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Paper 29

Power Supply: Oil - insulated Switchgear

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1. Introduction

The British Transport Commission's specification for power switchgear required single-phase oil circuit breakers, which in addition to complying with the relevant British Standards, could remain in service for long periods and operate repeatedly without significant deterioration.

It was therefore decided to design a totally enclosed indoor unit to include proved components, a fixed oil circuit-breaker, integral isolation and complete immersion of insulation in oil.

2. Requirements

There are two groups of switchgear:

(*a*) For 25 kV service with normal current up to 800 amps. and short circuit capacity up to 330 MVA at 27·5 kV and 260 MVA at 44 kV with an impulse withstand level of 200 kV.

(*b*) For 6·25 kV service with normal current up to 1,200 amps. and short circuit capacity up to 165 MVA at 6·9 kV and 130 MVA at 11 kV with an impulse withstand level of 110 kV.

3. Development

The design is based on established 3-phase switchgear, which has been in regular production and installation over the last seven years, with the following ratings and applications:

(*a*) 33 kV, 800 amps. 750 MVA controlling national supply and transmission.

(*b*) 11 kV, 1,200 amps. 500 MVA controlling national supply and large industrial equipment.

4. Basic 25 kV Oil Circuit-Breaker

Fig.1 shows a type 'K11' unit with its side cut away to reveal the internal layout.

4.1 *The Structure*

There are four fabricated steel oil-filled chambers, hydraulically separate and electrically connected through bushings.

Two isolator chambers, A and B and O.C.B. hood C are welded to a common baseplate. The hood carries a trapped grommet and fixing studs for a removable tank. An operating mechanism assembly and a cable box are bolted to the baseplate. This complete assembly is supported by four pedestals. A voltage transformer is mounted on top of the unit. Viewed from the front there is a hinged top door carrying relays etc., a central fixed operating and indicating panel and a lower hinged panel giving access to the O.C.B.

4.2 *The Main Circuit*

The main circuit traverses the four chambers as follows:

A busbar passes along the switchboard through flanged openings in the front chamber A, where an isolator connects the front bushing of the O.C.B. At the lower end of the O.C.B. bushings is the interrupter. A second isolator connects the O.C.B. rear bushing with the cable bushing. The cable box encloses an oil-immersed sealing gland.

5. The Interrupter

The interrupter shown diagrammatically in fig.2 has a high tensile bronze swinging contact arm which enters a Permali arc control stack to meet fixed butt contacts. The stack plates are held together to a fixed contact bell casting by four spring bolts.

The object of this patented design is to effect the interruption of the circuit with consistently low arc energy over the whole range of currents. The ducting and venting of the oil space within the stack are styled and proportioned to give efficient interruption of the lower currents. An arc is drawn and follows a sinuous path, as shown in fig.2a, due to the oil vapour pressure and flow. At the higher currents, the pressure generated is sufficient to overcome the compression spring and open the stack plates, automatically increasing the venting to an extent depending upon the magnitude of the current. The path is now nominally straight, fig.2b and the extinguishing effort is softened so that the contact gap exceeds its minimum stable breakdown value before the arc is extinguished. The arc energy is low and the risk of premature extinction and consequent restrike is eliminated. Fig.2c shows the arcing characteristics. Fixed and moving contacts are tipped with Elkonite.

6. The Isolators

The two isolators are similar. Each has three positions – ON, OFF and EARTH. A copper blade, driven by an insulation link from a shaft above oil level, is hinged on an O.C.B. bushing and engages fixed parallel entry high pressure block contacts. The earth fixed contacts are mounted on the earth band of the bushing. This arrangement provides interlocked integral earthing of the O.C.B., the circuit or the busbar.

7. The Mechanism

A combined operating mechanism is bolted to the lower front of the main chamber and presents control and indication at a convenient height in the front panel. Its functions are:

(*a*) D.C. solenoid closing of the O.C.B. through a trip free linkage.
(*b*) D.C. shunt tripping of the O.C.B.
(*c*) Direct hand tripping of the O.C.B.
(*d*) Separate hand control of each 3-position isolator.
(*e*) Hand operated O.C.B. tank lift.
(*f*) Interlocking of O.C.B. contacts, tank and isolators.
(*g*) Indication of the position of the O.C.B. and isolators.

By combining these functions into one assembly, the interlocking is reduced to its simplest and most reliable form.

The closing solenoid has a 30 minute rating. Its plunger closes the O.C.B. contacts via an external adjustable push rod and an internal insulation lift link. Hexagon shafts and broached levers simplify assembly and avoid the use of pins and keys on parts subject to high acceleration and reversal of motion.

A shunt trip and a push button release a stationary reaction latch in the closing linkage to open the breaker.

Two isolator operating levers present their handles one on each side of the mimic diagram. They can be locked in any position and a flap covers the handle when at rest.

8. Interlocks

O.C.B. can be closed when:

Isolators are in 'on', 'off' or 'earth' and their movement control stops are locking the handle and the O.C.B. tank is in position, or

the O.C.B. tank is off and both isolators are in the 'earth' position.

Isolators can be operated when:

The O.C.B. is open and its tank is in position.

When moving from 'on' to 'earth' or vice versa, a deliberate change of interlocks has to be made at the 'off' position.

Tank can be removed only if the O.C.B. is open and both isolators are in the 'earth' position.

Padlocks can be applied to the isolator handles and the front access doors.

9. Mimic Indicating Diagram

An embossed diagram shows the complete internal circuit. The position of the isolators and O.C.B. is mechanically indicated.

10. Insulation

A porcelain post insulator supports the busbar. Resin bonded paper links operate the O.C.B. and isolator contacts. The remainder of the insulation is in the form of stress controlled bakelised paper flanged bushings, which form a convenient rigid support for contacting members and a robust seal between chambers. All insulation is oil-immersed.

11. Current Transformers

Current transformers are all ring type, mounted over the earth band of the bushings and having external earthed steel shrouds.

12. Voltage Transformers

The voltage transformer is double wound, ratio 26,400/110, oil immersed in a welded steel tank and including a HV bushing and a high resistance H.R.C. fuse. It is hinge mounted with its bushing projecting downwards into the rear isolator chamber to contact the top of the O.C.B. rear bushing. Isolation is effected by means of a hand ratcheted screw jack at the rear of the unit which rotates the voltage transformer upwards through 90° to withdraw the bushing. An earthed flap covers the bushing orifice in the lid of the rear chamber when the voltage transformer is isolated.

13. Cable Box

A cable box is mounted at the rear of the unit. It can be arranged for oil, gas or compound filling and will take single or twin-core cable. In the latter case, an insulated neutral terminal and bar are provided. A busbar cable box can be fitted to the side of the unit.

14. Basic 25 kV Switch Fuse Unit

Fig.3 shows this unit which is styled after the O.C.B. unit and has the same overall dimensions and general external appearance.

14.1 *The Oil Switches*

The oil switches are fault making and load breaking. Their contacts are as used in the O.C.B. isolator, with the addition of flick blades. They are operated simultaneously from a single handle.

14.2 *The Fuse Compartment*

A 10 amps. HRC fuse is mounted in air across the lower ends of the bushing from the two oil switch chambers. Stress control spheres envelope the fuse clips. Access to the fuse is through the lower front panel and an inwardly opening slam door, which is interlocked with the oil switch. The door can only be opened when the oil switches are locked in the earth position.

14.3 *The Voltage Transformer*

A voltage transformer can be included as with the O.C.B. unit.

15. Typical Switchboard

Fig.4 shows a typical 25 kV installation which comprises from left to right:

4 track feeders
1 bus coupler
1 incoming supply feeder
4 track feeders
1 switch fuse unit

The top panel contains the protective relays, the eight track feeder panels having A.E.I. distance measuring equipment (refer to Paper 31).

The lower panels carry test terminals and control switches.

16. Operation

The switchboard in fig.4 is shown diagrammatically in fig.5. Figs.5a, 5b, 5c and 5d show the following operational conditions of an O.C.B. unit:

Normal service
Cable earthing through the O.C.B.
Busbar earthing through the O.C.B.
O.C.B. inspection and maintenance. Injection testing of C.T.s

17. 6·25 kV Gear

This gear is styled after the 25 kV gear and follows the same principles.

18. Dimensions

The dimensions of a single unit, including V.T. are as follows:

Voltage	*Pitch*	*Height*	*Depth*	*Front Space*	*Rear Space*
25 kV	2′ 0″	12′ 7″	6′ 0″	2′ 6″	2′ 0″
6·25 kV	2′ 0″	9′ 0″	5′ 6″	2′ 6″	2′ 0″

19. Type Tests

Both groups are fully type tested and those made on a 25 kV O.C.B. unit are summarised below.

19.1 *Short Circuit Tests*

Carried out at K.E.M.A., Holland. They comprise two complete B.S.116 series (one with busbars live and one with cable stem live) together with B.T.C. special requirements for low current, low power factor and over voltage. There was one change of oil, two of arc control stack and three of contacts. Unit otherwise unchanged.

(*a*) Short-time current tests:

12 kA for 3 seconds			4 tests

(*b*) Short circuit tests:

30 kV	5 amps.	0·08 pF lag	11 tests
30 kV	3 to 30 amps.	0·08 pF lead	6 tests
27·5 kV	400 amps.	0·08 pF lag	3 tests
27·5 kV	1·2 kA	0·08 pF lag	9 tests
27·5 kV	3·6 kA	0·08 pF lag	6 tests
27·5 kV	7·2 kA	0·08 pF lag	6 tests
27·5 kV	12·0 kA	0·08 pF lag	19 tests
44 kV	6·0 kA	0·08 pF lag	4 tests
Total (including 27 shots at full rating)		=	68 tests

Fig.6 shows typical oscillograms of tests at low current, high current and at $\sqrt{3}$ normal voltage.

Site tests on the Manchester/Crewe line have confirmed the appropriate type tests.

19.2 *Impulse Voltage Tests*

Carried out at Hackbridge and Hewittic, Walton on Thames.

Five positive and five negative 200 kV 1/50 wave tests were applied to:

(*a*) The complete unit to earth
(*b*) Across the open breaker from the busbar side
(*c*) Across the open breaker from the cable side
(*d*) Across an open isolator.

19.3 *Current Carrying Tests*

Carried out at Switchgear and Cowans, Manchester.

The maximum temperature rise at 800 amps. was 36°C.

19.4 *Mechanical Endurance Tests*

Carried out at Switchgear and Cowans, Manchester.

2,000 close-open operations, including 200 against a prepared trip circuit were made at full closing power. At the end of the tests, the breaker was in good condition and would operate at minimum closing and tripping power.

20. Maintenance

Maintenance is reduced to a minimum; some ten to twenty short circuits can be made and broken and the gear will still carry full load and clear maximum fault.

21. Installations

255, 25 kV units and 85, 6·25 kV units have been installed to date on the London Midland Region and the Scottish Region of the B.T.C.

22. Conclusion

Some merits of the gear are:

Total enclosure in sectionalised earthed metal compartments unaffected by atmospheric conditions.

Compact design requiring minimum floor area.

Main insulation immersed in oil; ideal for electrical stress control and dielectric stability.

Simple interrupter with current responsive vent control given a widely extended optimum performance with low tank pressures. High pressure faced block contacts for repetitive duty.

Integral earthing of main circuit through O.C.B. Integral double isolation and earthing of O.C.B.

Interlocks grouped with mimic diagram for clarity.

A simple main circuit with a minimum of moving parts.

SUMMARY

Two groups of single phase switchgear have been developed, one for 25 kV 330 MVA and one for 6·25 kV 165 MVA ratings. They are of similar style, being totally enclosed and oil immersed with fixed O.C.B. and integral double isolation and earthing.

The paper describes the design, its basis in established 3-phase gear and its facilities for operation, testing, maintenance and general safety.

Each group comprises O.C.B. units controlling incoming and outgoing feeders and bus sections, HRC switch fuse units supplying auxiliaries and V.T. units supplying a voltage reference for the distance measuring feeder protection.

The O.C.B.s have a patented self-compensating interrupter which maintains a consistently low level of arc energy over the interrupting range and are, therefore, most suitable for repetitive duty.

Particulars of selected type tests are given and these are confirmed by site tests.

RÉSUMÉ

On a développé deux postes équipés de disjoncteurs l'un pour 25 kV, 330 MVA et l'autre pour 6·25 kV, 165 MVA. Ils sont de forme semblable c'est-à-dire de construction fermée à bain d'huile, munis de disjoncteur fixe à huile, de sectionnement double et de mise à terre incorporés.

L'exposé en décrit la construction, tout en indicant comment celle-ci a pour base des appareils triphasés de conception courante, et les facilités qu'elle prévoit pour le fonctionnement, des essais, l'entretien et la sécurité générale.

Chaque groupe comporte des disjoncteurs à bain d'huile pour les feeders et les départs ainsi que des secteurs de barres omnibus, des coupe-circuits à haut pouvoir de coupure pour le branchement des dispositifs auxiliaires, aussi bien que des transformateurs de tension qui fournissent la tension de référence pour les dispositifs de protection des feeders par relais de distance.

Les disjoncteurs à bain d'huile sont munis d'un interrupteur breveté d'auto-compensation qui maintient l'énergie d'arc à un niveau uniformement bas sur toute la gamme d'interruption; ils conviennent donc pour service avec fonctionnement fréquent.

On donne des détails d'essais de type sélectionnés, qui se sont confirmés par des essais effectués sur place.

ZUSAMMENFASSUNG

Es wurden zwei Gruppen von Schaltanlagen entwickelt, die eine für 25 kV 330 MVA—und die andere für 6·25 kV 165 MVA Nennleistung. Die Ausführungen sind ähnlich, geschlossene, ölgekapselte Bauart mit eingebautem Oelschalter und zwangsläufiger Doppelabschaltung und Erdung.

Der Bericht beschreibt die Konstruktion, wie ihre Grundzüge in den 3-phasen Anlagen basieren, und die Vorteile der Konstruktion bezüglich Betätigung, Prüfung, Wartung und allgemeiner Sicherheit.

Jede Gruppe enthält Oelschalter-Einheiten, welche die ankommenden und abgehenden Speiseleitungen und Sammelschienenabschnitte schalten, Hochleistungs-Trennsicherungseinheiten die die Hilfsgeräte speisen, und Spannungstransformatoren die eine Bezugsspannung für den Distanzschutz liefern.

Die Oelschalter haben selbstausgleichende Patent-Unterbrecher, welche die Lichtbogenenergie im ganzen Unterbrechungsbereich auf einem ständig niedrigen Wert halten; die Oelschalter eignen sich daher für wiederholte Abschaltungen. Einzelheiten von ausgewählten Typenprüfungen sind angeführt, diese werden von Prüfungen an Ort und Stelle bestätigt.

RESÚMEN

Dos grupos de interruptores oonofásicos han sido desarrollados, uno para una potencia de 25 kV 330 MVA y otro para una de 6·25 kV 165 MVA. Son de forma similar, a saber, de construcción cerrada en baño de aceite, con interruptor fijo, tambien en baño de aceite, y equipados con seccionamiento doble y puesta a tierra incorporados.

La memoria describe la construcción su orígen en aparatos trifásicos ya en servicio general, y las posibilidades que proporciona al usuario para el funcionamiento, los ensayos, el mantenimiento y la seguridad general.

Cada grupo consta de interruptores con baño de aceite para conectar y desconectar cables alimentadores de entrada y salida asî como secciones de barras colectoras, de fusores desconectables de alta capacidad de ruptura para el suministro de corriente a aparatos auxiliares, asî como de transformadores de tensión que suministran un volraje de referencia para los dispositivos de protección de los cables alimentadores telemétricos.

Los disyuntores con baño de aceite van provistos con un interruptor patentado autocompensador, que mantiene un nivel reducido constante de energîa del arco sobre toda la gama de interrupción, y por eso son muy apropiados para el servicin de repetición.

Se comunica detalles de ensayos típicos seleccionados, que se han confirmado por ensayos efectuados en sitio.

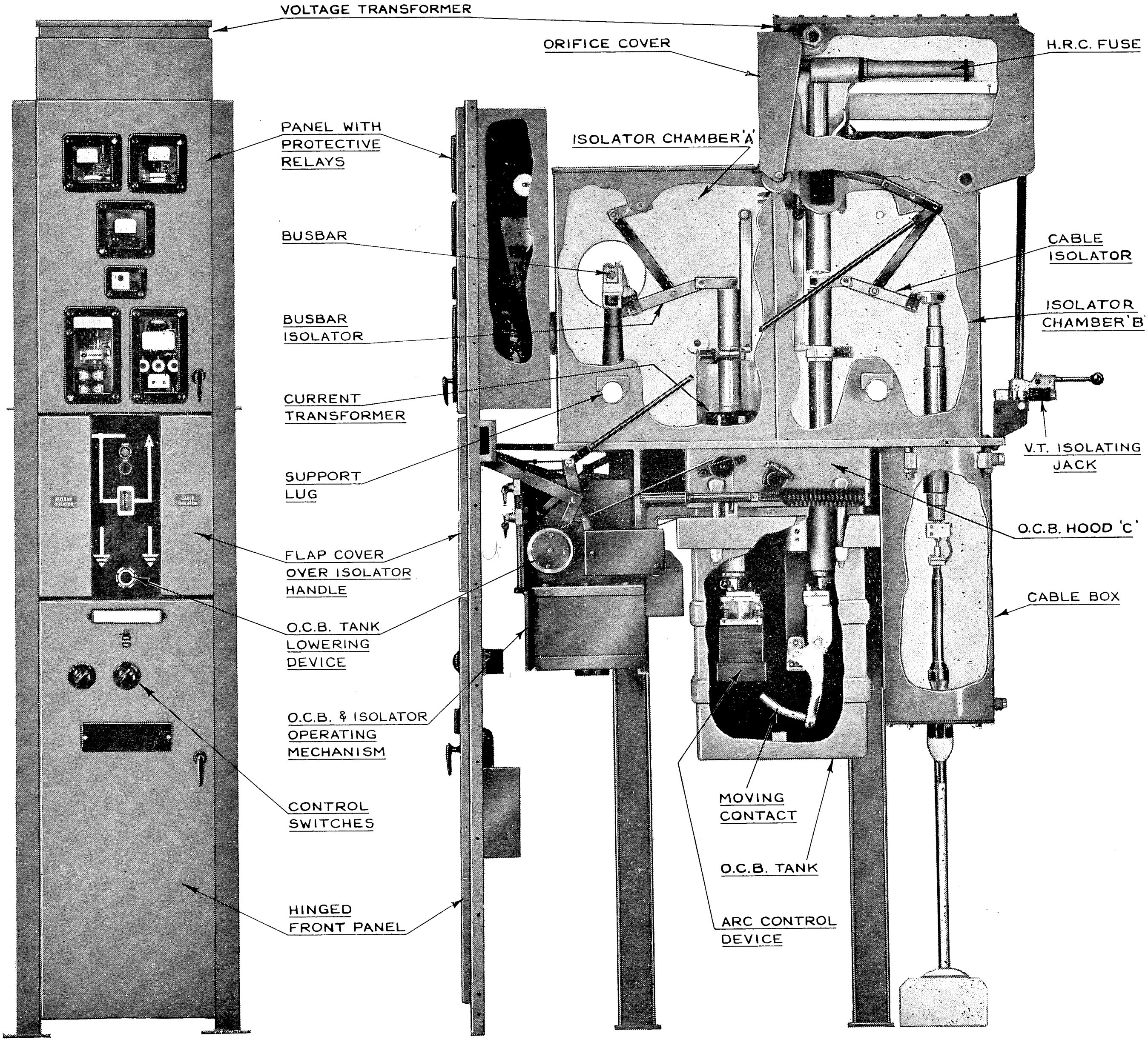

Fig.1 25kV 330 MVA O.C.B unit with side cut away

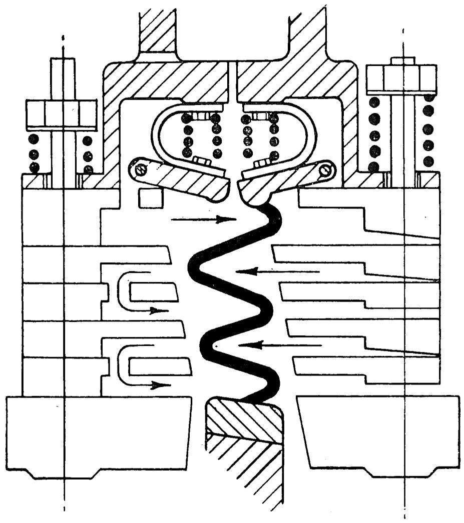

Fig.2a Opening on low currents

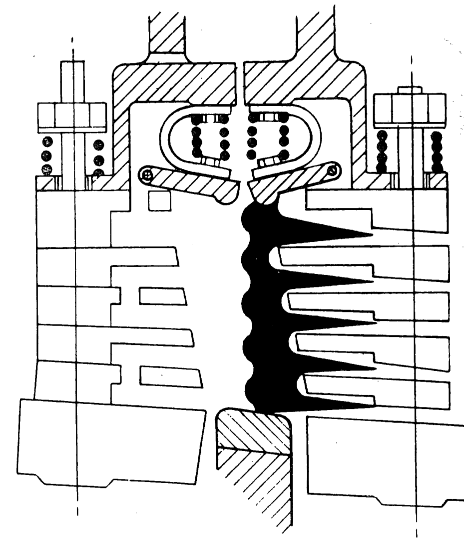

Fig.2b Opening on high currents

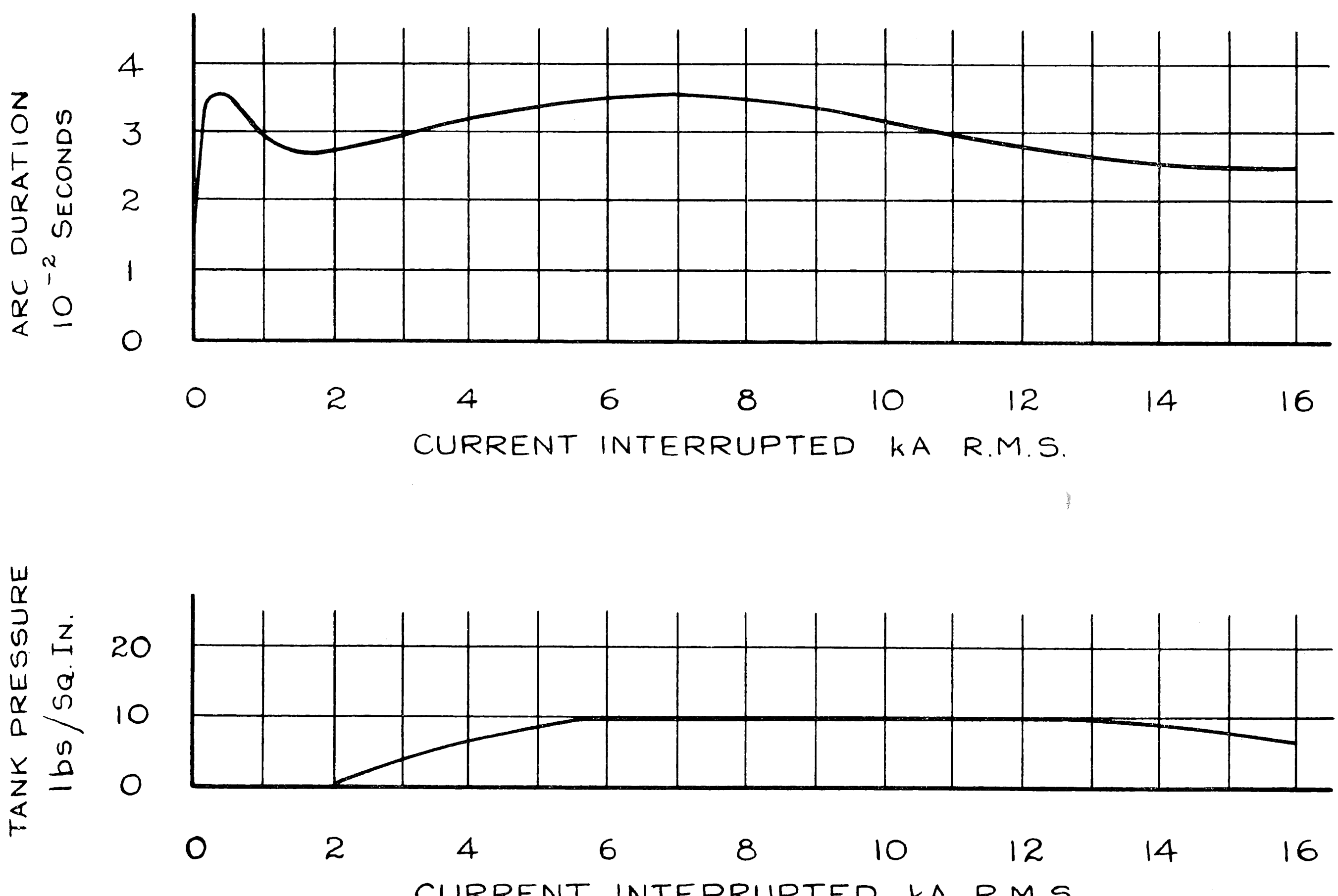

Fig.2c Interrupter Characteristics

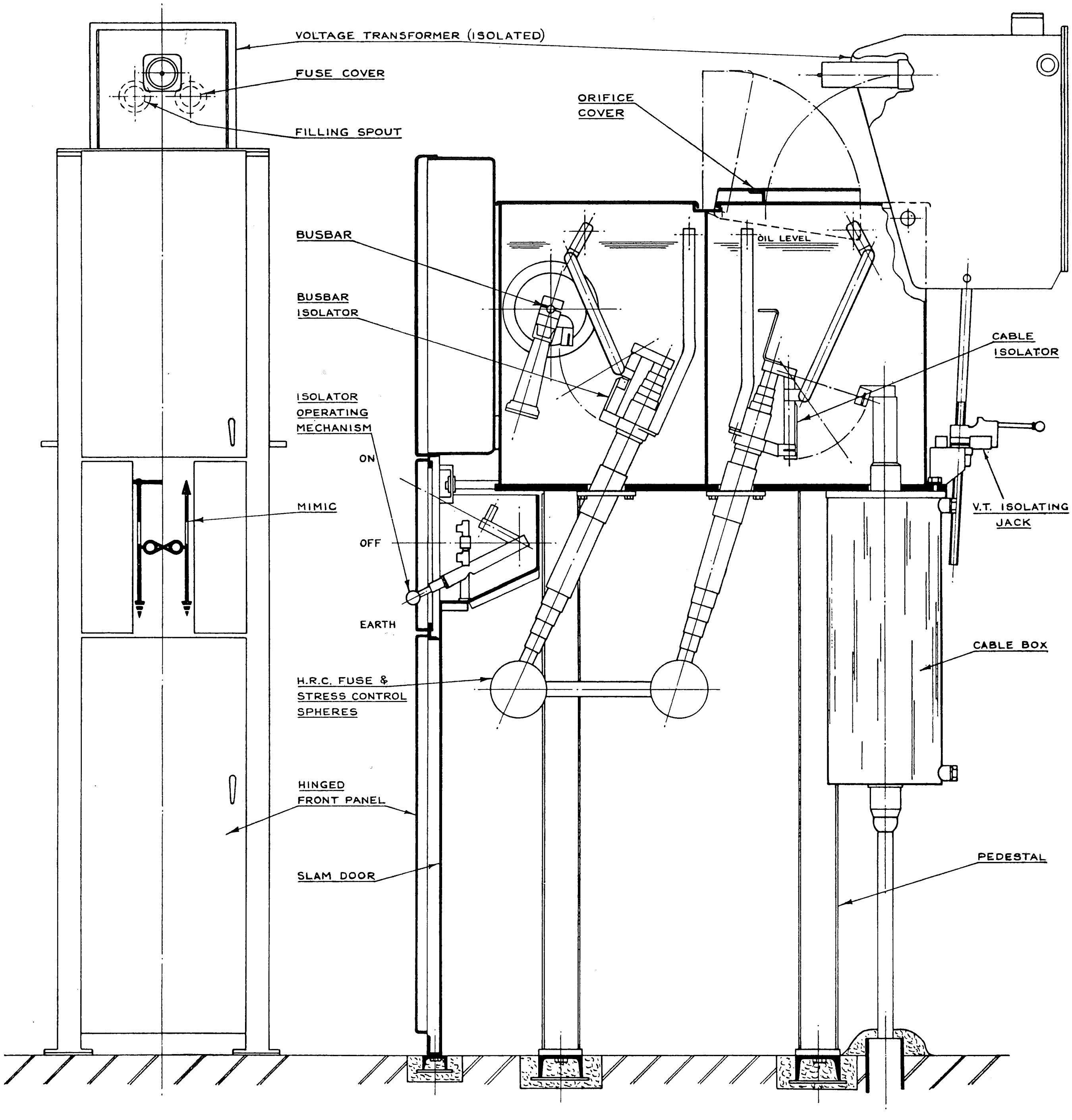

Fig.3 General Arrangement of 25kV Switch Fuse Unit

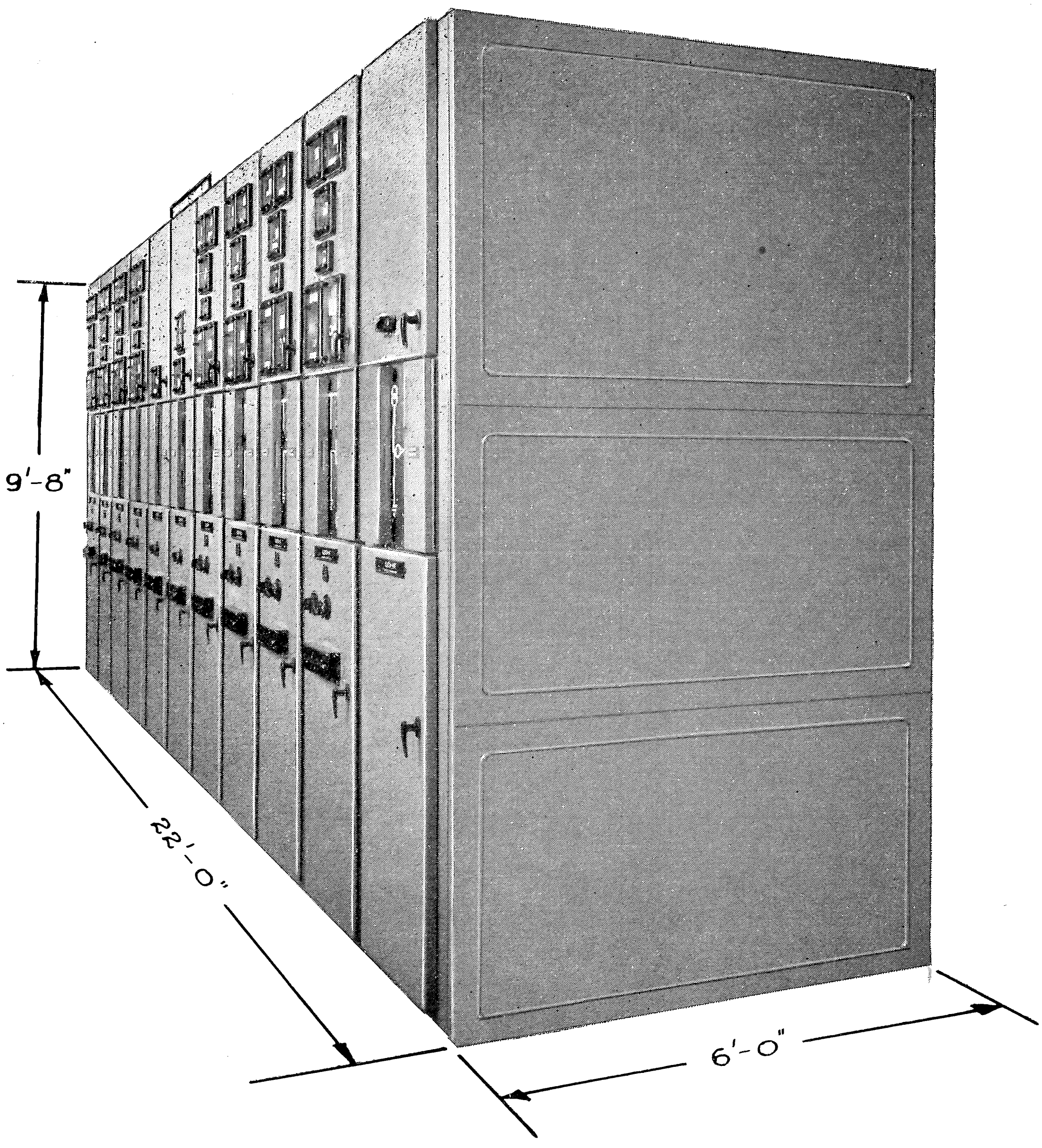

Fig.4 An 11 panel 25kV 330 MVA switchboard

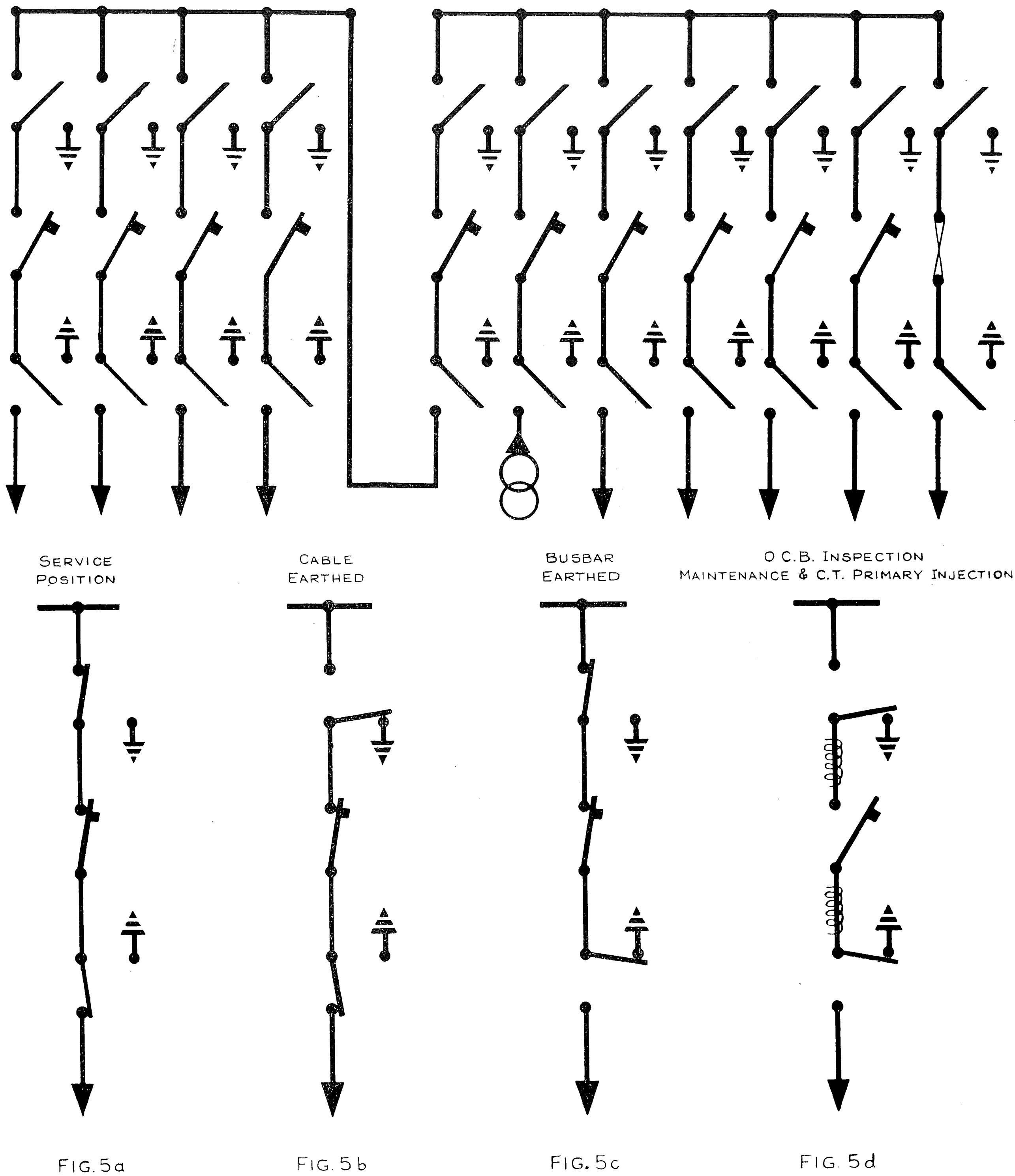

Fig.5 Diagram of switchboard shown in Fig.4

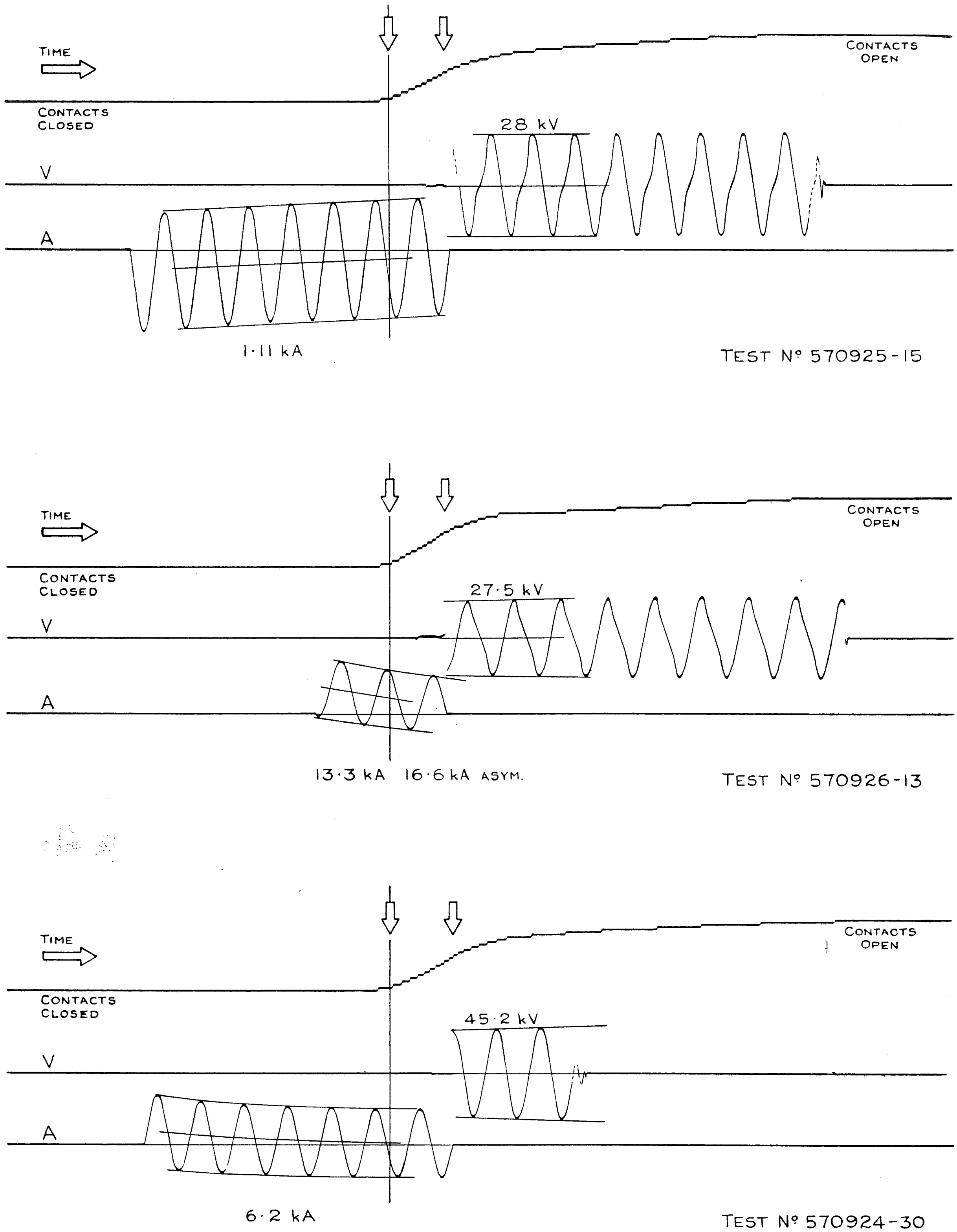

Fig.6 Oscillograms showing 31 MVA, 366 MVA, and $\sqrt{3}$V break tests

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