ALSTOM

CDG

AC Series Tripping Relays

Application Notes R5884P

ALSTOM T&D Protection & Control Ltd St Leonards Works, Stafford ST17 4LX, England
Tel: +44 (0) 1785 223251 Fax: +44 (0) 1785 212232

SAFETY SECTION

This Safety Section should be read before commencing any work on the equipment.

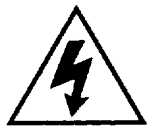
Health and safety

The information in the Safety Section of the product documentation is intended to ensure that products are properly installed and handled in order to maintain them in a safe condition. It is assumed that everyone who will be associated with the equipment will be familiar with the contents of the Safety Section.

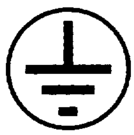
Explanation of symbols and labels

The meaning of symbols and labels which may be used on the equipment or in the product documentation, is given below.

Caution: refer to appropriate product documentation



Caution: risk of electric shock



Protective/safety *earth terminal

Functional *earth terminal, note: this symbol may also be used for a protective/safety earth terminal if that terminal is part of a terminal block or sub-assembly eg. power supply.

*Note: The term earth used throughout product documentation is the direct equivalent of the North American term ground.

Installing, Commissioning and Servicing

Equipment connections

Personnel undertaking installation, commissioning or servicing work on this equipment should be aware of the correct working procedures to ensure safety. The product documentation should be consulted before installing, commissioning or servicing the equipment.

Terminals exposed during installation, commissioning and maintenance may present a hazardous voltage unless the equipment is electrically isolated.

If there is unlocked access to the rear of the equipment, care should be taken by all personnel to avoid electric shock or energy hazards.

Voltage and current connections should be made using insulated crimp terminations to ensure that terminal block insulation requirements are maintained for safety. To ensure that wires are correctly terminated, the correct crimp terminal and tool for the wire size should be used.

Technical Specifications

Protective fuse rating

The recommended maximum rating of the external protective fuse for this equipment is 16A, GEC Red Spot type or equivalent, unless otherwise stated in the technical data section of the product documentation or application notes.

Insulation class:	IEC 1010-1: 1990/A2: 1995 Class I EN 61010-1: 1993/A2: 1995 Class I	This equipment requires a protective (safety) earth connection to ensure user safety.
Installation Category (Overvoltage):	IEC 1010-1: 1990/A2: 1995 Category III EN 61010-1: 1993/A2: 1995 Category III	Distribution level, fixed installation. Equipment in this category is qualification tested at 5kV peak, 1.2/50μs, 500Ω, 0.5J, between all supply circuits and earth and also between independent circuits.
Environment:	IEC 1010-1: 1990/A2: 1995 Pollution degree 2 EN 61010-1: 1993/A2: 1995 Pollution degree 2	Compliance is demonstrated by reference to generic safety standards.
Product safety:	73/23/EEC	Compliance with the European Commission Low Voltage Directive.
CE	EN 61010-1: 1993/A2: 1995 EN 60950: 1992/A3: 1995	Compliance is demonstrated by reference to generic safety standards.

Older Products

Electrical adjustments

Equipments which require direct physical adjustments to their operating mechanism to change current or voltage settings, should have the electrical power removed before making the change, to avoid any risk of electric shock.

Mechanical adjustments

The electrical power to the relay contacts should be removed before checking any mechanical settings, to avoid any risk of electric shock.

Draw out case relays

Removal of the cover on equipment incorporating electromechanical operating elements, may expose hazardous live parts such as relay contacts.

Insertion and withdrawal of extender cards

When using an extender card, this should not be inserted or withdrawn from the equipment whilst it is energised. This is to avoid possible shock or damage hazards. Hazardous Live voltages may be accessible on the extender card.

Insertion and withdrawal of heavy current test plugs

When using a heavy current test plug, CT shorting links must be in place before insertion or removal, to avoid potentially lethal voltages.

Decommissioning and Disposal

Decommissioning: The auxiliary supply circuit in the relay may include capacitors across the supply or to earth. To avoid electric shock or energy hazards, after completely isolating the supplies to the relay (both poles of any dc supply), the capacitors should be safely discharged via the external terminals prior to decommissioning.

Disposal: It is recommended that incineration and disposal to water courses is avoided. The product should be disposed of in a safe manner. Any products containing batteries should have them removed before disposal, taking precautions to avoid short circuits. Particular regulations within the country of operation, may apply to the disposal of lithium batteries.

Before energising the equipment it must be earthed using the protective earth terminal, or the appropriate termination of the supply plug in the case of plug connected equipment. Omitting or disconnecting the equipment earth may cause a safety hazard.

The recommended minimum earth wire size is 2.5 mm^2, unless otherwise stated in the Technical Data section of the Product documentation.

Before energising the equipment, the following should be checked:

Voltage rating and polarity;

CT circuit rating and integrity of connections;

Protective fuse rating;

Integrity of earth connection (*where applicable*).

Equipment operating conditions

The equipment should be operated within the specified electrical and environmental limits.

Current transformer circuits

Do not open the secondary circuit of a live CT since the high voltage produced may be lethal to personnel and could damage insulation.

External resistors

Where external resistors are fitted to relays, these may present a risk of electric shock or burns, if touched.

Battery replacement

Where internal batteries are fitted they should be replaced with the recommended type and be installed with the correct polarity, to avoid possible damage to the equipment.

Insulation and dielectric strength testing

Insulation testing may leave capacitors charged up to a hazardous voltage. At the end of each part of the test, the voltage should be gradually reduced to zero, to discharge capacitors, before the test leads are disconnected.

Insertion of modules and pcb cards

These must not be inserted into or withdrawn from equipment whilst it is energised, since this may result in damage.

Fibre optic communication

Where fibre optic communication devices are fitted, these should not be viewed directly. Optical power meters should be used to determine the operation or signal level of the device.

APPLICATION NOTES ON THE TYPE CDG RELAYS FOR AC SERIES TRIPPING

1. INTRODUCTION

Series tripping of circuit breaker is used where there is no reliable auxiliary supply available to operate the shunt trip coils. In the series tripping arrangement, the trip coil, which is current operated, is connected in the current transformer secondary circuit. The trip coil is normally shunted by the normally closed contact of the relay, which opens out on operation, thus diverting the current through the trip coil.

2. TRIP COILS:

Since both the trip coil and the relay operate from the CT secondary current, a separate trip coil is required for each pole of the relay. Thus, two overcurrent and one earthfault relay arrangement requires two trip coils on the phases associated with the overcurrent relays and a trip coil in the residual circuit.

It is also necessary that the pick-up current of the trip coil is equal to or less than the minimum setting available on the relay to ensure that all the tap settings on the relay can be effectively used. When earthfault protection is used, it may not be possible to have a trip coil with a pick-up current less than the minimum setting available on the relay and in such cases, it has to be ensured that the earthfault relay is set at a value equal to or more than the pick-up level of the trip coil.

For applying a series trip relay, it is necessary that the typical impedances at 'plunger up' and 'plunger down' positions are known.

'Plunger down' is the reset position and on receipt of the trip signal, the plunger rises and operates a mechanical latch which trips the breaker and then the plunger resets.

As the plunger rises during operation, the air gap in the circuit decreases and so the impedance increases. The 'plunger up' value of the impedance is, therefore, greater than the 'plunger down' value. The ratio can be as high as 6 to 1.

3. SERIES TRIP RELAY:

The relay, for series tripping applications, is specially designed with normally closed hand reset contacts provided on a built-in auxiliary unit. An interposing current transformer is provided within the relay and the auxiliary unit connected to its secondary gets energised when the disc contact closes. The application diagram (Fig 1) shows the typical internal schematic arrangement of the relay.

The CDG relay, for series tripping applications, is available with standard inverse (CDG11/31), very inverse (CDG13/33) or extremely inverse (CDG14/34) characteristics. Instantaneous units type CAG13/CAG17 can also be provided with the above relays.

The impedance of the operating coils of the inverse relays are given in Figures 2 to 10. The internal current transformer impedance is furnished in Table 1. The total relay impedance is the sum of (i) operating coil impedance and (ii) the internal current transformer impedance. The ohmic burden of the instantaneous units at high values of currents is very low and hence, can be ignored when calculating the CT requirements.

4. GENERAL APPLICATION CONSIDERATIONS:

The following points are to be considered when applying series trip relay type CDG.

4.1 In application of the CDG series trip relay, the contact rating of the relay is the main consideration since the contacts cannot handle currents in excess of 150A and likewise the trip coil voltage which appears across the open contact must be limited to 150V. The figures of 150A and 150V are absolute maxima and are not to be exceeded.

4.1.1 With 5A current transformers, the maximum voltage produced by the CT very rarely exceeds 150V and only the current limitation is important.

4.1.2 For 1A current transformers, the current limitation of 150 times secondary rating is not realistic and so, only the voltage limitation has to be considered for the application.

4.2 Series Resistor:

A series resistor is recommended to limit the current to 150A in cases, where the maximum current in the CT circuit exceeds 150A during fault conditions. When 5A CTs are used, the value of the current in the secondary circuit depends on the maximum voltage produced by the CT and the CT connected burden and a figure of more than 150A can be easily achieved.

For calculating the value of resistance, only the burden of the secondary circuit prior to relay operation is considered i.e. CT secondary, lead and the relay burdens.

When the maximum voltage from the CT exceeds 150V, the value of series resistor has to be calculated such that the current in the circuit would limit the contact recovery voltage to 150V. The contact recovery voltage is the product of the current through the relay contact prior to relay operation and the trip coil impedance at plunger down position.

4.3 With the resistance in the secondary circuit, the adequacy of the current transformer is checked for a current of 20 times the setting current to flow through the connected burden. If instantaneous units are used, the maximum setting of the instantaneous unit can be considered, instead of 20 times the IDMT maximum setting.

For the above calculation, the IDMT setting in use can be considered, but, if this is unknown, the maximum IDMT setting has to be considered so that the complete setting range can be effectively used.

If the current transformer knee point voltage is adequate to meet the above requirements, the relay will operate satisfactorily with the series resistance in the circuit and no saturating choke will be required.

4.4 Saturating Choke:

4.4.1 A saturation choke is required for the application when the introduction of series resistor saturates the current transformer for fault currents below the values of 20 times the setting (or maximum setting of the instantaneous when used), thus, introducing timing errors in the relay.

4.4.2 The purpose of the choke is that at low currents, it has a high impedance and, therefore, does not affect the circuit whilst at high currents, it saturates providing a low impedance path for the current to the CDG relay. This allows sinusoidal current to flow to a higher multiple of plug setting than before and helps maintaining the accuracy of the relay. It has to be noted that the choke has nothing to do with the contact limitation which is overcome by the addition of the resistance.

4.4.3 The requirements to be met by the choke are:

(i) at the minimum IDMT Setting, which is the lowest current to cause tripping, the choke impedance must be high enough to allow the rated tripping current to flow in the trip coil i.e when the trip contacts open, the choke must not short out the resistor and the trip coil.

(ii) the choke impedance at high currents, ie its saturated value should be low enough to allow sinusoidal current of up to 20 x maximum tap settings to flow (up to 200A for 5A relay).

4.4.4 (i) Generally, a saturating choke is required whenever the maximum voltage obtainable from the CT exceeds 150V. This is so because in such cases the current in the circuit is limited to less than 150A and for CT to circulate 20 times the IDMT setting through the relay without getting saturated, a choke across the resistor and contact is required.

(ii) If the maximum voltage obtainable from the CT marginally exceeds 150V, the contact recovery voltage may not exceed 150V, since it will be a fraction of the CT voltage in the ratio of $\frac{Z_{TC}}{Z_{TC} + R + R_1}$ where R = series resistor in ohms (limiting current to 150A), R_1 burden in ohms of CT secondary, lead and relay. Thus, a contact breaking voltage of less than 150V can be achieved, even if the maximum voltage obtainable from the CT is more than 150V. In such cases, if the use of series resistor does not introduce any timing errors in the relay up to 20 times the setting current, a saturating choke will not be required.

(iii) Most CTs use stalloy core and the ratio of maximum voltage to the knee point voltage is about 1.4 : 1 for these CTs. If the setting in use is 5A, the CT will be able to circulate 100A rms current (20 times setting), since, with the maximum current limited to 150A by series resistor, the maximum rms current obtainable would be $\frac{150A}{1.4}$, which is more than 100A. Thus, in such cases, saturating choke will not be required and only for higher IDMT settings, it will be found necessary.

5. TYPICAL APPLICATIONS CHECKS:

5.1 For carrying out a detailed application check and decide the values of the choke and resistance, the following details are required.

(i) the knee point voltage (V_K) and the maximum voltage (Vmax) obtainable from the CT.

(ii) the trip coil rating.

(iii) the trip coil impedance with 'plunger down' and with 'plunger up' at maximum and minimum tripping currents.

(iv) the secondary resistance of the CT and the lead burden.

(v) the protective relay burden.

(vi) the fault level of the primary circuit.

5.2 Since the value of the current in the secondary circuit must be limited to 150A,

$$R = \frac{Vmax}{150} - (R_{CT} + R_{RELAY} + R_{LEADS}) \qquad \ldots\ldots (1)$$

For a CT wound on Stalloy core, Vmax is approximately equal to 1.4 x the knee point voltage.

This formula is used provided that the Vmax does not exceed 150V. When V_{max} is marginally higher than 150V, the introduction of series resistor as above can limit the contact recovery voltage to 150V as mentioned in 4.4.4 (ii). In such cases, the above formula can be applied.

5.3 If contact recovery voltage is also to be limited to less than 150V, the value of the series resistor is given by

$$R = \frac{Vmax}{\text{current at which 150V is developed across trip coil}} - (R_{CT} + R_{RELAY} + R_{LEADS})$$

$$= \frac{Vmax \times TC\ impedance}{150} - (R_{CT} + R_R + R_L) \qquad \ldots\ldots (2)$$

where the trip coil impedance is the plunger down figure, measured at the maximum trip current.

5.4 With the value of resistor, selected as above, the adequacy of the current transformer has to be checked as below.

$$V_K \geqslant 20 \times I_S (R_{CT} + R_L + R_R + R) \qquad \ldots\ldots (3)$$
$$\geqslant I_{TC} (R_{CT} + R_L + R_R + R + Z_{TC}(\text{Plunger Up})) \qquad \ldots\ldots (4)$$

Where I_S - Maximum Tap Setting or the adopted setting of the relay
I_{TC} - Maximum Current required to operate the trip coil.
Z_{TC} - Plunger Up impedance of trip coil.

5.4.1 If overcurrent and earthfault protection is used connected to the same CTs, and if they are likely to operate simultaneously (when instantaneous units are used), the adequacy of the CT has to be checked for circulating the trip coil current through both overcurrent and earthfault trip coils.

5.4.2 When two overcurrent and one earthfault protection arrangement is used, a resistor is required in the Y phase; value of resistance being the sum of the series resistor value calculated for use with overcurrent relays and the overcurrent relay impedance.

5.4.3 For earthfault relays, which are used with overcurrent relays connected to the same CTs, no series resistor is required in the residual circuit since the phase connected resistor limit the current to less than 150A in the residual circuit also.

5.5 The impedance of the choke, when required, has to satisfy two conditions. (The saturating choke is generally required when resistor is chosen based on 5.3 and V_K of CT does not satisfy 5.4.

5.5.1 At IDMT setting current the trip coil must recieve sufficient current to lift the plunger fully and, therefore, the minimum impedance can be calculated as below

$$Z(\text{unsaturated}) = \frac{(\text{Trip Coil Rating, amps})\ (\text{Trip Coil } Z + R)}{\underset{(\text{min tap})}{(1.2 \times \text{IDMT Setting})} - \underset{(\text{Amps})}{(\text{Trip coil rating})}} \qquad (5)$$

The trip coil impedance in this case is the 'plunger up' impedance at the minimum operating current.

5.5.2 To minimise the timing error in the CDG relay the CT must not saturate at 20 x setting current. Therefore, the choke impedance should be low enough to allow the CT to push the current through the relay with the trip contacts closed, at the knee point voltage of the CT.

The maximum value of choke impedance at 20 x the setting current is given by

$$Z = \frac{R\left(\frac{V_K}{I_M} - K\right)}{R + K - \frac{V_K}{I_M}} \qquad (6)$$

Where R = Series resistor as from equation (1) or (2),
V_K = Kneepoint voltage of the CT
I_M = 20 x CDG setting in use
$K = R_{CT} + R_L + R_{Relay}$

The impedance as given by this formula is often impossible to achieve in practice ie a ratio of Z unsaturated/Z saturated = 200/1 is common. Practical limitations mean that the best attainable ratio is approximately 40-50, so a compromise has to be made and timing errors accepted below 20 x the setting.

It is often possible to avoid the use of the choke by suitably specifying the requirements, i.e. V_K to meet the requirement as given in equation (3) & (4) and Vmax of the CT less than 150V.

6. EXAMPLE

Current transformer

Ratio 200/5

Kneepoint voltage 52V

Vmax = 1.4 V_K = 72.8V

Secondary resistance = 0.102 ohm

Breaker Trip Coil Overcurrent

2 Amps, nominal

Z = 3.125 ohm, plunger up at 2A

Z = 1.5 ohm, plunger down and saturated.

Earthfault

1 Amp, nominal

Z = 15 ohms, plunger up at minimum current

Z = 7 ohm, plunger down and saturated.

Lead Resistance : 0.01 ohms

Relays

Overcurrent CDG11 - 1VA - 50-200% of 5A

Earthfault CDG11 - 1VA - 20-80% of 5A

6.1 Phase Fault

6.1.1 There is no problem with contact secondary voltage since Vmax 150 volts.

6.1.2 Required series resistor is given by

$$R = \frac{V_{max}}{150} - (R_{CT} + R_L + R_R)$$

$$= \frac{72.8}{150} - (0.102 + 0.01 + 0.028)$$ (Relay impedance at 20 times maximum setting = 0.028 ohm)

$$= 0.35 \text{ ohm}$$

6.1.3 The minimum kneepoint voltage of CT

$V_K = 20 \times I_S (R_{CT} + R_L + R_{relay} + R)$

For a maximum setting of 10A

$20 \times 10\ (0.49) = \underline{98V}$

If the overcurrent setting in use, is only 5A,

$V_K = 20 \times 5\ (0.49) = 49V$

For satisfactory operation of trip coil,

$V_K = 2\ (R_{CT} + R_L + R_{relay}$ at $2A + R + Z_{TC})$ where R_{relay} - Relay impedance at 2A = 0.066

$= 2\ (3.653)$

$= \underline{7.4V}$

Z_{TC} = Plunger up impedance of trip unit

The selected CT will work satisfactorily for settings upto 5A.

If setting more than 5A is used, CT will saturate at currents less than 20 times settings and hence, a saturating choke will be required.

6.1.4 To effectively use the complete setting range of the relay, a choke is required and the value is found out as below.

$$Z\text{Choke (min) (Unsaturated)} = \frac{(\text{Trip Coil Rating})\ (Z_{TC} + R)}{1.2 \times \text{CDG min setting} - \text{Trip Coil Rating}}$$

$$= \frac{2\ (3.125 + 0.35)}{1.2 \times 2.5 - 2} = 6.95\text{ohm}$$

The impedance of standard choke is 18 ohm at 1 Amp. Therefore, if the CT is delivering 3 Amps, more than 2 Amps will flow in the trip coil and the standard choke is satisfactory.

6.1.5 The maximum value of choke impedance at 20 times the relay setting current.

$$ZC = \frac{R\left(\frac{V_K}{I_M} - K\right)}{R + K - \frac{V_K}{I_M}}$$

Where I_M = 20 x setting 200A if setting 200% used.

$$= \frac{0.35\ \left[\frac{52}{200} - 0.14\right]}{0.35 + 0.14 - \frac{52}{200}}$$

$K = R_{CT} + R_L + R_{relay}$

$\underline{= 0.18 \text{ ohm}}$

The current, through the choke

$$= \frac{V_K - 200 \times K}{0.18} = 133.4A$$

The Saturated impedance of the standard choke is given by

$$= \frac{2.4}{I_{CH}} + 0.015$$

$$= \frac{24}{133.4} + 0.015 = 0.195 \text{ ohm}$$

6.1.6 Padding Resistor for yellow phase = Equivalent impedance in R or B phase.

<u>When both choke and resistor used</u>

$$= \frac{V_K}{\text{Max. Relay Current}} - (R_{CT} + R_L)$$

$$= \frac{52}{200} - (0.102 + 0.01)$$

$$= 0.148 \text{ ohm}$$

<u>When resistor only used</u>

$$= \frac{V_{max}}{150} - (R_{CT} + R_L)$$

$$= \frac{72.8}{150} - (0.102 + 0.01)$$

$$= 0.373 \text{ ohms}$$

6.2 <u>Earthfaults:</u>

6.2.1 Series resistor is not required with the earthfault relay, when only series resistor is used with the overcurrent relay.

6.2.2 When combination of choke and resistor are used with the overcurrent relay, a resistor may be required in the earchfault circuit and the value is given by

$$= \frac{V_{max}}{150} - (R_{CT} + 2R_L + R_{relay}\ o/c) + R_{relay}\ E/F + R_2)$$

where R_2 = Equivalent impedance of series resistor and choke (at max, current) in parallel.

$$= \frac{72.8}{150} - (0.102 + 0.02 + 0.028 + 0.163 + 0.119)$$

$$= 0.485 - 0.432$$

$$= \underline{0.053}$$

$$= 0.06 \text{ ohm (approx)}$$

6.2.3 Maximum sinusoidal current through the relay

$$= \frac{VK}{0.432 + 0.06} = 105A$$

Since this value is more than 20 times the maximum setting of earthfault relay (20 x 4 = 80A), a saturating choke is not required.

Table 1

	VA Burden at 20 times tap current						
Tap No.	1	2	3	4	5	6	7
Standard	55	94	140	190	255	370	440
Preferred	55	70	94	140	180	255	440

Note: The standard coil has seven equally spaced current taps.
The preferred coil has seven unequally spaced current taps.

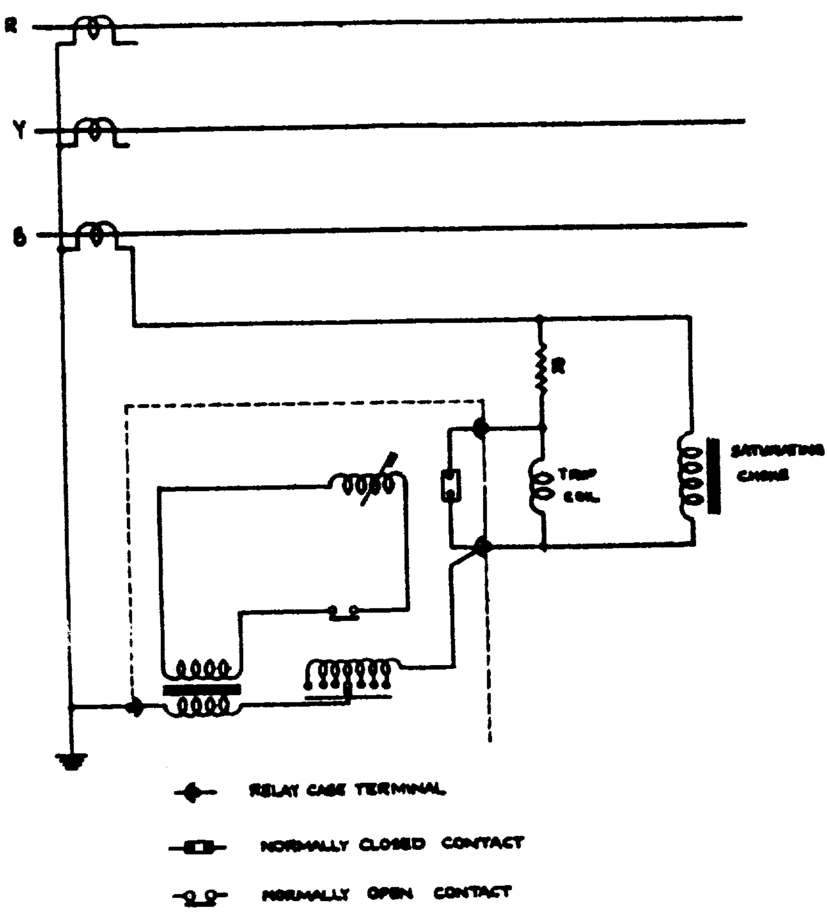
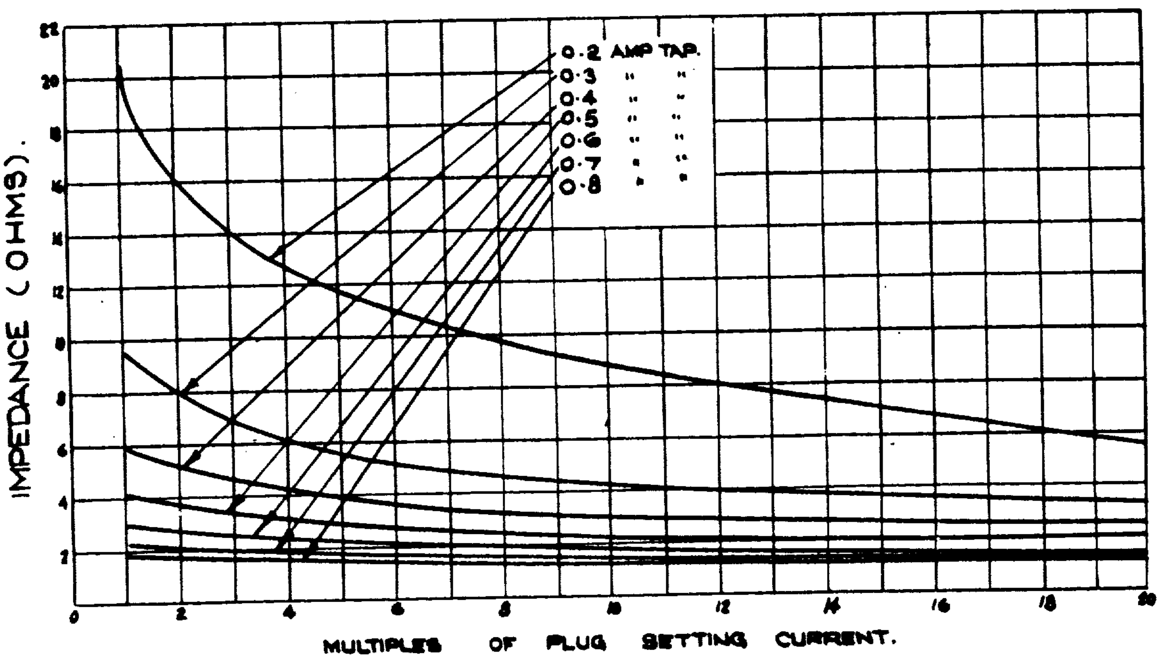


FIG I CDG RELAY FOR AC. SERIES TRIPPING

B.2:12:63 S77308Z06·040



IMPEDANCE / CURRENT CURVES FOR TYPE CDG11 RELAYS

FIG 2. 0·2 - 0·8 AMP 1VA 50 CYCLE MULTI-STRAND COIL.

A. 30:5:62. S77308Z06·024

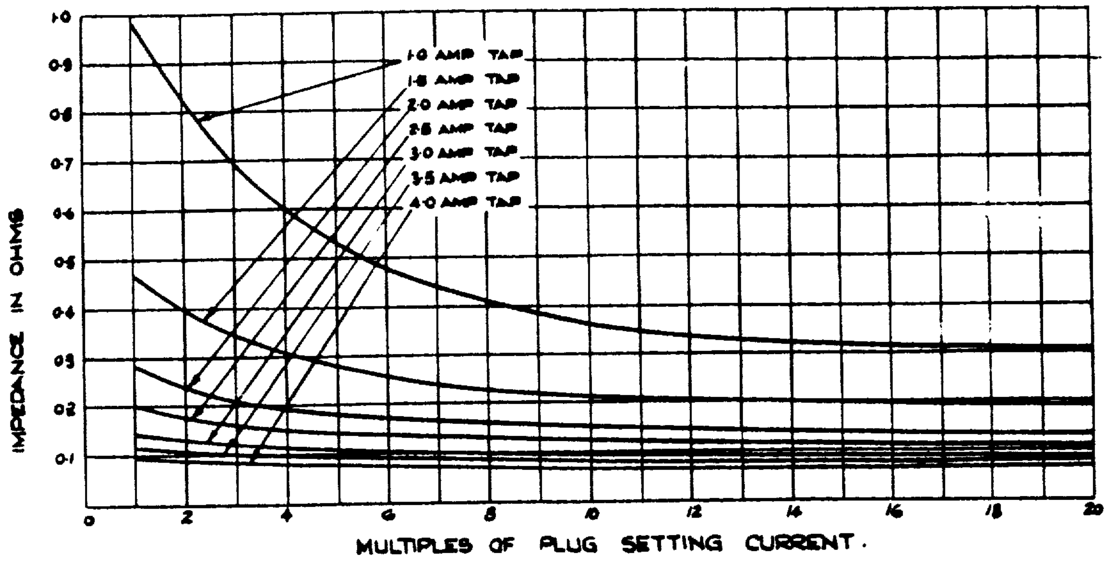


FIG 3. STANDARD INVERSE (STANDARD TAPS)
TYPE CDG11 IVA 50 CYCLES.

A.30:5:62

877308Z06.026.

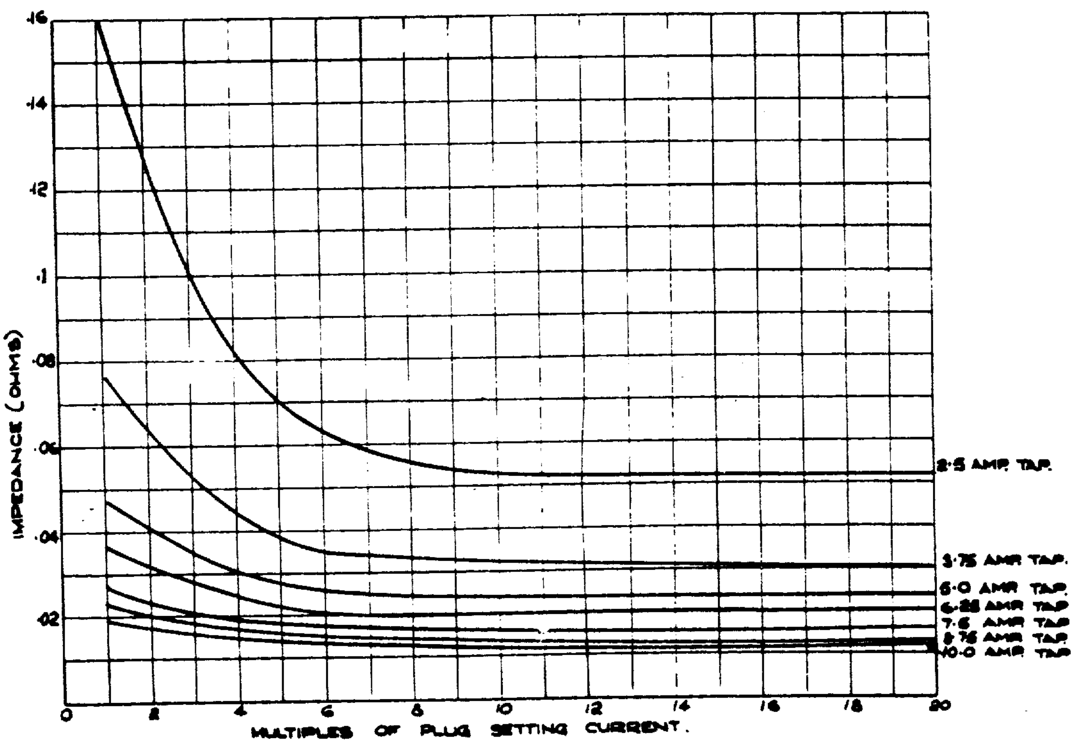
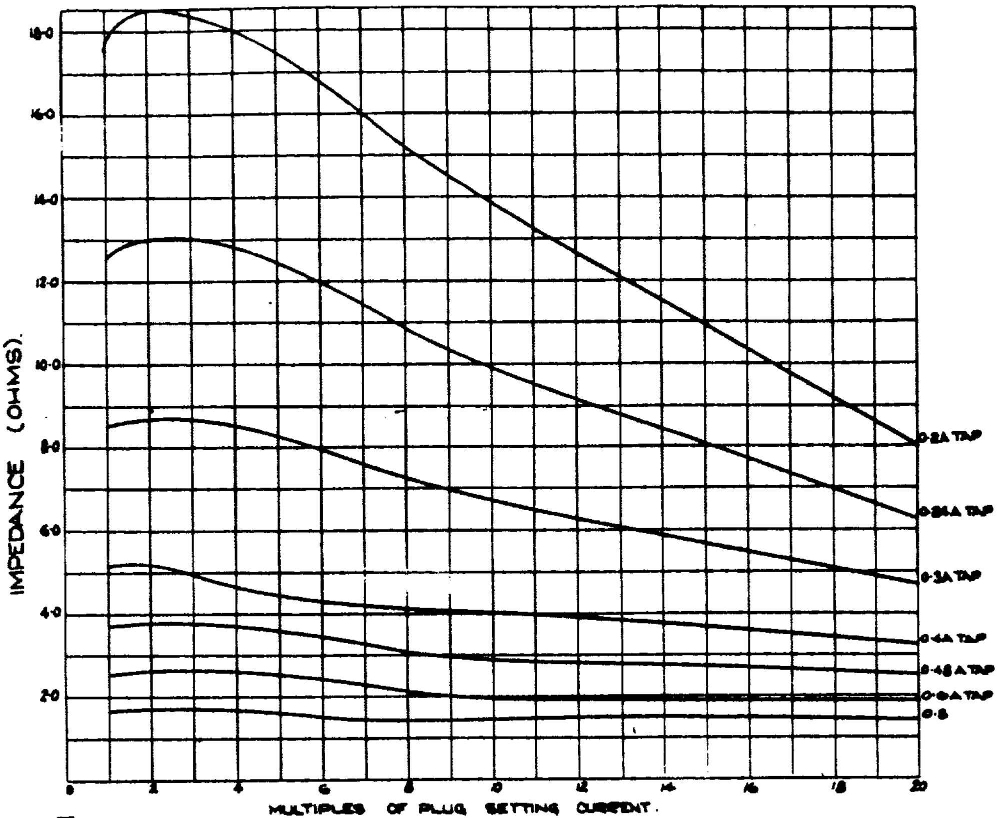


FIG. 4. IMPEDANCE / CURRENT CURVES FOR TYPE CDG11 RELAYS.
2·5-10 AMP. IVA 50 CYCLE MULTI-STRAND COIL.

S.S: 3:62.

877393Z163.



A.30:5:62 **FIG 5.** CDG13 (0·2 - 0·8A) IVA VERY INVERSE 50 CPS. 877398Z06,025

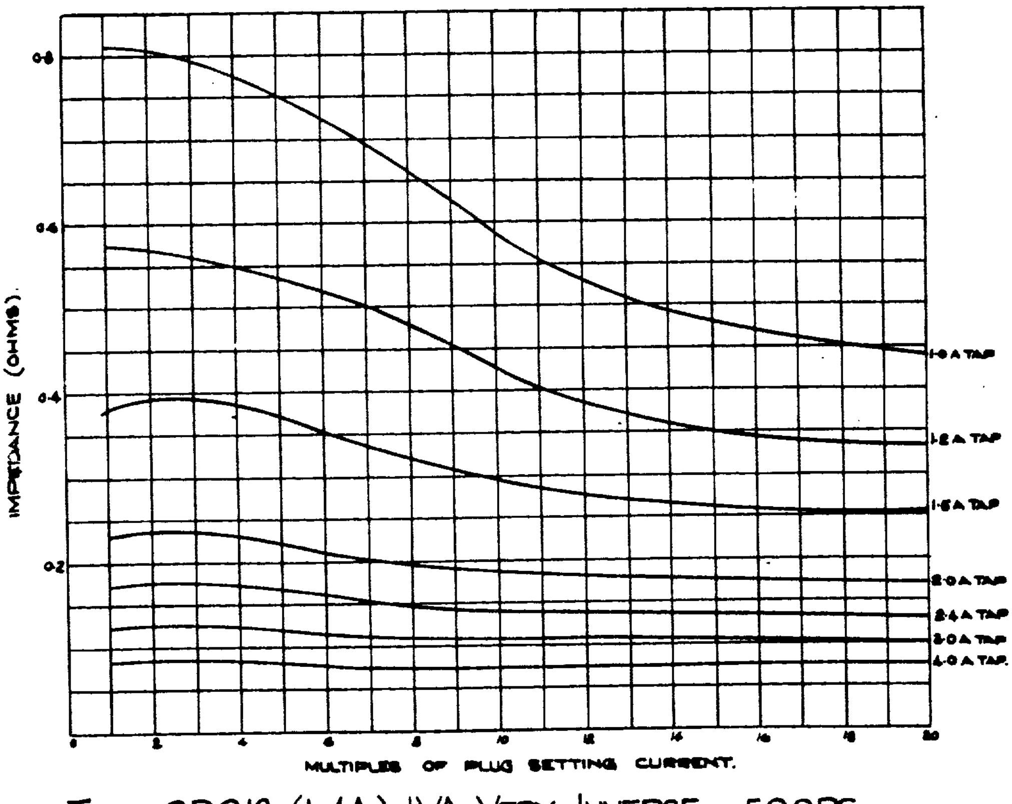
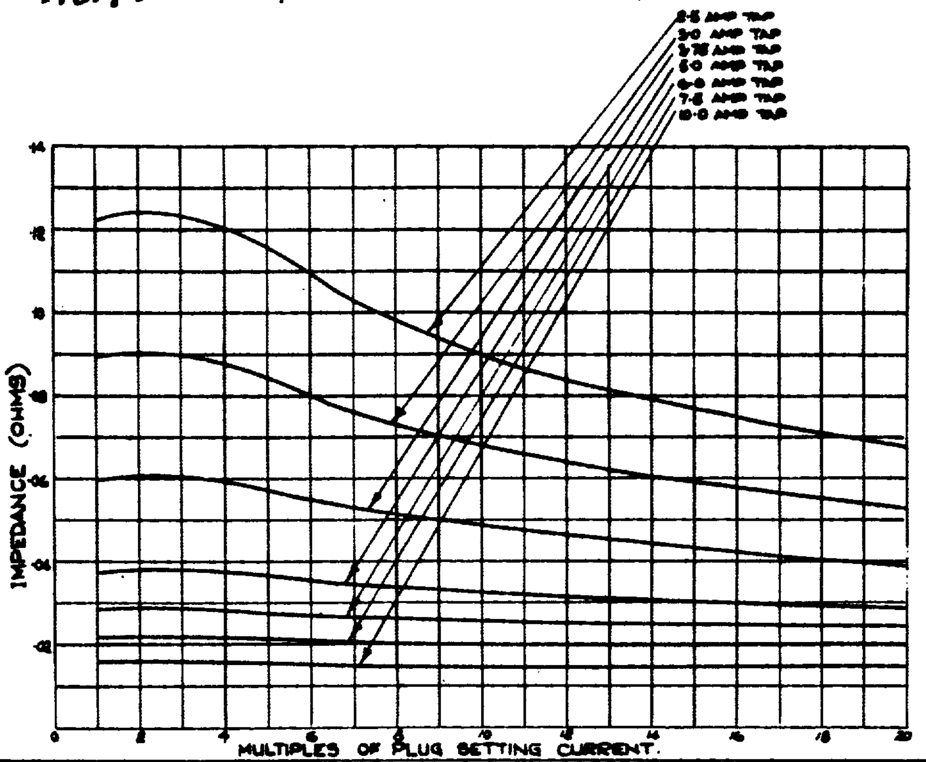


FIG 6. CDG13 (1-4A) IVA VERY INVERSE 50CPS.

A.30:5:62. 877398Z06,027

FIG 7. IMPEDANCE/CURRENT CURVES FOR TYPE CDG 13 RELAY. 50 CRS.



A. 23: 6:60 S7739BZ06.01

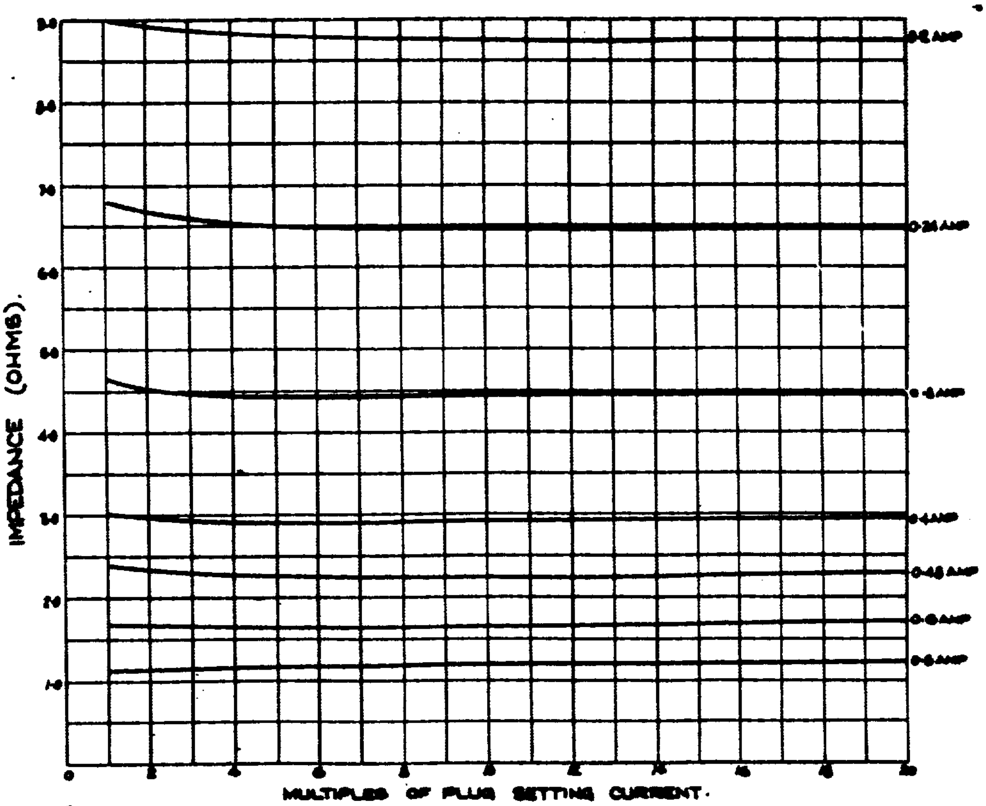


FIG 8. CDG14 (·2-·8) IVA EXTREMELY INVERSE 50 CRS.

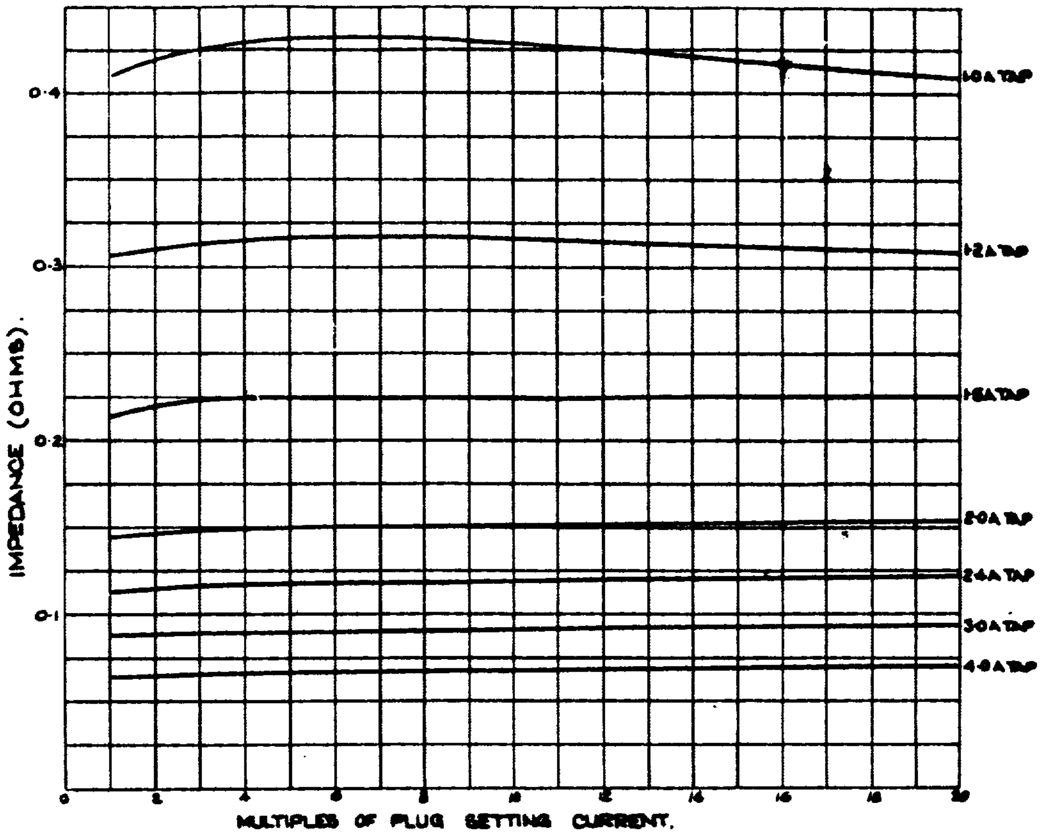
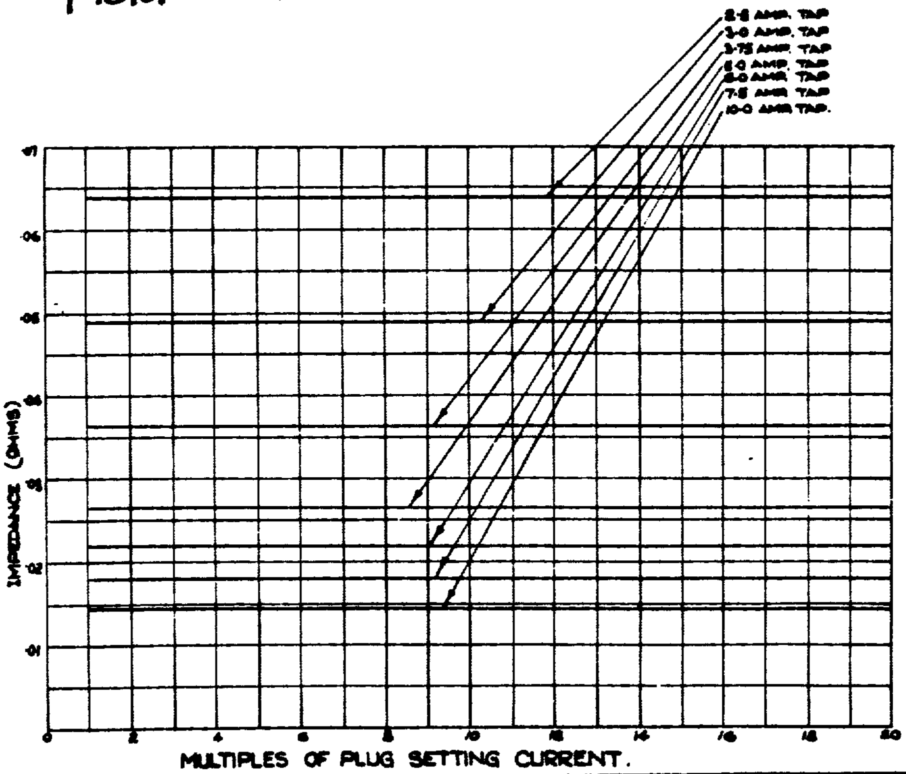


FIG 9. CDG14 (1-4A) IVA EXTREMELY INVERSE 50 C.P.S.

30:5:62. 87738Z06.028

FIG 10. IMPEDANCE/CURRENT CURVES FOR TYPE CDG14 RELAY. 50 C.P.S.



A.23:6:60 87738Z06.02.