Chapter IV

MATERIALS AND DETAILS

4.1 Silicon Steel

Special alloy steel of high resistance and low hystersis loss is used almost exclusively in transformer cores. The comparatively pure iron sheet used in the early days of electrical engineering construction has given place to alloy steels. The chief alloying constituent is silicon. It increases the permeability at low density, reduces the hystersis loss and by augmenting the resistivity decreases the eddy current loss. The greater the silicon content, the better is the steel magnetically from the viewpoint of losses, but the properties are very variable particularly after punching, shearing, bending,etc.

As the flux in the transformer cores is a pulsating one, the magnetic circuit must be laminated and the seperate laminations insulated in order to retain the advantages of subdivision. The thickness of laminations is a factor in the eddy-current loss. This loss may be reduced by using thinner laminations.

For the transformer designed, the magnetic circuit is built up of RG-8H silicon steel laminations 0.30 mm. thickness, which has the following characteristics and specifications.

Characteristics

Uniformity of Properties:

RG-8H's magnetic and mechanical properties are highly uniform

Good Magnetic Properties:

RG-8H has low core loss and high magnetic flux density.

Excellent Insulating Coating:

RG-8H is tighly coated with superior insulating films which has excellent heat and high corrosion resistance.

High Lamination Factor:

RG-8H has a high lamination factor as cold rolling provides smooth surface and even thickness.

Specifications:

Silicon content	4%
Specified thickness	0.30 mm.
Density	7.65 grams per cu.cm.
Specific resistance	45.0 $\mu\Omega$-cm.

The D.C. Magnetization and D.C. Permeability Curves, Core Loss Curve, and Exciting RMS Current Curve of RG-8H silicon steel are shown in Fig. 4.1, 4.2, 4.3 respectively.

4.2 Magnet Wire

Magnet wire is the wire used for coils in transformers and other electric appliances. It plays the important role of converting electric energy into magnetic energy and then into kinetic energy. In this role, it is quite different from other kinds of electric wires and cables.

Magnet wire may be divided into two major classification enameled magnet wire and fiber-insulated magnet wire. It may be further classified according to the kind and grade of insulation and thermal class. Magnet wires mainly used in the past were cotton covered, silk covered, and paper covered. With the development of various synthetic insulating materials and the progress of manufacturing techniques, synthetic enameled magnet wires are now being used widely.

For the transformer designed, No. 37 SWG polyvinyl formalenameled round copper magnet wire is used in high voltage winding. It has excellent abrasion resistance, good dielectric strength and insulation resistance, high moisture resistance and good film uniformity. Its dimensions are as follows:

The nominal diameter of bare conductor	=	0.1727 mm.
The nominal diameter of insulated conductor	=	0.214 mm.
The cross section area of bare conductor	=	0.02348 sq.mm.

In low voltage winding, a triple kraft paper insulated rectangular copper magnet wire is used. Its dimensions are as follows:

Bare	7.0 x 1.5 mm.
Insulated	7.6 x 2.1 mm.
Area	10.017 sq.mm.

4.3 Insulation

The insulation of the windings may be divided into two mains classes:

(i) Major Insulation

(ii) Minor Insulation

Major insulation comprises the insulation cylinders between the low voltage winding and the core and between the high voltage and low voltage winding, the insulating barriers which is inserted between adjacent limbs when necessary and the insulation between the coils and the core yokes. The cylinders consist of a number of layers of selected kraft paper.

Minor insulation is the insulation on individual turns and between layers of the coils.

The principal material used for this transformer is kraft paper. The material for the manufacture of kraft paper is wood fiber which can be classified as a natural product. Kraft paper has excellent dielectric strength and low dielectric loss when it is dry, but it very readily absorbs moisture. In order to overcome this difficulty it must be dried and impregnated in some liquid (oil, varnish, resin) to exclude moisture and maintain its dielectric strength. Such treatment fills the spaces between fibers and increases the dielectric strength. The dielectric strength of the pressphane insulation is shown in Fig. 4.4

4.4 Bushing Insulators

Up to voltages of about 33 KV, ordinary porcelain insulators can be used, which do not require special comment. Above this voltage the use of condenser and oil-filled terminal bushings, or, for certain cases, a combination of the two, has to be considered. The surface of the bushing insulators should conform approximately to the shape of the electric field. In the case of transformer for indoor installation the porcelain contour should be as simple as possible.

The oil-filled bushing used by this transformer, consists of a hollow porcelain cylinder of the shape in Fig. 4.5 with a conductor through its center. The space between the conductor and the porcelain is filled with oil, the dielectric strength of which is greater than that of air. The dielectric strength is greatest at the surface of the conductor, and this breaks down at a much lower voltage in air than in oil. Oil is fed into the bushing at the top, where there is a glass cylinder to indicate the oil-level and to act as an expansion chamber for the oil when the bushing temperature rises. Under the influence of the electric field, foreign substances in form of dust, moisture or metallic particles, have a tendency to arrange themselves in radial lines, giving rise to path of low diefectric strength, with consequent danger of breakdown. To prevent such action by unavoidable impurities in the oil, kraft paper tubes are used to surround the conductor concentrically. The effect is to break up radial chains of semi-conducting particles.

In Fig. 4.5 and Fig. 4.6 The high voltage and low voltage bushing used for this transformer are shown.

4.5 Transformer Oil

Oil in transformer construction serves the dubble purpose of cooling and insulating. For use in transformer tanks, oil has to fulfill certain specifications and must be carefully selected. All oils are good insulators but animals oils are either too viscous or tend to form fatty acids, which attack fibrous materials and so are unsuitable for transformers. Vegetable oils are apt to be inconsistent in quality and, like animal oils. tend to form destructive, fatty acids. Of the mineral oils, which alone are suitable for electrical purposes.

In choice of an oil for transformer use the following characteristics have to be considered.

Viscosity--- This determines the rate of cooling, and varies with the temperature. A high viscosity is an obvious disadvantage because of the sluggish folw through small apertures which it entails.

Insulating Property--- It is usually unnecessary to trouble about the insulating properties of an oil, since it is always sufficiently good. A more important matter, however, is the reduction of the dielectric strength due to the presence of moisture, which must be rigorously avoided. A very small quantity of water in oil greatly lowers its value as an insulator, while the presence of dust and small fibers tends to paths of low resistivity.

Flash Point --- The temperature at which the vapour above an oil surface ignites spontaneously is termed the flash point. A flash point of not less than about 160 degree celcius is usually demanded for reasons of safety.

Fire Point --- The temperature at which an oil will ignite and continue burning is about 25% above the flash point.

Purity --- The oil must not contain impurities such as sulphur and its compounds. Sulphur when present causes corrosion of metal parts, and accelerates the production of sludge.

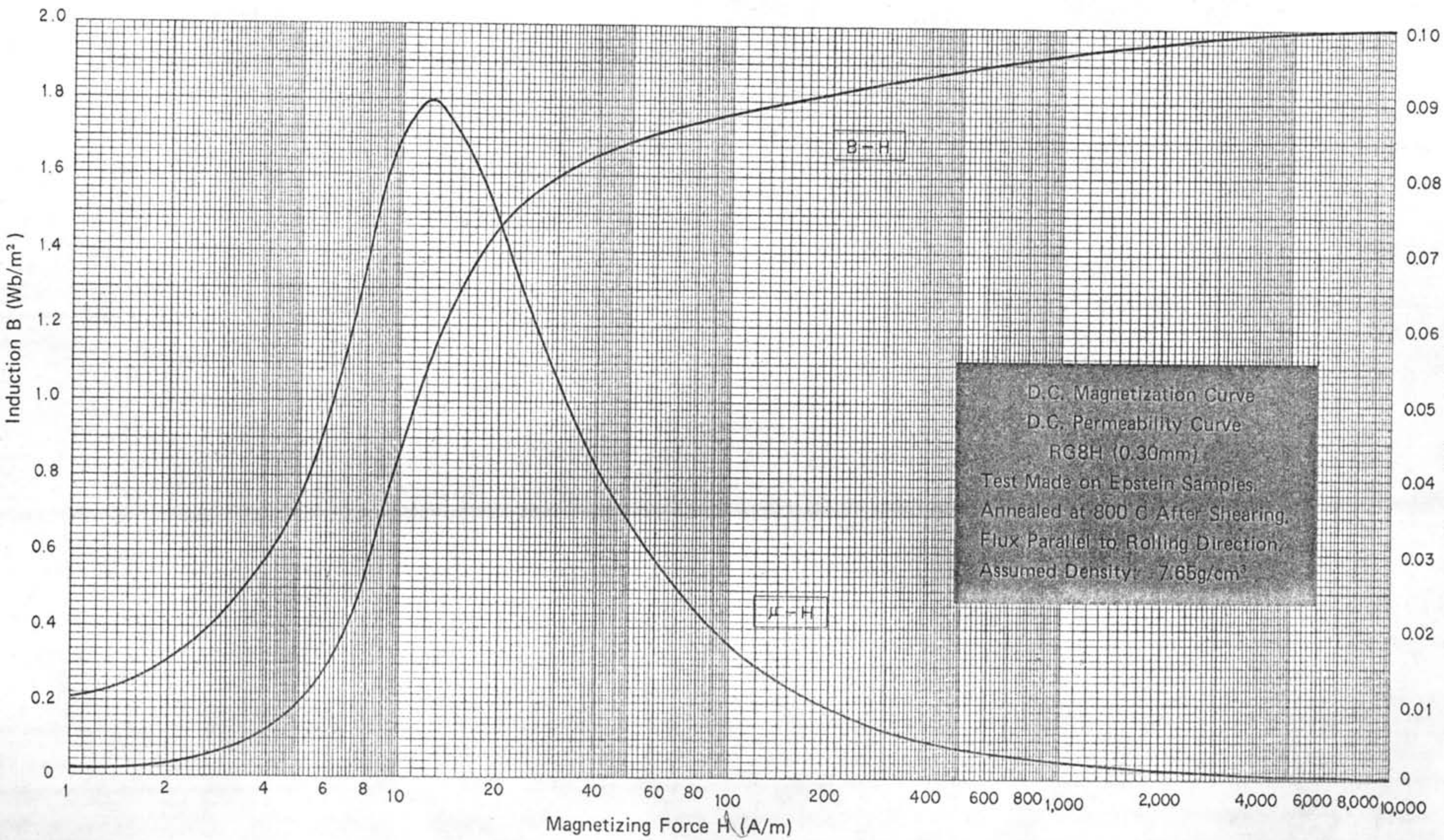
Sludging --- This is the most important characteristic. Sludging means the slow formation of semi-solid hydrocarbons, which are deposited on windings and tank walls. The formation of sludge is due to heat and oxidation. In its turn it makes the whole transformer hotter, thus aggravating the trouble, which may proceed until the cooling ducts are blocked and the transformer becomes unusable owing to overheating. The chief remedy available is to use oil which remains without sludge formation after long periods of heating in the presence of oxygen, and to employ expansion chambers to restrict the contact of hot oil with the surrounding air.

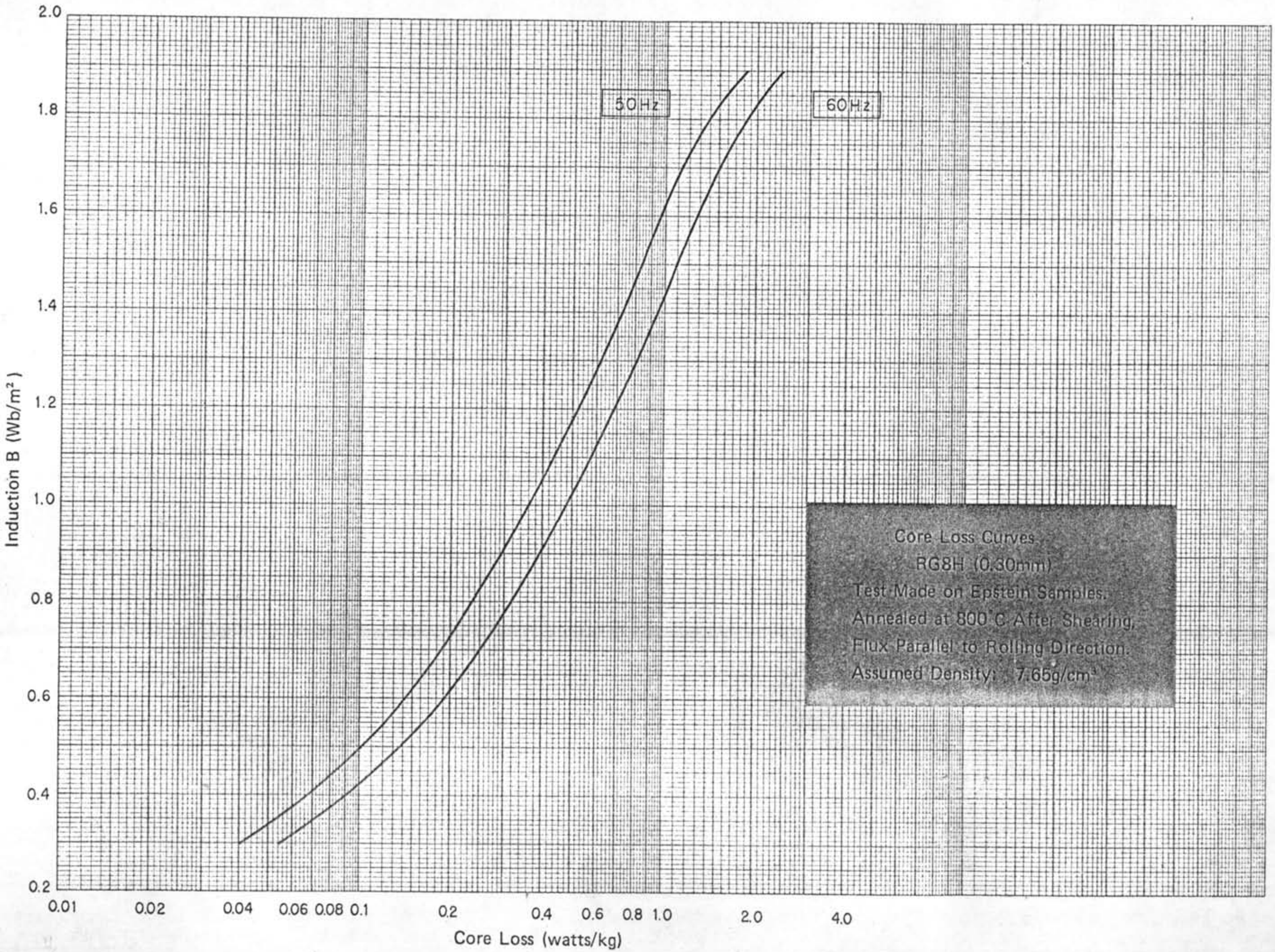
The typical transformer oil characteristics are shown below:

1. Color	nearly water white
2. Reaction	neutral
3. Neutralization number (milligrams of potassium hydroxide per gram sample).......	0.03 max.
4. Precipitation number	zero
5. Free sulphur and corrosive compounds	none
6. Steam emulsion number (seconds)	25.0 max.
7. Flash point	(275°F) 135°C min.
8. Fire point	(305°F) 152°C min.
9. Pour point	(-50°F) 45.6°C
10. Viscosity at 38.8°C (100°F) SU	60.0 sec. max.
11. Viscosity at 0 C (32°F) SU	280 sec.max.

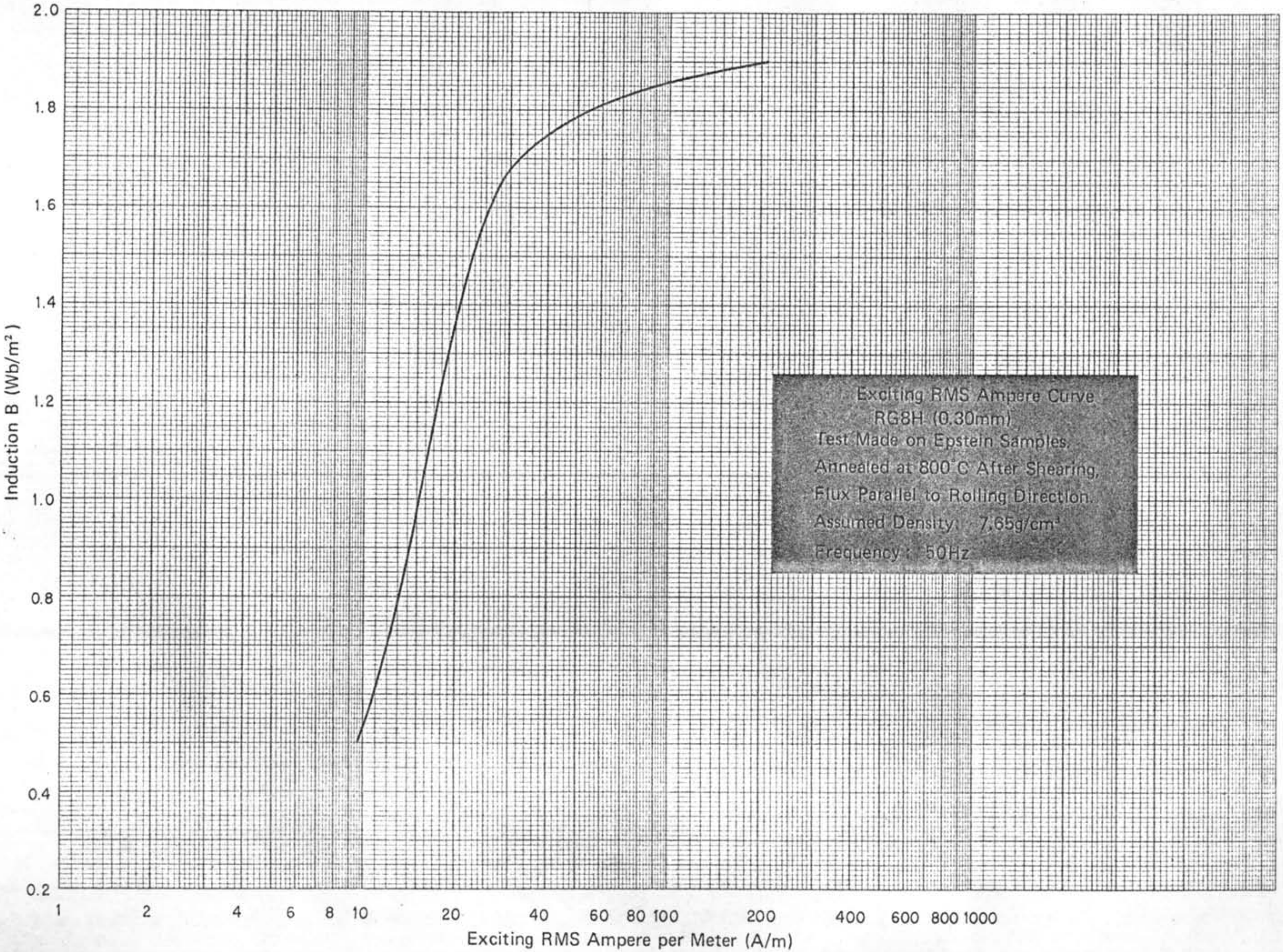
12. Specific gravity at 15.5° C (60° F) 0.898
13. Specific heat .... 0.488 approx.
14. Coefficient of expansion at 0° C (32° F)........ 0.000725
15. Coefficient of expansion at 100° C (212° F)..... 0.000755
16. Interfacial tension (dynes/sq.cm.) .... 40.0 min.
17. Dielectric constant 2.2
18. Dielectric strength (min. standard cup) at
    point of shipment .... 26,000 volts
    (min. standard cup) at point of delivery .... 22,000 volts
19. Weight per gallon .... 7.5 lbs.

The Shell Diala Oil D are used and the dielectric strength of the vacuum and non-vacuum are shown in Fig. 4.7 , test by insulation tester. The insulation spark gap has disk terminal 2.54 cm. in diameter.


Induction B (Wb/m²)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
Permeability μ (H/m)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
B−H
μ−H
D.C. Magnetization Curve
D.C. Permeability Curve
RG8H (0.30mm)
Test Made on Epstein Samples.
Annealed at 800 C After Shearing.
Flux Parallel to Rolling Direction.
Assumed Density: 7.65g/cm³
1 2 4 6 8 10 20 40 60 80 100 200 400 600 800 1,000 2,000 4,000 6,000 8,000 10,000
Magnetizing Force H (A/m)



Core Loss Curves
RG8H (0.30mm)
Test Made on Epstein Samples.
Annealed at 800°C After Shearing.
Flux Parallel to Rolling Direction.
Assumed Density: 7.65g/cm³
50Hz
60Hz
Induction B (Wb/m²)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.01
0.02
0.04
0.06
0.08
0.1
0.2
0.4
0.6
0.8
1.0
2.0
4.0
Core Loss (watts/kg)


Exciting RMS Ampere Curve
RG8H (0.30mm)
Test Made on Epstein Samples,
Annealed at 800°C After Shearing,
Flux Parallel to Rolling Direction.
Assumed Density: 7.65g/cm³
Frequency: 50Hz
Induction B (Wb/m²)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1
2
4
6
8
10
20
40
60
80
100
200
400
600
800
1000
Exciting RMS Ampere per Meter (A/m)

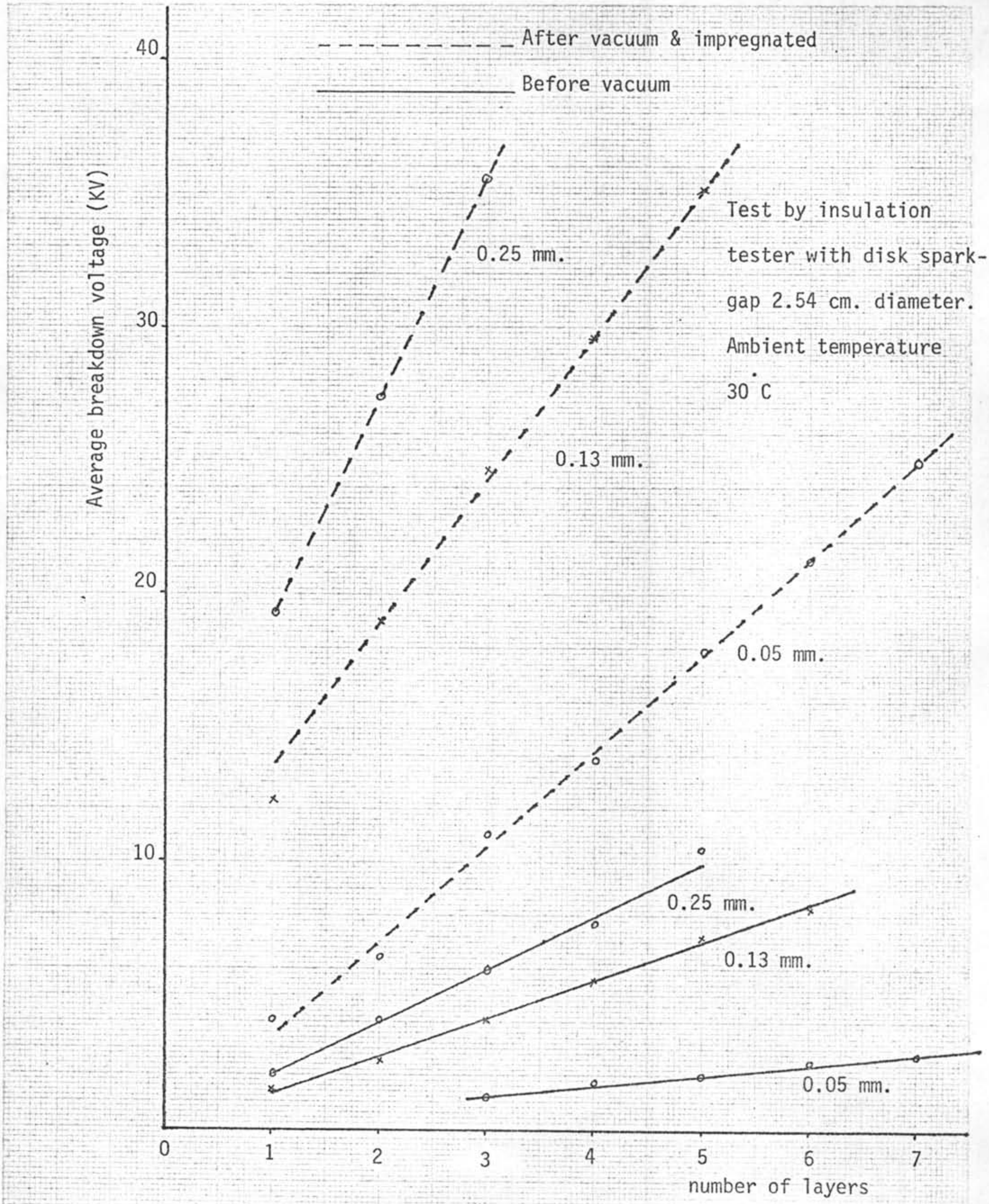


Fig. 4.4 The dielectric strength of pressphane insulations

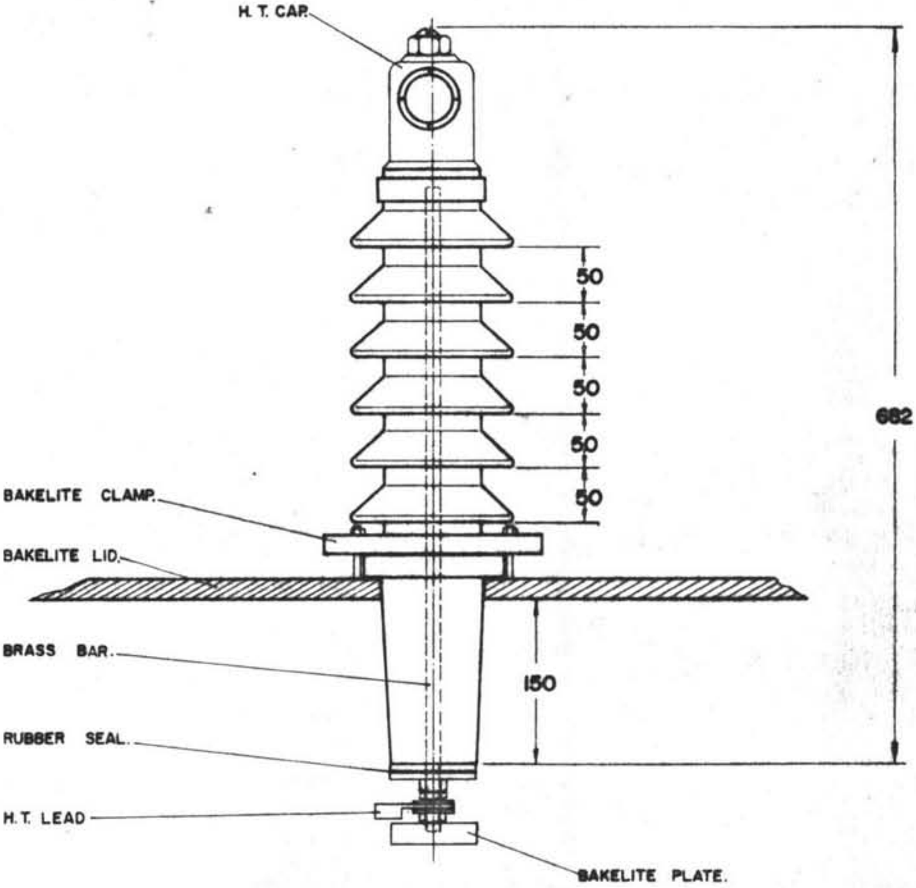
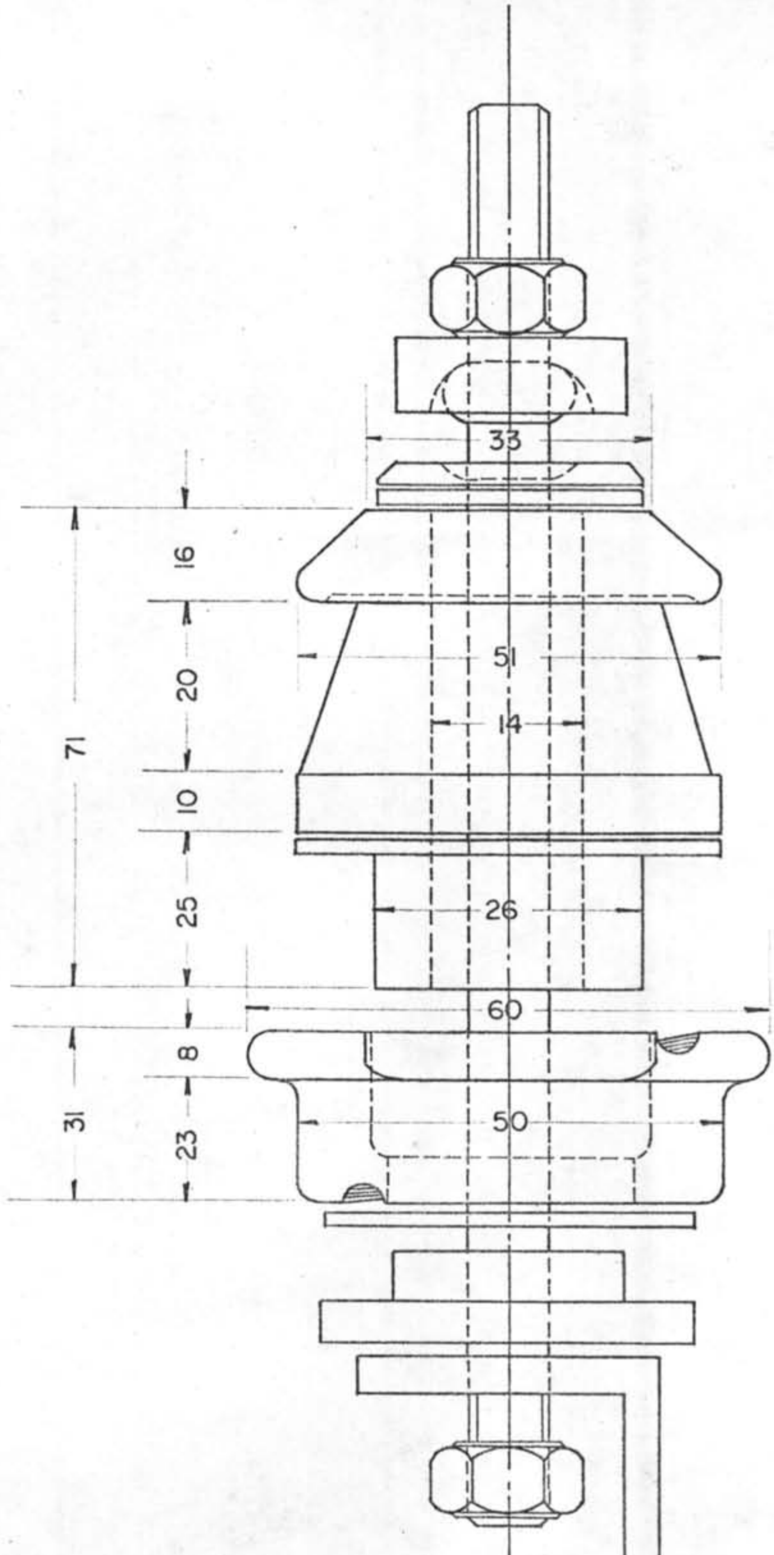


Fig 4.5 Oil-Filled high voltage bushing (millimetres)



(Dimension in Millimeters)

Fig. 4.6

LOW VOLTAGE BUSHING.

(SCALE 1: 1.25)

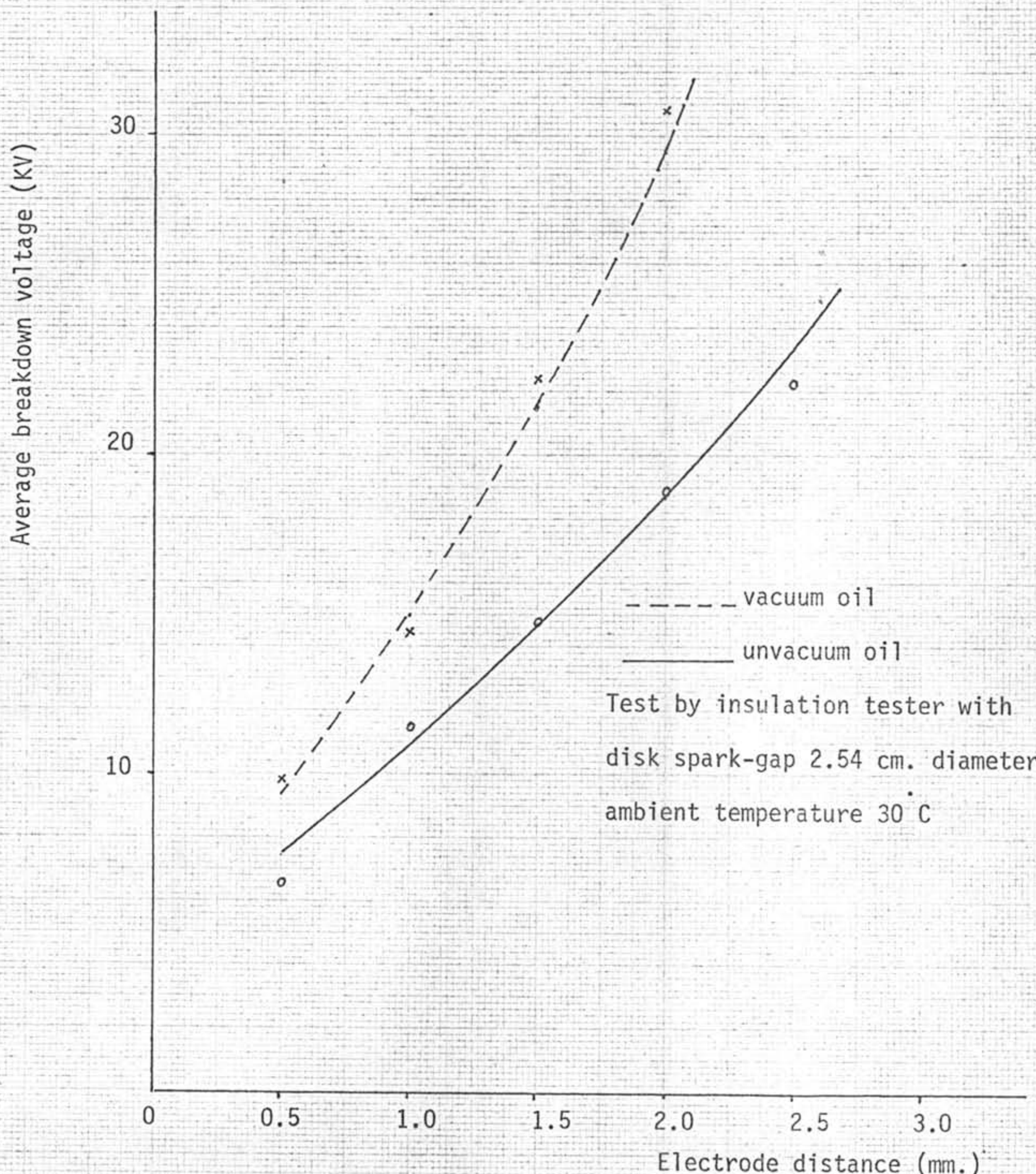


Fig. 4.7 Transformer oil dielectric strength