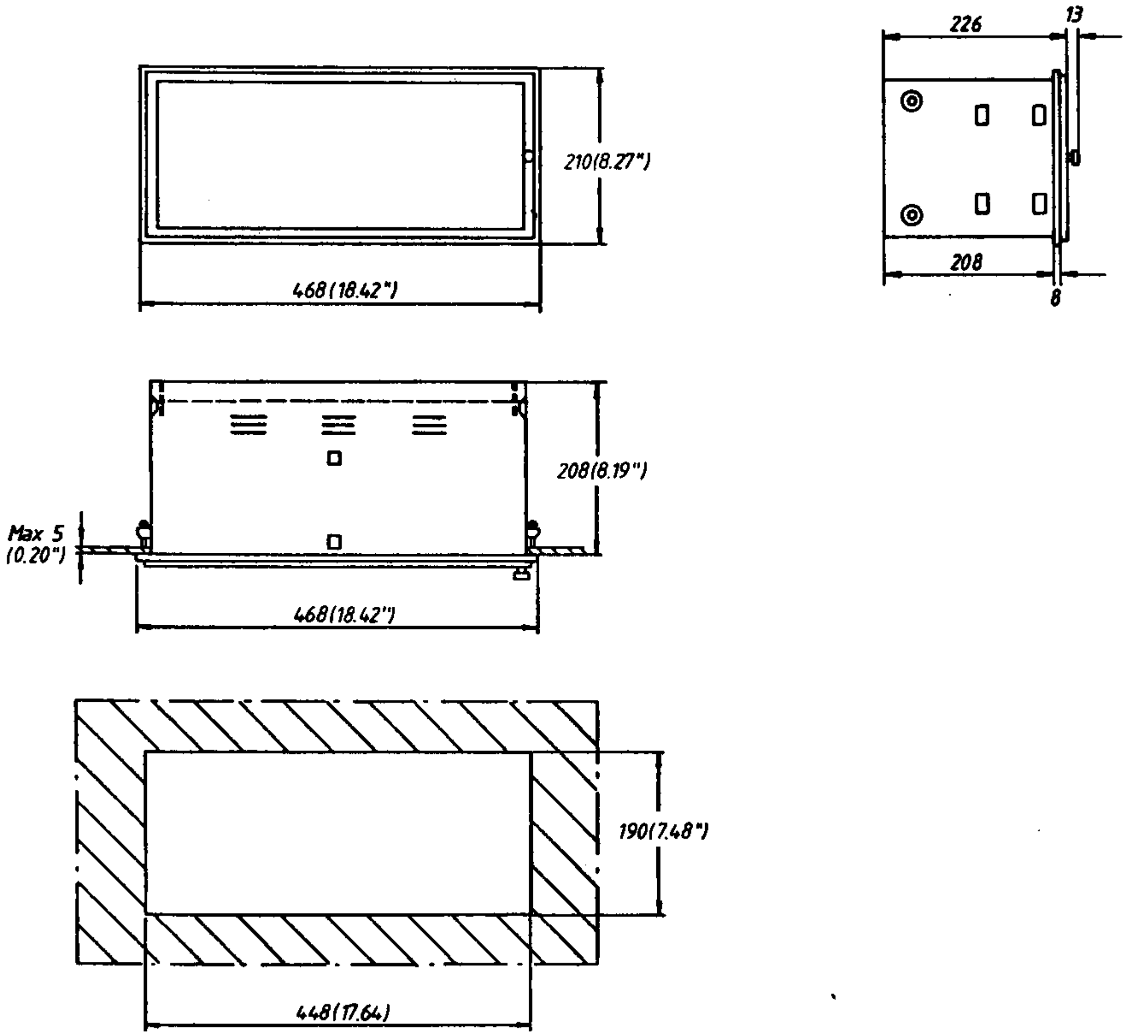


Fig. 24. Physical dimensions of relay case type RHGX 12 and cutout.

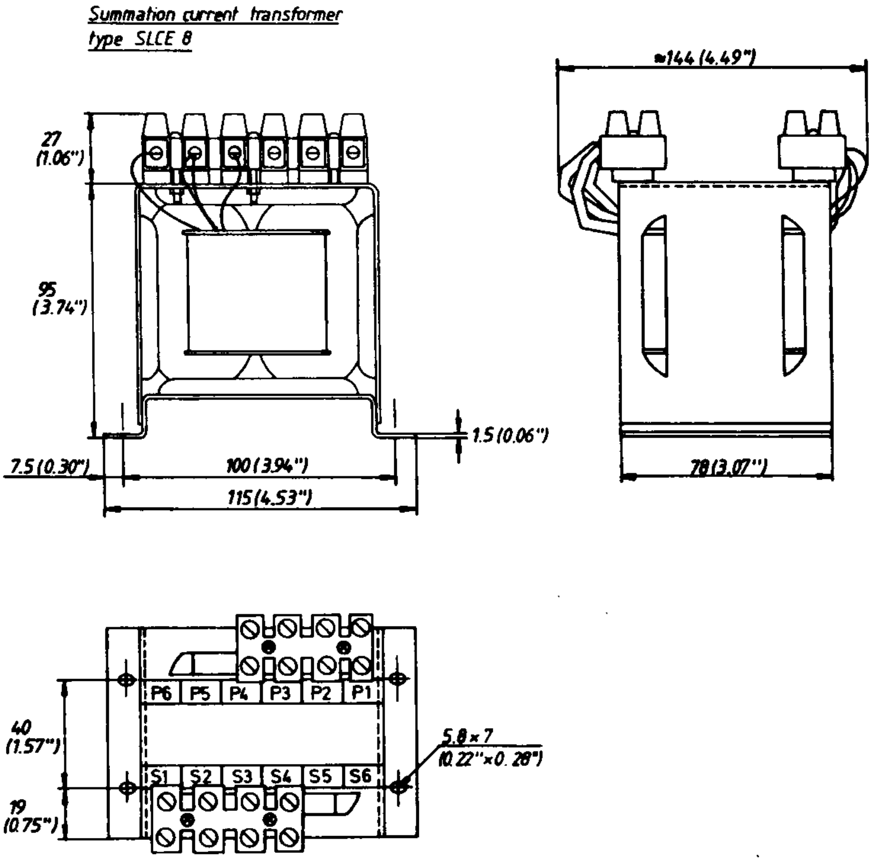


Fig. 25. Dimensions of summation CT type SLCE 8.