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CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART II GLASS ENAMEL LINING

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART II GLASS ENAMEL LINING

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Indian Standard

CODE OF PRACTICE FOR LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES

PART II GLASS ENAMEL LINING

0. FOREWORD

0.1 This Indian Standard (Part II) was adopted by the Indian Standards Institution on 10 October 1969, after the draft finalized by the Chemical Engineering Sectional Committee had been approved by the Mechanical Engineering Division Council.

0.2 This standard is being issued in many parts. The lass enamel lining of vessels and equipment is covered in this part; the other types of linings are covered in the remaining parts of this standard.

0.3 The word glass does not describe one material but is a general term applied to many families of compositions both inorganic and organic. As a result of the wide range of compositions which can be produced, an extremely wide range of chemical and physical properties can be obtained. This standard covers essentially glass like inorganic composition chemically bonded to the base metal by fusion on the metal.

The terms porcelain enamel, vitreous enamel, glass and glass enamel are synonymously applied for these linings. The term glass enamel is preferred to others in this standard.

0.4 Although glass has many applications in its own right in the field of chemical plant construction, it is more advantageous to combine the high chemical resistance, non-toxic and non-flavouring characteristics of glass with the mechanical strength of metals by applying a coating of the glass enamel to the surfaces exposed to the corrosive media. A variety of metals can be protected this way, but the most extensive use of the technique is in the production of glass enamel lined steel equipment.

0.5 Early consultation and exchange of information should be arranged between all parties concerned with the design, use, manufacture and erection of vessels and equipment to be lined. Appendix A gives details of information to be exchanged.

0.6 In the preparation of this standard considerable assistance has been derived from BS CP 3003: Part 2 : 1966 ' Lining of vessels and equipment for chemical processes ' issued by the British Standards Institution.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part II) lays down recommendations on the selection, design, application, inspection, testing and maintenance of glass-enamel-lined vessels and equipment for chemical processes.

2. TERMINOLOGY

2.1 Definitions commonly used in connection with the equipment covered by this standard are given in Appendix B.

3. COMPOSITION OF LININGS

3.0 General — The glass enamel linings referred to in this code are essentially glass-like inorganic compositions, chemically bonded to mild steel or cast iron by fusion on the metal at temperatures in excess of 750°C. Enamels fusing at lower temperatures can be applied to mild steel and cast iron and, at still lower temperatures, to aluminium and other metals; these are not, however, suitable for most chemical plant purposes, although they are widely used for domestic and architectural application.

3.1 Composition and Manufacture of Enamel Frits — The enamels used for chemical plant purposes are in general highly acid resistant and similar in composition to the borosilicate and alumino silicate glasses. A brief cutline of the method of manufacture is given below for the information of the user.

3.1.1 A wide range of materials is used for compounding glass enamels but the raw batch consists essentially of a mixture of finely divided refractory materials (for example, quartz, sand, felspar, alumina and titania) and fluxes (for example, borax, soda ash, cryolite, zinc oxide and fluorspar) together with colouring oxides and if necessary opacifying agents. The well-mixed batch is fused at temperatures in excess of

*Rules for rounding off numerical values (*revised*).

1 000°C in either rotary or box-type smelters. When the smelting process is completed, the molten mass is quenched by pouring it into water or by passing it through water-cooled rollers. The resultant material in granulated or flake form is referred to as 'enamel frit'.

If required for the dry dusting process, the frit is ground to a powder of suitable fineness and is then ready for use. Otherwise, the frit is mixed with water, electrolytes, suspending agents and possibly additional refractories opacifying or colouring materials and ground in a ball mill to produce a suspension of the enamel in water; this suspension is known as 'slip' and is applied to the equipment by spraying, dipping or brushing.

3.2 Factors Affecting Choice of Enamel — The manufacturers produce several types of enamels and the choice of material to be employed for any particular application is determined by several factors as follows:

a) The nature of the base metal;

b) The method of lining to be employed;

c) The chemical, thermal and pressure conditions to which the lining will be exposed in service, including the possibility of abrasion; and

d) The design of the equipment to be enamelled.

4. PROPERTIES OF LININGS

4.1 Physical and Chemical Data — The following figures are typical of the properties of applied enamel coatings:

Specific gravity	2·50
Specific heat	0·21
Softening point	About 500°C

4.2 Heat Transfer — Within a useful range of operating conditions, the bonding of glass enamel to a metal wall is unaffected by heating or cooling. In addition, a useful rate of heat transfer is obtainable because the lining is thin and does not readily foul; thus, jacketed vessels are practical pieces of equipment. Surfaces protected by some commonly used non-metallic materials do not have these desirable characteristics.

4.2.1 The thermal conductivity of the glass enamel is quite low in comparison with that of the material of the lining. As a consequence, the resistance of a glass-enamel-lined wall is several times larger than that of a plain wall. In practice, other factors also decide the overall rate of heat transfer and, in some cases, these factors may have a greater effect than the conductivity of the wall. A measure of the effect of the coating on heat transfer rate may be obtained from the fact that, when steam is used to boil water under atmospheric pressure in equipment lined with glass enamel having a thermal conductivity of 0·9 kcal/m h deg C, the overall heat transfer coefficient is about 440 kcal/m^2 h deg C. In these particular circumstances, the resistance to the flow of heat of the lining alone, compared with the combined resistances of the metal and various films, is in the ratio of about 3 : 2.

4.2.2 In other operational circumstances, when factors, such as the character, temperature and rate of motion of the fluids involved assume an importance such that their combined effect is as much or more than that of the coating, lower values of thermal conductance are obtained. With steam or water in the jacket and aqueous or organic fluids of a mobile nature in the inner vessel, values of thermal conductance for jacketed reaction vessels have been obtained in the range 170 to 420 kcal/m^2 h deg C. The degree of agitation imposed and the physical nature of the fluids in the inner vessel are predominant factors in fixing the actual performance figure obtained. The thermal conductance of condensers has been found to lie in a similar range to that quoted for reaction vessels. If, however, incondensable gases are present in the condensing vapours or sub-cooling of the condensate is required, lower values are often obtained.

4.2.3 The use of fluids other than steam or water in the jacket of a vessel, such as special heat transfer oils, even when circulated above economic rates, will result in a lower thermal conductance than quoted above. The heating or cooling of very viscous fluids inside the inner vessel will also result in a very low conductance. If brine is used in place of water for cooling, the overall thermal conductance is not materially altered.

4.3 Resistance to Acids — Vitreous enamels vary considerably in their acid resistant properties. In the enamelling industry, the term 'acid-resistant enamel' has a different significance depending upon the purpose for which the enamelled item is to be used.

4.3.1 The conditions to which glass enamel may be exposed in service in the chemical and related industries vary widely in respect of the acid corrosive nature of the fluid encountered. At one end of the scale are applications in which equipment is used for the storage or treatment of cold liquors, such as formaldehyde, milk and beverages. These liquors have little or only slight corrosive action on mild steel or cast iron, but need to be stored in clean conditions which permit satisfactory sterilization when necessary, which prevent contamination of the liquors by rust and other metallic compounds and which do not provide cracks and crevices in which the growth of moulds and bacteria may be facilitated. For such applications it is not necessary to employ very highly acid-resistant linings. At the other end of the scale, enamel-lined reactors, stills, autoclave liners, etc, may be required to withstand repeated exposure or prolonged exposure or both to strong boiling mineral acids, such as concentrated hydrochloric, hydrobromic, nitric and sulphuric acids, sometimes under high pressure or under vacuum or alternating under both conditions and often mixed with solvents. For such items it is essential that the enamels employed be of a very high acid resistant quality and that the lining be free from any discontinuity or defect which will permit the access of the corrosive liquors to the underlying metal. Sometimes the lining is also required to withstand intermittent exposure to hot alkaline liquors as well as highly corrosive acids.

4.3.2 Generally most highly acid-resistant enamels are resistant to most mineral and organic acids at temperatures up to a maximum lying in the range 150° to 250°C, depending on the acidic concentration involved; hydrofluoric acid is an exception, as it attacks the silica in the glass. Special mention should be made of phosphoric acid which, if pure, has no more corrosive action than other mineral acids, but which, in its commercial form, may give rise to quite severe attack on glass enamel due to the presence in the acid of impurities containing fluorine. When glass enamel is being considered for possible use for reactions in which phosphoric acid is involved, it is recommended that tests be made on samples of the proposed enamel, using the liquors which it will be required to resist.

4.4 Resistance to Alkalis — All highly acid-resistant glass enamels contain a high proportion of silica and cannot, therefore, be expected to be resistant to hot, strong alkalis. Some enamels of this class, however, have very useful resistance to boiling dilute alkaline solutions and to much stronger solutions at lower temperatures. This permits their use for some neutralization processes and some polymerization and condensation reactions.

4.4.1 At atmospheric temperatures even concentrated caustic alkalis have little corrosive effect on most of the enamels used for chemical plant but, when the temperature exceeds about 40°C, the solutions begin to attack the enamel end, as the temperature rises further, the corrosive rate increases appreciably. Some enamels developed for particular characteristics (for example, good thermal shock resistance) may be suitable only for boiling alkaline solutions with *p*H values up to 9, but a good acid-alkali-resistant hard glass enamel will be suitable for prolonged use in contact with alkaline liquors with *p*H values up to 12 at 100°C. Alkaline liquors having *p*H values above 12 are sometimes employed for neutralizing acid batches in enamel-lined vessels. In such processes efficient agitation is essential and the rate at which the alkali is added needs to be carefully controlled. Care should always be exercised when glass enamel linings are exposed repeatedly to hot alkaline solutions since the rate of attack, unlike that in hot acid solutions, increases the more often the coating is exposed to the alkali and, if too strongly alkaline liquors are used, there is a risk that small local defects may eventually appear in the lining and later cause failure to occur when the lining is exposed to acid conditions.

4.5 Resistance to Distilled Water — Distilled water and steam attack some glass enamel linings, particularly at high temperatures, but such attack is materially reduced by small concentrations of acid.

It is now possible to produce glass enamels which are less liable to attack but, where linings are likely to be exposed to water or steam alone at temperatures above about 150°C, the manufacturer should be consulted.

4.6 Limitations of Temperature and Pressure

4.6.1 *Temperature* — Equipment may operate from −20° to +300°C. The maximum operating temperature of any piece of equipment is determined by the corrosive nature of the liquor in contact with the lining. Manufacturers should be consulted where vessels are to operate below −10°C, in view of the danger of low temperature embrittlement of the metal.

4.6.2 *Pressure* — With correctly formulated glass enamel linings failure of the lining is not likely to occur unless the metal is stressed beyond the elastic limit. Decent work indicates bond strengths of the order of 3 to 7 kgf/mm² are obtained between the glass enamel lining and the metal.

4.7 Thermal Shock — Thermal shock (that is, a sudden change in temperature)is a major cause of failures in linings.

Operations likely to cause damage are:

a) the introduction of a cold charge into a hot vessel or a cold medium into the jacket of a hot vessel,
b) the introduction of a hot charge into a cold vessel or a hot medium into the jacket of a cold vessel,
c) flame impingement or local hot spots in furnace settings, and
d) welding or torch cutting on or close to a glass enamel surface.

NOTE — Operations (c) and (d) above should be avoided whenever possible.

Most manufacturers of glass enamel-lined equipment supply information regarding the degree of thermal shock to which their equipment may be safely exposed and should be consulted in doubtful cases. Some manufacturers can supply enamels which have specially high resistance to thermal shock; these, however, have lower alkali resistance than those normally applied.

4.7.1 The temperature differences which can be tolerated vary with the operating temperature; the higher the temperature range involved, the lower the safe temperature difference. For example, whilst for a vessel lined with a particular type of enamel it might be safe to charge liquors at 15°C into the vessel at 100°C it would not be safe to charge liquors at 115°C into the same vessel at 200°C.

4.7.2 A single exposure to a sudden change in temperature may cause a lining to crack, although this may not become immediately apparent. Equipment may continue in use until the cracks develop sufficiently to permit access of the vessel contents to the base metal.

4.8 Hydrogen Penetration — When certain acids come into contact with steel, hydrogen is evolved. The nascent hydrogen formed can diffuse through the shell of the vessel to the interface of enamel and metal and form there molecular hydrogen; the pressure thus built up can cause a breakdown. The most usual cause of this form of damage is acid spillage during charging. The same effect may also result from condensation in acid laden atmospheres. Protection may be attained by painting the outside of the vessel with acid-resistant paints, based on chlorinated rubber, epoxy resins, etc. This type of breakdown is also possible if an acidic liquor is passed through jacket spaces; when the jacket spaces require cleaning, the advice of the manufacturer should be sought as to the most suitable cleaning agent.

5. DESIGN OF VESSELS AND EQUIPMENT

5.1 General — Equipment which is to be enamelled should be designed with the enamelling process in mind. Although it is possible to line other metals, nearly all of the equipment used in the chemical industry is of cast iron or mild steel. The choice between these two metals will be decided by the size and operating conditions of the particular piece of equipment.

5.2 Mild Steel — Mild steel vessels should be cylindrical in shape with domed ends attached by butt welding or by flanged joints having welded-on flanges. Attachment by riveting is unsuitable.

The design of the vessel should be such that it is suitable both for enamelling and for service as an enamelled vessel. Some guidance on the design of these vessels is offered in IS : 2825-1969*. A typical vessel is illustrated in Fig. 1.

*Code for unfired pressure vessels.

Steels suitable for enamelling are usually low carbon steels having a tensile strength not less than 34 kgf/mm².

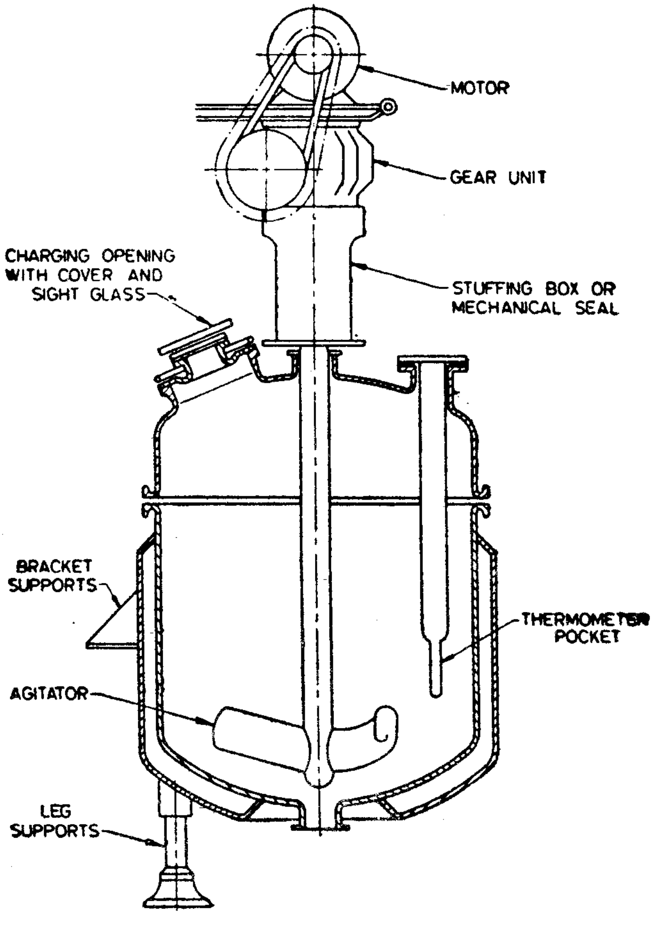

FIG. 1 A TYPICAL GLASS-ENAMEL-LINED MILD STEEL VESSEL

5.2.1 Since the efficiency of a flanged joint depends largely on the surface finish, every effort should be made to ensure a uniform and flat finish of flanges when enamelled. Branch and flange faces up to 200 mm bore may be lapped after enamelling to give a continuous flat band of contact, allowing a standard flat gasket to be used without shimming to obtain a tight joint.

Flanges of large openings, such as manholes are prone to distortion, to reduce this effect these flanges should be of the type shown in Fig. 2. They should have generous inside radii.

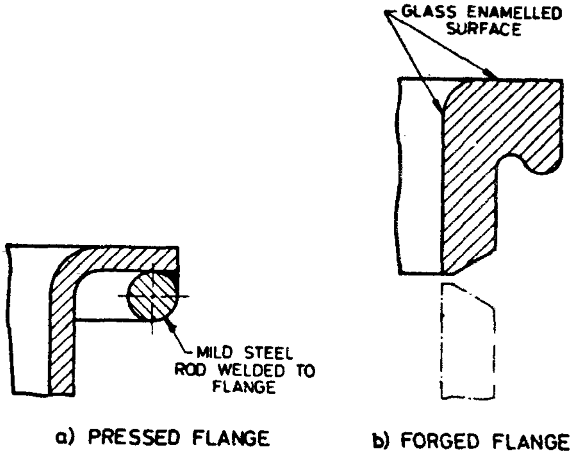

FIG. 2 FLANGES

5.2.2 All branches are, due to limitations of radii at the point of entry possible sources of weakness in the enamel lining [illegible] may, therefore, be desirable to group several such connections in the cover of one large opening. This enables the large opening to be so proportioned as to ensure good enamelling conditions, and avoids the need to re-enamel the whole vessel in the event of the failure of a minor branch.

Branches should be welded to the main shell or cover, for example, as shown in Fig. 3; generous radii are important. These branches should be as few as possible and arranged as symmetrically as possible. Small bore branches on medium and large size units should be avoided; 75 mm bore branches are often the smallest size which can be enamelled satisfactorily.

5.2.3 Jackets may be detachable or welded to an apron and may be of lighter construction. Aprons should be welded on before enamelling takes place and jackets should be welded on after enamelling.

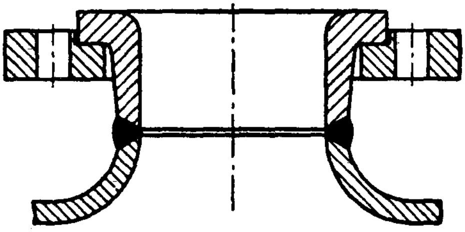

FIG. 3 WELDED BRANCH

5.3 Cast Iron

5.3.1 The chemical composition of the cast iron used for enamelling can vary over a fairly wide range but for satisfactory enamelling, all casting should be made from a good quality close-grained grey iron. The design of the vessel and the foundry technique in moulding and casting are just as important as the composition if the enamel is to be free from defects.

High tensile cast iron is not normally employed for enamelling and Grades 15 to 25 of IS : 210-1962* are typical of those used.

For satisfactory enamelling, the castings should be free from blowholes, cavities, porosity and other defects. Filling or repairing is not permissible. Cored holes should be made without chaplets, wherever possible; when the use of chaplets is unavoidable, bright, turned, untinned cast iron chaplets should be used.

5.3.2 The ideal design is one which enables the casting to heat up uniformly in the furnace and so avoid the possibility of some parts being overfired or other parts being under fired or both. This does not necessarily mean that the thickness of metal need be uniform throughout as projections and edges tend to heat more quickly than other regions. Heavy bosses and protruding parts should be kept to a minimum as they retard the heating of adjacent metal. Consideration should also be given at the design stage to factors which will reduce the distortion or warping which may occur in firing.

A typical design of a glass-enamel-lined cast iron vessel is shown in Fig. 4. The working pressures of such vessels will vary considerably, but should not normally exceed that given in Table 1. For pressures higher than in Table 1, it is preferable to use mild steel vessels.

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*Specification for grey iron castings (*revised*) (Since revised).

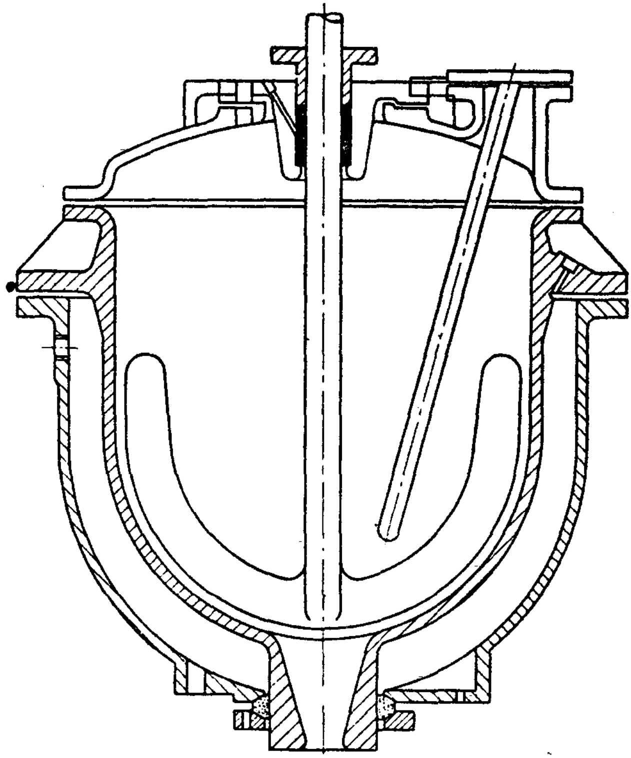

FIG. 4 A TYPICAL GLASS-ENAMEL-LINED CAST IRON VESSEL

TABLE 1 MAXIMUM WORKING PRESSURE OF CAST IRON VESSELS

(*Clause* 5.3.2)

CAPACITY litres	MAXIMUM WORKING PRESSURE kgf/cm^2
Under 1 000	6·3
1 000 to 2 500	5·0
Over 2 500	2·5

5.3.3 Although many rectangular cast iron tanks are glass enamel lined, it is preferable to use vessels with a cylindrical body and an end whose contour is either hemispherical or dished to a spherical radius not greater than the diameter of the vessel. The ratio of overall depth to diameter should not exceed 3 : 2 to facilitate handling and dusting. Vessel flanges are machined and strengthening ribs provided to reduce distortion in firing. If a bottom outlet is provided, it should be of the gland type to allow for movement when the vessel is subjected to jacket heating or cooling.

5.3.4 All edges and corners which are to be glass enamel lined should be given as generous a radius as possible. The minimum radius recommended for pipe flanges and for branches on covers is 10 mm; for vessels the flange radii should not be less than the wall thickness.

5.3.5 Cast iron vessels which are to be enamelled by the hot dust process should always have detachable covers, as enamelling by this process is not otherwise possible. Covers should be domed; the number of openings should be kept to a minimum and should be in the form of flanged branches. Branches should be kept as short as possible; enamelling will be simplified if they are tapered in the bore (with the widest portion at the junction with the cover) and if they are kept to the same height. Branch bores should be not less than 50 mm in diameter and should be increased where they join the shell of the cover. Branches with bores smaller than this are possible, especially on small vessels, but they are frequently a source of difficulty. If the bore of a pipe connection to a branch needs to be less than 50 mm in diameter, it can usually be accommodated by using enamelled flanged taper pieces.

Where a multiplicity of branches is required, it may be preferable to have three or four relatively large elliptical openings in the cover and make pipe and other connections to enamelled manifolds which are bolted to the main branches.

5.3.6 Jackets for glass-enamel-lined cast iron vessels can be made in either cast iron or mild steel depending upon the purchaser's preference. Cast iron jackets can be used for working pressures up to about 5 kgf/cm² depending on the size of the vessel. Jackets are provided with inlet and outlet connections for heating or cooling media and also with an air vent and, if required, safety valve connection. Connections are usually in the form of tapped bosses on cast iron jackets and are provided with spreaders to avoid direct impingement of the heating or cooling medium on the enamelled inner vessel. Cast-on supporting brackets can be provided, if required.

5.4 Fittings

5.4.1 *Agitators* — Agitators should be of simple design to facilitate enamelling. The coupling to the driving shaft should be outside the vessel. Because of the difficulties in achieving balance and providing footstep bearings, the following maximum speeds are recommended:

Impeller and propeller type	150 rev/min
Anchor type	660 rev/min

5.4.2 *Thermometer Pockets and Baffles* — Thermometer pockets and baffles should be of adequate strength to avoid overstressing during agitation; such pockets and baffles may be combined and made adjustable for position. They should be sufficiently long to project well down into the liquor and should be welded to a flange which may be bolted into position.

Thermometer pockets and baffles should be coated with glass enamel on the outside and under the flange. If they are to be used with viscous liquors, the manufacturer of the vessel should be consulted.

5.4.3 *Stuffing Boxes* — Stuffing boxes should be so designed that:

a) the contents of the vessels do not attack the unenamelled parts of the agitator shaft,
b) they are capable of withstanding the working pressure of the vessel, and
c) they are completely accessible for maintenance.

It may be desirable to use mechanical seals instead of stuffing boxes, such as in vacuum installations.

5.4.4 *Dip-Pipes* — Dip-pipes are difficult to enamel satisfactorily internally and externally. Therefore, it may be found economically preferable to make these of resistant materials which would be too costly to use for other items.

5.5 Pipes — The maximum length pipe which can be satisfactorily lined varies from 1 to 3 m depending on the bore of the pipe.

5.6 Methods of Heating and Cooling

5.6.1 The following methods of heating and cooling the contents of vessels are recommended:

a) Jacket heating with circulating steam, hot water, hot oils or other suitable heat transfer fluids;
b) Jacket cooling with circulating water or refrigerated brine; and
c) Electric mantle heating on an unjacketed vessel.

5.6.2 The following methods of heating are not recommended:

a) Direct flame heating of unjacketed vessels;

b) Direct flame heating of jacketed vessels with stagnant oil in the jacket; and

c) Electric immersion heaters in narrow oil-filled jackets.

5.7 Gaskets — The choice of gasket material for glass-enamel-lined vessels, pipes and flanges is, in general, governed by the same factors as is the choice of such material for any chemical plant. Users will, from their own experience, be able to select materials resistant to the chemical attack to which they will be exposed.

There are, however, several special factors in glass-enamel-lined plant which should be allowed for. Due to the relatively fragile nature of the glass enamel, it is desirable that the softer grades of suitable gasket material be used and, in addition, gaskets which make a joint with the minimum of bolting pressure are desirable.

5.7.1 The first condition indicates the use of such material as woven asbestos, compressed asbestos, natural and synthetic rubbers. Where chemical conditions render these unsuitable, the basic resilient gakset material may be sheathed in thin envelopes of some harder resistant material; in practice considerable use is made of PTFE*/rubber, PTFE/asbestos, lead/rubber and lead/asbestos composite gaskets. Under conditions of vacuum, a PTFE-sheathed gasket may be drawn into a vessel; suitable precautions should be taken to prevent this occurring. With flanges more than about 400 mm diameter, there is a danger of joints being over-tightened, with consequent cracking of the enamel lining.

5.7.2 The second consideration, that of low bolting pressures, depends on the degree of surface finish of both gasket and joint face; the truer and finer the finish, the lower the bolting load necessary to make a joint against a given pressure. In manufacture, therefore, considerable care shoule be taken to ensure a good and flat finish to the flange faces, and some surface grinding may be desirable. The surface finish of the gaskets is equally important and the choice, for example, of a graphited gasket material in a machined PTFE envelope will help to keep the bolting pressure to a minimum.

6. METHODS OF LINING

6.1 General — It is possible to line both mild steel and cast iron with a single cost of enamel and many such items are used for domestic purposes and some industrial processes; for the conditions involved in the chemical industry, however, it is always necessary to apply at least two coats and often necessary to apply several, particularly if the corrosive conditions to which the equipment is to be subjected are severe.

*Polytetrafluoroethylene.

Highly acid-resistant frits do not bond readily to cast iron and mild steel and an enamel of different composition (and less acid resistant) is generally used for the first layer in order to provide a 'ground' or 'grip' coat which has good adhesion to the metal and provides a suitable base over which the more highly chemical-resistant enamel can subsequently be applied.

Three methods of lining are employed as follows:

a) The wet spray process,
b) The hot dust process, and
c) The spray dust process.

6.2 Wet Spray Process — Both cast iron and mild steel can be enamelled by the wet spray process, but for equipment required for chemical plant, the process is used only on mild steel. The steel surfaces to be enamelled should be thoroughly cleaned, usually by blasting with steel or chilled iron shot or aluminium oxide. Acid pickling may occasionally be employed, but this method is more widely used in the domestic appliance field for items fabricated from sheet steel, which is too thin to be cleaned by blasting.

After cleaning the metal surface a ground coat of enamel is applied in slip form by spraying or, in the case of some small items, by mill, swilling or slushing. This coat is dried and the item is then fired in the enamelling furnace after which it is allowed to cool to atmospheric temperature. A second coat (of the same or a different enamel) is then sprayed on and is dried, fired and allowed to cool in the same way. Any subsequent coats are applied in similar fashion, the total number of coats required being determined by the grade and quality of the lining required.

6.3 Hot Dust Process — The hot dust process is used for both mild steel and cast iron items. After cleaning the metal surface a ground coat is applied by spraying, swilling or brushing and is then dried and fired. When the firing of the ground coat is completed, the item is removed from the furnace and the dry powdered cover coat enamel is dusted over the surface while the item is still at red heat. Several separate dustings of cover coat may be applied, the item being returned to the furnace between dustings, but normally it is not allowed to become cold until the complete coating has been applied.

An advantage of the hot dust process is that greater variations in design and in the section thickness of the metal can be tolerated than with the wet spray process since the item is not allowed to become cold until the enamelling operation is completed. With the wet spray process, however, it is possible to inspect each coating after the item has cooled and, if necessary, to apply corrective treatment at local defective places.

Because of the physical difficulty of coating large vessels in the hot state, the hot dust process is restricted to vessels of up to about 5 000 litres capacity, while with the wet spray process the size of item which can be enamelled is, in theory, limited only by the capacity of the furnace available. In practice the maximum size of item which can be enamelled by the wet spray process also depends upon the quality of the lining required.

The hot dust process can only be employed for items in which the dust can conveniently be applied to the whole of the surface to be enamelled while the item is at red heat. It is, therefore, not suitable for closed vessels but can be used for open vessels and those with flanged removable covers or ends.

6.4 Spray Dust Process — The spray dust process is a combination of the two methods of lining described above. A wet coat of enamel slip is sprayed on whilst the item is cold and powdered enamel frit is dusted on this coat whilst it is still wet and cold. After drying, the item is introduced into the furnace and the spray dust coating fired in the usual manner. The method can be applied to both open and closed vessels.

7. INSPECTION AND TESTING

7.1 Defects — The combination of acid-resisting glass supported by cast iron or mild steel appears in principle to be an ideal material for many applications in the chemical industry; its performance in practice, however, can be disappointing because of failure of the coating due to defects which either are inherent in the original enamel or develop during service. Defects appearing during inspection at the manufacturing stage may be repaired by agreement between the purchaser and the manufacturer (*see* **10**). Defects can arise through mishandling, mechanical shock (such as accidental dropping of hard objects into a vessel) or thermal shock (that is too rapid changes of temperature).

7.2 Tests for Continuity of Lining

7.2.1 *Visual Inspection* — All glass enamel linings should first be inspected visually for any major cracks or other defects. Presence of defects too small to be so observed can, however, allow the base metal to be attacked by the contents and the lining to fail. Where complete continuity of the lining is required the more searching electrical tests described in **7.2.2** are employed.

7.2.2 *Electrical Tests* — The following two electrical tests are commonly used, their object being to detect defects by observing leakage of current through the lining. These tests should be done after all mechanical work on the vessel or equipment has been completed.

7.2.2.1 *Resistance or wet test* — In this test, the negative terminal of a dry battery not exceeding 12V, or other suitable safe source of direct current, is connected to the base metal of the lined vessel and the positive terminal connected via a milliammeter to a swab saturated with a solution of sodium chloride and phenolphthalein. The swab is moved slowly over the whole surface of the enamel, and any detectable defect is indicated by a deflection on the milliammeter and the development of a red stain both at the defect and on the swab.

A satisfactory solution for use with this test is made up by adding 10 ml of industrial spirit and then adding 10 ml of a suitable wetting agent, for example, sodium alkylnaphthalene sulphonate; this mixture is then added to 4·5 litres of water in which 450 g of common salt has been dissolved.

7.2.2.2 *High frequency spark test* — In this test, a high-voltage, high-frequency spark discharge is directed at the lining, in the manner and using the apparatus described in Appendix C. This test is much more searching than that described in 7.2.2.1 above, and care should be taken in its use. The repeated application of the spark test may damage the lining and routine tests in the field at peak voltages in excess of 5 kV are not recommended.

7.3 Hydraulic Tests

7.3.1 *Cast Iron Vessels and Equipment* — As the flanges of cast iron vessels and covers are usually drilled after enamelling, hydraulic tests, where required, are normally applied after enamelling; the vessel chamber space should then be subjected to an internal pressure one and a half times the normal working pressure.

Cast iron jackets are normally subjected to an internal hydraulic pressure of not less than twice the working pressure.

7.3.2 *Mild Steel Vessels and Equipment* — Where a hydraulic test is required, the internal test pressure should be one and a half times the working pressure; the test may be done either before or after enamelling, by agreement between the purchaser and the manufacturer. If the hydraulic test is done before enamelling, the purchaser may require a further test to be done after enamelling at one internal pressure of 1·25 times the working pressure.

8. MARKING

8.1 Name-Plate — There should be permanently attached to the vessel in a visible position, a plate bearing the manufacturer's name or trade mark, the serial number and the maximum working pressure.

9. STORAGE INSTALLATION AND SERVICE

9.1 Receiving New Vessels — Vessels and equipment should be inspected immediately on delivery and any obvious damage should be brought to the notice of the delivering carrier and the documents endorsed accordingly. This procedure is absolutely necessary for satisfactory settlement of claims for damage in transit. The supplier should also be informed.

9.2 Storage — When it is necessary to store glass enamelled vessels and equipment, the following precautions should be taken for protection:

a) Jackets should be completely emptied to prevent damage due to freezing during cold weather;

b) All manhole and cover clamps or bolts, except a few that are necessary to hold the cover in place, should be removed; the clamps or bolts should then be stored in a drum or container with oil and the container sealed;

c) Open-top vessels should be adequately protected in store by fitting a wooden or other suitable cover;

d) Vessels and equipment should be stored in such positions that they are not subject to damage by being knocked by passing objects;

e) Rubber branch sheaths or plywood circles all round, threaded jacket connections should be adequately protected;

f) All bright exposed parts, such as agitator shafts, etc, should be coated with an anti-rust solution;

g) A protective coating or covering should be applied and the external surface maintained in good condition;

h) Steps should be taken to prevent the accumulation of moisture in vessels;

j) Thermometer pockets and other items of tubular construction should have their ends closed with some suitable plug of soft material to prevent the accumulation of moisture which could cause damage; and

k) If the use of chain slings is necessary, care should be taken to avoid damage to the lining.

9.3 Installation — The following precautions should be observed in the installation of all vessels and equipment:

a) During hoisting operations care should be taken to prevent the vessel from colliding with surrounding structures;

b) Wire or hemp rope slings of the appropriate load capacity should be used for hoisting; if it is necessary to use chain slings, care should be taken to avoid damage to the enamel;

c) Cylindrical vessels should not be rolled into position or turned on centre blocks, but moved on temporary cradles and rollers;

d) When manoeuvering a vessel into position, rollers should be placed under the skid and the unit worked around; blocks should not be placed under the centre of the vessel to spin it around;

e) All flanged openings should be protected against damage;

f) When it is necessary to enter the vessel, damage to the lining should be avoided by suitably covering footwear and ladders;

g) Vessels should be installed level; and

h) When tightening bolted or clamped joints, it is important to avoid strains which might distort the metal or fracture the glass enamel; tightening should be even, following the sequence North-South-East-West and preferably using a torque spanner set to a figure recommended by the supplier.

9.4 Change in Service Conditions — With new vessels and equipment, the service conditions will have been checked with the manufacturer of the unit when purchased. However, it is advisable to re-check the suitability of the units for any new conditions which may arise, should these differ from those originally specified. At the same time consideration should be given to the suitability of the following for the new conditions:

a) Gaskets,

b) Stuffing box packing and sealer rings,

c) Agitator sleeves and stuffing box housing rings, and

d) Repair plugs.

10. REPAIRS

10.1 Severe Chemical Service

10.1.1 *Small Damaged Areas* — In suitable positions, areas up to 125 mm in diameter can be very satisfactorily repaired with metal repair plugs. Two types of plugs are in common use; a three piece plug consisting of a stud, nut, disks of tantalum or other material and PTFE gaskets, and a single piece mushroom-headed plug with PTFE gasket. Both plugs require the application of a small amount of repair cement.

The fitting of repair plugs is a specialist's task which should be done only by those with the necessary skill and experience.

As tantalum and PTFE have similar chemical resistance to glass, these materials are most often used although other materials for plugs, such as stainless steel and nickel alloys are also in use. Figure 5 illustrates typical plug repairs of the type described above.

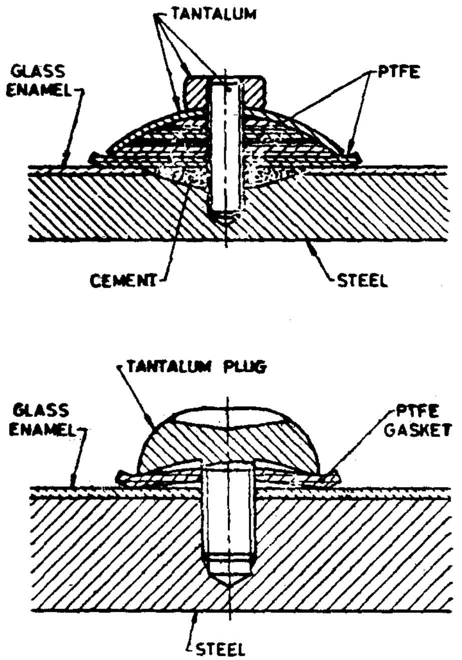

FIG. 5 TYPICAL PLUG REPAIRS

10.1.2 *Large Damaged Areas* — For damaged areas in excess of 125 mm diameter, special plates are normally used and with a suitable number of studs and nuts of the same material, a patch is formed over the affected area. Here again, a PTFE gasket and cement form the seal.

A less expensive alternative is the use of repair cement to coat the damaged area, but due to the limitation of most repair cements, such a repair should be considered only temporary in nature.

10.1.3 *Damaged Branches* — Branch damage may present a special repair problem. If a plug cannot be used, highly satisfactory repairs can be accomplished with a tentalum shield shaped to fit the branch, as shown in Fig. 6.

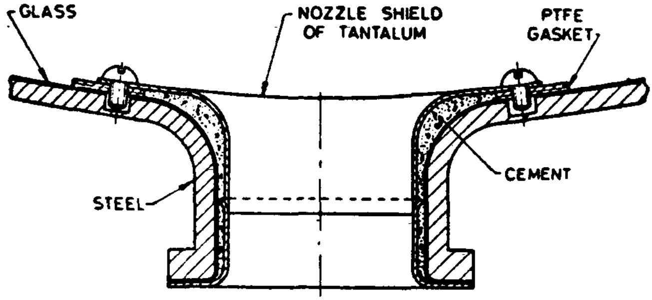

FIG. 6 DAMAGED BRANCH REPAIRS

10.2 Mild Chemical Service — Repair cements are generally quite satisfactory for mild chemical service and are effective over quite long periods. In addition they have the advantages of being inexpensive and easily applied.

10.3 Complete Re-enamelling — There may come a time in the life of the equipment when it can no longer be economically or satisfactorily repaired on site. It may still be possible to obtain further service by having the entire unit re-enamelled.

The time to re-enamel should be determined by the user and depends not only on the extent of the damage but also on the nature of the process. It is important to note that a damaged vessel should be withdrawn from service in good time in order that any attack which has taken place on the base metal should be a minimum.

It should be noted that complete re-enamelling usually results in distortion of the vessel, particularly in the position and inclination of flanges. Such distortion usually necessitates modifications to the pipework before the vessel can be re-installed.

10.4 Returning Equipment for Repair — To avoid delays in connection with equipment or accessories returned for repairs, the following procedure is recommended:

The supplier should be notified in writing describing in detail the equipment being returned, giving original order number if possible and at the same time stating what repairs are required. The equipment should be clearly marked with the conignee's address and adequately protected and packed against damage in transit.

APPENDIX A
(*Clause* 0.5)

EXCHANGE OF INFORMATION

Early consultation and exchange of information should be arranged between all parties concerned with the design, use, manufacture and erection of the vessels and equipment to be lined. Complete and accurate scale drawings should be available to all parties concerned.

Consultation may be desirable on the following points:

a) Site conditions which may affect the installation, and the availability of services on the site;

b) Design of the equipment to ensure its suitability for glass enamel lining;

c) Nature and concentration of the contents for which the vessel or equipment is required;

d) Operating temperatures and pressures, including the degree of thermal shock; and

e) Presence of abrasives and possible effect of the contents on the lining.

APPENDIX B
(*Clause* 2.1)

GLOSSARY OF TERMS IN COMMON USE IN THE VITREOUS ENAMELLING INDUSTRY

Term	Definition
Annealing	A process in which metal items for enamelling are heat-treated prior to cleaning, generally by heating to a temperature above the fusing temperature of the enamel and holding for a period at this temperature.
Base Metal	The metal on which enamel coatings are applied.

TERM	DEFINITION
Biscuit or Bisque	A coating of wet-process enamel which has been dried, but not fired.
Blisters	A bubble-like appearance on the surface of the enamel; generally the result of gas evolution while the enamel is molten.
Boiling	Defects in a fired enamel consisting of an aggregation of blisters, pinholes, black specks, dimples or spongy surface.
Chipping	Fracturing or breaking away of fragments of the enamelled surface.
Consistency	The properties of an enamel slip which control its draining, slushing and spraying qualities.
Copperhead	A defect occurring in fired ground coats on steel which appears as a small freckle or pimple-like, spot, reddish brown in colour.
Cover Coat	The top or later coats of enamel applied over the first or ground coat.
Crazing	A defect appearing as fine cracks in a finished enamel surface. Crazing may occur on cooling after firing, or after the item has been allowed to stand or may appear later due to heating and cooling of the enamelled item in use.
Dipping	a) *Wet Process* — The process of applying enamel to the base metal by immersion in enamel slip and allowing the excess slip to drain off upon removal from the bath. b) *Dry Process* — The method of coating by immersing the heated metal shape for a short time in enamel powder.
Dry Process	The application of dry powdered enamel to heated metal shapes.
Dusting	a) The application of dry enamel powder to hot metal shapes by screening, sifting or sieving (also referred to as dredging)·

Term	Definition
	b) In wet processing the application or piling up of almost dry enamel during spraying.
	c) The removal of extraneous material from the biscuit before firing.
Fire Cracking	The cracking or fracturing of a casting during the annealing or firing process.
Firing (Fusing)	Process of heating the item to fuse and mature the applied coating into a vitreous enamel coating.
Firing Temperature (Fusing Temperature)	The temperature attained by the item during the firing and maturing of the enamel coating.
Fishscaling	A defect appearing as small half-moon shaped fractures resembling the scales of a fish, detaching themselves from the enamel layer; this defect is usually associated with wet process enamelling.
Flow Coating	Process of coating items by flowing or pouring the enamel, slip over the surface and allowing it to drain.
Flux	A substance that promotes fusion in a given enamel mixture.
Frit	Small friable particles of enamel glass produced by discharging the molten enamel from the smelter into water, thus quenching and shattering it; the molten enamel is sometimes quenched between water-cooled rolls to produce the frit in flake form.
Glass	This term is sometimes used as a synonym for vitreous or porcelain enamel, particularly for the highly acid-resistant enamels applied on items of chemical plant.
Glass Eye	A defect consisting of a large unbroken blister in a finished enamel coating.

TERM	DEFINITION
Ground Coat	A coat of enamel applied directly to the base metal.
Hair Lines	Lines appearing in the top layer of enamel without breaking or cracking the enamel, caused by cracking of the bisque or previously fired coating before final fusion; the lines may show the colour of the ground coat (also known as strain lines).
Lamination	A fault in sheet iron or mild steel plate material; the cavity in the steel may enlarge during firing to produce defects in the enamel coating.
Mill Additions	Substances added to the mill charge of enamel frit to produce the required properties in the powder or slip.
Milling	The process of reducing enamel frit to fine particles by grinding in a suitable mill, generally a ball mill, with or without water and mill additions.
Orange Peel	A condition of the fired enamel coat showing an irregular surface pattern, characteristic of orange peel.
Pinholes	An enamel surface defect characterized by a small depression as though made by a pin, resulting from the breaking of a gas bubble and frequently reaching to the base metal.
Quenching	The operation of pouring the molten frit into water to produce small grains or cooling the molten frit by passing it through water-cooled rollers to produce small flakes.
Scale	Oxide on the surface of the metal, either remaining from the manufacturing process or caused by heating the material to a red heat.
Scumming	The formation of areas of poor gloss on the surface of an enamel during or after firing

TERM	DEFINITION
Set (noun)	The property which enables an enamel slip to leave a layer of definite thickness on a non-porous surface either by dipping or spraying.
Set (verb)	To adjust the flow properties of an enamel so that it will leave a layer of definite thickness on a non-porous surface either by dipping or spraying.
Slip	The prepared suspension of frit in water produced by the wet grinding operation.
Slushing or Swilling	The coating of items by pouring, or throwing the slip on to the item and subsequently draining or shaking off the excess.
Smelting	The process of melting together the raw materials required to produce a molten enamel or glass.
Softening Temperature	The temperature at which the enamel begins to soften or flow.
Spalling	The failure of the enamel due to stresses in the coating usually characterized by slivers of enamel breaking away with a conchoidal type of fracture, also referred to as flaking off, shaling and flying.
Specking	The formation or occurrence of small dark spots in the finished enamel surface; usually due to fortuitous particles of foreign matter in the enamel.
Tearing	A cover coat enamel defect distinguished by minute cracks or tears in the fired enamel which have failed to fuse together during the firing operation.
Vitreous Enamel	A substantially vitreous or glassy inorganic coating bonded to metal by fusion at temperatures in excess of 450°C; also known as porcelain enamel, enamel and glass enamel.
Warping	Change or distortion in the original contour of an enamelled item developed during firing.

APPENDIX C

(*Clause* 7.2.2.2)

SPARK TEST

C-1. The continuity of the glass enamel lining is tested by the application of a high-voltage test electrode to every part of the lining. The metal of the vessel is, during the test, connected to earth and maintained at earth potential. The high voltage is derived from a commercially available apparatus, preferably mains operated. The voltage applied is such as just to maintain a continuous discharge between a needle point connected to the test lead and the centre of an earthed disk situated in still air at normal barometric pressure, the point being 17 mm from the disk. Alternatively, the applied voltage is such as just to maintain a continuous discharge between two 100-mm diameter metal spheres, one connected to the test lead and the other to earth, both situated in still air at normal barometric pressure, the distance between the spheres being 6 mm (*see* IS : 1876-1961*).

*Method for voltage measurement by means of sphere-gaps (one sphere earthed).

(*Continued from page 2*)

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