OIL-FILLED ELECTRICAL DISTRIBUTION AND OTHER SWITCHGEAR

INTRODUCTION

1 This document contains internal guidance which has been made available to the public. The guidance is considered good practice but is not compulsory. You may find it useful in deciding what you need to do. However, the guidance may not be directly applicable in all circumstances and any queries should be directed to the appropriate enforcing authority.

2 This document contains information for the attention of both managers and technical staff concerning the electrical risks (see para 5) that can arise from the use of high-voltage and low-voltage oil-filled electrical distribution and other switchgear which was manufactured prior to 1970. The term 'switchgear' includes : oil-switches, oil-isolators, oil- switch fuses and, in particular, oil circuit-breakers (see Appendix 1 for definitions). Advice is given on the precautions which should be taken to eliminate or control these risks. (Because of the nature of this subject many of the terms used will be more easily understood by electrical engineers than by managers).

3 The document is based upon accident/incident investigations, the testing of some types of equipment, users' experience, advice from manufacturers and information from British and international standards.

4 The guidance does **not** address direct current (dc) systems or single-phase alternating current (ac) traction systems of any voltage, but users of such systems may still find the document useful.

BACKGROUND

5 In general, oil-filled switchgear has a proven record of reliability and performance. Failures are rare but, where they occur, the results may be catastrophic. Tanks may rupture, resulting in the ejection of burning oil and gas clouds, causing death or serious injury to persons and major damage to plant and buildings in the vicinity of the failed equipment. Accident experience has shown that failure usually occurs at, or shortly after, operation of the equipment. Thus, the way switchgear is operated, its condition and the circumstances existing in the system at the time of operation, to a large extent, determines whether the equipment will safely perform its duty.

6 Switchgear of all types and ratings has been manufactured in accordance with British and international standards for a period in excess of 60 years. As with most equipment, however, current specifications bear little resemblance to those of earlier years in that the previous specifications have been shown, by subsequent experience and by technical developments, to be deficient. Examples of differing

requirements between earlier and current standards are those relating to operating mechanisms and fault test sequences

LEGISLATION

7 The Health and Safety at Work etc Act 1974 (HSW Act), the Management of Health and Safety at Work Regulations 1992 (Management Regulations) and the Electricity at Work Regulations 1989 (EAW Regulations) apply. The HSW Act contains requirements to the effect that anyone employing people should ensure their safety so far as is reasonably practicable. The Management Regulations require an employer (or self-employed person) to make an assessment of risks to employees or others, taking specialist advice where necessary. The level of detail in the assessment should be broadly proportionate to the risk, which means it needs to be fairly detailed in the case of oil-filled switchgear as the risk is one of death. The EAW Regulations require electrical equipment for use at work to be constructed, maintained and operated in such a way as to prevent danger so far as is reasonably practicable. Equipment should also not be used where its strength and capability may be exceeded and it should be protected from excess current.

EQUIPMENT AND ITS LOCATION

8 The incoming electrical supply to any premises which requires a high voltage supply often passes through switchgear. Switchgear varies in size, age and appearance. Typical examples are shown at Appendix 2 , Figures 1 and 2.

9 The purpose of oil-filled circuit breakers is to interrupt, without danger, electrical faults which develop on the system and switch electric current ON or OFF safely, particularly when operated by hand.

10 Such switchgear tanks contain insulating oil and the contacts, which open and close the electrical circuits, are immersed in the oil. The oil provides for insulation and acts as an aid to arc extinction when the contacts open.

11 Switchgear is generally located in substations and switchrooms, ie areas that are separated from the day-to-day activity of the premises and which, in many instances, are visited on a very infrequent basis. Such rooms are generally locked and access is usually restricted to authorised persons.

12 In some premises low-voltage switchgear will be found located in work activity areas. There will also be cases where high-voltage switchgear and starters are found adjacent to the machinery which it controls, a typical example being a large rubber mill. Occasionally switchgear is located outdoors.

13 Much of the equipment still in service is some 20 years old or more. Equipment that is 30 or more years old is usually of particularly robust construction. As a result it is often assumed, incorrectly, that the equipment has an unlimited life in service. Much of the older equipment has a limited operation capability and these limitations are not always understood by present-day operating staff

POTENTIAL PROBLEMS WITH SWITCHGEAR

14 There are a number of potential problems that may be encountered with oil-filled electrical switchgear that is more than 20 years old. These include:

(1) lack of knowledge of the equipment;

(2) being overstressed;

(3) not being modified as per manufacturer's advice;

(4) having dependent manual operating switchgear, ie where the movement of the contacts is directly dependent on the movement of the handle by the operator;

(5) not being maintained properly; and

(6) being fitted with operating handles which are not anti-reflex type (high-voltage oil-switches and isolators only).

Knowledge of the equipment

15 Switchgear is usually operated by trained staff who are often known as "authorised persons ". In the past these were generally works' electrical engineers and senior supervisors but due to changing employment patterns this is no longer the case. Some organisations may not have any "authorised persons " on their staff and may have chosen to contract out all operational work and maintenance of their switchgear. As a result there may be no-one in the organisation who understands the equipment, its safe operation (particularly when it is the dependent manually-operated type) and either the need for maintenance or maintenance procedures.

Overstressing of switchgear

16 The switchgear is described as being 'overstressed' when the potential fault energy of the electrical system (eg from a short-circuit) at the switchgear location , exceeds the fault energy rating of the switchgear. When it is operated under fault conditions it is unable to cope with the resulting electrical and thermal stress which can sometimes lead to catastrophic failure, ie total destruction of the switchgear. Such failures are accompanied by burning gas clouds and oil mist which envelop anyone near the switchgear and have resulted in death or serious burn injuries.

Equipment modifications

17 Manufacturers have, over the years, issued details of modifications to existing equipment which should be carried out on oil-filled switchgear to improve its safety. However, in many cases, users are unaware of the need to carry out these modifications . As a result the equipment may be incapable of performing its duty satisfactorily.

Dependent manually-operated switchgear

18 The operating mechanisms of most switchgear, ie independent manual, dependent power, independent power and stored energy, do not, in themselves result in any particular risks. However where switchgear is dependent manually-operated (DMO), the operator closes or opens the switchgear by moving a lever or handle by hand. DMO levers/handles are fitted to both high and low-voltage switchgear (see Appendix 2 Figures 1 and 2). These types of operating mechanism are no longer made. Movement of the contacts is totally dependent upon the speed and actions of the person operating the levers/handles. Any hesitancy on the part of the operator is likely to lead to a serious and potentially fatal failure of the switchgear, eg operators may not realise that they have failed to close the circuit breaker completely, and release the operating lever/handle thus drawing an arc within the oil tank which can result in catastrophic failure. It is essential that these levers/handles are operated in a decisive and positive manner without any hesitation and as rapidly as possible, particularly over the latter portion of the closing operation. In addition, should a lever/handle be closed onto a system fault, the force needed is significantly greater than when closed in a normal system load current. In some cases it may be physically impossible to close (or open) the device under fault conditions, again this may result in failure. The risks resulting from the use of DMO switchgear which is overstressed, are particularly high.

Lack of maintenance

19 It is not unusual to find that these switching devices, particularly the low-voltage devices, have been neglected. Routine servicing such as oil changing, lubrication, contact refurbishment, and verification of contact engagement has often not been carried out for many years. Deterioration due to corrosion may also have occurred.

20 This is usually the result of oversight, lack of knowledge of the equipment, or pressures to keep the equipment, and hence the plant, in operation. In many cases the expertise in handling and maintenance techniques for insulating oil is lacking. Where oil-filled switchgear has been neglected, it is difficult to assess the actual fault capability of the switchgear in the state in which it is found.

Provision of anti-reflex operating handles

21 A common cause of accidents/incidents with high-voltage **oil-switches** and **isolators** is when an operator carries out an incorrect operation when moving the operating handle, eg switching from OFF to EARTH instead of from OFF to ON and then immediately tries to reverse that incorrect operation thus inducing a further

fault. Any attempt to open these types of switching device when fault current is flowing is likely to lead to the operator being enveloped in a cloud of burning oil and oil vapour. Operators have been killed as a result. To combat this, many manufacturers have produced anti-reflex operating handles for their equipment (see Appendix 2 Figure 3). These handles are a one-way operating device and have to be removed and relocated before carrying out a further operation. This built-in time delay means that when the incorrect operation is reversed, NO fault current is flowing (as the circuit protection will have operated to interrupt the current flow), and there is no likely failure of the switch. The built-in time delay is also important when closing from OFF to ON onto a known fault.

ACTION TO BE TAKEN

22 Before deciding upon the precautions to be taken, all such switchgear that is in service should be identified. The potential risks, eg overstressing, dependent manual operation, should be assessed so that any necessary remedial action can be identified to ensure that the equipment and systems are being operated safely, and that work is put in hand to eliminate or reduce the risks (see paragraph 24 onwards).

23 In some cases, sufficient technical expertise may not be available in-house to carry out an assessment of risk and to decide on the appropriate precautions. However, having identified that a problem exists or may exist, switchgear users should be able to reach decisions about seeking further help from suitably competent organisations. Such organisations include:

(1) regional electricity companies;

(2) switchgear manufacturers (see Appendix 3 for list of medium and high-voltage switchgear manufacturers and their contact points);

(3) switchgear maintenance companies with particular expertise in older types of switchgear; and

(4) consulting organisations specialising in switchgear.

Note The Trade Association, British Electrotechnical and Allied Manufacturers Association (BEAMA) may also be able to provide help and guidance as to other sources of information and expertise (see Appendix 3 for their address).

Identify the switchgear

24 All organisations with responsibility for oil-filled switchgear ought to have available a record of their switchgear. Where there are doubts about the accuracy or validity of records then a new inventory should be prepared as a matter of urgency. Typical information that is required for each item of equipment at each location, (there may be several switchrooms or substations on any one site), include:

(1) location;

(2) manufacturer and type reference for each item of equipment and type of equipment;

(3) serial number and year of manufacture;

(4) date of installation;

(5) voltage rating;

(6) current rating;

(7) fault rating and whether it is a certified or assessed rating;

(8) type of operating mechanism (dependent manual, independent manual, dependent power, independent power and stored energy);

(9) details of any modifications or repairs, eg fitted anti-reflex handles;

(10) date equipment last maintained/serviced;

(11) if the equipment is an oil circuit-breaker whether it is a plain break equipment (ie equipment without arc control devices) or not; and

(12) type of electrical protection fitted and details of the settings, eg HRC fuse 30amps.

Compare fault levels and ratings

25 For each item of switchgear identified in the inventory (in particular the DMO switchgear), on site:

(1) identify the British or other standards relevant to the individual switchgear;

(2) calculate fault energy levels at the output terminals of each item of switchgear. In some cases it will be necessary to include the fault energy contribution from rotating plant on site. The electricity supply company can provide, on request, the maximum short-circuit current at the incoming supply terminals. (Electricity Supply Regulations 1988 regulation 32);

(3) determine the switchgear rating. Where necessary, seek re-assessment of the rating by manufacturers or specialists of those items of switchgear designed to obsolete British standards (see paragraph 46), taking account of those standards identified at (1) above; and

(4) compare the fault energy levels calculated at (2) above with those certified or assigned switchgear fault energy ratings determined at (3)

above, to establish whether the equipment is overstressed. Through-fault ratings for the switchgear and any assigned ratings given by the manufacturer or specialist resulting from re-assessment of previous fault energy ratings should be included.

26 It is recommended that the procedures are applied to both high-voltage (ie 3.3 kV, 6.6 kV, 11 kV, 22 kV, and 33 kV) systems and low-voltage (230/415 volt) systems as separate exercises. It may be easier to deal with each individual system at each voltage separately as the individual systems may have very different problems.

PRECAUTIONS TO REDUCE THE RISK

27 The need for precautions and how quickly they should be instigated will depend on whether the equipment is overstressed, whether it has been modified in accordance with manufacturer's instructions, the type of operating mechanism, the maintenance condition etc.

Overstressed switchgear

28 Where the switchgear fault energy ratings are **less** than the potential fault energy levels the following action should be taken, regardless of the type of operating mechanism:

(1) **Prohibit all live operation and automatic tripping of the switchgear.** This action will necessitate re-adjustment of electrical protection further back towards the source of supply in order that the electrical protection at the switchgear can be made non-operative. The re-adjustment is needed to ensure adequate levels of electrical protection for the system.

(2) **Prevent access by persons to the switchgear whilst it is live.**

(3) The switchgear should be maintained in accordance with manufacturer's advice by trained personnel. Particular attention should be paid to insulating oil, solid insulation, contact assemblies, operating mechanisms, seals and gaskets (see paragraph 37).

(4) Reduce the fault energy levels. In some cases changing system operating conditions will achieve this, for example operating transformers as single feeders to switchboards and not in parallel with other transformers. These changes should be made as soon as possible to reduce the fault energy level to as low a value as practicable.

(5) Longer-term measures that can be taken to reduce fault energy levels include fitting reactors or re-cabling of systems. These measures may be used to reduce fault energy levels to values less than the fault energy ratings of switchgear. They will not overcome the problems associated with switchgear that has no fault energy rating. This action

is normally only a solution for high-voltage switchgear.

Note: The cabling might be as old as the switchgear, hence other problems such as cable failure could occur as a result of disturbing it.

29 Where the action in paragraph 28 reduces the fault energy levels below the ratings of the switchgear then electrical protection and live operation can be restored, **after** interlocks or other measures have been provided to prevent the rating being exceeded at any time, eg to prevent the paralleling of transformers onto the switchgear busbars.

30 If this action (in paragraph 28) does **not** reduce the fault energy levels below the ratings of the switchgear, and it is sited in open workshop areas, the provision of blast protection should be considered. This may take the form of suitable walls, or sand-bagged enclosures. The purpose of these is to contain any failure of the switchgear whilst it is energised and prevent injury to persons. However, this is a complex matter and it is often more practical to make the switchgear dead and provide alternative electrical supplies.

31 Where high-voltage and low-voltage switchgear share the same switchroom and only one set of switchgear is under-rated, it will be necessary to either:

(1) keep personnel out until the under-rated switchgear is made dead; or

(2) where space permits, erect a suitable blast wall around that switchgear, so permitting personnel access to the other switchgear. (See paragraph 30)

32 Arrangements should be made to replace the under-rated switchgear as soon as possible. This will often be made easier by re-design of the electrical system. Priority should be given to replacing such switchgear that is both overstressed and DMO.

Dependent manually-operated switchgear

33 All operation and maintenance of dependent manually-operated switchgear (DMOS) on site should be restricted to those personnel trained in the operation of the switchgear concerned and who are conversant with the dangers of mal-operation, the construction of the switchgear and the manufacturer's maintenance requirements. These personnel will need to be conversant with the safe system of work outlined in paragraph 34(4). Where this switchgear is also overstressed the precautions in paragraph 28(1) and (2) are particularly important in the short term.

34 Where the switchgear is **not** overstressed (ie ratings are **greater** than the actual fault energy levels), the following precautions are needed to reduce the risks that result from the fact that it has dependent manual operation:

(1) All DMOS should be maintained in accordance with manufacturer's advice. This should include the checking of seals and gaskets which should be properly installed and in good condition. An annual maintenance schedule for this equipment should be prepared and be implemented, see paragraph 37.

(2) Power closing mechanisms should be fitted as a matter of urgency to all high- voltage DMOS (ie 3.3 kV, 6.6 kV, 11 kV). However, this should only be carried out in accordance with the manufacturer's advice. It may not be possible to obtain the necessary guidance and advice where the original manufacturer no longer exists and there are no agents. In these cases it is **not advisable** to fit power closing mechanisms.

(3) A phased replacement programme for all the switchgear should be prepared and implemented for **all** DMOS manufactured prior to 1960 and for those high-voltage systems manufactured and installed after 1960, which cannot be fitted with power closing mechanisms. In some cases it is possible to obtain replacement circuit breakers of modern (airbreak) design (often called cassettes) which can be used to replace old high and low-voltage units and which can use the existing switchgear busbar housings and support arrangements. This approach can mitigate the costs of replacement. Advice should be sought from the manufacturer regarding this approach.

(4) When a DMO circuit-breaker is to be closed the preferred method of operation is as follows (in order to achieve this preferred method of operation it may be necessary to change system running conditions and adjust the electrical protection accordingly):

   (a) make the system dead upstream using a suitably rated independent operated switch or circuit-breaker;

   (b) check, where practicable, the system beyond the DMO circuit-breaker to ensure that it is fault-free. This will mean applying various electrical tests to the system;

   (c) If the system is healthy, close the DMO circuit-breaker to ON; and

   (d) energise the system from the remote point ensuring that no personnel are in the vicinity of the DMO circuit-breaker.

(5) The following can however, be operated with the system live:

   (a) bus section couplers on a fully energised system; and

   (b) circuits that have been tested immediately before closure.

(6) Where the circuit-breaker has recently been operated for the purpose of routine isolation, it may be reclosed manually providing the electrical circuit it feeds has not been disturbed.

35 Where work has been undertaken on the electrical system normally made live by a DMO circuit-breaker, the circuit should be comprehensively tested prior to the operation of the circuit-breaker.

Modifications

36 Where possible, details of any modifications, recommended by the switchgear manufacturer to improve safety, should be identified and put in hand.

Maintenance

37 It is essential that oil-filled switchgear is properly maintained. If any overstressed switchgear and/or dependent manual equipment has not been serviced or maintained within the past 3 years such maintenance should be carried out immediately. This work should include:

(1) cleaning of the internal mechanism, contacts and the oil tank;

(2) replacement of the existing insulating oil with new or reconditioned insulating oil;

(3) dressing, refurbishing or replacing contacts as appropriate;

(4) replace seals and gaskets;

(5) adjusting mechanisms; and

(6) testing electrical protection periodically and, where necessary, after fault operation.

Thereafter it should receive maintenance at a frequency appropriate to the equipment. The manufacturer, or others, may be able to give advice on this.

Post-fault maintenance

38 It is strongly recommended that all oil-filled circuit-breakers are maintained as soon as possible after they have either been closed onto a fault or have operated automatically to disconnect a fault from the system. This maintenance should include checking of contacts for wear, arc erosion, alignment, and contact pressures. Refurbishment or replacement of both fixed and moving contacts as necessary should be carried out. The maintenance should include the cleaning of the whole of the interior of the circuit breaker and tank, replacement of the insulating oil with new or reconditioned oil and replacement of tank sealing gaskets. The wiping out and cleaning of the interior should be done using either chamois leather cloths rinsed out in clean insulating oil or synthetic sponges. This will avoid leaving fibres in and on the circuit breaker which can lead to subsequent electrical tracking and failure. Any means provided for venting should be checked to ensure that it is not obstructed and any seal is intact and functioning. Further guidance on maintenance can be found in manufacturers' manuals and in the relevant British standards.

Anti-reflex operating handles

39 Anti-reflex operating handles should be fitted to all oil switches and oil-switch fuses to enable their safe operation.

Oil isolators

40 These have limited capability and should only be operated when dead. They should be labelled "Dead Operation Only". They should be fitted with non-standard operational locks whose key should be kept in a secure place under the control of a responsible person. They should only be operated by trained competent staff who understand the limitations of the equipment.

Motor starters

41 These are devices intended to start and accelerate motors to normal speed, to ensure continuous operation of motors, to switch off the supply from the motor and to provide means for the electrical protection of motors and associated circuits against operating overloads. Usually they are not intended nor designed to interrupt short-circuit currents in the system beyond them.

42 Short-circuit protection is afforded by other switchgear such as circuit-breakers or fuses. For high-voltage systems, the usual device is a circuit-breaker.

43 It is important that the incoming device is fully capable of dealing with the energy levels present. These devices should be assessed in the same manner as all other switchgear. Where deficiencies or short-comings are found appropriate remedial action should be taken.

44 Due to the more frequent operation of these units compared to other electrical switchgear, suitable maintenance procedures are particularly important.

CONCLUSION

45 It is important that programmes of work are developed in order to ensure that action to eliminate or reduce the risks will take place. In most instances it should be possible to put in hand modifications to operating procedures immediately. However, replacement of overstressed switchgear or DMO mechanisms will take time.

46 Appendix 4 contains a list of useful references, including obsolete British standards which may now only be available through the archives of switchgear manufacturers and specialists.

47 Further advice or information can be obtained from the local HSE area office.

March 1995

APPENDIX 1
(para 2)

TECHNICAL DEFINITIONS

Low voltage normally exceeding 50V ac or 120V dc but not exceeding 1000V ac or 1500V dc between conductors, or 600V ac or 900V dc between conductors and earth.

High voltage normally exceeding 1000V ac or 1500V dc between conductors, or 600V ac or 900V dc between conductors and earth.

Note: Some companies and persons use the term "medium voltage" to describe distribution voltages in range 3.3 kV to 72.5 kV to distinguish these from the higher values of voltage associated with transmission systems. There is no International Electrotechnical Vocabulary (IEV) meaning which specifies values; all that is stated is that the upper value lies between 30 kV and 100 kV. The term has not been used in the UK to prevent confusion with the widely understood use of the term for 415 V 3 phase systems.

It is possible to separate switching devices into the following groups and to define the type of switching device. It should be noted that they are **all** electro-mechanical devices.

Oil-isolator this is a switching device which is used to open (or close) a circuit *in oil* either when negligible current is interrupted (or established) or when no significant change in the voltage across the terminals of each pole *or phase* of the isolator will result from the operation.

(This definition is based on that in British Standard BS 3078: 1959.)

Oil-switch this is a switching device suitable for making *or closing* a circuit under normal and abnormal conditions such as those of short-circuit, and capable of breaking *or opening* a circuit in oil under normal conditions.

(This definition is based on that in British Standard BS 2631: 1955.)

Oil circuit-breaker this is a switching device capable of making and breaking, or *closing and opening*, a circuit in oil under normal conditions and under abnormal conditions such as those of short-circuit.

(This definition is based on that in British Standard BS 116: 1952.)

Oil-switch fuse This is a switching device in which the fuses, which may be mounted in air or be immersed in oil, are connected in series with an oil-switch in a combined assembly.

The operating duties of the above switching devices may be summarised as follows:

An oil-isolator has no rated making or breaking capability, ie these devices shall only be used for **OFF-LOAD or DEAD** switching.

An oil-switch is a **FAULT MAKE LOAD BREAK** device, an oil-switch fuse is the same.

An oil circuit-breaker is a **FAULT MAKE FAULT BREAK** device.

Note: All of these types of switching devices can be found in service on high voltage systems. The devices found in service on low-voltage systems will be oil circuit-breakers.

The types of operating mechanisms used for these switching devices are defined as:

Dependent manual operation (of a mechanical switching device)

(IEV Definition 441-16-13)
An operation solely by means of directly applied manual energy such that the speed and force of the operation are dependent upon the action of the operator

Independent manual operation (of a mechanical switching device)

(IEV Definition 441-16-16)
A stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator.

Dependent power operation (of a mechanical switching device)

(IEV Definition 441-16-14)
An operation by means of energy other than manual, where the completion of the operation is dependent upon the continuity of the power supply (to solenoids, electric or pneumatic motors etc).

Independent power operation (of a mechanical switching device)

(IEV Definition 441-16-6)
A stored energy operation where the stored energy originates from an external power source and is released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator.

Stored energy operation (of a mechanical switching device)

(IEV Definition 441-16-15)
An operation by means of energy stored in the mechanism itself prior to the completion of the operation and sufficient to complete it under predetermined conditions.

Note: This kind of operation may be subdivided according to:

-1 the manner of storing the energy (spring, weight, etc);

-2 the origin of the energy (manual, electric etc);

-3 the manner of releasing the energy (manual, electric etc).

APPENDIX 2
(paras 8, 18 and 21)

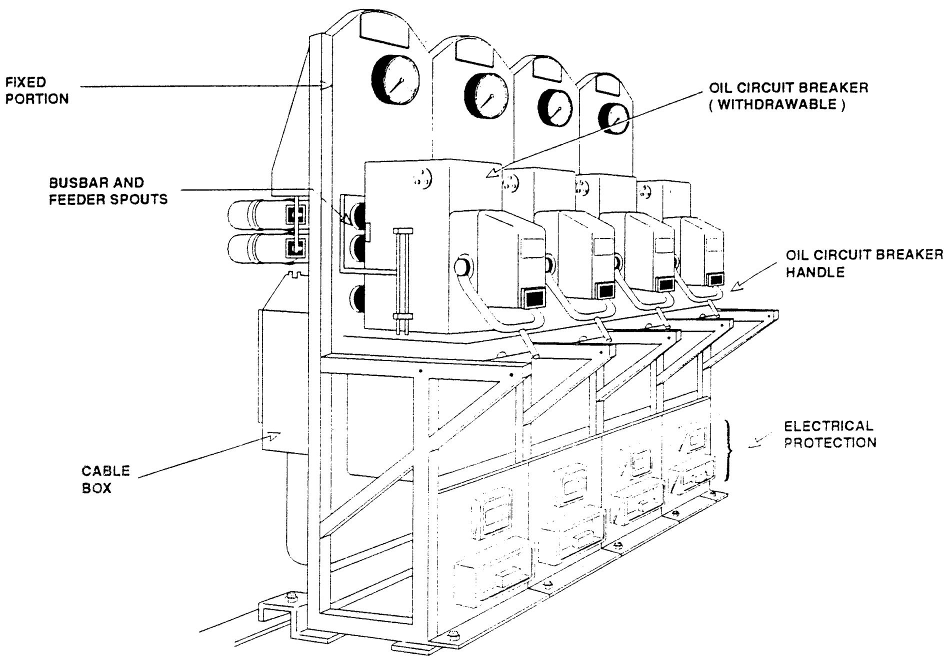
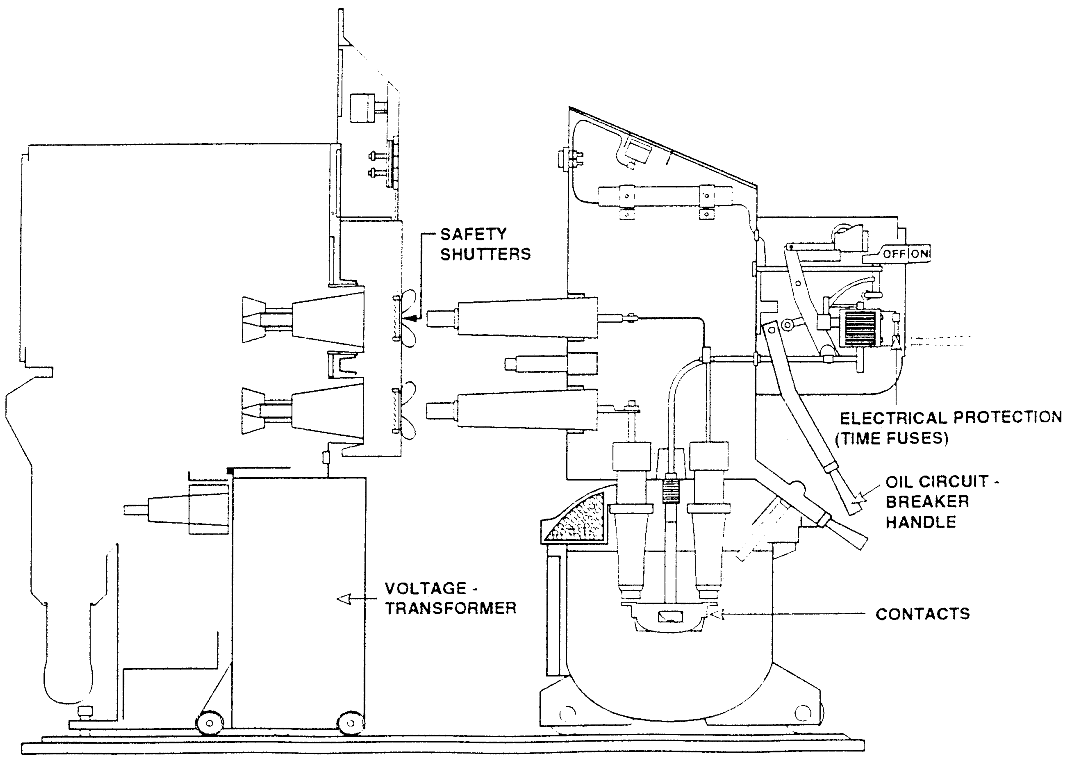


FIGURE 1. OIL-FILLED DISTRIBUTION SWITCHGEAR



FI

GURE 2. CROSS-SECTION THROUGH ANOTHER MAKE OF SWITCHGEAR

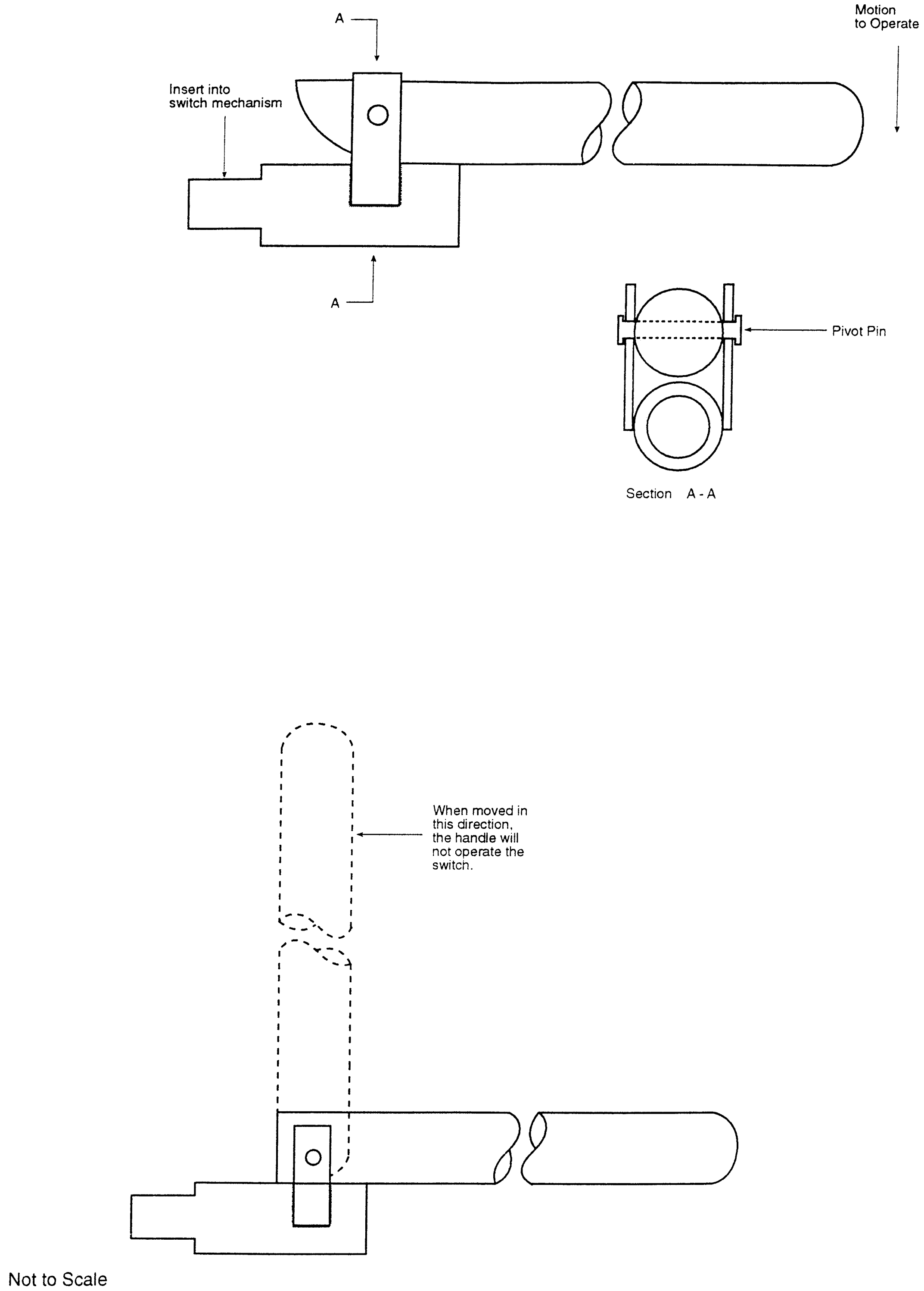


FIGURE 3. TYPICAL ANTI-REFLEX OPERATING HANDLE
(that can be fitted to oil switches and oil-switch fuses)

APPENDIX 3