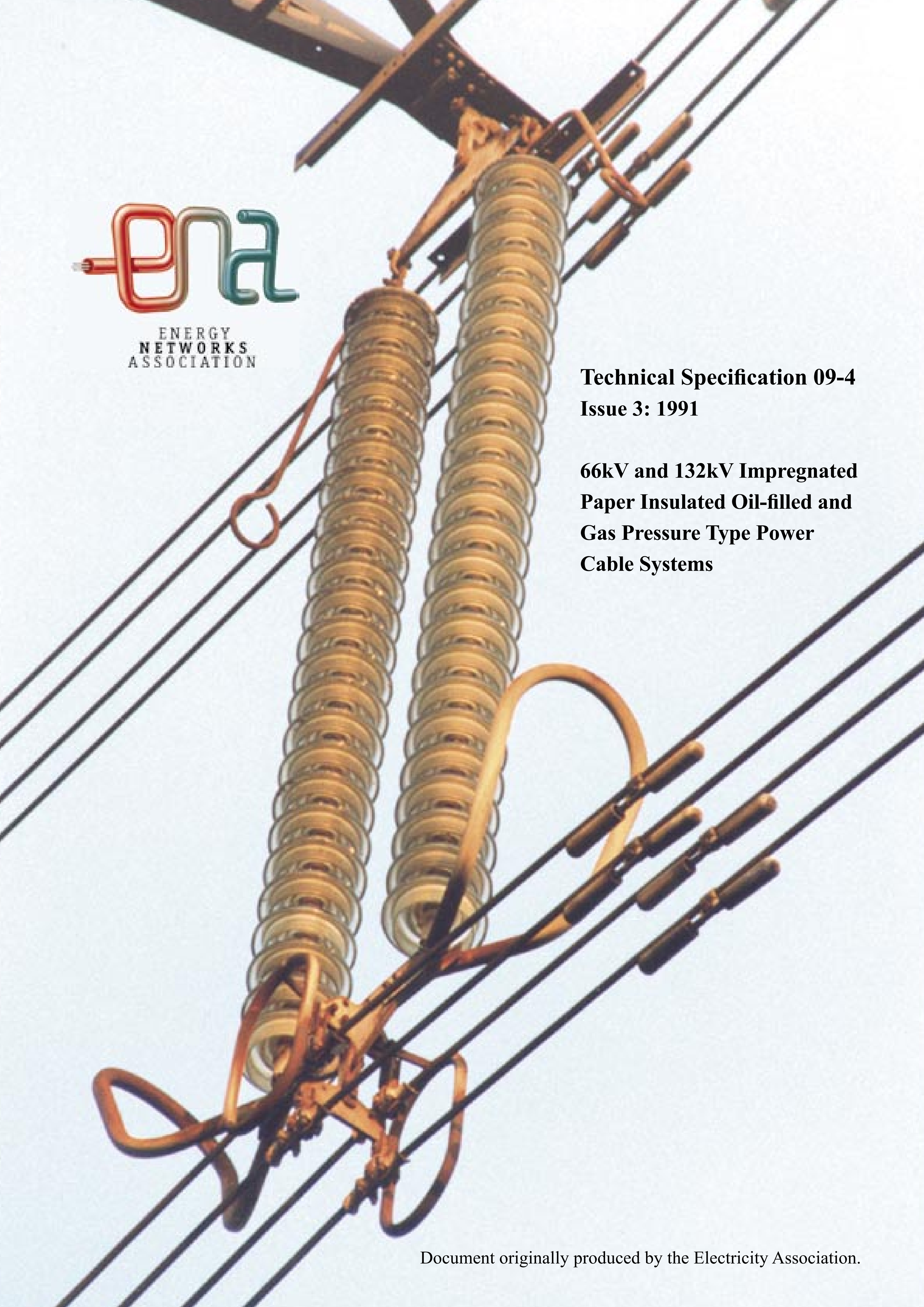

ENERGY NETWORKS ASSOCIATION

Technical Specification 09-4
Issue 3: 1991

66kV and 132kV Impregnated Paper Insulated Oil-filled and Gas Pressure Type Power Cable Systems

Document originally produced by the Electricity Association.

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AMENDMENT 1, 1995

Technical Specification 09-4, Issue 3, 1991

66kV and 132kV impregnated paper insulated oil-filled and gas-pressure type power cable systems

Page 1, FOREWORD Insert new paragraph at end of this section:

"This Specification has been amended to introduce the changes necessary to ensure that it meets the requirements of Clause 11 of the Utilities Supply and Works Contracts Regulations 1992 (S.I. 1992 No. 3279)."

Page 1, REFERENCES

Delete the complete Clause and **insert** the following:

BS 729	Specification for hot dip galvanised coatings on iron and steel articles (Associated Standards: ISO 1459, ISO 1460, ISO 1461)
BS 1780	Specification for bourdon tube pressure and vacuum gauges
BS 2000 Part 132	Methods of test for petroleum and its products Determination of dropping point of lubricating grease (Associated Standards: IP 132, ASTM 566)
BS 3631	Method for determination of ash of paper and board (Associated Standard: ISO 2144)
BS 5045 Part 3	Transportable gas containers Specification for seamless aluminium alloy gas containers above 0.5 litre water capacity and up to 300 bar charged pressure at 15°c
BS 5430	Specification for periodic inspection, testing and maintenance of transportable gas containers (excluding dissolved acetylene containers)
BS 5626	Cellulosic papers for electrical purposes (Associated Standard: IEC 554)
BS 6360	Specification for conductors in insulated cables and cords (Associated Standards: IEC 228 and HD 383)
BS 6746	Specification for PVC insulation and sheath of electric cables (Associated Standards: IEC 811 series and HD 505 series, IEC 502, IEC 227)

BS 6802	Specification for unused insulating liquids based on synthetic aromatic hydrocarbons (Associated Standard: IEC 867)
EA TS 09-2	The installation of 33kV and higher voltage power cables and associated auxiliary cables
EA TS 09-10	Porcelain insulators for 33, 66, 132, 275 and 400kV pressure-assisted cable outdoor sealing ends
EA TS 12-18	Polyester resin/glass fibre protection boxes and protective shrouds for oil-filled and gas-pressure cable accessories
EA TS 50-1	Direct reading pressure gauges (for oil-filled cable systems)
ER C28/4	Type approval tests for impregnated paper insulated gas pressure and oil-filled power cable systems from 33 to 132kV inclusive
ER C39/5	Identification of buried plastic cables
ER C48/1	Type approval tests for anti-corrosion coverings for pressure type cables including pipe line cables
ER C55/4	Insulated sheath power cable systems
ER C61	Installation bending radii of 33kV and higher voltage cables
ER C66/1	Type approval testing procedure: protective boxes for use with buried accessories employed on 33kV - 400kV insulated sheath power cable (and for sheath sectionalizing insulation embodied in such accessories)

Page 3, Clause 4.3 Paper

Paragraph (ii), **delete** BS 698, Appendix L and **insert** BS 5626.

Paragraph (iii), **delete** BS 698, Appendix K and **insert** BS 5626.

Page 4, Clause 4.8 Impregnation

After the first sentence **add** the following "Oil-filled cables shall be impregnated with alkylbenzene complying generally with BS 6802 Class 1 oil,"

Delete "as determined by the Institute of Petroleum testing method IP31/66" and **insert** "shall be measured according to BS 2000 Pt132, and"

Page 14, Clause 9.2 External Insulation

Delete "Engineering Recommendation C68" replace with EA Technical Specification 12-18.

Page 16, Clause 11.1.1

(iii) DC Conductor Resistance Test: **delete** "and BS 6791" and "respectively".

INDEX

66kV AND 132 kV IMPREGNATED PAPER INSULATED OIL-FILLED AND GAS-PRESSURE TYPE POWER CABLE SYSTEMS

FOREWORD

This Specification has been prepared in consultation with the Super Tension Cable Manufacturers and supersedes BEB Specification C4 (1969), Part II.

Issue 3 adds Clause 11.3.10.

1. SCOPE

The Specification, together with the manufacturer's declarations in Schedule D, determines the design, construction, testing and installation of three-core and single-core cables and accessories for operation on 66 kV and 132 kV systems of the following types:

(i) Oil-filled.
(ii) Gas-filled.
(iii) Gas Compression.

Unless otherwise stated all voltages quoted are rms values.

2. REFERENCES

This Specification makes reference to the following documents:

BS 698, 'Papers for Electrical Purposes'.
BS 729, 'Hot Dip Galvanized Coatings on Iron and Steel Articles'.
BS 1780, 'Bourdon Tube Pressure and Vacuum Gauges'.
BS 3631, 'Method for the Determination of Ash of Paper and Board'.
BS 5045, 'Transportable Gas Containers'.
BS 5430, 'Specification for Periodic Inspection, Testing and Maintenance of Transportable Gas Containers (Excluding Dissolved Acetylene Containers)'.
BS 6360, 'Copper Conductors in Insulated Cables and Cords'.
BS 6746, 'PVC Insulation and Sheath of Electrical Cables'.
BS 6791, 'Aluminium Conductors in Insulated Cables'.
Technical Specification 09—2, 'The Installation of 33kV and Higher Voltage Power Cables and Associated Auxiliary Cables'.
Technical Specification 09—10, 'Porcelain Insulators for 33, 66, 132, 275 and 400kV Pressure-assisted Cable Outdoor Sealing Ends'.
Technical Specification 50—1, 'Direct Reading Pressure Gauges (for Oil-filled Cable Systems)'.
Engineering Recommendation C28, 'Type Approval Tests for Impregnated Paper-insulated Gas Pressure and Oil-filled Power Cable Systems from 33kV to 132kV Inclusive'.
Engineering Recommendation C38, '33kV—132kV Inclusive Gas Pressure and Oil-filled Cable Systems, Record of Type Tests and Established Designs'.
Engineering Recommendation C39, 'Identification of Buried Plastic Sheathed Cables'.
Engineering Recommendation C48, 'Type Approval Tests for Anti-corrosion Coverings for Pressure Type Cables Including Pipeline Cables.
Engineering Recommendation C55, 'Insulated Sheath Power Cable Systems'.
Engineering Recommendation C61, 'Installation Bending Radii of 33kV and Higher Voltage Cables'.
Engineering Recommendation C66, 'Type Approval Testing Procedure: Protective Boxes for Use with Buried Accessories Employed on 33kV—400kV Insulated Sheath Power Cable (and for Sheath Sectionalizing Insulation Embodied in such Accessories).
Institute of Petroleum Testing Method — IP31/66.

3. CONDITIONS OF OPERATION

The following are the general conditions under which the cable systems will operate:

(i) Electrical energy is generated three-phase at a nominal frequency of 50Hz.
(ii) The working voltage of any part of the system does not normally exceed 10 per cent above the nominal value.
(iii) The following earthing arrangements will apply:

(a) 66kV System

The neutral point earthed either direct, through a resistance or reactance at one or more points, or through an arc supression coil in which arrangements are made for isolation of the coil within a maximum of 8 hours of the occurrence of a fault, and the maximum time in which the coil is in service per annum, shall not exceed 125 hours.

(b) 132kV System

The neutral point directly earthed.

(iv) The systems are in continuous operation during the varying atmospheric and climatic conditions occurring at all seasons.

4. CONSTRUCTIONAL DETAILS

4.1 Conductors

Conductors shall be stranded from annealed high conductivity copper, or from aluminium of at least 99.5 per cent purity, round or flat wires and/or segments. Conductors of the 'Milliken' type shall be bound with non-ferrous metallic tape(s).

The standard range of metric conductor sizes and the maximum dc resistances are given in Table 1.

Table 1 — Conductor Sizes and Resistances

Nominal Cross-Sectional Area mm^2	Maximum d.c. Resistance $\mu\Omega/m$ at 20°C			
	Copper		Aluminium	
	*Single-Core**	*3-Core*	*Single-Core**	*3-Core*
120	150	153	248	253
150	122	124	202	206
185	97.2	99.1	161	164
240	74.0	75.4	122	125
260	68.4	69.8	113	115
300	59.0	60.1	97.6	100
350	51.4	52.4	85.1	86.8
400	46.1	47.0	76.3	77.8
500	36.6	37.3	60.5	61.7
630	28.3	28.9	46.9	47.8
800	22.1	—	36.7	—
1000	17.6	—	29.1	—
1150	15.6	—	25.8	—
1300	13.8	—	22.8	—
1600	11.2	—	18.6	—
2000	8.97	—	14.9	—
2500	7.17	—	11.9	—

* In the case of single-core cables supplied as part of a 3-core installation, eg, fluted lead sheath cables, the resistance values quoted for 3-core cables shall apply.

The conductor design types (see item 4.2 of Schedule D) are as follows:

Type 1	Uncompacted circular.
Type 2	Uncompacted circular with central spiral duct.
Type 3	Compacted circular.
Type 4	Compacted circular with central oil duct formed from segmental strips and layers of flat strips or rolled wires or died-down circular wires.
Type 5	All segmental strips forming central duct.
Type 6	Milliken with central oil duct.
Type 7	Uncompacted oval.
Type 8	Compacted oval.

4.2 Conductor Screens

Where a conductor screen is employed, it shall consist of metallized paper, carbon paper, metallized carbon paper, or two-ply carbon/insulating paper, either individually or in combination.

4.3 Paper

All paper used for cable insulation shall be uniform in texture, long fibred, and free from imperfectly pulped materials, woody matter, lime spots, metallic particles or other deleterious substances. It shall contain no mechanical wood pulp or esparto. Chemicals used in pulping, bleaching, or other process of manufacture shall be removed. The paper shall be free from loading materials and from gelatine, albumen and resin size and shall comply with the following requirements:

(i) The paper shall be free from chemical impurities, acids, alkalies and salts to the extent that not more than 0.6 per cent by weight is soluble in water when tested in accordance with the method described in 11.2.1(v).
(ii) The conductivity of water extract shall not exceed 1.6 mS/m when tested in accordance with BS 698, Appendix L.
(iii) The pH value of the water shall be not less than 5.5 and not more than 8.0 when tested in accordance with BS 698, Appendix K.
(iv) The ash content of the paper shall not exceed 0.7 per cent oven dry basis when determined by the method given in BS 3631.

The paper shall be applied in the form of tapes laid helically. Successive layers, when applied in the same direction, shall break joint so as to form a reasonably smooth, compact covering of uniform thickness.

4.4 Insulation Thickness

The thickness of insulation, when determined by the method described in 11.2.1(i), shall be not less than the minimum value declared in Schedule D.

4.5 Identification of Cores

All three-core cables shall have the cores identified by the numbers 1, 2 and 3 printed in white on the outer layer(s) of paper. The size of the figures shall be not less than 4.5mm and they shall be sufficiently closely spaced to provide complete and ready identification of all cores in any 25mm of cable. Any dyes used shall not fade unduly, shall be chemically neutral and shall have no injurious effect on the fibres of the paper.

4.6 Core Screens

The screen applied over each individual core shall consist of metallized paper, carbon paper, metallized carbon paper, two-ply carbon paper/insulating paper or non-ferrous metal tape, either individually or in combination and intercalated, where appropriate, with each other or with insulating paper. In order to give added protection to the screen against mechanical damage, a copper woven fabric tape may be applied over the screen where considered necessary by the Manufacturer.

4.7 Laying-up of Three-core Cables

(i) The cores of oil-filled cables and gas-filled cables shall have a right-hand lay. If the cores of gas compression pipeline cables are required by the Engineer to be laid up, these shall have a right-hand lay.

(ii) Gas-filled cables shall, where specified by the Engineer, have the interstices filled with jute. Lead sheathed oil-filled cables shall have an oil duct accommodated in each other interstice and the remaining space filled with paper.
Fillers are not required for aluminium sheathed oil-filled cables.

(iii) The ducts referred to in (ii) shall be of open helical construction formed from crowned aluminium strip.

(iv) A binder of copper woven fabric tape shall be applied overall.

4.8 Impregnation

The insulation shall be suitably dried and impregnated with an impregnating compound.

For oil-filled and gas compression cables the viscosity of the impregnating oil shall not exceed the appropriate value declared in Schedule D.

In the case of gas-filled cables, the drop point of the impregnant as determined by the Institute of Petroleum testing method IP31/66 shall be not less than the value declared in Schedule D.

4.9 Sheath

The pressure-retaining sheath shall consist of a seamless tube of lead alloy or aluminium.

The diaphragm sheath of gas compression cables shall consist of commercially pure lead.

The compositions of the various sheathing metals are listed in Table 2.

Table 2 — Compositions of Sheathing Metals

Material	Composition (Percentage by Weight)		
		Min.	*Max.*
Commercially pure lead	Antimony	—	0.15
	Tin	—	0.1
	Tellurium	—	0.005
	Silver	—	0.005
	Copper	—	0.06
	Bismuth	—	0.05
	Zinc	—	0.002
	(Total Others = 0.01)		
	Lead	99.8	
½C Lead alloy	Cadmium	0.06	0.09
	Tin	0.18	0.22
	Antimony	—	0.005
	Tellurium	—	0.005
	Silver	—	0.005
	Copper	—	0.06
	Bismuth	—	0.05
	Zinc	—	0.002
	(Total Others = 0.01)		
	Lead	The remainder	

Table 2 — Compositions of Sheathing Metals (Cont'd)

Material	Composition (Percentage by Weight)		
		Min.	Max.
E Lead alloy	Tin	0.35	0.45
	Antimony	0.15	0.25
	Tellurium	—	0.005
	Silver	—	0.005
	Copper	—	0.06
	Bismuth	—	0.05
	Zinc	—	0.002
	(Total Others = 0.01)		
	Lead	The remainder	
Aluminium	Copper	—	0.05
	Silicon	—	0.3
	Iron	—	0.4
	Manganese	—	0.05
	Zinc	—	0.10
	Copper + Silicon + Iron + Manganese and Zinc	—	0.5
	Aluminium	99.5	

The minimum thickness of the sheath, when determined by the method described in 11.2.1(ii), shall be not less than the appropriate value declared in Schedule D.

When a fluted sheath is used for single-core oil-filled cable each projection on the inside of the sheath shall have a semi-circular cross-section of nominal radius of 2mm.

4.10 Control Tapes over Diaphragm Sheath (Gas Compression Cables only)

The metallic control tapes applied to the diaphragm sheath shall be as declared in Schedule D.

4.11 Skid Wires (Pipeline Cable only)

When skid wires are used they shall be as declared in Schedule D.

4.12 Metallic Reinforcement and Bedding for Oil-filled and Gas-filled Cables

The metallic reinforcement of pressure-retaining lead alloy sheaths shall be as declared in Schedule D and shall be applied over a tape bedding.

Nothing in the bedding shall be of such a nature as to promote or assist corrosion of the reinforcing tapes or pressure-retaining sheath.

4.13 Pipes for Pipeline Cables

The pipes shall be hot finished, seamless or electric resistance welded mild steel tube having a carbon content not exceeding 0.25 per cent and an ultimate tensile strength of 435 N/mm^2. They shall be supplied in agreed random lengths, and shall be descaled, phosphate treated and painted externally.

The diameter and thickness of the pipe shall be as declared in Schedule D.

4.14 Oversheath

For all cables except pipeline type, the oversheath shall, unless otherwise approved, be extruded black PVC Type TM1 to BS 6746, or polythene. When installed indoors, eg, in buildings or cable tunnels, an extruded PVC oversheath shall be used. The minimum average thickness and minimum thickness at a point when measured in accordance with 11.2.1(iii) shall be not less than the values given in Table 3.

Table 3 — Thickness of Oversheath

Calculated Diameter Under Oversheath		Minimum Average Thickness	Minimum Thickness at a Point
Above	Up to and Including		
mm	*mm*	*mm*	*mm*
25	30	2	1.6
30	35	2.2	1.77
35	40	2.4	1.94
40	45	2.6	2.11
45	50	2.8	2.28
50	62.5	3.0	2.45
62.5	77.5	3.3	2.71
77.5	—	3.6	2.96

The oversheath used to protect an aluminium sheath shall be sealed to the aluminium sheath to prevent the passage of moisture between the two sheaths.

An outer graphite coating shall be applied to serve as an electrode for the voltage test on the oversheath.

For pipeline cables the anti-corrosion protection shall consist of an extruded tube of black polythene having a minimum thickness of 2.5mm. There shall be intimate contact between the steel pipe and the polythene coating. The polythene may be augmented by a similar layer of black PVC when installation conditions so indicate. At positions where the polythene coating is removed, eg, at welded joints, the pipe welds shall be protected with suitable tapes or extruded materials so as to give similar electrical and mechanical protection to that provided by the original coating.

An alternative anti-corrosion protection for pipeline cables installed above ground and where maintenance is possible, eg, in tunnels, shall be a coat of preservative fire-resisting paint.

4.15 Sealing Compound

The compound applied over the reinforcement and/or (aluminium) sheath shall be of such a nature that in the finished cable it does not crack or run at any temperature likely to be attained in transit to the site, during installation or when the cables are in operation. The compound used shall have no deleterious effect on the sheath, reinforcing tape and oversheath. It shall be derived from bitumen and shall be free from distillation products of coal or wood. The compound shall adhere to the aluminium sheath and the oversheath.

4.16 Identification (Embossing of Oversheaths)

All cables, except pipeline cables, having oversheaths shall be embossed with the Manufacturer's name and a legend as given in Table 4.

Table 4 — Embossing of Oversheaths

Voltage	Legend
66 kV	ELECTRIC CABLE 66 000 V
132 kV	ELECTRIC CABLE 132 000 V

(i) The embossed letters and figures shall be raised and consist of upright block characters along two or more lines, approximately equally spaced around the circumference of the cable.
(ii) The maximum size of the characters shall be 13mm and the minimum size of not less than 15 per cent of the nominal or specified external diameter of the cable, or 3mm, whichever is the greater.
(iii) The legend shall comprise the words 'ELECTRIC CABLE' together with the appropriate voltage as given in Table 4. The gap between the end of one set of embossed characters and the beginning of the next shall not exceed 150mm. Any additional information embossed on the sheath (eg, the Manufacturer's name) shall not affect the spacing between repetitions of the legend.

Pipeline cables having an extruded outer layer shall be embossed, the requirements of the latter being as above, except that it shall be a single line and the size of the letters/figure shall be 20mm for all sizes of steel pipe.

4.17 Drumming

Cable with ends suitably sealed shall be supplied on drums.

The drums (incorporating one or more oil tanks and a pressure gauge where necessary) shall be arranged to take a round spindle and be lagged with strong, closely fitting battens so as to prevent damage to the cable.

Any end which is left projecting from the drum shall be protected against damage.

Each drum shall bear a distinguishing number either branded or chiselled on the outside of the flange. Particulars of the cable, ie, voltage, length, conductor size, number of cores, finish, length number, gross and net weights shall be clearly shown on one flange of the drum. The direction for rolling shall be indicated by an arrow. The oil or gas pressure measured at the factory shall be recorded on the drum together with the temperature at which this measurement was made.

5. INSTALLATION PROCEDURE

5.1 General

The installation of all cable systems included in this Specification shall be carried out in accordance with the current edition of Technical Specification 09—2, except as otherwise agreed with the Engineer.

5.2 Oil-filled Cables

Immediately before laying, the oil pressure in the drum tank and the cable shall be checked and compared with the pressure at which the cable left the works, due allowance being made for any difference in ambient temperature.

Any difference in pressure not accounted for by a temperature change shall be investigated and remedial action taken.

The minimum pressure at which oil-filled cables shall be installed is dependent upon the profile of the route. Precautions shall be taken before installation to ensure that, when laying a drum length of cable on a route where the drum is located below the highest point of the route to be covered by the length concerned, the oil pressure, in mbar, at the drum position is at least equal to 87 times the difference in height, in metres, between the drum position and the highest point on the route to be covered by the drum length, plus 350 mbar.

6. OIL CONTROL SYSTEMS FOR OIL-FILLED CABLES

6.1 General

Hydraulically, the installation shall consist of one or more hermetically sealed closed oil sections in each of which pressure shall be separately maintained within specified limits by means of a pressure tank or tanks suitably spaced along the route.

An independent oil system shall be provided for each separate feeder. This principle may be extended to each of three single-core cables when the feeder is so constituted. A minimum surplus of ten litres of oil shall be available in each closed oil section under 'no load' minimum temperature conditions to assist in maintaining pressure under oil leak conditions until remedial action can be taken.

6.2 Pressure/Volume Characteristics of Oil Pressure Tanks

Each pressure tank as shown in Figure 1 contains a number of compressible corrugated metal gas filled cells which shall have a nominal initial pressure at 15°C of 1, 1.5, 2, 2.5 or 3 atmospheres absolute. Pressures greater than these values applied externally to the cell walls are transmitted to the enclosed gas with proportionate reduction in its volume, the change in volume thus produced becoming available for oil accommodation.

Pressure tanks are normally designated by the gas volume of the enclosed cells and the pre-pressure ratios indicated by appropriate indices, eg, 44 litre PP1 or 180 litre PP2. Tanks having a pre-pressure ratio of 1 are conventionally known as 'normal tanks'.

Within the working pressure range the theoretical change in gas volume (ie, the available oil volume accommodation) between any two selected pressures may be obtained from the relationship:

$$\Delta v = \frac{1.013 \times k \times V_o (p_2 - p_1)}{(p_1 + 1.013)(p_2 + 1.013)} \times \frac{273 + T_a}{288}$$

WHERE Δv = oil volume change in litres

V_o = volume of gas at 15°C in tank cells (litres)

k = pre-pressure ratio

p_1 = the smaller of the selected pressures in bar (gauge)

p_2 = the larger of the selected pressures in bar (gauge)

T_a = ambient temperature at time of test in °C

6.3 Oil Pressure Tank Centre Line

For tendering purposes the tank centre line shall be assumed as in Table 5.

Table 5 — Tank Centre Line

Tank Size (Gas Volume) *Litres*	Vertical Distance Tank Centre to Ground Level	
	Installed above Ground Level *m*	Installed below Ground Level *m*
44	0.5	1.25
88	0.5	1.25
135	0.5	1.25
180	0.75	1.5
225	0.75	1.5
300	1.0	1.75

6.4 Sealing End Position

Unless otherwise specified it shall be assumed that where sealing ends are mounted on a sealing end structure their bases will be 3 metres above ground level and where mounted on an overhead line terminal tower, 10 metres above ground level.

6.5 Hydraulic Feed Scheme

Calculations for hydraulic feeding schemes shall be based on the temperature and pressure ranges set out in Tables 6 and 7.

Table 6 — Temperature Ranges

Situation	Underground		In Air – Outdoors	
Temperature	*Minimum °C*	*Maximum °C*	*Minimum °C*	*Maximum °C*
Cable Conductor	5	90	-10	85
Outdoor Sealing Ends	–	–	-10	50*
Tanks	0	25	-10	50*

* 35 if shielded from direct sunlight.

Table 7 — Pressure Ranges

	Minimum Static Pressure		Maximum Static Pressure	Maximum Transient Pressure
	Surplus Oil* Lost	Surplus Oil* Present		
	bar(g)	*bar(g)*	*bar(g)*	*bar(g)*
Cable Joints and Terminals	0.20	0.30	5.25	8.0
Pressure Tanks:				
PP 1 (Normal)	0.20	0.30	3.0	—
PP 1.5	0.70	0.85	4.40	—
PP 2.0	1.20	1.35	5.25	—
PP 2.25	1.45	1.65	5.25	—
PP 2.5	1.70	1.90	5.25	—
PP 3.0	2.20	2.40	5.25	—

* This is the 'Surplus Oil' referred to under 6.1.

It may be necessary to increase the minimum static pressure with surplus oil present to provide a minimum of 10 litres surplus oil or to provide for double alarm system when required.

6.6 Position of Oil Pressure Tanks

The preferred positions for oil pressure tanks are as follows:

(i) At terminations — above ground, mounted on a concrete plinth or on a platform erected on an overhead line terminal tower.

(ii) At intermediate points — above ground, mounted on a concrete plinth, where local conditions permit. Where this is not possible and burial in a concrete tube or brick pit is necessary, all equipment must be of watertight type complying with the requirements of 11.2.2. The connections and any valves or gauges shall be easily accessible.

The housing of oil pressure tanks shall be approved by the Engineer.

6.7 Oil Feed Pipework

Feed pipes shall be of sufficient bore to avoid undue restriction to oil flow under all conditions of load and temperature. When installed underground they shall, apart from short copper connections to joints, be either armoured lead or corrugated aluminium. All pipework laid in the ground shall be protected by an approved covering. Above ground it shall be permissible to use bare copper piping. Details of the pipes and protective coverings shall be as specified in Table 8.

Table 8 — Feed Pipe Construction

Pipe Material	Details of Pipe		Details of Protective Covering
	Bore mm	*Wall mm*	
Corrugated Aluminium	20	1.0	2.5mm wall extruded PVC
Lead	13	3.2	2.0mm wall extruded PVC 1.6mm dia G.S. wires 2.3mm wall extruded PVC
Lead	20	3.2	2.0mm wall extruded PVC 2.0mm dia G.S. wires 2.3mm wall extruded PVC
Copper	13	1.2	Nil
Copper	20	1.6	Nil

The extruded PVC oversheath shall be embossed with the legend 'ELECTRIC CABLE OIL FEED'. The lettering shall be generally in accordance with 4.16.

In the case of insulated sheath systems, oil feed pipes connected to the bases of sealing ends or to joints shall be provided with approved insulating connectors as shown in Figures 7 and 8.

6.8 Leakage Indication

Unless otherwise agreed between the Engineer and the Contractor, each closed oil section shall be instrumented to provide remote warning of leakage by two-stage alarm, initiated in the event of oil pressure falling:

(i) below design minimum operating pressure and,
(ii) to a prescribed emergency minimum pressure.

The facilities provided shall embody the following features:

(a) instrumentation by electric contact type pressure gauges or other approved equipment;
(b) electrical contacts suitable for making or breaking loads up to 30W, 30VA, at voltages up to 240V;

(c) all live parts effectively protected and capable of withstanding a test of 2kV ac for one minute;
(d) the alarm pressure settings protected against unauthorized interference;
(e) visual means of reading oil pressure.

6.9 Pressure Gauges

Pressure gauges shall comply with Technical Specification 50—1, and, when required, shall be housed in a weatherproof cabinet to the design shown in Figure 9. Unless otherwise specified Class 1A or 2A gauges shall be offered.

6.10 Valves

The oil control system shall be designed such that leak location and testing may be carried out without the disconnection of any permanent pipework.

Valves additional to those specified below shall be installed only with the approval of the Engineer:

(i) three valves per tank: one to feed the system, one to fill or boost the tank, and one for the gauge, the latter being of a three-way, two-position type to facilitate testing of the gauge;
(ii) one per manifold where two or more tanks are installed in an inaccessible position and the tanks are feeding to a single position;
(iii) one for each individual oil feed, eg, where a main feed is split to feed three single-core joints or sealing ends.

Typical arrangements of pipework and valves, etc., are shown in Figures 2, 3, 4, 5 and 6. Unless agreed otherwise with the Engineer, valves shall be of an approved design in accordance with Figure 10, and valve manifolds shall be of an approved design in accordance with Figure 11.

7. GAS CONTROL SYSTEMS FOR GAS-FILLED CABLES

7.1 Operation

Gas-filled cable systems shall be so arranged that, should a leak occur, gas is fed automatically and continuously from a reserve supply.

(i) For charging the cable the gas used shall be commercial or oxygen-free specially dried nitrogen. When commercial nitrogen is used the cylinder pressure shall not be allowed to fall below 30 bar(g).
(ii) For the unattended gas supply, oxygen-free specially dried nitrogen only shall be used.

Each three-core or three single-core cable circuit shall be connected separately to the source of supply.

The operating pressures are as follows:

Maximum:	17 bar (g)
Normal:	14 bar (g)
Minimum:	12 bar (g)
Emergency:	9 bar (g)

7.2 Construction

There shall be two types of equipment, Outdoor and Indoor, and the arrangements of pipework, valves, etc, are shown in Figures 12 and 13 respectively.

For indoor installations the equipment shall comprise a cylinder control unit and cable control unit which can be fitted into generally similar cubicles or the frameworks mounted on a wall or floor. The cylinder control unit which reduces the pressure from

170 bar(g) to 28 bar(g) may be installed, together with the cylinder bank, remotely from the cable control unit where the second pressure reduction from 28 bar(g) to 14 bar(g) is made.

One cable control unit shall control one cable circuit but when a number of circuits are being supplied a second cylinder control unit with its bank of cylinders shall be installed to provide a duplicate supply.

For outdoor installations one equipment housed in a weatherproof kiosk shall be provided for each cable circuit. The equipment shall include a 6 cubic metre emergency cylinder of nitrogen, and shall provide for one pressure reduction from 170 bar(g) to 14 bar(g).

Access to all equipment shall be from the front.

7.3 Gas Charging and Discharging

The gas charging and discharging rates shall be as follows:

(i) Charging

Table 9 — Gas Charging Rates

Type of Cable	Single-core and Three-core with Fillers	Three-core without Fillers
Charging pressure initially	1.4 bar(g)	3.5 bar(g)
Maximum differential between charging point and next pressure gauge	1.0 bar	3.5 bar

(ii) Discharging

Discharging on any type of system shall be carried out through a restrictor at the ends of the route for the first 7 bar drop in pressure. After this stage, valves at intermediate positions may be fully opened. Discharging rate at initial supply pressure of 14 bar(g) through designed flow restrictor is 14 litres per minute.

7.4 Gas Feed Pipework

Feed pipes to cables shall be of copper and shall be of sufficient size to avoid undue restriction under all conditions of load and temperature. All pipework laid in the ground shall be protected by an approved covering. Details of the pipe covering shall be as specified in Table 10.

Table 10 — Feed Pipe Construction

Details of Pipe		Details of Protective Covering
Bore mm	*Wall mm*	
4.0	1.0	1.3 mm wall extruded PVC
4.0	1.0	1.3 mm wall extruded PVC 1.2 mm diameter G.S. wires 1.3 mm wall extruded PVC

The extruded PVC oversheaths shall be embossed with the legend 'ELECTRIC CABLE NITROGEN FEED'. The lettering shall be generally in accordance with 4.16.

Gas feed pipes connected to bases of sealing ends and to joints shall be provided with approved insulating connectors as shown in Figure 14. These insulating connectors shall be provided with suitable protection when installed underground.

7.5 Cylinders

The reserve gas supply per charging point per feeder shall consist of at least one cylinder of nitrogen, of 6 cubic metres capacity measured at N.T.P. and shall be fitted with an approved design of stop valve.

7.6 Alarm Pressure Gauges

The alarm pressure gauge shall be of the adjustable electric contact type and embody the following features:

(i) it shall be possible to set accurately the contact to the required pressure value whether the instrument is in operation or not;
(ii) all live parts are to be effectively protected and shall be capable of withstanding a test of 2kV ac for 1 minute;
(iii) the contact adjustment shall be protected against unauthorized interference.

All pressure gauges used shall comply with BS 1780.

7.7 Pressure Regulators

The pressure regulator shall be of the three stage type and shall be capable of passing gas at various rates of flow without undue fluctuations in pressure.

The regulator shall be tested for gas tightness and creep as detailed in 11.1.3(ii).

7.8 Stop Valves

Stop valves shall be of an approved design.

7.9 Safety Valves

The safety valve shall be set to operate at a pressure of not more than 3.5 bar in excess of the maximum pressure of 17 bar(g) and shall re-seat without leak after operation.

7.10 Alarm Circuits

The alarm pressure gauge connected to the reserve gas supply shall be set to give an alarm with a fall in cylinder pressure of 20 bar.

Unless otherwise agreed between the Engineer and Contractor the cable alarm pressure gauges shall be set to operate at the minimum operating pressure stated in 7.1 and shall be capable of being re-set after initial operation to operate at the emergency pressure stated in 7.1.

Unless otherwise specified by the Engineer, the electrical circuits from the alarm gauges shall be taken separately to a warning panel to enable the individual alarms to be annunciated independently.

8. GAS CONTROL SYSTEMS FOR GAS COMPRESSION CABLES

8.1 Operation

The gas compression type cable system operates on a closed principle in that no external gas reservoir is permanently connected. Temperature changes of the gas are accommodated by slight changes in system pressure. Expansion of oil in the termination is accommodated by compensator units which balance the oil pressure within the termination with the gas pressure in the system. All end equipment is to be suitable for outdoor use.

The operating pressures are as follows:

Maximum:	17 bar (g)
Normal:	14 bar (g)
Minimum:	10 bar (g)
Emergency:	10 bar (g)

8.2 Gas Feed Pipework

Feed pipes above ground shall be of copper, having a minimum bore of 6mm and adequate thickness to withstand the test pressure. Pipework laid direct in the ground shall be protected by an approved covering.

Gas and oil feed pipes connected to terminal equipment shall be provided with insulating connectors of an approved design.

8.3 Gas Feeding

The gas to be used shall be commercial nitrogen. The circuit will be charged via a gas control box. Each circuit shall have facilities at both ends for gas feeding.

8.4 Alarm Pressure Gauges

The alarm pressure gauge shall be of the adjustable electric contact type and embody the following features:

(i) it shall be possible to set accurately the contact to the required pressure value whether the instrument is in operation or not;
(ii) all live parts are to be effectively protected and shall be capable of withstanding a test of 2kV ac for 1 minute;
(iii) the contact adjustment shall be protected against unauthorized interference.

All pressure gauges used shall comply with BS 1780.

8.5 Setting Alarms

Unless otherwise agreed by the Engineer, alarm pressure gauges shall be set to operate on a 'falling alarm' at 1 bar below the normal operating pressure and on a 'low alarm' at 2.5 bar below the normal operating pressure of 14 bar(g).

9. JOINTS AND TERMINATIONS

9.1 Testing

The routine and sample tests applicable to joints and terminations are detailed in 11, 'Routine and Sample Tests at Works and Routine Tests on Site'.

9.2 External Insulation

Joint sleeves and bonding leads associated therewith shall be externally insulated in such a manner as to permit application on site of the specified dc high voltage withstand tests to the oversheath of the cable (see 11.3.3.). Where glass-fibre protection boxes are used, these shall comply with Engineering Recommendation C65.

9.3 Outdoor Sealing Ends

All porcelains used for outdoor sealing ends on oil-filled cables shall be in accordance with Technical Specification 09—10.

10. SHEATH BONDING AND EARTHING

The sheath bonding and earthing arrangements employed with all cables and accessories covered by this Specification shall comply with the requirements of Engineering Recommendation C55.

11. ROUTINE AND SAMPLE TESTS AT WORKS AND ROUTINE TESTS ON SITE

The following tests shall be carried out:

Test voltages shall be measured on the high voltage sides of the transformer supplying the test voltage, using either an electrostatic voltmeter or crest voltmeter, or on a suitably calibrated instrument on a lower voltage winding. The frequency of the testing supply shall be between 49Hz and 61Hz unless otherwise stated below. The waveform shall be substantially sinuoidal.

11.1 Routine Tests at Manufacturers' Works

11.1.1 Main Cable

(i) High Voltage Tests

Each drum length of completed cable shall withstand a voltage test between all conductors and the sheath for 15 minutes as specified in Table 11.

Table 11 — Voltages for High Voltage Routine Test at Works

System Voltage *kV*	Test Voltage (kV)		
	Oil-filled	*Gas-filled*	*Gas Compression*
66	86	25	38
132	162	50	76

The test shall be carried out at ambient temperature and at any pressure up to 2 bar(g).

(ii) Dielectric Loss Angle/Voltage Test

Each core of every drum length of completed cable shall be tested to determine the tangent of the dielectric loss angle at normal room temperature at the relevant voltages shown in Tables 12A, 12B, 12C and 12D and the values corrected to 20°C. In the case of oil-filled cables the dielectric loss angle and the loss angle difference shall not exceed the appropriate values given in Tables 12A and 12B, or the declared values, whichever are the lower. In the case of gas-filled or gas compression cables the dielectric loss angle and the loss angle difference shall not exceed the declared values in Schedule D.

Tests shall be carried out at any pressure up to 2 bar(g).

Table 12A — 66kV Oil-filled Cables

Test Voltages kV	Max. Value of Tangent of Dielectric Loss Angle x 10^4	
	Cables not Screened with Carbon Black Paper	Cables Screened with Carbon Black Paper
38	35	35
76	43	50
Maximum difference between 38kV and 76kV	10	18

Table 12B — 132kV Oil-filled Cables

Test Voltage kV	Max. Value of Tangent of Dielectric Loss Angle x 10^4	
	Cables not Screened with Carbon Black Paper	Cables Screened with Carbon Black Paper
76	33	33
152	40	45
Maximum difference between 76kV and 152kV	8	14

Table 12C — Gas-filled Cables

System Voltage kV	Test Voltage kV	
66	9.5	19
132	19	38

Table 12D — Gas Compression Cables

System Voltage kV	Test Voltage kV		
66	9.5	19	38
132	19	38	76

(iii) DC Conductor Resistance Test

The dc conductor resistance of each core of every drum length of completed cable shall be measured and, when corrected to 20°C by means of the temperature corrections factors in BS 6360 and BS 6791 for copper and aluminium respectively, shall be not greater than the figure declared in Schedule D.

(iv) Capacitance Test

The capacitance of each core of every drum length of completed cable shall be determined from 11.1.1(ii); it shall be not greater than the figure declared in Schedule D by more than 8 per cent.

(v) Voltage Test on Oversheath

Each drum length of completed cable shall withstand a voltage for one minute between the reinforcement or aluminium sheath and the external conducting surface, as follows:

Table 13 — Voltages for Routine Voltage Test at Works on Oversheath

Type of Covering	Voltage Test
Extruded PVC or polythene	8kV dc per mm of thickness, with a maximum of 25kV dc

In calculating the test voltages in Table 13, the minimum average thickness of serving as specified in 4.14 shall be used.

11.1.2 Oil-filled Cable Accessories

(i) Cable Joint Sleeves and Sealing End Porcelain Sub-assemblies

Each joint sleeve and sealing end porcelain sub-assembly shall be tested hydraulically for 15 minutes at twice the operating maximum static pressure stated in 6.5. At the conclusion of the test no leakage shall have occurred.

(ii) Pressure Test for Pressure Tanks

Before any outer protection has been applied a hydraulic pressure equal to 1.1 times the maximum static pressure specified in Table 7 shall be applied for a period of 8 hours. No leaks shall be visible.

(iii) Pressure/Volume Test for Pressure Tanks

The pressure/volume relationship shall be checked by carrying out the following:

(a) the tank shall be pumped up to the initial pressure shown in Table 14;
(b) the pressure shall be reduced in two successive steps to the appropriate pressures indicated in Table 14, and the volume of oil drawn off shall be measured at each step;
(c) the volumes so measured shall be corrected to a base temperature of 15°C by multiplying by the factor $\frac{288}{273 + T_a}$ where T_a is the measured ambient temperature at the time of the test in °C;
(d) the total corrected and integrated volumes corresponding to each step shall be compared with the volume obtained from Table 14 by multiplying the appropriate volume factor given therein by the nominal size of the pressure tank in litres.

No allowance shall be made for the pre-pressure ratio because this has already been allowed for in the volume factors. The difference between the measured volume and the theoretical volume obtained from Table 14 shall in no case exceed + 10 per cent or -2½% of the latter.

Table 14 — Pressure/Volume Characteristics

Pre-pressure Ratio	1	1.5	2	2.25	2.5	3
Initial Pressure bar(g)	3.0	4.4	5.25	5.25	5.25	5.25
Step 1						
Pressure bar(g)	2.0	3.25	4.0	4.0	4.0	4.0
Volume factor	0.0837	0.0757	0.0806	0.0907	0.1008	0.1210
Step 2						
Pressure bar(g)	1.25	2.25	3.0	3.0	3.0	3.0
Volume factor	0.195	0.185	0.181	0.204	0.227	0.272

11.1.3 Gas-pressure Cable Accessories

(i) Cable Joint Sleeves and Sealing End Porcelain Sub-assemblies

Each cable joint sleeve and sealing end porcelain sub-assembly shall be tested hydraulically for 15 minutes at twice the maximum pressure as given in 7.1 or 8.1. It shall then be charged with air or nitrogen gas to the operating maximum pressure, which shall be maintained for not less than 24 hours at ambient temperature. In neither case shall there be any leakage as indicated by gauge.

(ii) Gas Regulators

Each regulator shall be tested at the full input pressure for which it is designed. Pressure gauges shall be fitted on the high and low pressure sides of the regulator. After a period of 72 hours, with the regulator isolated from the high pressure supply, there shall be no variation in the initial readings other than that caused by ambient temperature.

(iii) Safety Valves

Each safety valve shall be operated ten times with nitrogen gas pressure and each time it shall show relief pressure greater than the maximum operating pressure stated in 7.1 or 8.1 but not more than 3.5 bar above this value. The safety valve shall re-seat without leakage at a pressure not less than the normal operating pressure stated in 7.1 or 8.1.

(iv) Pressure Gauges

All pressure gauges shall be tested in accordance with BS 1780.

(v) Alarm Pressure Gauges

The alarm operating pressures of the electric contact gauge shall be checked and shall not vary more than ± 5 per cent from the nominal settings.

(vi) Cylinders

All cylinders shall be tested in accordance with BS 5045 and BS 5430.

(vii) Membrane Fittings (Gas Compression Cable Only)

Fluted copper sleeves of joints and bellows of compensator units shall be filled with gas to a pressure of 1 bar(g) and immersed for 15 minutes in water at room temperature, then removed and immersed for a further 15 minutes in water at 90°C minimum, again removed and finally immersed for 30 minutes in water at room temperature. In no case shall there be any leakage of gas as indicated by gas bubbles in the water.

(viii) Compensator Units (Gas Compression Cable Only)

The casing of each compensator unit shall be filled with gas to a pressure of 28 bar(g) and then subjected to the immersion procedure described in (vii). If an alarm is fitted the electrical circuit shall be subjected to a 500 volt 'Megger' test.

(ix) Steel Pipes (Gas Compression Cable Only)

All steel pipes shall be tested hydraulically at twice the maximum operating pressure of 17 bar(g).

11.2 Sample Tests at Manufacturers' Works

11.2.1 Main Cable

(i) Thickness of Insulation

Measurement of the insulation thickness shall be made on a representative sample of each drum length of cable. The sample shall be not less than 300mm in length and taken not less than 300mm from the end of a factory length.

The insulation thickness shall be derived by taking half the difference of diameter tape measurements over the (screened) conductor and over the insulation after the insulation screen has been removed.

(ii) Thickness of Sheath

Measurement of sheath thickness shall be made on a representative sample of each drum length of cable.

The sample to be measured shall be taken not less than 300mm from the end of a factory length and shall consist of a ring carefully cut from the cable.

The thickness of the sheath shall be determined at a sufficient number of points around the circumference of the ring sample to ensure that the minimum thickness is measured.

The measurements shall be made with a micrometer having either one flat nose and a ball nose or one flat nose and flat rectangular nose 0.8mm wide and 2.4mm long. The ball nose or the flat rectangular nose shall be applied to the inside of the ring.

(iii) Thickness of Extruded Oversheath

Measurement of the thickness of the extruded oversheath shall be made on a representative sample of each drum length of cable. The sample shall be taken not less than 300mm from the end of the factory length.

The measurement shall be made either by micrometer or by an optical method in which the error of determination shall not exceed 0.03mm. In cases of dispute the optical method shall be used.

The measurements shall be made at six approximately equally spaced points around the periphery of the sample, and care shall be taken to ensure that the minimum thickness is measured. The smallest measurement and the average of the measurements shall be recorded.

(iv) Bending Test

The bending test in 11.2.1(iv)(d) shall be carried out on not more than 2 per cent of the drum lengths of every contract involving 50 or more drums of any one size and type of cable. For smaller contracts one bending test shall be taken on any size and type of cable if such bending test is specified.

(a) Test Installation

The cable sample shall have a length at least 5 times that of the test cylinder diameter.

(b) Test Requirements

The cable sample shall undergo at ambient temperature 3 bending cycles, after which the middle 1m shall be examined visually.

(c) Approval Performance

The bending performance of the cable shall be satisfactory when visual examination of the cable sample complies with the following:

(1) the oversheath shall be free from cracks and significant distortion;
(2) reinforcing tapes shall be free from cracks or tears and not noticeably displaced;
(3) the metallic sheath shall be free from cracks and splits;
(4) smooth sheath: the sheath shall be free from undue corrugation;
(5) corrugated sheath: the corrugations shall be substantially uniform and there shall be no undue local disturbance of the corrugations.

The insulation shall be examined for tears and gaps and the following requirements met:

(A) the number of insulating paper tapes and screening tapes in contact with the insulation which, on the central 300mm long piece of cable cut from the above 1m sample, contain longitudinal or edge tears exceeding 7.5mm shall be not more than two per core and,
(B) at no point throughout the insulation shall there be more than either two coincidental tears of any length in adjacent insulating papers except that the permissible number of said gaps is three if these coincide with the reversal of direction of lay. Carbon black papers are excluded from the requirements given above.

(d) Detailed Test Method

The test cylinder diameter shall be not greater than the value specified in Table 15.

Table 15 — Test Cylinder Diameter

Type of Cable	Diameter of Test Cylinder
Single-core cables with lead, lead alloy or corrugated aluminium sheaths	25 (D + d)
Three-core cables with lead, lead alloy or corrugated aluminium sheaths	20 (D + d)
All cables with smooth aluminium sheaths	36 (D + d)

Where D = measured diameter over pressure retaining sheath or over the crest of the corrugations of corrugated aluminium sheathed cable.

d = measured diameter of the conductor, or, if a non-circular, $\frac{1}{3.14}$ times the measured conductor perimeter.

The test cylinder shall be mounted on a horizontal axle about which it is able to rotate. The cable sample shall be laid out straight and level and one cable end secured to the test cylinder through a swivel connection. A reference line shall be rotated steadily so that all the cable is wound on in a close wrapped coil, the cable being prevented from twisting during the operation. The cylinder shall then be rotated in the opposite direction so that the cable is unwound and again laid out straight and level. The cable shall then be rotated through 180° around its longitudinal axis and the winding and unwinding processes repeated. Alternatively the bending of the cable in reverse directions may be achieved by winding the cable alternately 'under' and 'over' the cylinder. This complete bending cycle shall be carried out 3 times.

The middle 1m of the cable sample shall then be removed and stripped for visual examination.

(v) Quality of Insulation Paper
When requested, the amount of water-soluble impurities present in the insulating paper before impregnation shall be determined as follows.

Approximately 10g of paper shall be dried in an air oven at a temperature of 103—105°C for 1 hour and weighed. It shall then be cut into approximately 13mm squares and extracted in a porcelain dish or glass beaker on a boiling water bath with 0.2 litre distilled water for 15 minutes. The extract shall be decanted through a filter paper and the process shall be repeated until four filtrations have been made, the same filter paper being used in each case. The total extract shall be evaporated to dryness on a water bath and finally dried to constant weight at a temperature of 103—105°C. A blank determination shall then be carried out and any weight obtained in this shall be subtracted from the weight obtained in the test.

The value obtained shall be calculated as a percentage of the dry paper weight and shall comply with 4.3(i).

11.2.2 Accessories

11.2.2.1 Test of Watertightness of Enclosures

When required, it shall be demonstrated that the watertight fittings and accessories shall withstand without damage or leakage complete immersion in water to a depth of not less than one metre at the highest point of the enclosure, or subjection to an external pressure of 100mbar for a period of one hour.

The temperature of the apparatus during the test shall not exceed the temperature of the water in which it is immersed. The water used for the test shall be tap water at ordinary tap water temperature unless otherwise specified at the time of ordering.

Material used for the enclosure, including gaskets, if any, shall be unaffected by water.

11.3 Routine Tests on Site

11.3.1 High Voltage Test

Each complete circuit shall be tested for 15 minutes at nominal pressure with a dc voltage of the value shown in Table 16, applied between the conductor and sheath.

For cross-bonded systems the sheaths of each section shall be temporarily bonded together at each joint position and at each termination for this test.

Table 16 — Site High Voltage Test

Sysytem Voltage kV	Test Voltage kV (DC)	
	Oil-filled	Gas-filled or Gas Pressure
66	170	132
132	305	264

11.3.2 DC Conductor Resistance Test

The dc conductor resistance of each completed circuit shall be measured and recorded.

11.3.3 Voltage Test on Oversheath and Other Sheath-Insulating or Sheath-Sectionalizing Provisions

(i) Systems in General

Subject to 11.3.3(ii), after completion, all the sheath-insulating provisions, including external joint insulation, terminal base insulation, sheath-sectionalizing insulation (if any), the insulation of bonding leads and link boxes, and insulating sections in gas or oil feed pipes etc., shall be subjected to a voltage test in accordance with the requirements of Engineering Recommendation C55.

(ii) Specially Bonded Systems

After the temporary disconnection of Sheath Voltage Limiters* hereinafter referred to as SVLs (each comprising three star-connected non-linear resistors) which otherwise would be damaged or destroyed by the test voltage, such systems shall meet the requirements of 11.3.3(i)

11.3.4 Sheath Voltage Limiters (SVLs)

The SVLs shall be tested in accordance with the requirements of Engineering Recommendation C55.
The reconnection of the SVLs shall be witnessed by an authorized representative of the Engineer.

11.3.5 Verification of Specially Bonded Systems

In addition to the test specified below any tests required by Engineering Recommendation C55 shall also be carried out.

(i) Cross-bonded Systems

The Contractor shall demonstrate, after the installation of a cross-bonded system is complete, that the cross-bonded connections are correct by applying a three-phase current of approximately 100A to the phase conductors and measuring the resulting sheath currents and voltages to earth at the cross-bonding positions.

* Formerly termed Cable-Covering Protection Units (CCPU)

Having regard to the facts that, ideally, sheath currents would be non-existent and that, in practice, they often are extremely small, immediately after completing measurements on the first cross-bonded section the Contractor shall temporarily so re-disposition bonding links as to simulate inadvertent erroneous bonding and then demonstrate the ability of the sheath current measuring equipment clearly to indicate the presence of any substantial sheath current. (Dependent on cable design, system layout, etc, the sheath current under such artificial conditions will generally be about one order of magnitude less than the conductor current.) Following this demonstration, reinstatement of the normal bonding connections shall be officially witnessed, and link contact resistances tested in accordance with 11.3.6.

When appropriately scaled-up to correspond to the declared current rating of the cable, none of the sheath currents shall exceed a value which would affect the declared current rating of the cable by more than 3 per cent, and the measured voltage between any sheath and earth, when corrected for the declared current rating of the cable, shall not exceed the maximum stated in Engineering Recommendation C55.

In the exceptional case where the route necessitates deviation from these design limits, the values of the measured sheath current and voltage shall be submitted to the Engineer together with explanatory reasons for the deviations, for consideration.

The continuity shall be checked by sheath circuit resistance measurements.

(ii) Single Point Bonded Systems

Because the sheath bonding arrangements on systems of this class are very simple, demonstrations of the type described in 11.3.5(i) are not normally required, and are to be regarded as outside the scope of the present Specification.

11.3.6 Link Contact Resistance Test

A contact resistance test across all link contacts in each link box shall be carried out, and comply with, the requirements of Engineering Recommendation C55.

11.3.7 Oil Flow Test (For Oil-filled Cable Systems Only)

After laying and jointing, each oil section shall be subjected to an oil flow test to ensure that no abnormal restriction is present in the cable duct, joints, etc. This is done by measuring the drop in pressure in the section under measured oil flow.

The theoretical pressure drop which should be obtained, is given by:

$$P = QbL$$

Where P = The total pressure difference on the section (allowing for route profile) (bar)
Q = rate of flow (litres per second)
L = the length of cable section (m)
b = coefficient of friction of oil in the cable duct

For circular ducts or pipes:

$$b = \frac{25.5\eta}{r^4}$$

Where η = viscosity of oil (centipoise) at the test temperature
r = internal radius (mm) of the pipe or duct measured inside the spiral

(For three-core cable with ducts in the interstices the co-efficient 'b' is one third of that resulting from the above formula.)

The theoretical oil flow for a given pressure in a single-core cable is thus given by:

$$Q = \frac{P\,r^4}{25.5\eta L} \quad \text{litres per second}$$

In comparing the flows obtained on finished cable installations it should be remembered that joints are included and the theoretical figures can only serve as a guide. The test serves to show that no undue obstructions are present in the system.

11.3.8 Impregnation Coefficient (For Oil-filled Cable Systems Only)

After completion of the laying and jointing, each oil section shall be tested for efficiency of impregnation as follows:

A measured quantity of oil shall be drawn from the cable system (with feed tanks shut off), and the consequent drop in pressure noted.

The impregnation coefficient (K) defined as follows, shall be not greater than 4.5×10^{-4}

$$K = \frac{dV}{V} \times \frac{1}{dP}$$

Where dV = the volume of oil withdrawn (litres)
dP = drop in pressure (bar)
V = the volume of oil in installation (litres)

11.3.9 Pneumatic Test on Gas-Pressure Cables

The gas pressure on each completed circuit, including all associated accessories, shall be raised to 17 bar(g) for 7 days. The cables shall then be maintained at normal gas pressure for a further 7 days. Throughout the latter 7 days, there shall be no leakage of gas.

11.3.10 Positive and Zero Sequence Impedances

Measurements should be made and recorded on all single core 132kV oil-filled cable circuits where the route length exceeds 400m, to determine positive and zero sequence impedances. This will necessitate three-phase and single-phase current injection tests, preferably in the range 25—100A, together with measurements of current, voltage and power or alternatively current, voltage and phase angle.

All sheath bonding and earthing connections shall be as for normal circuit operation.

Where there is more than one cable per phase, the conductors and sheaths shall be connected as for normal operations and the tests detailed below carried out on the total circuit.

Particular care should be taken to ensure that contact resistances are small compared with the resistance of the conductors. At the time of the tests, an estimate should be made of cable temperature so that allowance can be made for the temperature dependence of resistance.

For measurements of positive sequence impedance, it is preferable that the cable conductors should be bonded together and earthed at the end remote from the test. A three-phase star connected supply with the star point unearthed is required for this test. If the supply is not so isolated, the three cable conductors at the remote end should be bonded together to form an unearthed star point.

For measurements of zero sequence impedance, it is necessary that the conductors are shorted together at the test end. At the remote end, the conductors shall be bonded together and to the cable sheaths and to earth.

A single-phase supply is applied between the shorted conductors and the earthed cable sheaths. One phase of the transformer used for the measurement of positive sequence impedance may be used for this purpose.

(i) Positive Sequence Impedance (Z_1)

Three-phase currents should be injected, equalizing the magnitudes of the currents so far as possible. Measurements of current, voltage and either power or phase angle should be made on each of the single core cables. From these measurements, the following are calculated:

Using Wattmeter

$$Z_p = \frac{V_p}{I_p}$$

$$R_p = \frac{W_p}{I_p^2}$$

$$X_p = \sqrt{Z_p^2 - R_p^2}$$

Using Phase Angle Meter

$$Z_p = \frac{V_p}{I_p}$$

$$R_p = \frac{V_p}{I_p} \cos \phi$$

$$X_p = \frac{V_p}{I_p} \sin \phi$$

and

$$Z_1 = \frac{\Sigma Z_p}{3} \text{ ohms/phase}$$

$$R_1 = \frac{\Sigma R_p}{3} \text{ ohms/phase}$$

$$X_1 = \frac{\Sigma X_p}{3} \text{ ohms/phase}$$

Where V_p = measured phase voltage (volts)
I_p = measured phase current (amps)
W_p = measured phase power (watts)
ϕ = measured phase angle (degrees)

(ii) Zero Sequence Impedance (Z_o)

Single-phase currents should be injected into the cables connected in parallel, with the test current returning through the sheaths and earth.

Measurements of current, voltage and either power or phase angle shall be made, from which the following are calculated:

Using Wattmeter

$$Z_o = \frac{3V}{I}$$

$$R_o = \frac{3W}{I^2}$$

$$X_o = \sqrt{Z_o^2 - R_o^2}$$

Using Phase Angle Meter

$$Z_o = \frac{3V}{I}$$

$$R_o = \frac{3V}{I} \cos \phi$$

$$X_o = \frac{3V}{I} \sin \phi$$

giving Z_o R_o X_o in ohms/phase

Where V = measured conductor to earth voltage (volts)
I = measured total current (amps)
W = measured total power (watts)
ϕ = measured phase angle (degrees)

SCHEDULE D (to be completed by the Manufacturer)
General Particulars
66 and 132 kV Oil-filled and Gas-pressure Cables

Item		
1	Voltage between phases of three-phase circuit	kV
2	Number of cores	
3	Nominal cross-sectional area of conductor(s)	mm^2
4	Conductor details:	
	4.1 Material	
	4.2 Design type *	
	4.3 Overall dimensions	mm
5	Oil ducts:	
	5.1 Material	
	5.2 Nominal internal diameter	mm
6	Conductor screen:	
	6.1 Material	
	6.2 Diameter over conductor screen	mm
7	Maximum dielectric stress at the conductor screen (assumed smooth)	MV/m
8	Minimum radial thickness of insulation between conductor screen and core screen	mm
9	Insulating paper:	
	9.1 Type	
	9.2 Nominal thickness	µm
10	Core screen:	
	10.1 Material	
	10.2 Nominal thickness	µm
11	Impregnant:	
	11.1 Type	
	11.2 Viscosity at:	
	20°C	cP
	50°C	cP
	90°C	cP
	11.3 Drop Point (Gas-filled cable only)	°C
12	Binder over cores:	
	12.1 Material	
	12.2 Nominal thickness	mm

* Conductor Design Type numbers as given in 4.1 of this Specification.

Item		
13	Diaphragm sheath:	
	13.1 Composition	
	13.2 Minimum radial thickness	mm
	Pressure-retaining sheath:	
	13.3 Composition	
	13.4 Minimum radial thickness	mm
14	Number and nominal dimensions of flutes (fluted sheaths only)	-/mm
15	Nominal diameter over sheath	mm
16	Control tapes over diaphragm sheath:	
	16.1 Material	
	16.2 Nominal thickness	mm
	16.3 Nominal width	mm
	16.4 Number of tapes per layer	
	16.5 Number of layers	
17	Bedding under reinforcement:	
	17.1 Material	
	17.2 Nominal thickness	mm
18	Reinforcement:	
	18.1 Material	
	18.2 0.10% proof stress	N/mm^2
	18.3 Nominal thickness	mm
	18.4 Nominal width	mm
	18.5 Number of tapes per layer	
	18.6 Number of layers	
	18.7 Maximum working stress	N/mm^2
19	Protective outer covering:	
	19.1 Material	
	19.2 Minimum average thickness	mm
20	Nominal overall diameter of completed cable	mm
21	Skid wires (for pipeline cables):	
	21.1 Material	
	21.2 Dimensions	mm
	21.3 Number	
	21.4 Nominal lay length	mm

Item		
22	Nominal weight per metre of completed cable (excluding pipe for pipeline cable)	kg
23	Pipe for pipeline cable:	
	23.1 Overall diameter	mm
	23.2 Thickness	mm
	23.3 Nominal weight per metre	kg
24	Minimum radius of bend round which cable can be laid:	
	24.1 Laid direct or in air	m
	24.2 In ducts	m
	24.3 With cables placed in position adjacent to joints and terminals	
	(i) Without former	m
	(ii) With former	m
25	Nominal internal diameter of pipes or ducts for self-contained cable	mm
26	Maximum dc resistance of conductor per m of cable at 20°C	μΩ
27	Maximum continuous conductor temperature	°C
28	Maximum ac resistance of conductor per m of cable at maximum continuous conductor temperature	μΩ
29	Equivalent star reactance per m of three-phase circuit at 50 Hz	μΩ
30	Nominal electrostatic capacitance per core m of cable	pF
31	Maximum charging current per conductor per m of cable at nominal voltage	mA
32	Current carrying capacity (see also Item 42)	A
33	Maximum value of tangent of dielectric loss angle of cable when when laid direct in the ground at nominal voltage, normal frequency and operating oil/gas pressure, at a conductor temperature of:	
	20°C	
	Maximum continuous conductor temperature	
34	Maximum dielectric loss of cable per m of three-phase circuit when laid direct in the ground at nominal voltage, normal frequency and operating oil/gas pressure at maximum conductor temperature	W

Item		
35	Maximum value of tangent of dielectric loss angle of cable at normal frequency and at following oil/gas pressure, at a conductor temperature of 20°C	
	35.1 At factory test oil pressure (as specified in 11.1.1) Nominal voltage 200 per cent nominal voltage	
	35.2 At factory test gas pressure (as specified in 11.1.1) 25 per cent nominal voltage 50 per cent nominal voltage	
36	Maximum change in tangent of dielectric loss angle between nominal voltage and 200% nominal voltage at 20°C	
37	Sheath loss (including reinforcement) of cable per m of three-phase circuit at nominal voltage, normal frequency and operating oil/gas pressure, at current rating given in Item 32	W
38	Conductor short circuit current carrying capacity for 1 second, cable loaded as in Item 32 before short circuit, and final conductor temperature 160°C	kA
39	Oil feed pipes:	
	39.1 Material	
	39.2 Dimensions	mm
	39.3 Protective covering	
40	Gas feed pipes:	
	40.1 Material	
	40.2 Dimensions	mm
	40.3 Protective coverings	
41	Oil content per metre	litres
42	Installation and operating conditions on which current carrying capacity stated in Item 32 is based	

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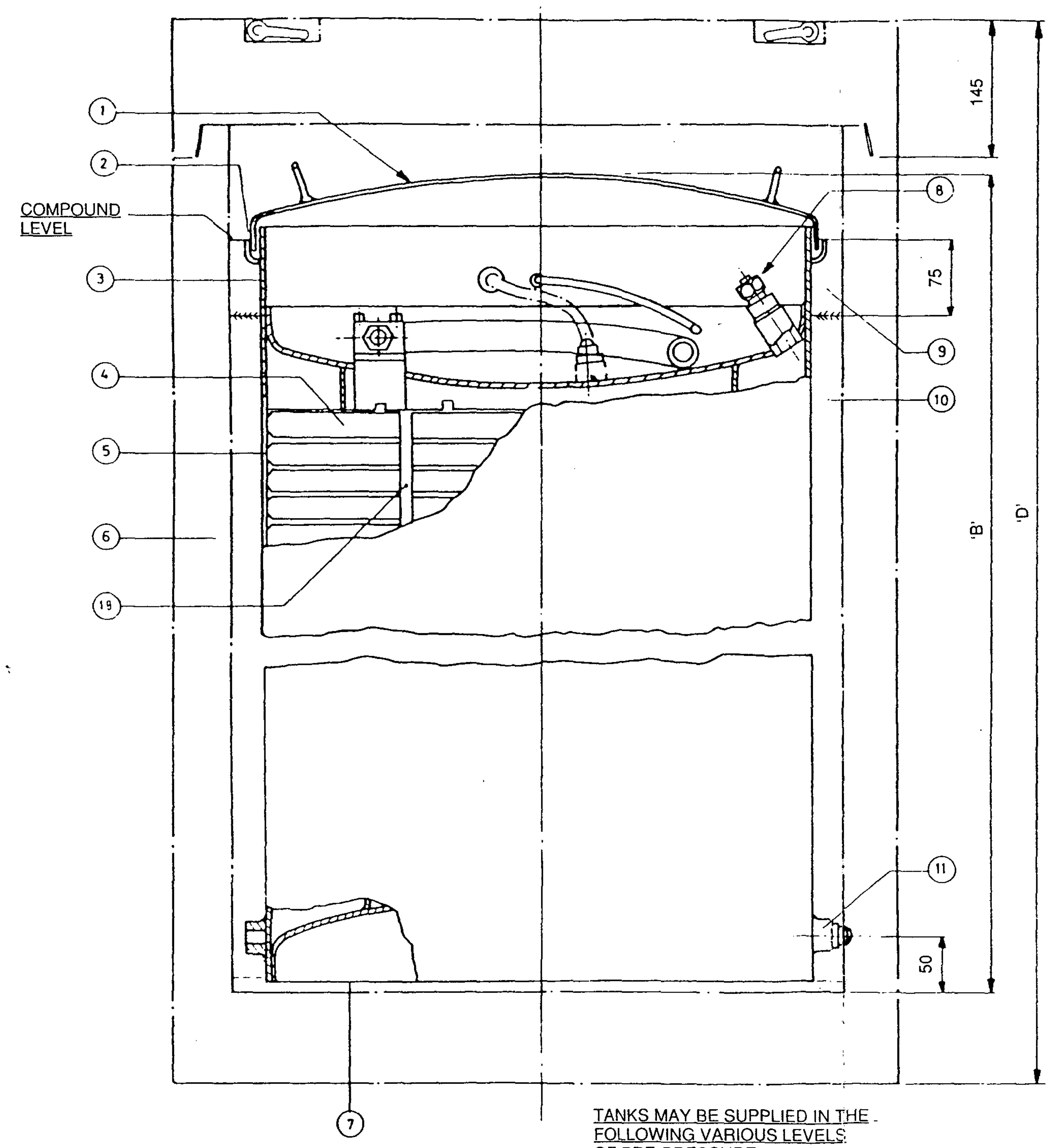

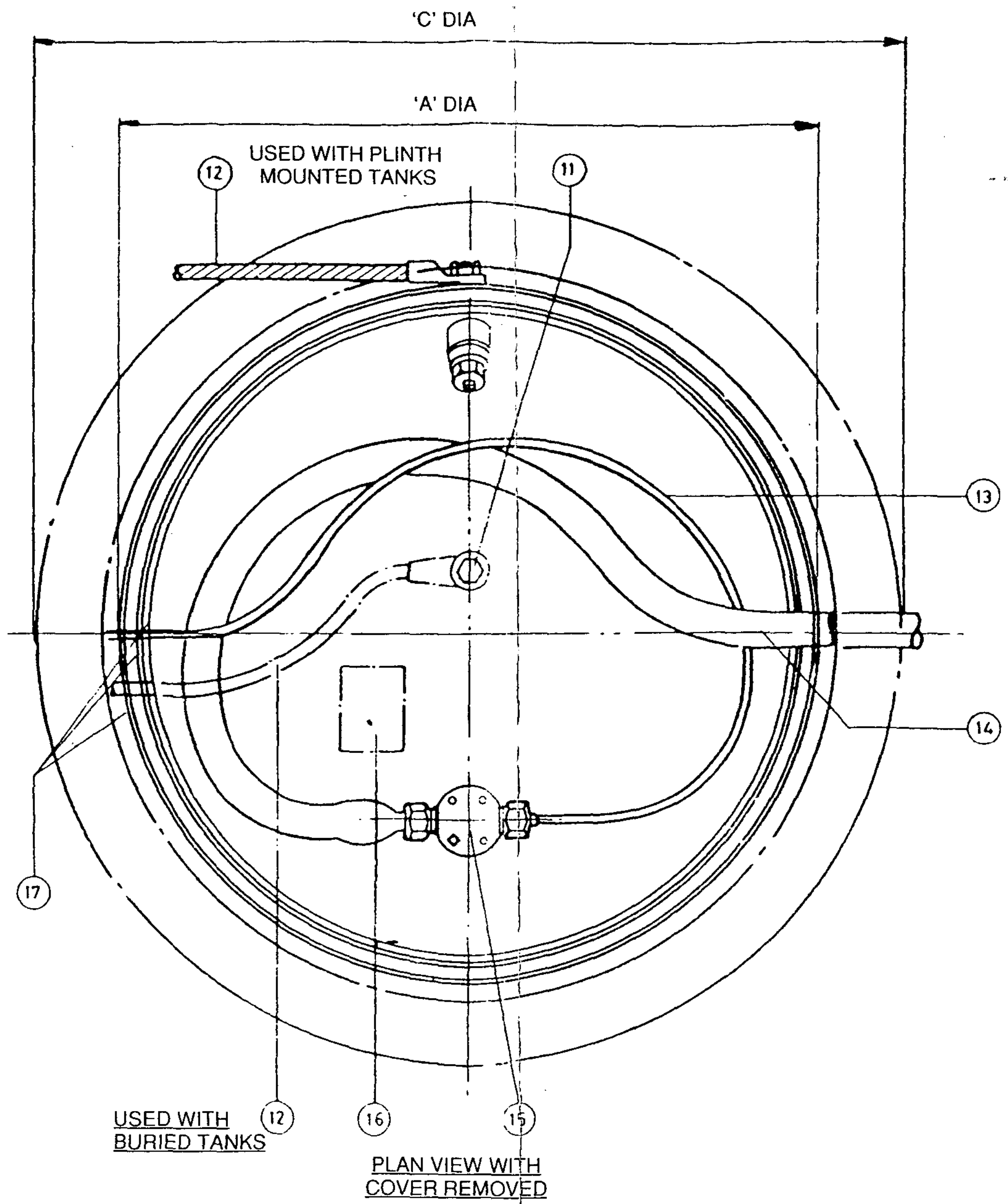

TANKS MAY BE SUPPLIED IN THE FOLLOWING VARIOUS LEVELS OF PRE-PRESSURE:-

1 atmos (NORMAL)
1.5 "
2.0 "
2.25 "
2.5 "
3.0 "

MAX. WEIGHT OF TANK & OIL (excluding concrete shell)	kg		160	250	290	340	380	510
MAX. HEIGHT OF CONCRETE SHELL & LID	mm	'D'	940	1250	1500	1750	2015	2475
MAX. DIA. OF CONCRETE SHELL	mm	'C'	710	710	710	710	710	710
MAX. HEIGHT OF TANK	mm	'B'	640	970	1230	1500	1730	2200
MAX. OVERALL DIA. OF TANK	mm	'A'	565	565	565	565	565	565
INITIAL ELEMENT VOLUME	Litres		44	88	135	180	225	300

DESCRIPTION	ITEM
M.S. STRAP (WHEN APPLICABLE)	18
RUBBER BUSHES	17
LABEL (BURIED TANKS ONLY)	16
BRASS TEE VALVE	15
MAIN OIL CONNECTION	14
BRANCH OIL CONNECTION	13
EARTH LEAD	12
EARTH CONNECTION	11
BITUMEN BASE COMPOUND	10
OIL RESISTANT COMPOUND	9
BRASS FILLING VALVE (WITH MILD STEEL INLET TUBE)	8
SUPPORTS	7
SPUN CONCRETE SHELL & LID (BURIED TANKS ONLY)	6
MILD STEEL CASING & DISHED ENDS ASSY	5
ELEMENT ASSY	4
LABEL (PLINTH MOUNTED TANKS ONLY)	3
SEALING COMPOUND	2
MILD STEEL COVER WITH HANDLES	1

Fig 1 – Arrangement of Oil Pressure Tank for Normal and Pre-pressured Types

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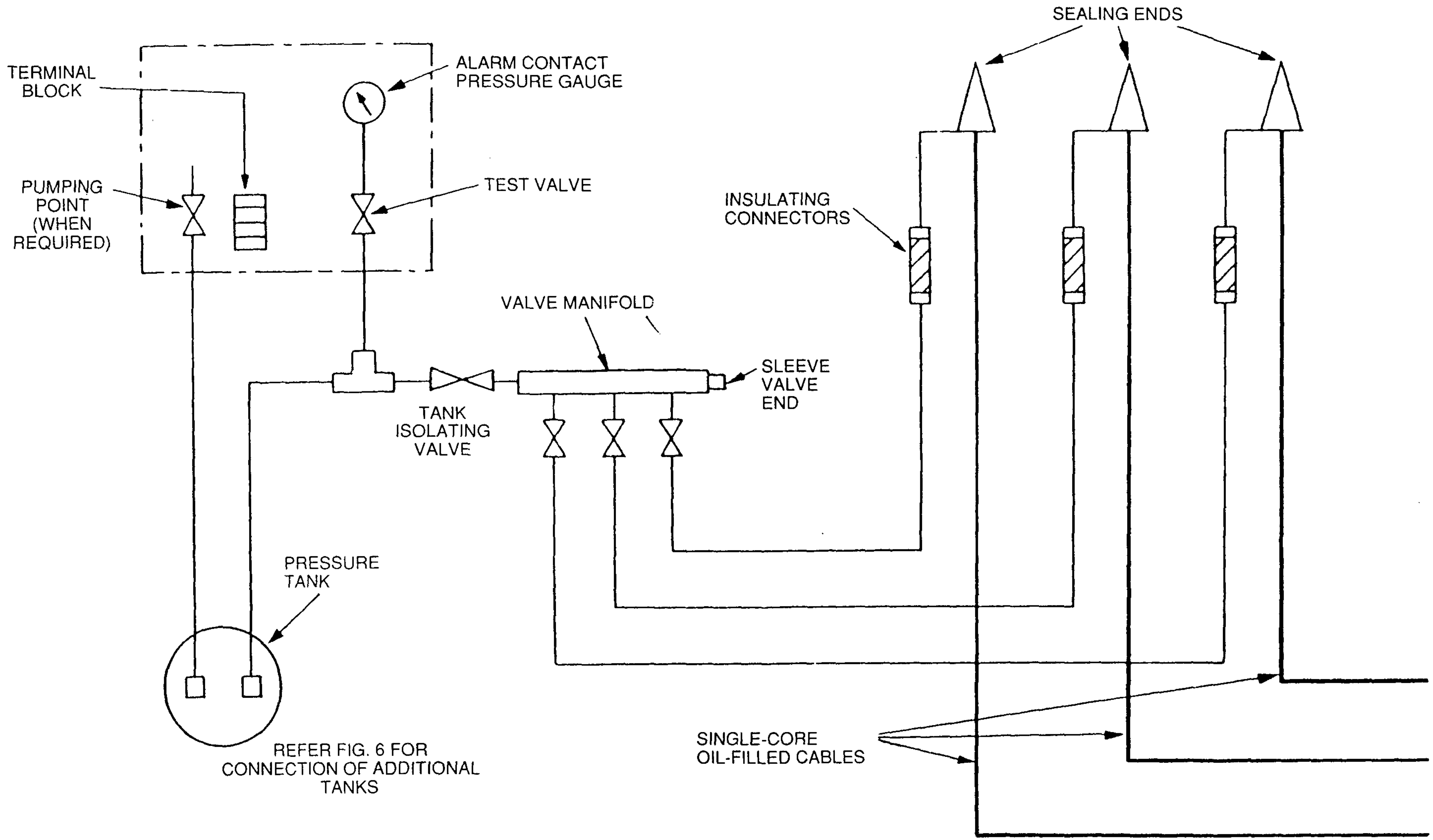

Fig 2 – Arrangement of Oil Equipment at Terminations (Single-core Oil-filled Cable)

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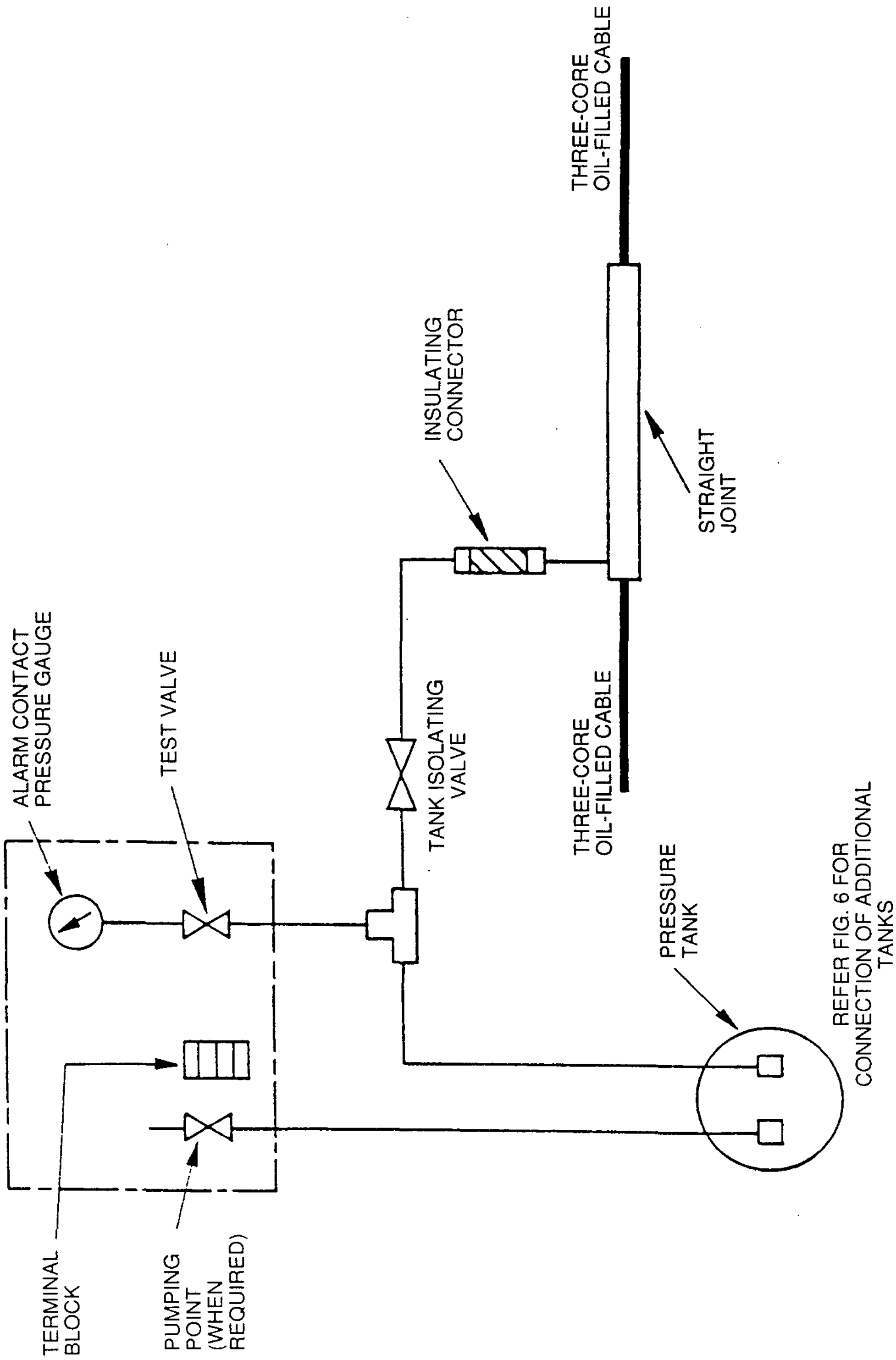

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Fig 3 – Arrangement of Oil Equipment at Three-core Straight Joints (Oil-filled Cable)

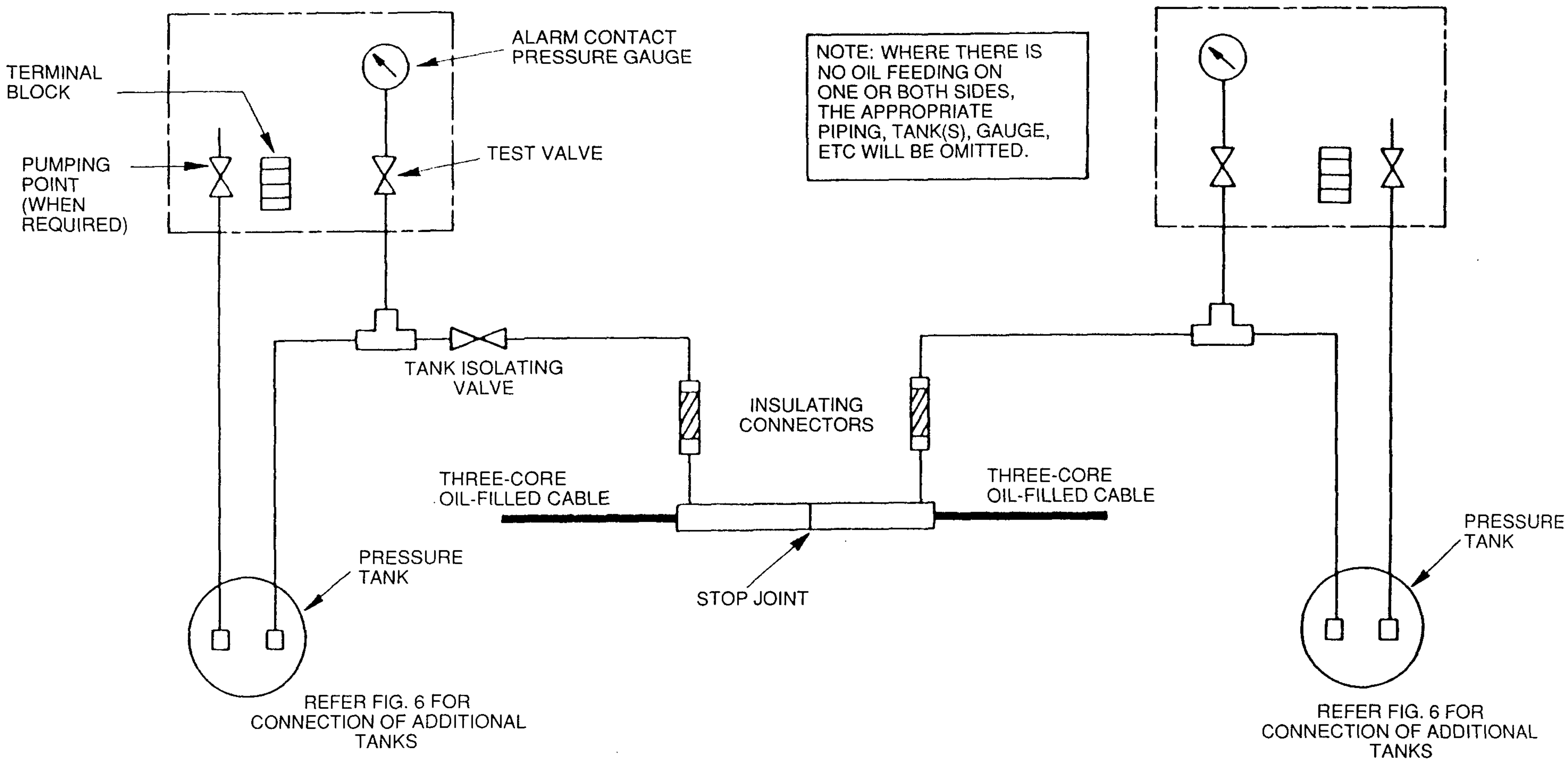

Fig 4 – Arrangement of Oil Equipment at Three-core Stop Joints (Oil-filled Cable)

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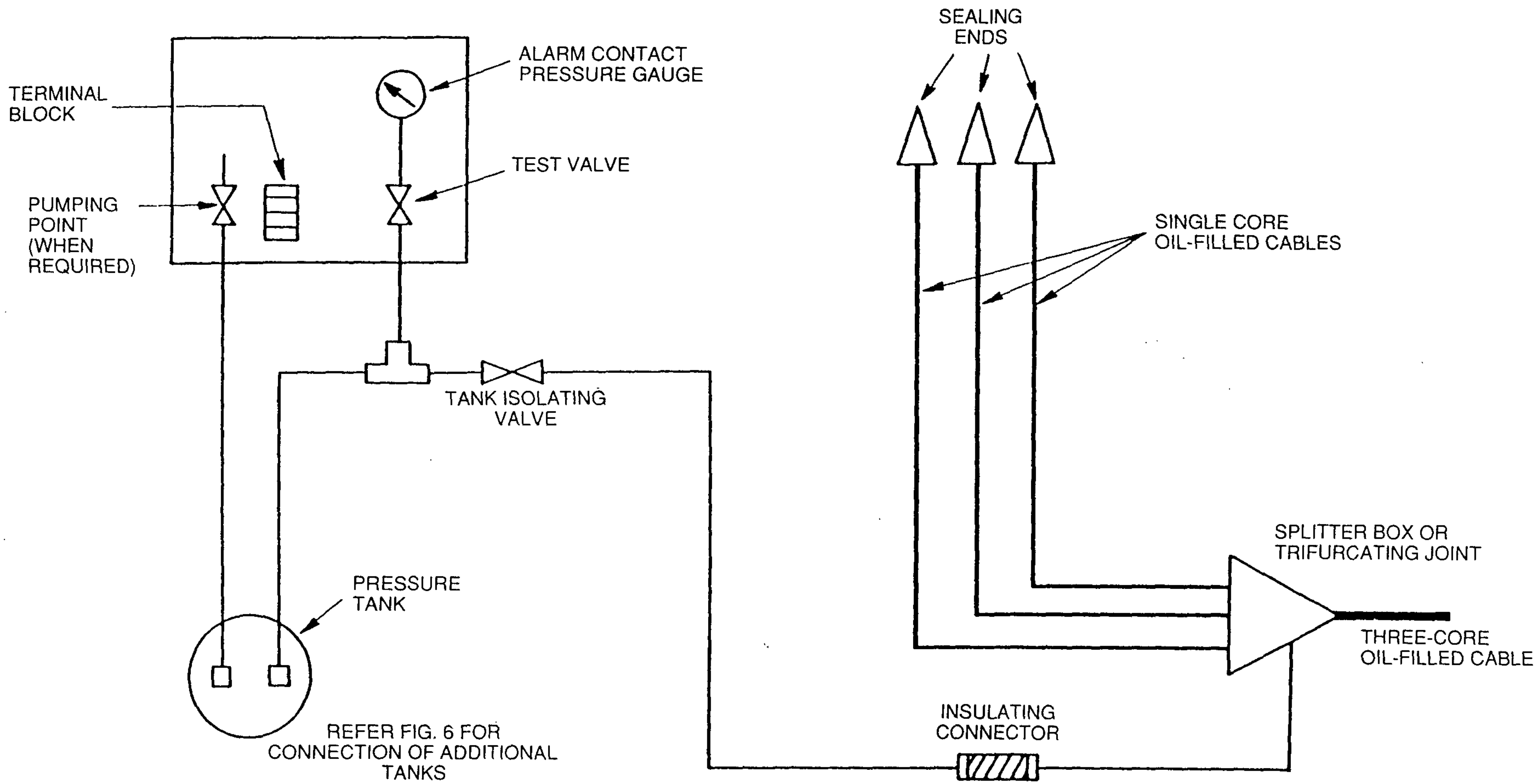

Fig 5 – Arrangement of Oil Equipment at Splitter Boxes or Trifurcating Joints (Oil-filled Cable)

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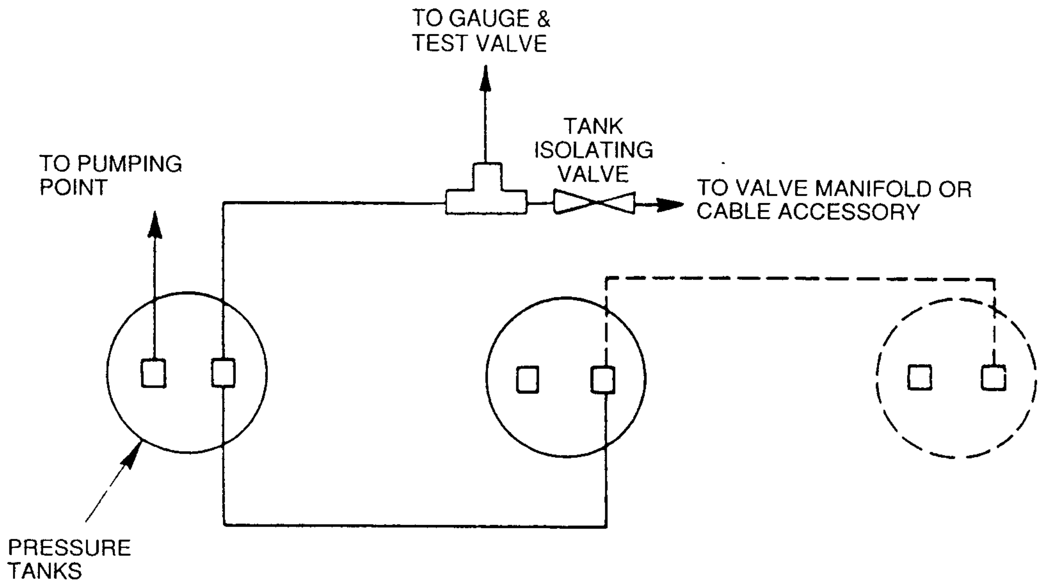
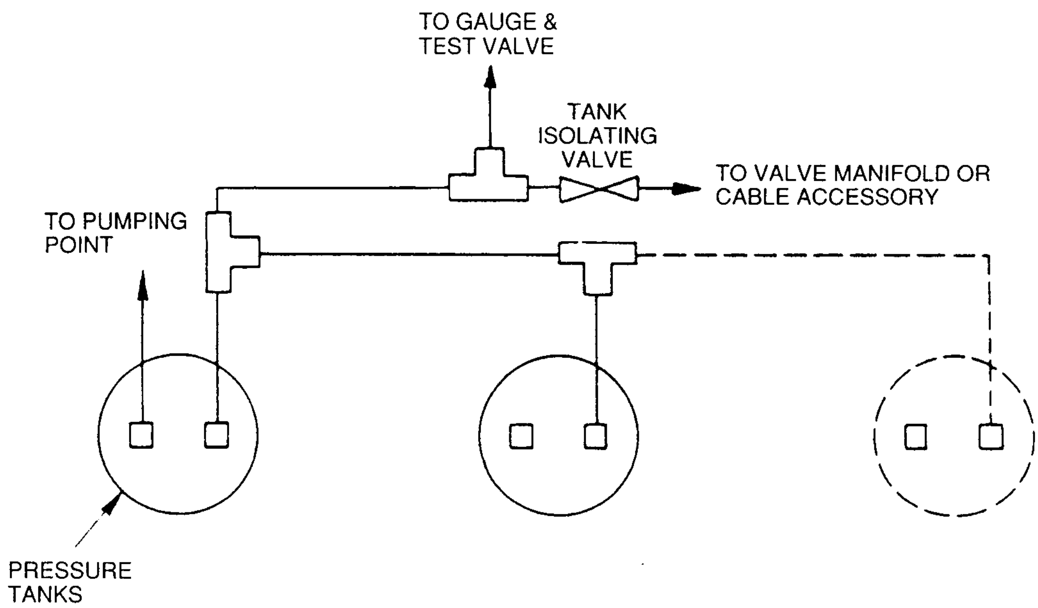


METHOD 'A'



METHOD 'B'

Fig 6 – Methods for Connection of Additional Tanks (Oil-filled Cable)

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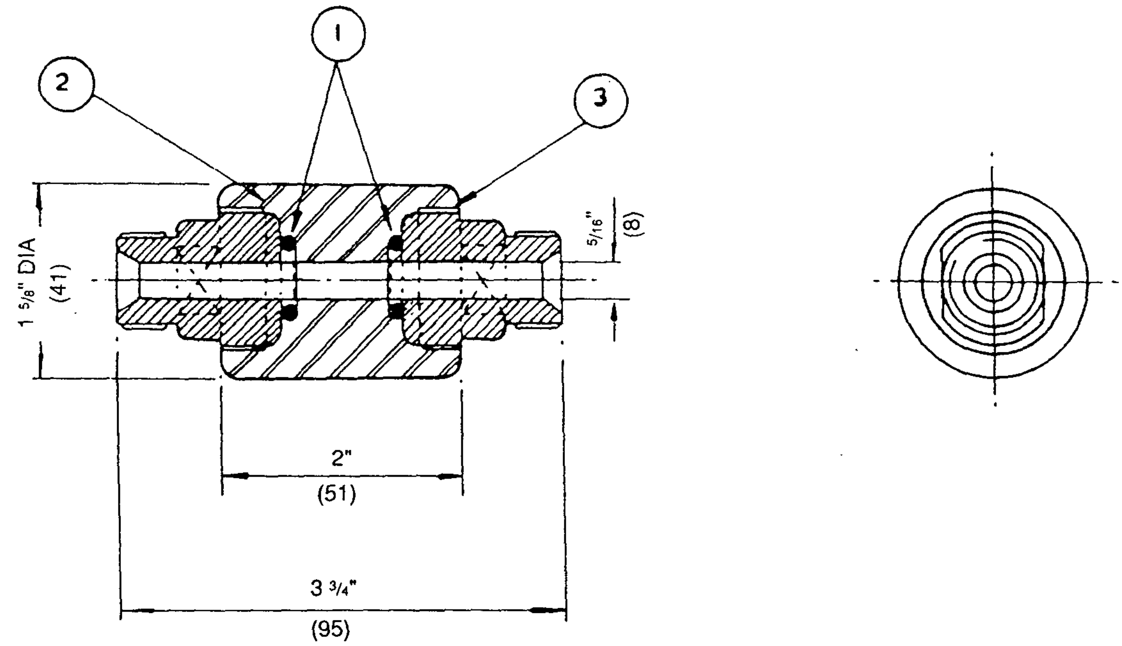

1. 'O' RING (OIL RESISTING RUBBER)
2. CAST EPOXY RESIN
3. BRASS INSERT ELEC. TINNED

DO NOT SCALE

ALL DIMENSIONS IN BRACKETS ARE IN MILLIMETRES UNLESS OTHERWISE STATED

Fig 7 – Oil Feed Pipe Insulating Connector Double Union

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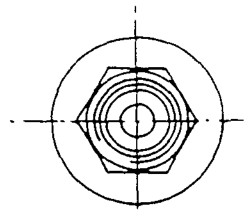
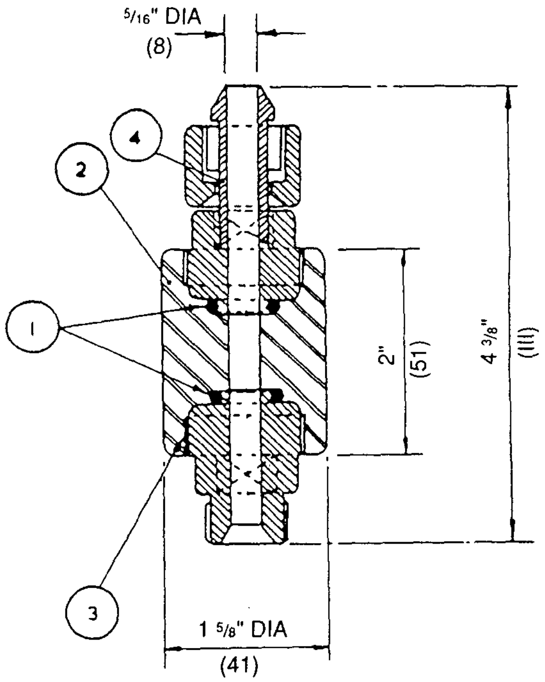
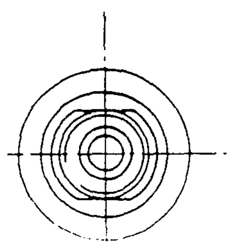


1. 'O' RING (OIL RESISTING RUBBER)
2. CAST EPOXY RESIN
3. BRASS INSERT ELEC. TINNED
4. NIPPLE SILVER SOLDERED INTO INSERT





DO NOT SCALE

ALL DIMENSIONS IN BRACKETS ARE IN MILLIMETRES UNLESS OTHERWISE STATED

Fig 8 – Oil Feed Pipe Insulating Connector Union and Coupling

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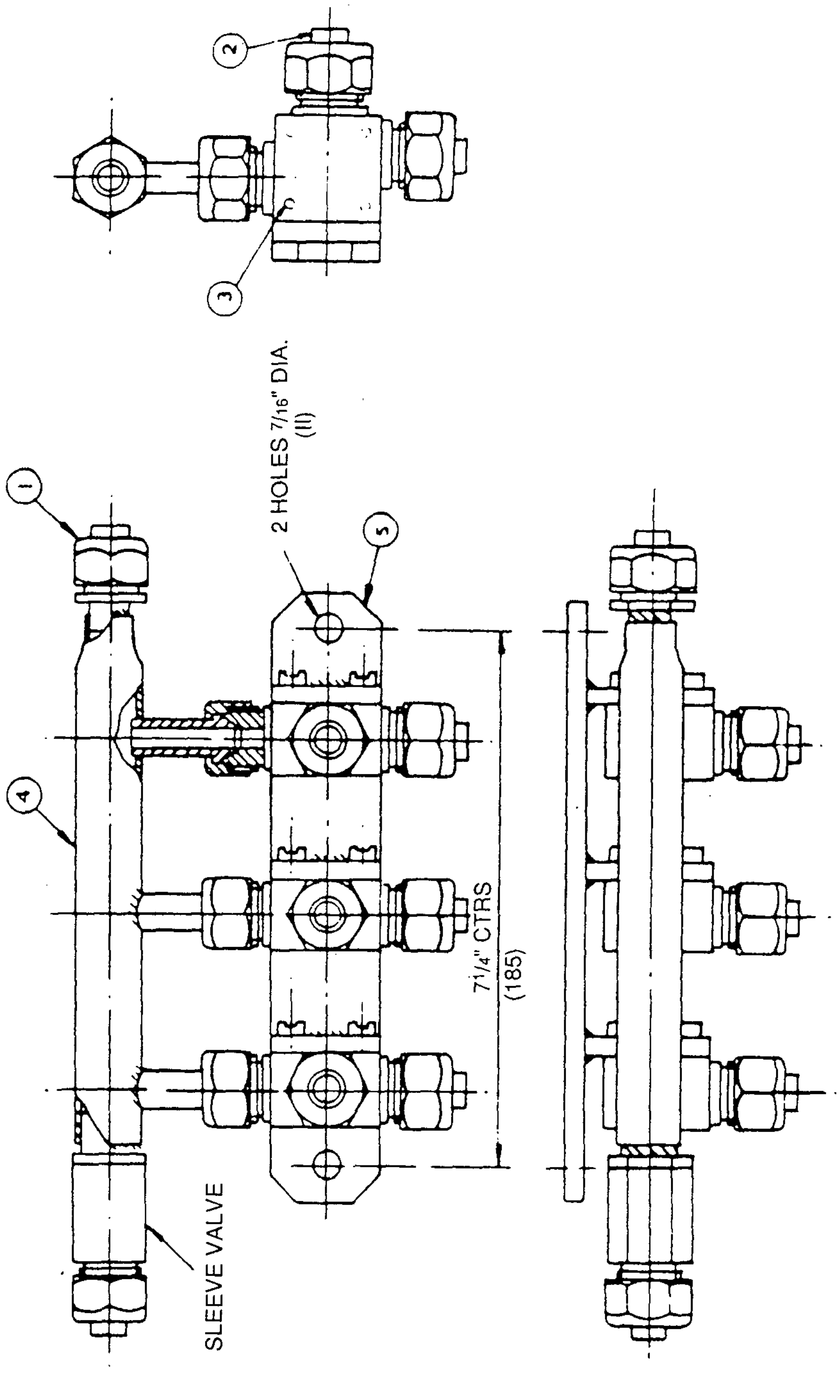

1	PHOSPHOR BRONZE NUT	
2	BLANK NIPPLE	MATERIAL-BRASS
3	VALVE BODY	
4	COPPER MANIFOLD	
5	GALVANISED MS BRACKET	
ITEM	DESCRIPTION	

ALL DIMENSION IN BRACKETS ARE IN MILLIMETRES UNLESS OTHERWISE STATED
DO NOT SCALE

Fig 11 – 3-way Valve Manifold (With Sleeve Valve Connection)

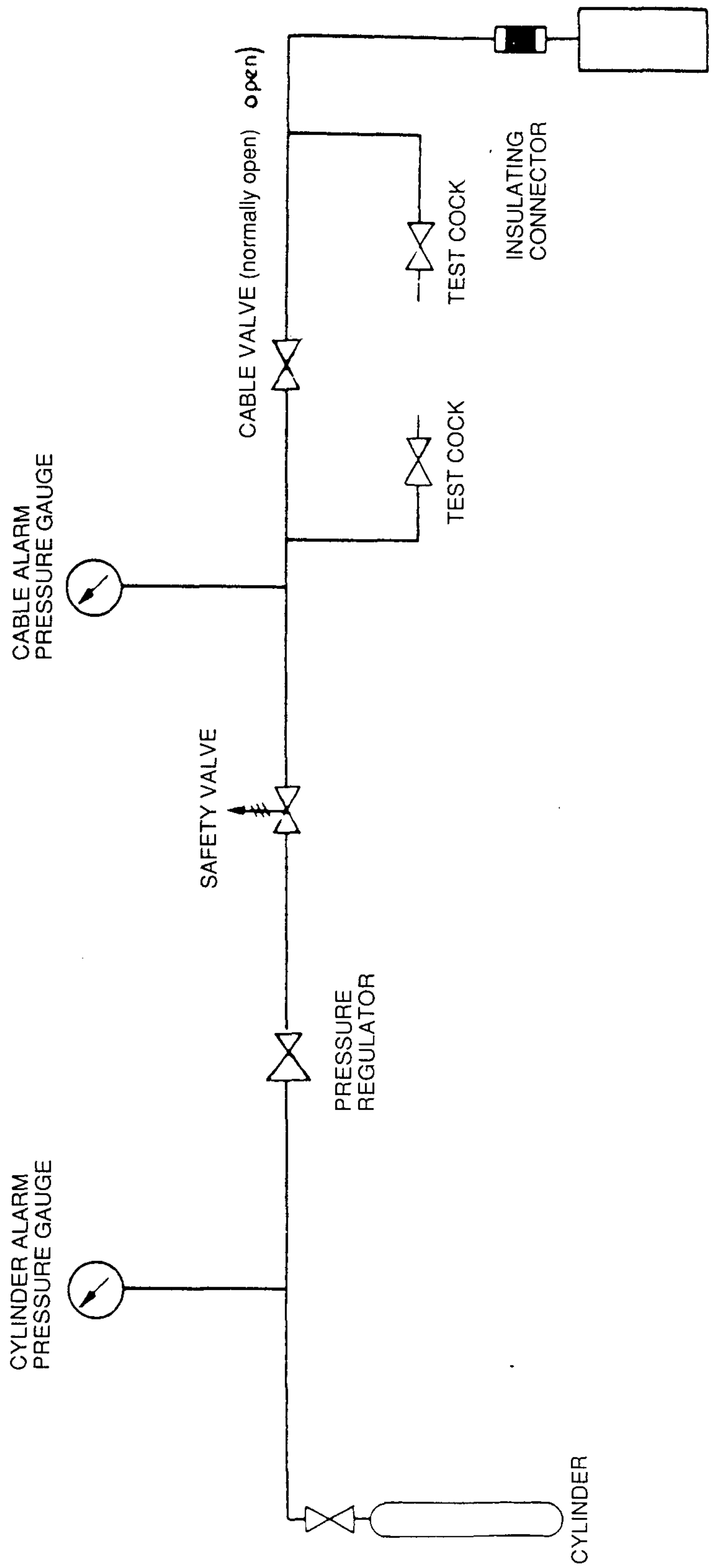

Fig 12 – Gas-filled Cable System – Outdoor

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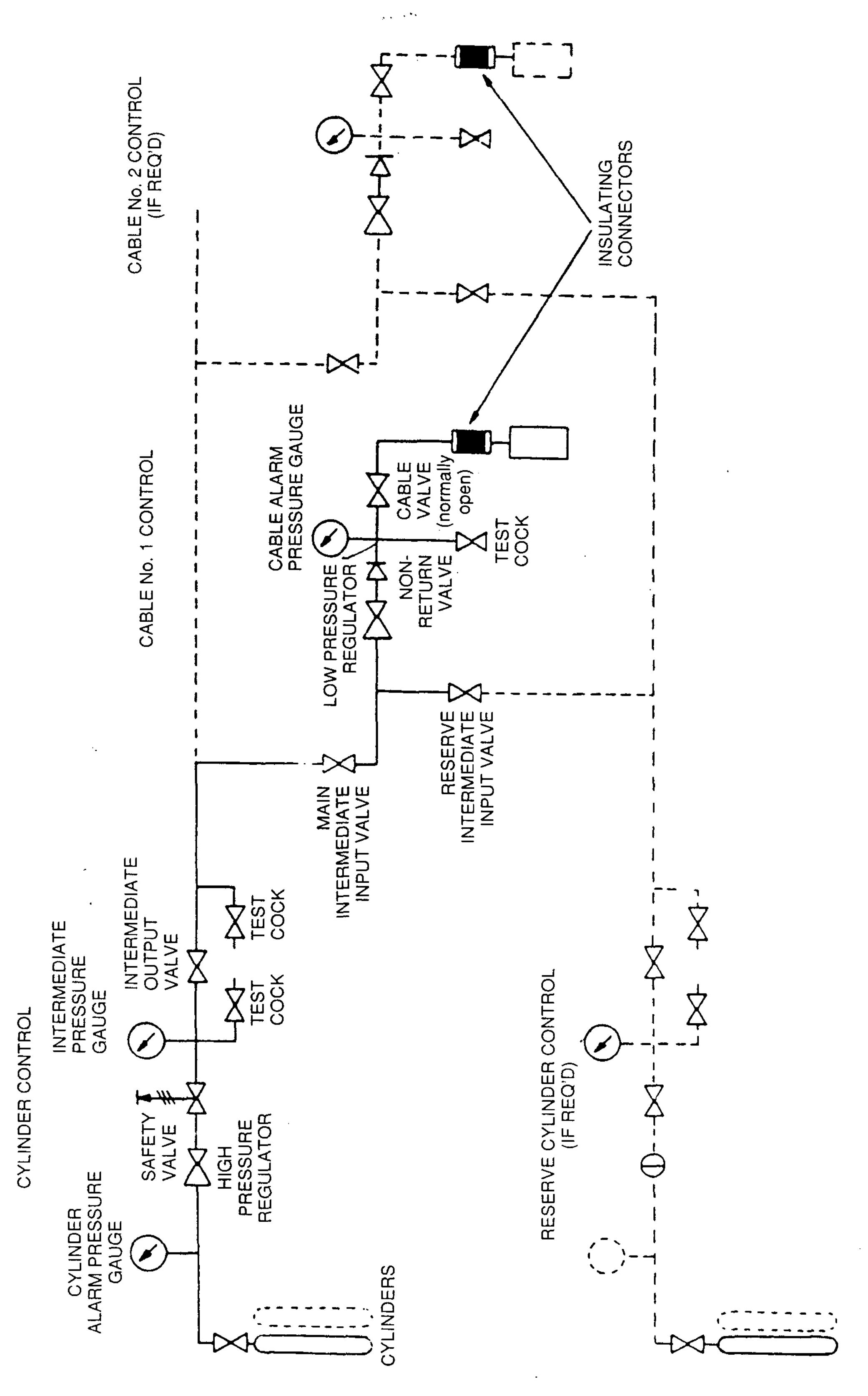
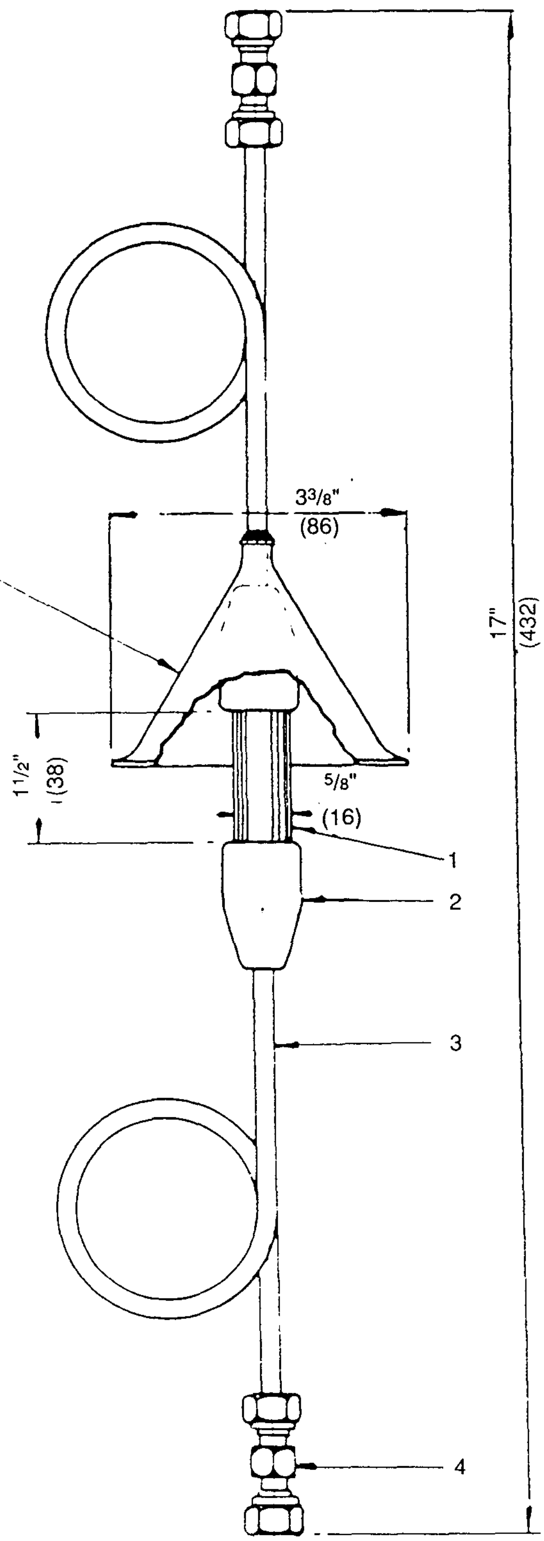


Fig 13 – Gas-filled Cable System – Indoor

89 296



1. PORCELAIN INSULATOR, SOFT SOLDERED INTO END PIECES.
2. BRASS END PIECES.
3. COPPER GAS PIPE 0.25" (6) 0/DIA x 0.178" (4) 1/DIA.
4. BRASS ERMETC CONNECTOR.

DIMENSIONS IN BRACKETS ARE IN MILLIMETRES.

DO NOT SCALE

Fig 14 – Gas Feed Pipe Insulating Coupling

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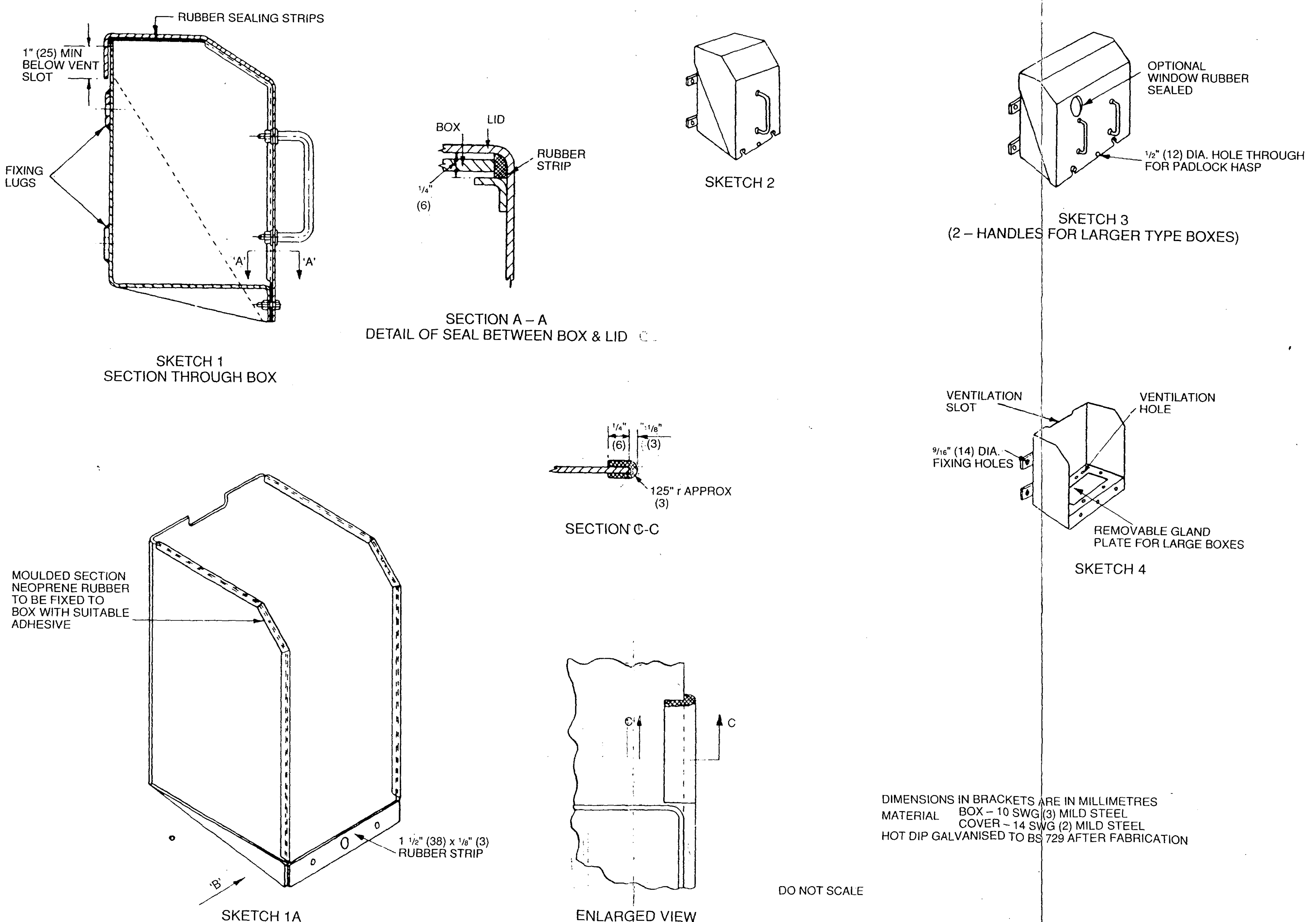
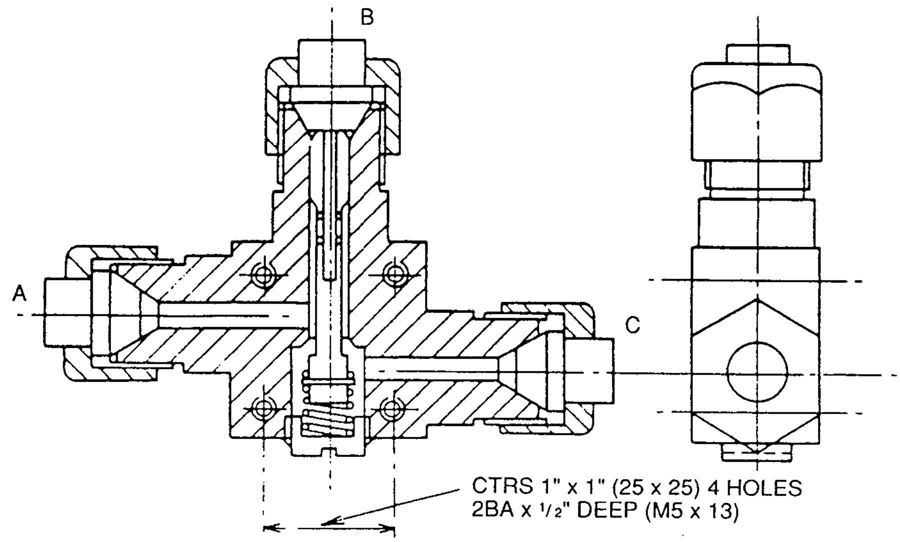
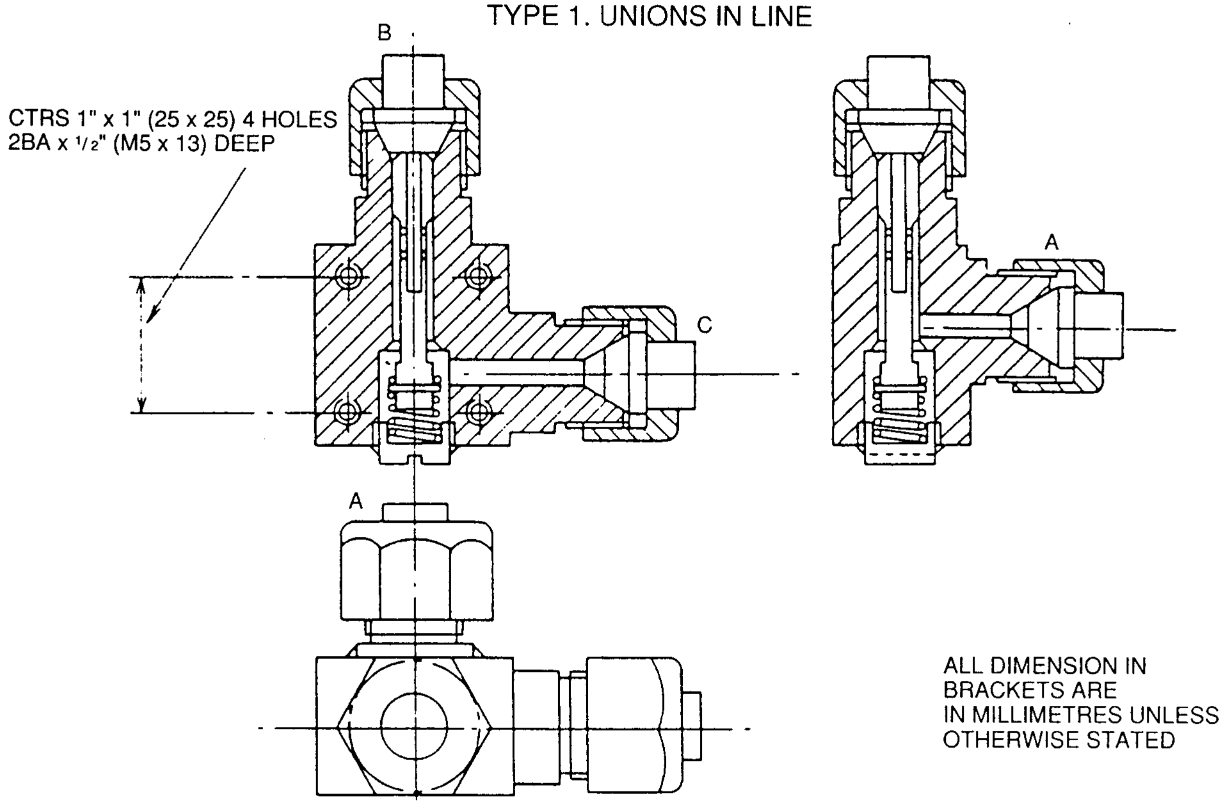


Fig 9 – Wall Mounting Weatherproof Box for Housing Links, Pressure Gauges, etc.



TYPE 1. UNIONS IN LINE



TYPE 2. UNIONS AT RIGHT ANGLES

WHEN BLANKING PLUG "B" IS REMOVED, THE SLIDE VALVE RISES AND CLOSES OFF "C"
A TEMPORARY CONNECTION FOR TEST OR FEEDING PURPOSES CAN THEN BE MADE AT "B"

C	TANK	TANK/ACCESSORY
B	ISOLATING/FEED	TEST
A	JOINT OR TERMINATION	GAUGE
CONNECTION	ISOLATING VALVE	GAUGE TEST VALVE

Fig 10 – Arrangement of Valves for Oil-filled Cable Systems

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