CONSTRUCTION STANDARD

FOR

LINING

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APPENDICES:

1. SCOPE

1.1 This construction Standard covers the minimum requirements for application and installation of organic and inorganic lining for equipment. This Standard includes requirements for preparation of material for use, application, drying or curing, transportation, installation, repair of lining and inspection of lined parts.

1.2 It applies to equipment fabricated in metal or concrete and in both bonded and loose linings.

1.3 Requirement for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to the editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor.

ACI (AMERICAN CONCRETE INSTITUTE)

ACI 506 R-85	"Guide to Shotcrete"

API (AMERICAN PETROLEUM INSTITUTE)

API-RP-1631	"Interior Lining of Underground Storage Tanks"
API-RP-10E	"Recommended Practice for Application of Steel Tubular Goods, Handling, Installation and Joining"
API-RP-5L	"Recommended Practices for Unprimed Internal Fusion bonded Epoxy Coating of Line Pipe"

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

ASTM-C-93	"Test Methods for Cold Crushing Strength and Modulus of Rupture of Insulating Fire Brick"
ASTM-C-143	"Test Methods for Slump of Portland Cement Concrete"
ASTM-C-268	"Preparing and Curing refractory Concrete Test Sample"
ASTM-D-412	"Test Methods for Rubber Properties in Tension"
ASTM-D-429	"Test Methods for Rubber Property Adhesion to Rigid Substrates"
ASTM-D-471	"Test Methods for Rubber Property-Effect of Liquids"
ASTM-D-573	"Test Methods for Rubber-Property-Deterioration in an Air Oven"
ASTM-D-865	"Test Methods of Rubber Property-Deterioration in Heating in Air" (Test Tube Enclosure)
ASTM-D-2228	"Test Methods for Rubber Properties-Abrasion Resistance (Pico Abrader)"
ASTM-D-2240	"Test Methods for Rubber Properties-Durometer Hardness"

ASTM-D-2563 "Recommended Practice for Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts"

ASTM-D-3182 "Material, Equipment and Procedures for Mixing Standard Compounds and Preparing Standard Vulcanized Sheets"

ASTM-D-3183 "Practice for Rubber-Preparation of Pieces for Test Purposes From Products"

ASTM-D-3486 "Installation of Vulcanizable Rubber Tank Lining and Pipe"

ASTM-D-3491 "Method of Testing Vulcanizable Rubber Tank and Pipe Lining"

ASTM-D-3567 "Practice for Determining Dimensions of Reinforced Thermosetting Resin Pipe and Fitting"

ASTM-D-4787 "Practice for Continuity Verification of Liquid or Sheet Lining Applied to Concrete Substrates"

ASTM-G-14-77 "Test Method for Impact resistance of Pipeline Coatings (Falling Weight Test)"

AWWA (AMERICAN WATER WORKS ASSOCIATION)

AWWA-C 101/ A 21.4 "Cement-Mortar Lining for Ductile-Iron Pipe and Fitting for Water"

AWWA-C 203 "Coal-Tar Protective Coatings and Linings for Steel Water Pipelines-Enamel and Tape, Hot Applied"

AWWA-C 205 "Cement-Mortar for Protective Lining and Coating for Steel Water Pipe-Shop Applied"

AWWA-C 210 "Liquid Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipeline"

AWWA-C 213 "Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines"

AWWA-C 602 "Cement-Mortar Lining of Water Pipelines 4 in. and Large-Inplace"

BS (BRITISH STANDARD INSTITUTION)

BS 358 "Method for the Measurement of Voltage with Sphere Gaps"

BS 490: Section 10.4 "Method for Determination of Adhesion Strength of Rubber and Plastics Belting of Textile Construction"

BS 903: Part A 21 "Determination of Rubber to Metal Bond Strength"

BS 903: Part A 26 "Determination of Hardness"

BS-1344 "Methods of Testing Vitreous Enamel Finishes"

BS-2719 "Methods of Use and Calibration of Pocket Type Rubber Hardness Meters"

BS-2782, Method 320A to 320F "Methods of Testing Plastics, Tensile Strength, Elongation and Elastic Modulus"

BS-6374: Part 1 "Specification for Lining with Sheet Thermoplastics"

BS-6374: Part 2	"Specification for Lining with Non-Sheet Applied Thermoplastics"
BS-6374: Part 3	"Specification for Lining with Stoved Thermosetting Resins"
BS-6374: Part 4	"Specification for Lining with Cold Curing Thermosetting Resins"
BS-6374: Part 5	"Specification for Lining with Rubbers"
BS 6466	"Code of Practice for Design and Installation of Ceramic Fiber Furnace Linings"

DIN (DEUTSCHES INSTITUTE FÜR NORMUNG)

DIN-4753: Part 3	"Water Heaters and Water Heating Installations for Drinking Water and Service Water"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-C-TP-101	"Surface Preparation"
IPS-C-TP-102	"Painting"
IPS-E-TP-100	"Paint"
IPS-E-TP-350	"Lining"
IPS-M-CE-105	"Building Material"
IPS-M-TP-105	"Bitumen Mastic"
IPS-M-TP-230	"Coal Tar Mastic"
IPS-M-TP-280	"Coal Tar Primer"
IPS-M-TP-285	"Bitumen Primer"
IPS-M-TP-290	"Coal Tar Enamel"
IPS-M-TP-295	"Bitumen Enamel"

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO 2722	"Vitreous and Porcelain Enamel-Determination of Resistance to Citric Acid at Room Temperature"
ISO 2723	"Vitreous and Porcelain Enamels for Sheet Steel-Production of Specimens for Testing"
ISO 2724	"Vitreous and Porcelain Enamel for Cast Iron-Production of Specimens for Testing"
ISO 5256	"Steel Pipes and Fittings for Buried or Submerged Pipelines-External and Internal Coating by Bitumen or Coal Tar Derived Materials"
ISO 8289	"Vitreous and Porcelain Enamel-Low Voltage Test for Detecting and Locating Defects"
ISO 9004	"Quality Management and Quality System Elements"

JGS (JAPAN GASOLINE STANDARD)

JGS-652-322-5-03E	"Installation of Glass Lined Piping"

NACE (NATIONAL ASSOCIATION OF CORROSION ENGINEERS)

NACE	"Coating and Lining for Immersion Service"
NACE-6F 164	"Curing of Interior Tank Lining"
NACE-6F 166	"Recommended Practices for Inspection of Lining on Steel and Concrete"
NACE RP 0274	"High Voltage Electrical Inspection of Pipe Line Coating Prior to Installation Item"
NACE-6H 160	"Glass Lining and Vitreous Enamels"

SIS (SWEDISH STANDARD)

SIS 05 59 00	"Rust Levels of Steel Structure and Quality Levels for Preparation of Steel Surface for Rust Protecting Paints"

3. DEFINITIONS AND TERMINOLOGY

3.1 Definitions

Applicator

Is the party which applies the chemical resistant linings specified by the Company.

Blister

A gas or liquid filled cavity within the lining material or between the lining and substrate.

Ceramic

Articles with a glazed or unglazed body of crystalline or partly crystalline structure or of glass, produced from essentially inorganic, non-metallic substances and formed either from a molten mass solidified on cooling, or simultaneously or subsequently matured by the action of the heat, ASTM-C-242.

Chemical Resistant Resin Mortar

Mixture of liquid resinous material, selected filler material, and setting agent forming a trowelable mortar that hardens by chemical reaction, ASTM-C-904.

Designer

Person or party responsible for all or part of design and engineering of project.

Dew Point

The temperature at which moisture will condense.

Etch

To corrode the surface of a metal in order to reveal its composition and structure.

Fabricator

The party which manufactures components to perform the duties specified by the Company. It is generally considered to be synonymous with the term manufacturer.

Glass

Inorganic fusion product that has cooled to a rigid condition without crystallizing.

Hydraulic Cement

Cement that sets and hardens by chemical interaction with water and capable of doing so under water.

Inspector

The inspector or engineer employed by the Purchaser and acting as the Purchaser’s representative, the inspector’s engineer’s respective assistants properly authorized and limited to the particular duties assigned to them, or the Purchaser acting as the inspector.

IRHD

International Rubber Hardness.

Laitance

A milky white deposit on new concrete.

Lining

Any sheet or layer of material attached directly to the inside face of form work to improve or after quality and surface texture.

Lump

In porcelain enamels, a rounded projection in the enamel surface, usually a defect.

Mop

An implement made of absorbent material fastened to a handle and used for cleaning floors.

Orange Peel

A surface condition characterized by an irregular waviness of the porcelain enamel resembling an orange skin in texture, sometimes considered a defect.

Pinhole

A small defect in the lining that would permit corrosion of the substrate under the conditions for which the lining is designed.

Note:

The word ’pinhole’ is synonymous with ’holiday’ and ’pore’.

Plastic

A material that contains as an essential ingredient a high polymer and which at some stage in its processing into finished products can be shaped by flow.

Plastisol

A dispersion of finely divided resin in a plasticizer.

Porcelain

Glazed or unglazed vitreous ceramic whiteware matured like ceramic and glazed together in the same firing operation.

Pozzolanic Material

A volcanic dust, first discovered at Pozzuoli in Italy, which has the effect when mixed with mortar, of enabling the latter to harden anywhere, in air or under water.

Powder Organic Coating

A product containing pigments, resins and other additives which is applied in the form of a powder on to a metallic substrate and is fused to form a coherent continuous finish.

Prestressing

To introduce internal stresses into (as a structural beam) to counteract later load stresses.

Quartz/Silica

Glass made either by flame hydrolysis of silicon tetrachloride or by melting silica, usually in the form of granular quartz, i.e. fused silica, ASTM-C-162.

Ram Extrusion

A continuous process in which compaction of the granular PTFE at a relatively low temperature, sintering at a temperature of approximately 380°C and cooling are carried out in a single piece of equipment. The extruder is fed by a reciprocating cylinder (ram) under high pressure.

Refractories

Non-metallic materials with chemical and physical properties applicable for structures and system components exposed to environments above 538°C (1000°F), ASTM-C-71.

Resin

A solid, semisolid, or pseudo solid organic material that has an indefinite and often high relative molecular mass, exhibits a tendency to flow when subjected to stress, usually has a softening or melting range and, usually fractures conchoidally. In a broad sense, the term is used to designate any polymer that is a basic material for plastics.

Rubber

A material capable of quickly and forcibly recovering from all deformations. It can be modified to be essentially insoluble, but it can swell in boiling solvents, e.g. benzene, methyl ethyl ketone and ethanol/toluene azeotrope. Rubber in its modified state, free of diluents, stretched at 18 to 29°C and held for 1 minute before release, retracts within 1 minute to less than 1.5 or 2 times its original length, ASTM-D-1566.

Sagging

1) A defect characterized by a wavy line or lines appearing on those surfaces of porcelain enamel that have been fired in a vertical position.

2) A defect characterized by irreversible downward bending in an article insufficiently supported during the firing cycle.

Skive

To cut off in thin layers or pieces.

Squeegee

A blade of leather or rubber set on a handle and used for spreading, pushing or wiping liquid material on, across, or off a surface.

Squeegeeing

To smooth, wipe or treat with a squeegee.

Stone Ware

Vitreous or semi-vitreous ceramics of fine texture made primarily from non-refractory fire clay, ASTM-C-242.

Surface Profile

Surface profile is a measurement of the roughness of the surface which results from abrasive blast cleaning. The height of the profile produced on the surface is measured from the bottoms of the lowest valleys to the tops of the highest peaks.

Tearing

A defect in the surface of porcelain enamel, characterized by short breaks or cracks which have been healed.

Thermoforming

Forming of thermoplastic sheet by heating it and then pulling it down on to a mold surface to shape it.

Thermoplastic Material

A plastic that repeatedly will soften by heating and harden by cooling within a temperature range characteristic for the plastic. In the softened state it can be shaped by flow into articles, e.g. by molding/extrusion, ASTM-D-883.

Thermosetting Material

A plastic being substantially infusible and insoluble after curing by heat or other means, ASTM-D-883.

3.2 Abbreviations

BR	Polybutadiene Rubber
CSM	Chlorosulfonated Polyethylene (Chlorinated Rubber)
CR	Chloroprene Rubber
ECTFE	Ethylene-Chlorotrifluoro-Ethylene

EPDM	Ethylene-Propylene Diene Monomer
EPR	Ethylene-propylene Rubber
EVA	Ethylene Vinyl Acetate
FEP	Fluorinated Ethylene Propylene Copolymer
FKM	Fluorinated Rubber (Polymethylene Type)
IIR	Butyl Rubber
IR	Synthetic Polyisoprene
NBR	Nitril Rubber
NR	Natural Rubber (Polyisoprene)
PA	Polyamide
PE	Polyethylene
PF	Phenol-Formaldehyde
PFA	Perfluoroalkoxy
PP	Polypropylene
PTFE	Polytetra Fluoro Ethylene
PU	Polyurethane
PVC	Polyvinyl Chloride
PVDF	Polyvinylidene Fluoride
SBR	Styrene butadiene Rubber
XNBR	Carboxylated Nitril Rubber

4. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

5. PROCEDURE, QUALITY CONTROL AND CONTRACT DOCUMENTS

5.1 Quality Control

5.1.1 The Contractor shall set up and maintain such quality assurance and inspection systems as are necessary to ensure that the goods or services supplied comply in all respects with the requirements of this construction standard.

5.1.2 The Company will assess such systems against the recommendations of the applicable parts of ISO 9004 and shall have the right to undertake such surveys as are necessary to ensure that the quality assurance and inspection systems are satisfactory.

5.1.3 The Company shall have the right to undertake inspection or testing of the goods or services during any stage of work at which the quality of the finished goods may be affected and to undertake inspection or testing or raw material or Purchased components.

5.1.4 The contractor's equipment for surface preparation and lining shall be of such design and manufacture and in such condition as to comply with the procedure and obtain results prescribed in this Standard.

5.1.5 All materials furnished by the contractor shall be of the specified quality. All work shall be done in a thorough, workmanlike manner. The entire operation shall be performed by, and under the supervision of, experienced persons skilled in the application of specified lining.

5.2 Contract Document

5.2.1 The contractor shall submit to the Company the design documentation before fabrication and installation commence.

5.2.2 The Company may required the contractor to furnish an affidavit that all materials and work furnished under the Company order will comply, or have complied, with the applicable requirements of this Standard.

5.2.3 The contractor's equipment for lining shall be of such design and manufacture and in such condition as to permit applicators to follow the procedure and obtain results prescribed in this Standard.

5.2.4 All materials furnished by the contractor shall be of the specified quality. The entire operation shall be performed by, and under the supervision of experienced persons skilled in the application of lining.

6. GENERAL REQUIREMENTS

6.1 Selection of Process and Material

6.1.1 The final selection of the type and thickness of the lining, and the method of application, shall be made in conjunction with the materials specialist and the lining contractor.

6.1.2 The following details shall be included on the requisition sheet of the equipment concerned:

- materials to be handled;
- temperature } minimum, maximum, normal
- degree of vacuum or pressure;
- cycle of operations;
- abrasion and erosion aspects;
- immersion conditions;
- storage.

6.2 Applicator Qualification

Lining installation shall be done only by applicator qualified by commercial experience in installing the type lining proposed. To satisfy this experience requirement, the applicator shall submit a list of application and installation, and where such data is available, the service condition and reported record of performance.

6.3 Inspector Qualification

6.3.1 All inspections, whether for the Company or the applicator, shall be performed only by a qualified inspector. The extent and time of any inspection by the Company, or his duly appointed representative, shall be a part of the job specifications.

6.3.2 A qualified inspector shall have the following prerequisites as a minimum:

- Complete knowledge of the job specifications and their requisities.
- A practical knowledge of all phases of lining application work including:

  a) pre-application surface finish requirements such as grinding of welds, sharp edges, etc.;
  b) surface preparation;
  c) lining application techniques and workmanship;
  d) lining materials;
  e) continuity, thickness, cure tests and tolerances of standards, and;
  f) equipment and tools used in all phases of lining application work.

- Adequate experience and training in the inspection of lining applications; the instruments used for inspection and evaluation of lining applications.

6.3.3 The specification should so stipulate if final acceptance of the work is to be made by a duly appointed representative of the user. If so, it is wise for that representative to be a qualified inspector (see 6.3.1).

6.4 Qualification Testing

6.4.1 The full program of qualification testing is required before a manufacturer will be allowed to deliver for the first time. The Company may require the qualification testing of a certain make to be repeated completely or in part, for example because of time elapsed or new developments.

6.4.2 Changes in the design and/or method of manufacture of parts will in any case require new or additional qualification tests.

6.4.3 The qualification testing shall be carried out on products with representative diameters. The type of product, the number, etc. shall be mutually agreed with the company.

6.4.4 Qualification testing shall be carried out by the manufacturer and witnessed and certified by an independent authority recognized by the Company. Alternatively, testing and certification may be carried out by an independent testing organization. This shall be confirmed by submitting a certificate stating the test results.

6.4.5 Qualification testing program to which a manufacturer is subjected before his delivery to ensure that he can fulfill the requirements as follows:

a) Surface preparation inspection according to IPS-C-TP-101.

6.5 Responsibility for Inspection and Testing

The manufacturer of the equipment and the applicator and/or contractor of the lining are responsible for performance of all inspections and tests specified shall provide a certificate of inspection and testing. The stage of inspection shall be according to, but not limited to, the followings:

a) the equipment as fabricated;
b) surface cleanliness;
c) application techniques;
d) visual appearance of lining;
e) adhesion of lining;
f) continuity of lining;
g) thickness of lining;
h) cure evaluation of lining.

Note:

No test instrument which is destructive or detrimental to the integrity of an applied lining shall be used for any test.

7. SHEET APPLIED THERMOPLASTIC RESIN LINING

7.1 General

7.1.1 This Clause 7 specifies requirements for the lining of equipment using sheet thermoplastics.

7.1.2 The thermoplastics can be used for sheet lining includes:

- Polyethylene .... (PE),
- Poly Propylene .... (PP),
- Poly Vinyl Chloride .... (PVC),
- Poly Vinylidene Fluoride .... (PVDF),
- Fluorinated Ethylene Propylene copolymer .... (FEP),
- Per-Fluoro Alkoxy .... (PFA),
- Poly-Tetra-Fluoro Ethylene .... (PTFE) and,
- Ethylene-Chloro Tri-Fluoro Ethylene copolymer .... (E-CTFE).

7.1.3 Sheet thermoplastics applies to equipment fabricated in metal or concrete and in both bonded and loose lining.

7.1.4 Requirements for lining design including fabrication of the equipment, selection of lining, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350 "Lining".

7.1.5 The thermoplastic sheets are installed in vessels in one of two ways: they are either combined with a backing material, (usually fiberglass, cloth or carbon fiber) and bonded to the wall with an epoxy-or rubber-based adhesive; or left loose, attached only at flanges, as a gasket would be.

In both cases, the sheets are welded together at their edges, with a rod of like material employed to seal the joints.

7.1.6 The Company inspector may stop lining operations when conditions such as weather, improper surface preparation, improper application procedure, or poor material performance indicate that an inferior lining will result. In case of bonding liner the lining operation shall be suspended by either the contractor or the Company inspector when local relative humidity exceeds 90%, if the atmospheric temperature is less than 7°C, or if the temperature in the vicinity of the lining operations is less than 4°C. If the atmospheric temperature in the vicinity of the lining operation goes below 4°C, supplementary artificial heat may be used to keep temperatures above 4°C.

7.2 Preparation

7.2.1 Preparation of material for use

Sheet thermoplastic are as a general rule manufactured by extrusion.

The width, length and thickness of sheeting shall be as specified by the Company with reference to IPS-E-TP-350 as part of the contract if manufacturer applies the lining.

7.2.2 Preparation of surface to be lined

7.2.2.1 Metal

7.2.2.1.1 All grease oil, temporary protectives and chalk shall be removed from the surface to be lined.

7.2.2.1.2 All welds shall be ground smooth to prevent mechanical damage to the liner.

7.2.2.1.3 Equipment to which liners are to be fitted shall be free from loose rust and dirt.

The flange edge covered by the loose liner shall be rounded off.

7.2.2.1.4 All surfaces to which a lining is to be bonded shall be maintained at least 3°C above the dew point throughout the preparation and lining processes. If there is a risk that this condition will not be maintained owing to ambient conditions or a change in ambient conditions, dehumidifying and/or heating equipment shall be used.

7.2.2.1.5 All surfaces to which liners are to be bonded shall be blast cleaned.

In the case of carbon steel and cast iron the standard shall be Sa 2½ as defined in Swedish Standard SIS 05 5900. The average surface profile of blast cleaned surfaces measured peak to valley shall be 150 μm for sheet applied thermoplastics.

7.2.2.1.6 When thermosetting resin-based adhesives are to be used to bond linings to the equipment a minimum temperature of 10°C shall be maintained from the start of the lining process until the adhesive is fully cured.

7.2.2.1.7 All dust, residues and debris left on the surface after blast cleaning shall be removed by brushing or vacuum cleaning.

7.2.2.2 Concrete

7.2.2.2.1 Any external corners not formed with a chamfer shall be rubbed down to a radius not less than 5 mm.

7.2.2.2.2 Equipment to which loose liners are to be fitted does not require further surface preparation provided that all surfaces are clean and smooth.

7.2.2.2.3 All surfaces to which a lining is to be bonded shall be treated to remove laitance and shutter release agents. The specified method for this operation is blast cleaning. The blast cleaning process shall be controlled so that all laitance is removed without exposing the profile of the aggregate. After blast cleaning all dust and debris shall be removed.

7.2.2.2.4 Following the removal of laitance from concrete surfaces to which linings are to be bonded any small holes exposed shall be filled.

Note:

One material recommended for this Purpose is a smooth paste made from a water miscible epoxy resin, cement and a fine filler.

7.2.2.2.5 All surfaces to which a lining is to be bonded shall be maintained at least 3°C above the dew point during the lining processes. If there is a risk that this condition will not be maintained owing to ambient conditions or a change in ambient conditions, dehumidifying and/or heating equipment shall be used.

7.2.2.2.6 When thermosetting resin-based adhesives are to be used to bond linings to the equipment a minimum temperature of 10°C shall be maintained from the start of the lining process until the adhesive is fully cured.

7.3 Application of Lining

7.3.1 General

7.3.1.1 Following the blast cleaning of metal surfaces to which a liner is to be bonded the clean surface shall be primed as soon as possible and in any case, not more than 4 hours later and before any visible rusting occurs.

7.3.1.2 In the case of concrete equipment to which linings are to be bonded, lining shall not proceed until the free water content is down to a level compatible with the adhesive system used. Contractor shall provide prove documents.

7.3.1.3 Whether the lining is to be bonded or not sheets shall be cut and where necessary hot formed so that there is a tight fit between the liner and substrate. Wherever possible corners in the plastic sheets shall be hot formed so that welding in corners is avoided.

Note:

In the case of pipework special expansion techniques may be employed in the fitting of the liner.

7.3.1.4 When linings are being bonded to the substrate the material shall be fitted in such a way that air is not trapped behind the sheet.

When adhesives are used for bonding, the batch shall be used within its pot life, or discarded.

7.3.1.5 The welding process used for joining the lining shall be appropriate to the material and circumstances.

The fabricator of the lining shall provide evidence that the operators engaged on lining the vessels are capable of making good welds.

When required the applicator of the lining shall provide type welds for testing. These welds shall have at least 85% of the strength of the parent material when tested in accordance with BS 2782: Methods 320A to 320F. Welds made in a lining forming a mating surface shall be ground flat.

7.3.2 Bonding

7.3.2.1 Sheet thermoplastics are installed in equipment in one of two ways: bonded and loose, as will be specified by the designer with reference to IPS-E-TP-350. In both cases, the edges with a rod of like material employed to seal the joints.

7.3.2.2 Bonded sheet applied process

The sheets are combined with a backing material (usually fiber glass, cloth or carbon fiber) and bonded to the wall with an epoxy-or rubber-based adhesive. Rubber-based compounds shall not be used when organic solvent are present, or when process temperature exceed 100°C. In these cases, epoxy-based adhesive shall be used for bonding.

Unless specified otherwise bonded liners shall be specified when the equipment has a complex shape (dished heads or conical section, for example), or has internal components and when there are wide swings in the equipment's operating temperature (37 to 50°C in magnitude).

7.3.2.3 Loose sheet applied process

In this process the sheet left loose, attached only at flanges, as a gasket would be.

Where the shape of the equipment is relatively simple, process temperature are not cyclic and pressures are low, non-bonded liners offer users the same chemical resistance as bonded liners at a lower cost.

The saving are realized by eliminating the costs of the backing material, adhesive and labor required to bond the liner. The designer will specify the case.

Under vacuum conditions, loose liners will quickly collapse. Metal rings, lined with the same polymer as the vessel walls, shall be used to hold them in place.

7.3.2.4 Unless specified otherwise by the designer, when deciding whether to install a bonded or non-bonded liner in a pressurized vessel, use 3.5 bar.g as the dividing line. If the vessel's working pressure is below 3.5 bar.g a loose liner can safety be used, provided the vessel's interior has a relatively simple shape, and processing temperature do not swing widely. Above 3.5 bar.g a bonded liner shall be used.

7.3.3 Selection of process

The lining process shall be appropriate to the grade of material selected for the lining.

7.3.3.1 Polyethylene (PE)

There are two types of sheet available Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE). Polyethylenes sheets are not normally used as a bonded liner. These are easy to weld but complicated shapes are not easily formed.

7.3.3.2 Polypropylene (PP)

Polypropylene is used with a glass or synthetic fibre or rubber backing and therefore can be bonded to substrates. The backing material can impose limitation on the thermal forming process. Glass fibre backed polypropylene is not readily formed into complex shapes, but can be welded easily.

7.3.3.3 Polyvinyl Chloride (PVC)

There are two types of sheet available, Unplasticized Polyvinyl Chloride (UPVC) and Plasticized PVC. UPVC softens and loses strength as the temperature increases. When fully bonded to a substrate it may be used as a lining material up to 85°C, UPVC can be shaped easily and can be welded. Plasticized PVC is usually bonded to the substrate and can be shaped and welded.

7.3.3.4 Polyvinylidene Fluoride (PVDF)

PVDF is used with a glass or synthetic fibre or rubber backing and therefore can be bonded to substrates. The backing material can impose limitations on the thermal forming process. It is readily welded.

7.3.3.5 Fluorinated Ethylene Propylene copolymer (FEP)

FEP is used with a glass fibre backing to provide a bondable surface. When FEP is bonded to a substrate, the maximum service temperature will be determined by the adhesive used.

FEP can be thermo-formed, but in the case of glass backed material, the complexity of the formed shape may be limited. FEP can be welded.

7.3.3.6 Per Fluoroalkoxy (PFA)

PFA can be thermoformed and welded. It can be used as a loose or bonded liner.

7.3.3.7 Ethylene-Chloro Trifluoroethylene copolymer (E-CTFE)

E-CTFE is used with a glass-fibre backing and therefore can be bonded to a substrate; the backing material may impose limitation on the thermo-forming process. E-CTFE can be welded.

7.3.3.8 Polytetrafluoroethylene (PTFE)

PTFE sheet can not be thermo-formed but when heated it can be swaged over flanges.

PTFE sheet up to 4 mm thick may be welded.

It is usually used as a loose liner, although it is possible to etch the surface to make bonding to the substrate possible. It is also available with a glass fibre backing. The process is very difficult and requires special techniques and equipment.

Note:

PTFE sheets are sliced from a large block that has been produced either by ram extrusion or a combination of compression molding and sintering. For thicknesses that exceed 6 mm (0.25 in), PTFE sheets are molded.

7.4 Drying

After application of sheet lining if necessary, lined surface shall be dry in accordance with the manufacturer's recommendation (see also Appendix E).

7.5 Transportation and Storage

7.5.1 Lined equipment shall be stored under cover or in a protected compound. When necessary, linings shall be shielded from direct sunlight.

7.5.2 All branches, manholes and other openings shall be protected from mechanical damage by using wooden blanks or other suitable material.

In the case of some linings which are flared over flanges wooden blanks shall be fitted as soon as flaring is complete. These blanks shall be left in place until just before the mating flange is bolted in position.

If for any reason flange joints in such equipment are broken the wooden blanks shall be fitted until such time as the joint is remade.

Note:

It is recommended that such joints are broken only at ambient temperature.

7.5.3 Lifting shall be arranged so that chains and other lifting aids do not come into contact with lined surfaces.

7.5.4 High local loads on lined surfaces shall be avoided.

7.5.5 Loose fittings shall not be placed inside lined equipment whilst it is being transported.

7.5.6 Responsibility for arranging transport of lined equipment will vary and whoever is responsible (Company, fabricator or applicator) shall instruct the carrier about the precautions in handling.

7.6 Repair of Lining

7.6.1 When it is necessary to replace part of the lining, the sheet used for rectification shall be of the same grade as that used for the original lining.

7.6.2 In the case of linings bonded to the substrate the adhesive used for replacing part(s) of the lining shall be that specified for the original lining.

7.6.3 The process used for replacing part(s) of the lining shall be as specified in 7.3.

7.6.4 If more than one fault is found in a weld and those faults are less than 50 mm apart then for the purpose of rectification the faults shall be considered as one large defect.

7.6.5 After all rectification work the lining shall be subject to inspection as appropriate and in particular to continuity testing.

7.7 Inspection and Test Methods

7.7.1 Visual appearance of lining

The surfaces of the plastic liner before and after application shall be free from defects, such as blisters, cracks, scratches, dents, nicks, or sharp tool marks which would be expected to affect the performance of the liner.

Absence of these defects to be detected visually, with a dye penetrant or with continuity testing (wet sponge or spark testing).

- The plastic liner shall fit snugly to the steel housing and no entrapments shall be present between the plastic liner and the internal surface of the substrate.

- The adhesive shall be capable of maintaining a bond at the design temperature and after cycling between ambient and maximum surface temperatures.

- If the completed lining shown blistering, cracking, mechanical damage or unallowable variation in thickness, the lining shall be rejected and shall be entirely removed and redone at the contractor's expense.

7.7.2 Adhesion of lining

As far as possible adhesion testing of the applied lining shall be avoided because the test is destructive and the lining has to be repaired. All linings shall be inspected visually for evidence of lack of adhesion to the substrate.

If required test plates shall be used to demonstrate that the process employed does provide a lining with the required level of adhesion. These test plates shall be of the same material as the substrate and the lining process shall be the same as that employed for the lining of the equipment and done under the same conditions and at the same time.

- The minimum bond strength between the lining and the substrate shall be 3.5 N/mm² in direct shear and 5 N/mm width in peel at a test temperature of 20°C when tested in accordance with BS 490 Section 10.4.

7.7.3 Continuity of lining

The lining shall be tested for pinholes (see Clause 19). For non-corrosive conditions local repairs are permitted if the number of pinholes exceeds that specified. If local repairs are not possible, the lining shall be removed and replaced. The appropriate method for the continuity testing of sheet thermoplastic lining is the spark test.

7.7.4 Thickness of lining

The thickness of the finished lining will depend upon the material selected and the duties for which it is intended. The maximum thickness as well as a minimum thickness shall be specified according to IPS-E-TP-350 (Table 11). If necessary the material shall be capable of being thermo-formed and welded to give joints which are pinhole free.

7.8 Installation

7.8.1 At all times during installation of lined equipment, the contractor shall use every precaution to prevent damage to lining. No metal tools or heavy objects shall be permitted to come into contact unnecessarily with the lining. Any damage to the equipment from any cause during the installation and before final acceptance by the Company shall be repaired by and at the expense of the contractor.

7.8.2 When making up lined pipe a certain amount of judgment must be used because of the coating that is applied to the pin end and in the J area of the coupling. For stabbing, a plastic stabbing guide must be used to guide the pin end directly into the middle of the coupling, to eliminate any contact of the pin end with the coupling’s top edge. Because of the coating in the threads, initial make-up normally produces higher than normal torque values, but subsequent make and breaks of the same connection is more in line with published torque values. For this reason, initial make-up of lined pipe should first be made by position, plus-or-minus one thread from hiding the last scratch to ensure coating-to-coating overlap of the pin end with the coupling, while monitoring the torque. Keep in mind that maximum torque values may be observed until the coating is removed from the threads.

7.8.3 The installation of plastic-lined piping is performed in a way which is similar to that for flanged steel piping with respect to supporting, thermal expansion, etc. Lined piping is mainly used in aboveground installations.

7.8.4 Flange connections

The piping should be installed in such a way that no damage is caused to the flared or moulded liner facing. The use of smooth metal guide plates, 1 mm thick, is recommended when making connections or when installing individual sections in an existing line. Flange facings should be cleaned prior to installation. field flaring is not recommended, but when unavoidable 7.8.5 gives guidance.

A lap-joint type flange may be used on one end of each straight pipe to enable bolt alignment during installation, specially in combination with glass-lined piping or equipment; the other flange may be rigid to the pipe.

In the case of a totally plastic-lined system all flanges can be rigid to the pipes and fittings.

7.8.5 Flaring in the field

Whenever possible, as-supplied prefabricated line pipe lengths provided with flanges with shop-flared or moulded ends should be used.

To adapt an existing plastic-lined pipe to the designed length, spacers or distance pieces lined with the same polymer can be used.

Solid spacers should be used only to a maximum thickness of about 6 mm.

When unavoidable, flaring may be carried out only in a workshop with equipment supplied by the pipe manufacturer. The instructions should be provided by the manufacturer and must be closely adhered to.

Special attention has to be given to:

- cutting of steel tube (for swaged type pipes only);
- flare temperature;
- cooling rate after flaring.

The flaring tool should not be removed before the pipe has cooled down to room temperature.

For swaged-type pipes, only threaded flanges with straight or tapered thread are used for field fabrication. Flanges should be fully tightened and secured by tack welding in order to prevent inadvertent turning, which will damage the liner.

For that reason flanges must have tapered thread or be of the threaded-socket type. The pipe end shall be provided with sufficient threading to accommodate the flange.

A perforated metal ring must be used as a back-up gasket for pipes made in accordance with the swaging method. Obviously, no back-up gasket is required when a socket flange with a fully radiused edge is used.

Immediately after the flaring operation a wooden or metal flange protector is installed to prevent mechanical damage prior to installation and to keep the flared end in position.

7.8.6 Bolting

Flange bolts should be tightened with a torque wrench, using greased bolts and nuts, to the values specified and indicated on the piping by the pipe manufacturer in a criss-cross manner. Too great a bolt loading may damage the plastic flange face.

The use of appropriate spring washers between nut and flange is recommended. Bolts should be retorqued after a service period of 24 hours.

7.8.7 Welding

Under no circumstances should welding be performed on lined piping, nor should it be used as a welding ground, as this will cause irreparable damage to the liner.

7.8.8 Venting system

Care should be taken that the venting system does not become blocked by paint or other deposits. Regular inspection of the vent holes is recommended. No sharp tools should be used to clean the vent holes.

When lined piping is insulated the use of vent hole extensions is strongly recommended.

7.8.9 Heat tracing systems

When tracing of pipelines is required, the recommendations for the tracing system approved by Company shall be consulted.

7.8.10 Disassembling

Plastic-lined steel pipes and fittings should be dismantled from an existing pipeline only at temperatures below 40°C, to prevent retraction of the plastic flange face. Immediately after disconnection, a flange protector should be installed on each flange face.

7.8.11 Marking

For identification purposes it is recommended that the lined piping system is marked in order to prevent damage of the liner, e.g. by welding.

8. NON-SHEET APPLIED THERMOPLASTIC RESIN LINING

8.1 General

8.1.1 This Clause 8 specifies requirements for the lining of equipment using non-sheet applied thermoplastic resins.

8.1.2 The materials considered include thermoplastic powders, plastisols and dispersion.

8.1.3 The thermoplastics can be used for non-sheet applied include the polymers listed in 7.1.2 plus the following:

- Poly Amides (Nylon)
- Ethylene Vinyl Acetate copolymer (EVA)
- Fusion-bonded epoxy resin

8.1.4 Although not thermoplastics, fusion bonded epoxy resin powder are included in this category since the same application techniques are used.

8.1.5 Requirements for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350.

8.1.6 When the applicator is responsible for selecting the grade of lining to be applied, he shall verify that such a lining will withstand the chemical and physical conditions specified in IPS-E-TP-350 Table 1.

When The Company selects the grade of lining to be applied, the applicator shall be responsible only for correct application.

8.1.7 The applicator shall supply test pieces such as panels to which the lining has been applied and which will serve as reference samples.

8.1.8 The Company Inspector may stop lining operations when conditions such as 7.1.6.

8.1.9 Non-sheet applied thermoplastic resin shall not be used for lining of concrete and only be used for metal surfaces. These resin shall be applied with spraying, dipping or fluidized bed processes.

8.1.10 The lined equipment shall be identified with signs indicating the presence of interior lining, stating its specific type and prohibiting welding or burning operations on the exterior surface.

8.1.11 The applicator of the lining when requested shall provide a certificate of inspection and testing. The stages of inspection shall be as follows:

- The equipment after preparation.
- If appropriate after application of the primer.
- After application of the lining.

8.2 Preparation

8.2.1 Preparation of material f or use

Materials which have been mixed for application must be used within time limits as specified by the manufacturer. Such materials not used in the designated period will be discarded. Contractor shall handle, store, mix and apply the lining in strict accordance with the manufacturer's specification or as directed by an authorized representative of lining material manufacturer.

8.2.2 Preparation of surfaces to be lined

Surface preparation of metal prior to lining shall be in accordance with 7.2.2.

The average surface profile of blast cleaned surfaces for non-sheet applied thermoplastic lining shall be 75 μm.

8.3 Application Methods

8.3.1 General

8.3.1.1 The lining process shall start as soon as possible after blast cleaning is complete and before any visible rusting occurs. Unless maintained in a dehumidified atmosphere application of the lining shall commence within 4 hours. If signs of rusting occur then the surface shall be prepared again to the required standard.

8.3.1.2 Where necessary surfaces shall be primed in order to promote a bond with the lining material.

Note:

The primer should be pigmented to facilitate uniform application and to assist in establishing full coverage of the surface to be lined.

Once the primer has been applied the equipment shall be kept clean and the lining process shall continue as soon as possible.

8.3.1.3 The lining process shall be appropriate to the grade of material selected for the lining and the article to be lined. (see 8.3.2)

8.3.1.4 Non-sheet applied thermoplastics shall be used only for lining of metallic surfaces.

8.3.2 Lining processes

There are a number of lining processes. Three of the most widely used techniques are described below.

Included are Rotomold techniques for special cases.

8.3.2.1 Dipping into a liquid or plastisol (when applicable)

This method consists of dipping a heated and primed metal article into a tank of liquid or plastisol. The heat allows a layer of material to deposit and fuse with the primer. At a predetermined time the article is removed from the tank and cured in an oven at a carefully controlled temperature.

8.3.2.2 Fluidized bed process (when applicable)

This technique involves dipping a heated and, where specified, primed article into a tank of fluidized plastic powder for a predetermined time. The powder sinters and fuses into a homogeneous and adherent coating. For some materials a post-cure heating cycle may needed to achieve optimum properties of the lining. Fluidizing is achieved by passing air at low pressure through the tank. The air causes the powder to behave as if it were a liquid, reducing its resistance to items entering it and ensuring full coverage of the components.

8.3.2.3 Spraying

This involves spraying powder or liquid plastic on to a metal object which is either preheated or subsequently heat dried. Principal materials applied by spraying include the fluoro-plastic range, thermoplastics and fusion-bonded powder coatings. Application is by electrostatic or pressure spray. The reinforcements can be used.

8.3.2.4 Rotomold process

In addition to above three techniques Rotomold process can also be used. The piece of equipment to be lined is used as the mold for a Rotomolded lining. This is done by charging a preweighted amount of powder resin into a hollow mold. The part is then placed into a heated oven and rotated, depositing a seamless, pinhole-free liner to the interior of the part. This produces a perfect conformation of the liner to the vessel wall, eliminates the need for expensive internal tooling such as that required for transfer molding and also allows lining of the parts which could not be lined in any other way.

8.3.3 Selection of process

The lining process shall be appropriate to the grade of material selected for the lining.

8.3.3.1 Polyethylene (PE)

Polyethylene powder for lining is available in three grades, low, medium, and high density. The lining is applied with spray or fluidized bed process.

8.3.3.2 Polypropylene (PP)

Suitably formulated Polypropylene powders for lining are available in several grades including homopolymers, copolymers, and mixture with other polyolefins. Lining based on unmodified polypropylene will not normally be bonded to the substrate. Lining based on powders formulated with special additives will bond to substrates. Improved adhesion can be achieved by use of a liquid primer.

8.3.3.3 Polyamides (Nylon)

The grades of Nylon are available for powder lining are Nylon 11 and 12. Lining based on powder will bond to substrates.

8.3.3.4 Polyvinylchloride (PVC)

Two forms of Polyvinylchloride are used for lining: unplasticized (UPVC); and plasticized.

- Unplasticized Polyvinylchloride (UPVC) used for lining is normally a copolymer of PVC and PVA (Polyvinyl Acetate). UPVC is normally applied as a powder and bond to substrates.

- Plasticized PVC when used for lining is applied as a plastisol.

- Some solvents, e.g. aromatic hydrocarbons will extract the plasticizer and after evaporation of the solvent the lining will be hard and liable to develop cracks.

8.3.3.5 Ethylene Vinyl Acetate copolymer (EVA)

It can be applied to a variety of metals including zinc without the use of primer. The adhesion of EVA to the substrate is excellent.

8.3.3.6 Polyvinylidene Fluoride (PVDF)

PVDF lining may be applied as a dispersion lining or by powder lining processes. Reinforced lining systems are available. Priming of substrates is necessary to achieve adhesion. A processing temperature (curing) of 250°C is required.

8.3.3.7 Perfluoro Alkoxy (PFA)

Perfluoro Alkoxy is copolymer of Tetrafluoroethylene and Perfluoropropyl Vinyl Ether. Non-sheet PFA lining shall be applied as powder lining. A processing temperature (curing) of 350°C is required.

8.3.3.8 Polytetrafluoroethylene (PTFE)

PTFE is not melt processable and can be applied only as a dispersion lining. The lining produced are thin and are not pinhole free. It is necessary to use etching primers in order to promote adhesion.

The lining shall consist of at least 2 coats, uniformly applied with spraying method. The priming coat shall be applied immediately after cleaning of the surface. Application by brushing is allowed only for areas inaccessible to a spray gun.

Each coat shall be sintered separately. This shall be carried out by heating the entire piece of equipment between 380°C and 400°C followed by gradual cooling to ambient temperature.

8.3.3.9 Fluorinated Ethylene Propylene copolymer (FEP)

FEP lining may be applied as a dispersion lining. A processing temperature of 360°C is required.

8.3.3.10 Ethylene-Chlorotrifluoroethylene copolymer (E-CTFE)

E-CTFE lining may be applied by fluidized bed or electrostatic spraying. Adhesion to carbon steel surfaces is good but in the case of other metals a primer may be required to obtain good adhesion.

The processing temperature of 360°C to 400°C is required. These lining are available in thickness according to IPS-E-TP-350 Table 6. A lining thickness of up to 5 mm can be achieved by rotomolding.

8.3.3.11 Fusion-bonded epoxy

- Fusion-bonded epoxy resins are available in three grades of powder suitable for application by fluidized bed, electrostatic and normal powder spray.

- The equipment that has been cleaned shall be preheated so that the surface temperature at the entrance of the lining station is between 220°C and 245°C or as specified by the manufacturer.

- Graduated meltable temperature indicators shall be used to measure the temperature.

- The epoxy powder shall be applied to the preheated pipe, fitting or vessel, by the methods approved by the manufacturer at a uniform cured-film thickness (see IPS-E-TP-350).

- After the lining has cured according to the manufacturer's recommendations, it may be cooled with air or water spray to a temperature below 93°C for inspection and repair.

- The practices for unprimed internal fusion bonded epoxy coating of line pipe are recommended in API-RP-5L.

- For more information about using of fusion bonded epoxy for the lining of steel water pipelines see AWWA C 213.

8.4 Curing

8.4.1 For thermally cured materials, namely plastisols and fusion-bonded epoxy resins, the state of cure shall be tested as follows (see Appendix E):

8.4.1.1 Plastisols

The hardness of the lining shall be tested in accordance with BS 903: Part A 26. The hardness of the lining shall be within 5 IRHD of the hardness of the material specified (see Appendix C).

8.4.1.2 Fusion-bonded epoxy resins

The lining shall be tested for solvent resistance. This test shall be carried out by laying a cloth soaked in methyl isobutyl ketone over selected areas of the lining for 3 min. After this time the coating shall show no sign of softening when scratched with a finger nail.

Note:

Another method of estimating the cure is to carry out an impact test to ASTM G 14-77: Paragraph 4.2. If this test is to be used the impact resistance shall be specified by the material manufacturer.

8.4.2 In the case of dispute about the state of cure of fusion bonded epoxy resin linings, samples shall be taken and the state of cure measured by an independent authority using differential scanning calorimetry.

8.5 Transportation and Storage

Transportation and storage of lined parts shall be in accordance with 7.5.

8.6 Repair of Lining

8.6.1 Rectification of faults shall be done using the same material as originally used for the lining, or other materials that shall be used only with the Company's written consent.

8.6.2 Damage to lining attributable to the Contractor's operations shall be repaired by contractor at no cost to Company. Where the damaged area is large enough, in the judgment of the Company Inspector to require relining. It shall be relined at no cost to Company. Small areas, if approved by the Company Inspector, may be touched up with a brush or by spray.

Note:

The size of damage shall be specified by the designer.

8.6.3 Damage to lining attributable to the mill, and damaged lining resulting from equipment defect repairs, shall be repaired by Contractor at the sole expense of the equipment manufacturer and when in the opinion of the Company Inspector require relining, it shall be relined. Small areas, if approved by the Company Inspector, shall be touched up with a brush or spray by Contractor at no additional cost. The Company Inspector shall approve all relining and repairs to lining, and the Contractor shall maintain records of such work approved by the Company Inspector in order to receive reimbursement for same.

8.6.4 If the number of defects is large and covers a large surface area the lining shall be removed completely and the work of lining re-done.

8.7 Inspection and Test Methods

8.7.1 Visual appearance of lining

The lining shall be inspected visually for blisters, flaws, sagging and inclusions of foreign material. Defects in the lining shall be removed and the lining replaced. The repaired area shall be subjected to a full inspection.

The lining shall be inspected visually for blisters, flaws, sagging and inclusions for foreign materials.

The plastic liner shall fit snugly to the steel housing and no entrapments shall be present between the plastic lines and the internal surface of the substrate.

8.7.2 Adhesion

The lining shall be inspected visually for evidence of lack of adhesion to the substrate and, where applicable, lack of inter-coat adhesion.

Note:

As far as possible adhesion testing of the applied lining is to be avoided because the test is destructive and the lining has to be repaired.

If required, test plates shall be used to demonstrate that the process employed does provide a lining with the required level of adhesion. These test plates shall be of the same material as the substrate and the lining process shall be the same as that employed for lining the equipment and done under the same conditions and at the same time.

For thick linings such as plastisols the adhesion test shall be that given in BS 490: Section 10.4.

If evidence of lack of adhesion to a substrate or lack of inter-coat adhesion is found, the lining shall be removed totally or partially, dependent on the area which is suspect. The area shall be re-lined and subjected to full inspection.

8.7.3 Thickness of lining

A survey of the thickness of the lining shall be made. Of the instruments available those that operate on a single probe electromagnetic or eddy current principle shall normally be used. Selection shall be determined in other cases by the nature of the substrate. The instruments shall be calibrated against reference plates at least twice a day.

Note:

Attention is drawn to the fact that thickness measurements of thin films in corners and on curved surfaces of small radii may not be accurate.

The thickness of the liner of all pipes and fitting shall be measured at both ends of the pipes and fittings at the facing of each flange and meet the requirements of standard IPS-E-TP-350 (Table 10). A reduction of 10% at the flange facing due to the flaring exercise is acceptable. Variations in wall thickness of more than 20% are not allowed.

8.7.4 Continuity of lining

The lining shall be tested for pinholes (see Clause 19). If the number of pinholes exceeds the number specified, local repairs shall be carried out. if local repairs are not possible the lining shall be removed and replaced.

8.7.5 Curing of lining

The test methods for inspection of curing of lining are described in 8.4.

8.7.6 Hydrostatic pressure test

8.7.6.1 Ten percent of the pipes and fitting furnished under this construction standard shall be subjected to a hydrostatic pressure test. The Company shall be contacted for those cases where testing would result in damage of the pipe ends caused by the end caps. Alternatively an air-under-water test may carried out under conditions as agreed with the Company.

8.7.6.2 Installed piping systems shall be pressure-tested with water at ambient temperature at a pressure of 1.5 times the maximum working pressure for a period of at least 4 hours. No weeping at flanges or through vent holes, if present, is allowed during this test. Owing to variations in ambient temperature the pressure may fluctuate, and care should be taken that the test pressure does not exceed the lowest rated element in the system. All damages shall be repaired by contractor at no cost to the Company.

8.7.7 Thermal cycle testing

Pressure/temperature testing and vacuum testing will only be required for fluoropolymer lined piping intended for vacuum, pressure or heavy duty service and will be specified as such in the Company order.

8.8 Installation

Installation shall be in accordance with 7.8.

9. STOVED THERMOSETTING RESIN LINING

9.1 General

9.1.1 This Clause 9 specifies requirements for the lining of equipment using stoved thermosetting resins.

9.1.2 The material considered include:

- Phenol-formaldehyd resin
- Epoxy-phenolic resin

9.1.3 Stoved thermosetting resins shall not be applied to equipment manufactured in cast iron or concrete.

9.1.4 Requirement for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350.

9.1.5 The thermosetting stoved resin-based linings are used for a number of different duties, including protection against corrosive environments, prevention of contamination of products and provision of surfaces that do not foul easily or that can be cleaned easily.

9.1.6 The linings are normally applied as solvent solutions that may contain pigments and are then stoved at elevated temperatures to remove solvents and cure the resin.

The actual stoving temperatures are specified by the lining supplier but are normally in the range from 150°C to 200°C and it is therefore usual to carry out the stoving in an oven in the applicator's works. Heat curing in situ is however possible but presupposes adequate insulation of the vessel and careful temperature control.

9.1.7 Linings based on these resins are generally less than 300 μm in thickness and though they can be applied completely free from pinholes on relatively small vessels. It is very difficult to obtain linings that are pinhole free on large surface areas. Furthermore, even if linings as applied are free from imperfections, consideration shall be given to the possibility of damage in operation.

Before selecting a lining of this type, therefore, some knowledge is required of the likely rate of corrosion of the substrate and the causes of such corrosion. If the corrosion rate is low there may not be a problem. If the corrosion rate is high and is due to simple solution of the metal, then caution is advised because of the danger of severe corrosion through a pinhole. On the other hand if a high corrosion rate is due to an effect such as erosion/corrosion, then thin linings can be an effective barrier.

9.1.8 The Company inspector may stop lining operations when conditions such as 7.1.6.

9.1.9 The lined equipment shall be identified as stated in 8.1.10.

9.1.10 The applicator of lining shall provide a certificate of inspection and testing when requested, as specified in 8.1.11.

9.2 Preparation

9.2.1 Preparation of material for use

9.2.1.1 All material furnished by the contractor shall be of the specified quality.

9.2.1.2 To prepare the lining material for applicator, follow the instruction provided by the manufacturer.

9.2.2 Preparation of surface to be lined

Stoved thermosetting lining shall be used only for metallic equipment (except cast iron). The surface preparation of metal prior to lining shall be in accordance with 10.2.2.

9.3 Application Methods

9.3.1 The lining process shall start as soon as possible after blast cleaning is complete and before any visible rusting occurs. Unless maintained in a dehumidified atmosphere application of the lining shall commence within 4 hours.

If signs of rusting occur then the surface shall be prepared again to the required standard (see IPS-E-TP-350).

9.3.2 Several coats are necessary in order to achieve the thickness stipulated and each coat shall be allowed to air dry before application of the next coat. Any intermediate stoving shall be at a lower temperature than the final stoving temperature such that cure does not proceed beyond the stage that impairs intercoat adhesion.

All external angles and edges shall be "Strip Coated" by applying a thin coat before the rest of the surface is coated.

9.3.3 Before the final stoving takes place the lining shall be tested for continuity (see 9.7.4). If the continuity of the lined equipment meets the quality agreed at the tender stage, final stoving can proceed; if not, further coats shall be applied locally or over the whole surface until the specified standard is reached. When extra coats are applied, the final thickness shall not exceed the specified limit.

Note:

This procedure is necessary because once these materials have been cured at the final stoving temperature, it is not possible to obtain the same level of intercoat adhesion.

9.4 Curing (see also Appendix D)

9.4.1 The basic reasons for heating of backing type resin are to remove volatile solvent and products of polymerization from lining and tank and to accomplish polymerization or cure to obtain chemical and permeation resistance. If the lining has been properly heated for the correct period of time it should be polymerized completely with little or no solvent odor present.

9.4.2 The control required to assure that the necessary minimum metal temperature is obtained and that the maximum temperature, as specified by the resin manufacturer, is not exceeded at any given spot in equipment.

9.4.3 Determing whether or not the cure has been accomplished on an applied lining material by test methods are described in 9.7.5.

9.4.4 After the linings have been fully cured it is possible to achieve only a mechanical bond when further coats are applied. When repairs to fully cured linings are necessary, the procedure described in 9.6 shall be used to achieve an effective repair.

9.5 Transportation and Storage

9.5.1 The lined equipment shall be stored and transported in accordance with 7.5 with the following additional requirements.

9.5.2 When lined pipe transported by truck, a flatbed trailer must be used with at least three bolsters between each layer of pipe; the bolsters are aligned vertically above the previous layer to provide even support. The load shall be tied down to prevent any shifting, bending, or movement of pipe. All lined pipe shall be transported with closed thread protectors on both ends, preferably made of plastic or a plastic-lined steel (composite) protector.

9.5.3 To stack the lined pipe, wooden bolsters shall be placed between each layer, directly above the pipe racks, with each layer being blocked to prevent shifting.

9.5.4 If the lined pipe must be drifted, the yard personnel must use a wooden, polytetrafluoro ethylene, or plastic drift to prevent damage to the lining.

9.6 Repair of Lining

9.6.1 When defects or damage are discovered, the coating shall be cleaned and abraded wherever resin is to be applied. The area to be re-coated shall extend at least 50 mm in all directions beyond the defect. The extent of repair will determine the method of cure. If the defects are small, then local heating such as infra-red or hot air shall be used to cure the repair. For extensive repairs the whole of the equipment shall be heated, in which case care shall be taken to ensure that the original coating is not over-cured.

9.6.2 Use of cold curing, thermosetting resins for repairs shall not be permitted without the Purchaser's written consent.

9.7 Inspection

9.7.1 Visual appearance of linings

After application of the final coat, but before the cure cycle is complete the lining shall be visually examined for blisters, flaws and other imperfections. If such defects are found then the lining shall be removed in the affected area and replaced before final stoving.

9.7.2 Adhesion

The lining shall be inspected visually for evidence of lack of adhesion of the coating to the substrate and for lack of intercoat adhesion.

If evidence of lack of adhesion to a substrate or of intercoat adhesion is found, the lining shall be removed totally or partially, dependent on the area which is suspect. The area shall be re-lined and subjected to full inspection before final stoving.

9.7.3 Thickness of lining

A survey of the thickness of the lining shall be made before final stoving. Of the instruments available those that operate on a single probe electromagnetic or eddy current principle shall normally be used. Selection shall be determined in other cases by the nature of the substrate. The instruments shall be calibrated against reference plates at least twice a day.

Note:

Attention is drawn to the fact that thickness measurements of thin films in corners and on curved surfaces of small radius may not be accurate.

9.7.4 Lining continuity

The lining shall be tested for pinholes before final stoving. If the number of pinholes does not exceed, the number specified in design specification, final stoving can proceed (see also IPS-E-TP-350).

If the number of pinholes exceeds the number specified, further coats shall be applied to the lining either locally or over the whole surface, dependent upon the location and number of pinholes. After final stoving the lining shall be tested again for pinholes by spark testing or wet sponge testing according to Clause 19.

9.7.5 Test of curing (see also Appendix D)

9.7.5.1 Solvent wipe test

The lining shall be examined for the state of cure by placing a rag soaked in solvent, either methyl ethyl ketone or acetone on the lining for three minutes. After this the lining shall show no sign of softening when scratched with a finger nail. Any apparent softening indicates the lining is not fully cured and further curing shall be carried out.

The lining shall be visually inspected for over-curing and any over-cured linings shall be rejected.

Note:

The appearance of blisters after the final stoving and considerable darkening of the color of the lining compared with the normal color are evidence of over-cure.

9.7.5.2 Cure evaluation standard

Most heat curing phenolic and epoxy-phenolic resin linings will show a marked degree of color change between and inadequately and an adequately cured applied film. A set of cure color standards should be used to evaluate the degree of completeness of bake cure. The accepted degree of cure shall be well cured, over and under cured lining is rejected.

Variations of formulation, including amounts and types of pigments, will affect the characteristic color. Thus a set of bake cure color standards are required for each specific material as supplied by each manufacturer. Code symbols shall be used to identify each specific material and the degrees of color for each set of bake cure color standard.

9.8 Installation

Installation shall be in accordance with 7.8.1.

10. COLD CURING THERMOSETTING RESIN LINING

10.1 General

10.1.1 This Clause of the construction standard specifies minimum requirements for the lining of equipment using cold curing thermosetting resin.

It applies to equipment fabricated in metal or concrete.

10.1.2 The lining materials considered include:

- Liquid epoxies
- Polyesters
- Furanes
- Poly urethanes
- Polychloroprene.

10.1.3 Although not thermosetting resins, liquid elastomeric lining (such as poly urethanes) and solvated elastomeric lining (such as polychloroprene), are included since the same application techniques are used.

10.1.4 The resins may contain fillers and/or reinforcing agents.

10.1.5 Requirements for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350.

10.1.6 All materials furnished by the contractor shall be of the specified quality. The entire operation shall be performed by, and under the supervision of experienced persons skilled in the application of liquid epoxy linings.

10.1.7 The Company inspector may stop lining operations when conditions such as 7.1.6.

10.1.8 The lined equipment shall be identified as stated in 8.1.10.

10.1.9 The applicator of lining shall provide a certificate of inspection and testing, when requested, as specified in 8.1.11.

10.2 Preparation

10.2.1 Preparation of material for use

10.2.1.1 All materials furnished by the contractor shall be of the specified quality.

10.2.1.2 To prepare the primer and finish coat of lining materials for application, follow the instruction provided by the manufacturer.

10.2.1.3 Mix only the amount of material that will be used within its pot life.

10.2.2 Preparation of surface to be lined

10.2.2.1 Metal

- All grease, oil, temporary protectives and chalk shall be removed from the surface to be lined. Degreasing shall be carried out using vapor degreasing equipment or as recommended in IPS-C-TP-101.

- All surfaces to be lined shall be maintained at a temperature at least 3°C above the dew-point throughout the preparation and lining processes. If there is a risk that this condition will not be maintained owing to ambient conditions or a change in ambient conditions, dehumidifying and/or heating equipment shall be used.

- All surfaces to be lined shall be blast cleaned. In the case of carbon steel and cast iron the standard of blasting shall be as defined in Swedish Standard SIS 05 59 00 according to Table 1.

Only non-metallic grit shall be used for blast cleaning aluminum and its alloys. The average surface profile of the prepared substrate measured peak-to-trough shall be 40 μm.

Note:

Special treatment may be required for other metals (IPS-C-TP-101).

- All dust, residues and debris left on the surface after blast cleaning shall be removed by brushing and vacuum cleaning.

- Before abrasive blasting of steel tank, the tank shall be rechecked with the combustible gas indicator to ensure that no flammable vapors have entered the tank.

TABLE 1 - STANDARD OF BLASTING

TYPES OF LINING	GRADE	CLEANLINESS	AVERAGE SURFACE PROFILE (MEASURED PEAK-TO-TROUGH)
			μm
Polyester Polyester	A, B, C and D see 10.3.3.1	Sa 2½ Sa 2½	75 150
Epoxies Epoxies Epoxies Epoxies	A and B C and D C and D hot spray applied see 10.3.4.1 E	Sa 2½ Sa 2½ Sa 2½ Sa 2	40 75 150 75
Furane	All	Sa 2½	75
Polyurethane Polyurethane	Spray Trowel	Sa 2½ Sa 2½	75 75
Polychloroprene	All	Sa 2½	75

10.2.2.2 Concrete (see also IPS-C-TP-101)

- Remove forming oil with detergent before blasting.

- Any external corners not formed with a chamfer shall be rubbed down to a radius of not less than 3 mm.

- All surfaces to be lined shall be treated to remove laitance and shutter release agents. The specified method for this operation is blast cleaning. The blast cleaning process shall be controlled so that all laitance is removed without exposing the profile of the aggregate. After blast cleaning all dust and debris shall be removed.

Notes:

1) An alternative method of removing laitence which is sometimes used is that of acid etching. This process is only really applicable to horizontal surfaces. furthermore, the presence of shutter oils will reduce the effectiveness of acid etching. The thickness of the laitance of a concrete surface varies considerably and it is very important that acid is allowed to dwell on the surface a sufficient length of time to remove all the laitence. When acid etching is used the next operation should be water washing of the concrete, followed by a drying process.

Acid etching is not suitable when the equipment is to be lined with polyurethane.

2) Removal of laitance on concrete invariably leaves a surface which contains a large number of small holes which vary in diameter and depth.

- Unless the lining material will fill or effectively bridge the holes remaining after the removal of laitance, then these holes shall be filled before the work of lining commences. One material recommended for this purpose is a smooth paste made from a water-miscible epoxy resin, cement and a fine filler.

- After removal of laitance all surfaces to be lined shall be maintained at a temperature at least 3°C above the dew-point throughout the preparation and lining processes. If there is a risk that this condition will not be maintained owing to ambient conditions or a change in ambient conditions, dehumidifying and/or heating equipment shall be used.

- Fill and patch all holes with polymer mortar or putty. It is not possible to apply lining over a gap.

10.3 Application Methods

10.3.1 Surface preparation of components to be lined shall be according to 10.2.2.

10.3.2 The lining process shall be appropriate to the grade of material selected for the lining (see 10.3.3 to 10.3.7).

10.3.3 Polyesters lining

10.3.3.1 General

All polyester resins may be applied in a variety of ways (see 10.3.3.2 to 10.3.3.4) and it is usual to grade according to the thickness of the applied lining typical grades are as follows:

A) Reinforced linings up to 1 mm thick

These systems consist of a resin reinforced with mica, carbon or small diameter glass flakes. A resin primer is normally used. The systems are applied in two coats and are used for light corrosive duties and for situations where protection of the product from contamination is necessary.

B) Reinforced linings from 1 mm to 2 mm thick

These systems are made up from resins reinforced with glass flakes of up to 3 mm diameter. A resin primer is used. The systems are applied either in two coats or in two coats with a special top coat to provide a smoother surface. These systems provide a tough corrosion resistant lining.

C) Laminate reinforced linings

These systems are up to 5 mm thick and normally consist of:

1) a resin based primer;
2) glass fibre reinforcement (chopped strand mat or chopped fibre) thoroughly wetted out with resin;
3) a resin based top coat.

D) Laminate reinforced linings with screed

These systems are up to 5 mm thick and normally consist of:

1) a resin based primer;
2) a screed of resin and inert filler up to 2 mm thick;
3) glass fibre reinforcement laid on top of the screed and thoroughly wetted out with the resin;
4) a resin based top coat.

They are applied by trowel and roller.

10.3.3.2 Hand-lay-up mat lining

These consist of two layers of glass fiber mat lay up over a blasted primed substrate and finish off with a coat of resin. Typically, the liner is 2.5 to 3.5 mm thick and averages 20-25% glass and 75-80% resin.

This type of lining is used extensively in immersion service on steel and concrete substrates.

With all systems applied to metal substrates a resin based primer shall be sprayed or brushed on to the substrate immediately after preparation. The resins shall be catalyzed immediately before application and thorough mixing with a mechanical mixer is essential.

Systems which incorporate a layer or layers of glass fibre reinforcement shall be rolled to ensure proper consolidation. Care shall be taken during the rolling operation to fully wet out the glass and expel all air. Adjacent pieces of reinforcement shall be overlapped by not less than 50 mm. The edges shall be worked out by brushing with a stippling action. If more than one layer of glass reinforcement is used then all joints shall be staggered through the thickness of the laminate.

When the outer layer is reinforced with chopped strand material then an additional layer of resin and surface tissue shall be applied.

The final coat shall consist of a flow coat of resin.

Note:

This resin should normally contain 0.4% to 0.6% paraffin wax (with a melting point of 55°C to 60°C) to prevent loss of styrene and minimize air inhibition of the cure.

The work shall be scheduled so that good adhesion is obtained between successive layers in adjacent areas. To attain this, any coat shall be applied before the previous coat has reached a state of cure which would prevent good inter-coat adhesion.

If work is interrupted so that one layer is fully cured before work is complete then the surface of the resin of the previous coat shall be removed by grinding. If the previous coat contains glass fibres then these shall be exposed in the grinding process.

For good long-term lining performance, limit the temperature to 60°C.

Avoid temperature shocks. Do not drain a 60°C solution from the tank and turn a 15°C water hose on the lining to wash out the vessel.

Good results have been obtained with a high elongation resin (10%) prime coat followed by a 4% elongation lay-up.

For polyester lining of under ground storage tanks see API-RP-1631.

10.3.3.3 Flake glass lining

For application of flake glass-polyester lining over steel surface, the prepared surface (see IPS-E-TP-350) shall be primed with the lining manufacturer's primer, by spraying or brushing.

The prime coat shall be cured for a period of time in accordance with the manufacturer's recommendations.

Prior to application of the intermediate coat, the primer coat shall be tack free but shall not have set any longer than 8 weeks (nor less than 8 hr. minimum).

Prior to application of intermediate coat the primer shall be checked for styrene sensitivity (see test method). If it does not exhibit styrene sensitivity, it must be abraded by sanding, grinding, or sandblasting. At least 75% of the original surface must be uniformly removed. Any exposed steel shall be reprimed.

The primed surface shall be wiped down with styrene prior to lining to ensure removal of all dust and other forms of contamination.

The application of the liner intermediate coat shall not proceed if any of the following conditions exist:

a) The relative humidity in the work area is greater than 90%.
b) The surface temperature is less than 3°C above the dew point of the air in the work area.

A color differentiation shall exist between the intermediate coat and the top coat to ensure by an optical scan that coverage has been obtained (for example, an ultramarine base and a pink top coat).

The liner intermediate coat shall be trowel applied to a minimal thickness of 0.75-1 mm. The surface of the liner intermediate coat shall be styrene rolled with a short-nap paint roller dampened with styrene. Avoid excessive application of styrene to prevent softening of the lining.

Prior to the top coat application, the intermediate coat shall be tack free and have set less than 14 days.

If the intermediate coat has set more than 14 days it shall be abraded by sanding, grinding, or sandblasting. At least 75% of the original surface must be uniformly removed. More important, the intermediate coat should be checked for styrene sensitivity. If styrene is sensitive, good intercoat adhesion will exist.

If blasting has been done in the vessel after application of the intermediate coat or if the surface is otherwise visually dirty, the intermediate coat shall be wiped with styrene to ensure removal of dust and other contaminants.

The top coat application shall not proceed when any of conditions described in 10.3.3.2, exist.

The top coat shall be trowel applied to a thickness of 0.75 to 1 mm or as specified by the designer and/or Company.

Sharp edges shall be protected with multiple layers of glass mat-reinforced polyester extending a minimum of 100 mm. on the adjacent flat surfaces. Layers shall be built up with 450 g/m² mat. The 450 g/m² mat shall be sized, silane finished, and dry. The minimum of two layers (1.1 mm layers) will be applied. On top of this will be placed one layer of 0.25 mm above the lining. A bisphenol resin will be used. All reinforced lining will be finished off with a wax coat containing approximately 0.2% reinforcing strips. Some manufacturers cover the mat with flake glass, ending with 4.5-5 mm thickness on sharp edges and adjacent surfaces.

10.3.3.4 Troweled mortar lining

This filled polyester lining stabilized with a light roving are very important in pumps, trenches, concrete tanks, and vessels. These can be further modified to provide additional abrasion resistance, which in many cases is extremely important.

A silical-filled base coat is applied to the primed substrate. A light roving is embedded in it and rolled with resin until wet through. A top coat follows and, if abrasion is a problem, is enhanced with a corundum filler. The surface may be rolled with styrene to provide a glazed slick surface.

10.3.4 Epoxy lining

10.3.4.1 Typical grades of epoxy materials used for lining are as follows:

A) Amine cured solvent containing systems

These systems can be based on liquid epoxy resins but more often a solid resin is used, the latter tending to give a better performance. The hardener is usually in the form of an amine adduct. Sensitivity to temperature and humidity depends upon the type of hardener, that is used. The lining is applied as a multi-coat system which may well include a primer.

B) Polyamide cured solvent containing systems

In these systems a polyamide resin is used as the hardener in place of an amine. They are not often used as lining materials as their general properties are substantially reduced compared with amine cured systems. They are generally sensitive to conditions of high humidity.

C) High solids epoxy systems

These systems are similar to (A) and (B) except that the solvent content is very low. They are nearly all based on liquid epoxy resins. Hardeners will be either an amine, aromatic or aliphatic polyamine or a polyamide. Sensitivity to temperature and humidity depends on the type of hardener that is used.

The lining is usually applied in two coats.

D) Solvent-free epoxy systems

These systems are similar to (C) except that they are based on liquid epoxy resin with no solvent present. When the hardener is an aromatic polyamine a 3-pack system consisting of base, hardener and accelerator is used.

These systems are suitable for use with food and drink products provided a suitable non-toxic and taint-free resin is used.

These resins also may be reinforced with glass flake or glass fibre to provide additional strength.

E) Coal tar epoxy systems

These are 2-pack systems containing either coal tar or coal tar pitch. The epoxy may be liquid or solid resin. Amounts of solvent are small or the systems may be solvent-free.

Corrosion resistant properties vary markedly depending on the coal tar/epoxy resin ratio and it is important that this is specified. For instance, where good resistance to sulphuric acid is required, a proportion of at least 40% epoxy resin is required.

Hardeners such as amines, amine adducts and polyamides are commonly used depending on temperature and humidity. Systems are usually two or three coats.

10.3.4.2 For preparation of substrate to be epoxy lined see 10.2.2.

10.3.4.3 Some of the resin systems are moisture sensitive and in the case of site work it may be necessary to install and operate dehumidifying equipment during the lining process. The temperature of the mixed coatings and of the substrate at the time of application shall not be lower than 13°C. It is permissible to use in-line heaters or to otherwise heat the substrate to 49°C to facilitate application and cure.

10.3.4.4 The lining system shall consist of a liquid two-pack chemically cured rust-inhibitive epoxy primer and one or more coats of a liquid two-pack epoxy finish coat. Primer and finish coat(s) shall be preferably from the same manufacturer.

The lining system may alternatively consist of two or more coats of the same epoxy material without the use of a separate primer.

10.3.4.5 The total system shall provide in two or more coats and a total dry film thickness of not less than 365 µm nor more than 635 µm.

10.3.4.6 Both primer and finish coat shall be spray-applied in accordance with the manufacturer's recommendation. Application by airless spray or centrifugal wheel (see IPS-C-TP-102) is the preferred method.

10.3.4.7 The primer after mixing shall be applied without thinning to a dry film thickness of 25-40 µm. A minimum of 4 hours drying time and a maximum drying time as recommended by manufacturer is required before application of the finish coat. If more than maximum drying time elapse, the primer must be removed or abraded to roughen its surface. In either case, the surface must be reprimed.

10.3.4.8 When the resin system contains solvents the interval between coats shall be sufficient to allow the solvent to evaporate.

10.3.4.9 The epoxy finish coat(s) shall be applied over the dry primer or first coat as recommended by manufacturer. If more than one coat is applied, the second coat shall be applied within time limits recommended by the manufacturer to prevent delamination between coats. If the recommended period between coats is exceeded, a recommended repair procedure shall be obtained from the coating manufacturer.

10.3.4.10 For epoxy lining of under ground storage tanks see API-RP-1631.

10.3.4.11 For more information about using of liquid epoxy lining systems for steel water pipelines see AWWA C 210.

10.3.5 Furanes

10.3.5.1 All surfaces to which furane linings are to be applied shall be primed before the application of any furane resin.

10.3.5.2 The primer shall be fully cured before the application of the furane.

10.3.5.3 The components of the resin system shall be mixed thoroughly and applied within the time limit specified by the manufacturer of the lining.

10.3.5.4 Application by brush, roller, trowel or special spray equipment is permissible. When glass fibre reinforcement is used the coats shall be well rolled to ensure a void-free laminate.

10.3.5.5 It is usual for more than one coat of resin to be applied, and the work shall be scheduled so that good adhesion is obtained between successive layers in adjacent areas. To attain this any coat shall be applied before the previous coat has reached a state of cure which would prevent good inter-coat adhesion.

10.3.5.6 When a final top coat of un-reinforced resin is applied the thickness shall not exceed 0.5 mm.

10.3.5.7 Cure of furane resin linings shall be in accordance with the resin manufacturer's recommendations. When the conditions of cure involve heating, hot air shall be used. No part of the lining shall be heated above 50°C during the early stages of the cure.

10.3.6 Polyurethane

10.3.6.1 All the polyurethane systems used for lining process equipment shall be multi-component. The components shall be mixed thoroughly before application.

10.3.6.2 When polyurethane systems used for lining contain solvents the interval between coats shall be sufficient to allow the solvents to evaporate.

10.3.6.3 The work of applying successive coats shall be scheduled so that the next coat is applied before the preceding coat is fully cured, otherwise poor inter-coat adhesion will result.

Note:

All the polyurethane systems used for lining are sensitive to moisture. A small amount of moisture will accelerate the cure of the lining. Excessive moisture has an adverse effect and it may be necessary to control the moisture content of the atmosphere during the application of the lining.

Where concrete equipment is to be lined the free water content of the concrete is of particular importance.

10.3.7 Polychloroprene

10.3.7.1 Special primers shall be used to promote a bond between substrates and liquid polychloroprene.

10.3.7.2 The liquid rubber contains solvents and the lining process requires the application of a number of coats. The lining process shall be scheduled to allow the evaporation of the solvents from one coat before the next coat is applied.

10.3.7.3 The work of applying successive coats shall be scheduled so that the next coat is applied before the preceding coat has fully cured, otherwise poor inter-coat adhesion will result.

Note:

Cure of the lining is dependent upon the type of curing agent and the temperature. At 15°C the cure time is approximately 7 days. The process may be accelerated by the application of heat.

10.4 Curing (see Appendix D)

10.4.1 After application the lining shall be cured in accordance with the manufacturer's recommendations.

10.4.2 There is no suitable procedure for evaluating (at the time of application). The adequateness of cure of chemically cured lining. However hardness of the applied coating has been used as a guide in that, film hardness may be proportional to the degree of cure achieved (see 10.6.6).

10.5 Repair of Lining

10.5.1 When rectification of faults is to be made in linings which are fully cured special attention shall be paid to the problems of achieving adhesion between new resin and the cured lining.

10.5.2 In the case of linings based on polyester resins the first step shall be to remove the surface wax over a patch which extends 50 mm beyond the area to be repaired.

10.5.3 With all linings a patch which extends 25 mm beyond the area to be repaired shall be ground to remove the gloss.

10.5.4 When priming of the substrate is an essential part of the system the first step after preparation shall be to establish whether the primer is intact. If the primer is damaged then it shall be repaired before the rest of the work proceeds.

10.5.5 Rectification of faults shall be done either with the same material as originally used for the lining, or other materials that shall be used only with the Purchaser's written consent.

10.5.6 After all rectification work the lining shall be subject to inspection as appropriate and in particular to continuity testing.

10.5.7 Repairs shall be electrically inspected using continuity test (see 10.6.4).

10.6 Inspection

10.6.1 Visual inspection of lining

The lining shall be inspected visually for blisters, flaws, sagging and inclusions of foreign material. Defects shall be removed and the lining replaced. If the number of defects is large and covers a large surface area the lining shall be removed completely and the work of lining re-done.

Visual inspection shall be per ASTM D 2563:

a) Acceptance Level I for aggressive environments.
b) Acceptance Level II for all other environments.

10.6.2 Thickness of lining

A survey of the thickness of the lining shall be made. Of the instruments available those that operate on a single probe electromagnetic or eddy current principle shall normally be used. Selection shall be determined in other cases by the nature of the substrate. The instruments shall be calibrated against reference plates at least twice a day.

Notes:

1) For determining thickness of reinforced thermosetting resin linings see ASTM D 3567-85, and for thickness of unreinforced thermosetting resin lining, see IPS-C-TP-102 Section 22 (Dry film thickness measurement of paint).

2) Attention is drawn to the fact that thickness measurements of thin films in corners and on curved surfaces of small radii may not be accurate.

3) If concrete is the substrate it may be appropriate to monitor thickness of the linings as applied by use of wet film thickness gages.

10.6.3 Adhesion of lining

The lining shall be inspected visually for evidence of lack of adhesion to the substrate and, where applicable, lack of inter-coat adhesion.

Note:

As far as possible adhesion testing of the applied lining is to be avoided because the test is destructive and the lining has to be repaired.

If required, test pieces (see 10.6.7) shall be used to demonstrate that the process employed does provide a lining with the required level of adhesion. These test pieces shall be of the same material as the substrate and the lining process shall be the same as that employed for lining the equipment and done under the same conditions and at the same time.

10.6.4 Continuity testing (see also 19)

10.6.4.1 The lining shall be tested for pinholes.

There are two main types of instrument used for continuity testing.

10.6.4.2 Wet sponge testing

It is usual for wet sponge probes operating on low voltage to be used for lining up to 350 μm thick.

The sponge probe of the instrument shall be wetted with a 3% solution of sodium chloride to which a small amount of wetting agent (detergent) has been added. If the substrate is austenitic steel then a 3% solution of ammonium sulfate shall be used instead of the salt solution.

The sponge shall be moved across the surface in a systematic way so that the whole of the surface is examined.

The speed of travel shall be controlled so that time is allowed for imperfections in the lining to wet out. When a pinhole is discovered, the position of the hole shall be clearly marked.

Before proceeding with further testing the surface of the lining adjacent to the pinhole shall be dried thoroughly in order to avoid tracking back to the pinhole(s) already discovered.

10.6.4.3 Spark testing

The finished lining shall be tested using a high voltage, high frequency spark tester set for the following voltage levels:

a) Glass flake reinforced linings: 2500 to 5000 volts, depending on composition.
b) Lay-up and Spray linings: 5000 volts to 1.5 mm (60 mils) thickness
10000 volts to 3 mm (125 mils) thickness.

A probe shall be moved continuously over the surface of the lining at a speed not exceeding 100 mm/s. Applying the spark to one spot for any appreciable length of time shall be avoided as prolonged exposure to the spark can cause damage to the lining.

When a defect in the lining is discovered, it shall be clearly marked.

Note:

When concrete is the substrate the only method of testing for pinholes is by spark testing using an a.c. type instrument.

10.6.4.4 For continuity test the surface of all but small equipment shall be divided up by chalk line or other suitable marks into smaller areas of about 1 m².

10.6.4.5 Local repair are permitted if the number of pinholes does not exceed that 5 pinholes/m². If local repair are not possible the lining shall be removed and replaced (see 10.5).

10.6.5 Cure of lining

- The lining shall be examined for the state of cure.

- The hardness of the lining is a good indication of the cure and shall be the minimum specified (see 10.6.6).

- The lining shall be tested for solvent resistance using the specified solvent.

- This test shall be carried out by laying a cloth soaked in the specified solvent over selected areas of the lining for 3 min. After this time the lining shall show no sign of tackiness.

- In the case of linings based on polyester resins any wax shall be removed from the surface before applying this test.

- If the lining is found to be under-cured and the appropriate curing schedule has been followed then remedial action shall be investigated. If this treatment is not successful then the lining shall be removed and replaced.

10.6.6 Hardness of cured lining

10.6.6.1 Hardness

The average of hardness readings, made with the Barcol impressor on reference sample, shall at least be equal to the minimum specified by the lining manufacturer based on the type and material of lining selected.

10.6.6.2 Frequency of hardness checks

A minimum of one reading shall be made for each 10 m² (100 sq.ft) of lining installed and for each opening (nozzle, manway).

10.6.6.3 If the required hardness is not obtained, remedial procedures shall be as mutually agreed by Company, and contractor.

10.6.7 Reference samples

Reference samples prepared by the applicator, and meeting all quality requirements, shall be supplied to the Company prior to execution of the work:

a) Samples shall be (150 × 150 mm) (6 × 6 in.).

b) One sample shall be prepared of the complete system, to be used as a standard by the inspector for quality and finish of the completed work.

c) For all systems which require a seal coat, an additional sample shall be prepared without this finish coat. This sample shall be used by the inspector as a standard and calibration for hardness tests, 10.6.6 thickness measurements, 10.6.2 and spark test 10.6.4.3.

10.7 Transportation and Storage

10.7.1 Lined equipment shall be stored and transported in accordance with 7.5 with the following additional requirements:

10.7.2 When lined pipe transported by truck, a flatbed trailer shall be used with at least three bolsters between each layer of pipe, the bolsters are aligned vertically above the previous layer to provide even support.

10.7.3 The load should then be tied down to prevent any shifting, bending, or movement of the pipe. All pipe should be transported with closed end thread protectors on both ends, preferably made of plastic or a plastic-lined steel (composite) protector.

10.7.4 For storage, the pipe should be placed on at least three racks or wooden sills evenly spaced to support the pipe (48 cm) off the ground. To stack the pipe, wooden bolsters should be placed between each layer, directly above the pipe racks, with each layer being blocked to prevent shifting. When movement of the pipe is required on the racks, bars or similar objects should never be placed in the pipe inside diameter. If thread protectors have come loose, the threads and lining should be inspected for damage, and the thread protector reinstalled prior to any movement.

10.7.5 When running the pipe, it is important to select the best tools available, especially the best tools available, especially slips, power tongs, back-up tongs, and slip-grip elevators. Equipment with as much surface contact as possible to the pipe, e.g., full wrap-around tongs, should be used. When the tubing is lifted onto the rig floor, the pin-end thread protector must be in place to protect the threads and lining that covers the chamfer and typically the first two threads. It is removed just prior to stabbing for make-up.

10.8 Installation

Installation shall be in accordance with 7.8.1.

11. RUBBER LINING

11.1 General

11.1.1 This Clause 11 specifies minimum requirements for the lining of equipment using cold rubber.

11.1.2 The material considered include natural and synthetic rubbers applied as unvulcanized or prevulcanized sheet.

11.1.3 Brushed or sprayed rubber lining are not included.

11.1.4 The rubbers can be used for lining include:

- Natural polyisoprene	(NR),
- Synthetic polyisoprene	(IR),
- Butyl rubber	(IIR),
- Nitril rubber	(NBR),
- Chloro sulfonated polyethylene	(CSM),
- Hard and Ebonite rubber	
- Fluorinated rubber	(FKM),
- Chloroprene rubber	(CR).

11.1.5 Rubber lining applies to equipment and construction fabricated in metal or concrete.

11.1.6 Requirements for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350.

11.1.7 Rubber lining are mainly used for two purposes, either for corrosion protection or for protection against abrasion. In brick-lined equipment they perform as an impermeable membrane between the brick lining and the load-bearing construction.

11.1.8 Rubber lining are used economically for chemical service in the range of temperature from -20 to +200°C. In many cases of high-temperature service, protective brick lining are used to reduce the actual temperature at rubber lining and extend the expected service life by along enough time to justify the added expense (see IPS-E-TP-350).

11.1.9 Alternating from one chemical service to another is not recommended.

11.1.10 Lining shall not be applied when the temperature of surface is less than 3°C above the dew point of the air in the work area and/or the relative humidity is higher than 80%.

11.1.11 The Company inspector may stop lining operations when conditions such as 7.1.6.

11.1.12 The lined equipment shall be identified as stated in 8.1.10.

11.1.3 The applicator of the lining shall provide a certificate of inspection and testing when requested, as specified in 8.1.11.

11.2 Preparation

11.2.1 Preparation of material for lining

11.2.1.1 Unvulcanized lining materials

Lining materials shall be produced using a calender, extruder or roller die.

When linings are produced by calendering, multi-ply construction shall be employed.

Note:

The minimum number of plies employed in the manufacture of a finished sheet depends upon the rubber compound. A guide to the number of plies related to a given thickness is given below:

THICKNESS OF LINING	MINIMUM NUMBER OF PLIES
mm	
3 to 5	3
6	4

When roller die or extrusion methods are used for the production of lining materials then single-ply or multiply sheets are permissible.

11.2.1.2 Pre-vulcanized lining materials

The unvulcanized lining sheet shall be prepared in accordance with 11.2.1.1 and shall then be vulcanized by heating (normally under pressure in an autoclave) or by a rotary vulcanization process (see also ASTM D-3182).

11.2.1.3 Preparation of unvulcanized rubber sheets

Unless otherwise specified, condition the sheeted compound for 1 to 24 hours at 23 ±3°C at a relative humidity not greater than 55%. For maximum precision, condition for 1 to 24 hours in a closed container to prevent absorption of moisture from the air, or in an area controlled at 35 ±5% relative humidity.

Place the sheeted compound on a flat, dry, clean metal surface and cut pieces that are 4.5 ±1.5 mm shorter in width and length than the corresponding dimensions of the mold cavity. Mark the direction of the milling on each piece.

The mass of a 150 by 150 mm sheet or a 150 by 75 mm sheet to be vulcanized in the molds described in 11.4 shall be as shown in Table 2.

TABLE 2 - MASS OF UNVULCANIZED RUBBER SHEET, g

DENSITY OF COMPOUND	150 by 150 mm (6 by 6 in.)	150 by 75 mm (6 by 3.0 in.)
0.94	52 ±3	26 ±1.5
0.96	53	27
0.98	54	27
1.00	55	28
1.02	56	28
1.04	57	29
1.06	58	29
1.08	59	30
1.10	60	30
1.12	61	31
1.14	62	31
1.16	63	32
1.18	64	32
1.20	65	33
1.22	66	33
1.24	67	34
1.26	68	34
1.28	69	35
1.30	70	35

A film of suitable material, such as a non-lubricated aluminum foil 0.1 mm thick, may be placed above and below the sheet in the mold to prevent contamination with materials remaining in the mold from previous cures. The mass of the unvulcanized sheet shall be reduced to compensate for the thickness of the foil.

11.2.2 Preparation of surface to be lined

11.2.2.1 Metal

The surface to be lined should be smooth, free from pitting, cavities, porosity or other surface irregularities. The surface should be free also from oil, grease and other foreign matter.

All surfaces of carbon steel and cast iron to be lined shall be blast cleaned. The standard of blasting shall be Sa 2½ as defined in Swedish Standard SIS 05 5900 (see IPS-C-TP-101).

After this operation the surface roughness should have a peak-to-valley height of 50 µm to 75 µm.

The thoroughly cleaned surface should be pretreated before application of the lining.

In the case of metals other than carbon steel and cast iron, methods of preparation of the substrate shall promote an acceptable bond between the substrate and the lining. Immediately after the surface treatment of the metallic substrate the grit, dust, etc., is removed and a layer of adhesive primer with a dry-film thickness of approximately 30 µm shall be applied.

Unless maintained in a dehumidified atmosphere application of the primer shall commence within 4 hours. Should signs of rusting occur then the surface shall be prepared again to the required standard.

All surfaces to be lined shall be maintained at a temperature of at least 3°C above the dew point throughout the preparation and lining processes. If there is a risk that this condition will not be maintained owing to ambient conditions, dehumidifying and/or heating equipment shall be used.

Unless otherwise stated, all parts which are not rubber-lined should be derusted and painted with one coat of a suitable epoxy resin-based primer. This should be carried out after vulcanization of the rubber.

11.2.2.2 Concrete (see also IPS-C-TP-101)

11.2.2.2.1 Any external corners not formed with a chamfer shall be rubbed down to a radius of not less than the thickness of the rubber to be used for lining.

11.2.2.2.2 Lining of concrete equipment shall not proceed until at least 28 days after the concrete was cast and when the free water content is down to a level of less than 5% wt.

Notes:

1) Satisfactory adhesion of rubber lining to concrete depends upon the water content of the concrete. It is desirable that the free water content is less than 5%. If the concrete mix used is carefully controlled it is possible that after a curing period of 28 days the water content will be down to 5% but the required curing period may be longer.

2) There are no reliable methods for measuring the absolute water content of concrete although moisture meters may be useful in determining problem areas. It is advisable to line a test area and measure the adhesion before proceeding with a complete lining.

11.2.2.2.3 Surfaces to be lined shall be treated to remove laitance and shutter release agents. Of the two possible methods for this operation the one preferred is blast cleaning. The blast cleaning process shall be controlled so that all laitance is removed and exposure of the profile of the aggregate kept to a minimum. After blast cleaning all dust and debris shall be removed.

Note:

The alternative method of removing laitance is that of acid etching. The process is more difficult to control on vertical and overhead surfaces and the presence of shutter oils will reduce its effectiveness. The thickness of the laitance of a concrete surface varies considerably and it is very important that acid is allowed to dwell on the surface a sufficient length of time to remove all laitance. When acid etching is used the next operation is water washing of the concrete, followed by a drying process.

11.2.2.2.4 Unless the lining material will fill or effectively bridge the large number of small holes (of varying diameter and depth) that invariably remain in the concrete surface following the removal of laitance, then these holes shall be filled with any appropriate mortar, before the work of lining commences.

Note:

One material recommended for this purpose is a smooth paste made from a water miscible epoxy resin and a fine filler and cement.

11.2.2.2.5 After removal of laitance all surfaces to be lined shall be maintained at a temperature at least 3°C above the dew point throughout the preparation and lining processes. If there is a risk that this condition will not be maintained owing to ambient conditions or a change in ambient conditions, dehumidifying and/or heating equipment shall be used.

11.3 Application Methods

11.3.1 Prepare all metal surfaces to be lined in accordance with 11.2.2.

11.3.2 Apply one coat of adhesive primer immediately after blasting to prevent rusting. Apply additional coats of adhesive primer, if necessary, as specified by the lining manufacturer.

11.3.3 Apply required number of coats of intermediate or tie adhesives, or both, as specified by the lining manufacturer. Allow sufficient drying time between adhesive coats so the coat being applied does not lift up the preceding coat.

11.3.4 Apply the type and thickness of lining specified using a minimum number of sheets and splices consistent with good lining practice. Overlap the edges of the sheets approximately 50 mm, unless restricted by dimensional tolerances. The rubber lining sheets may be washed with recommended solvent and allowed to dry before application. During the application, roll the sheets and carefully stitch all the seams and corners to eliminate all trapped air between the lining and adhesive-coated surfaces, so there is full contact with all coated areas (see also ASTM D 3486).

11.3.5 Skive the edges of all the sheets at a 45° angle (minimum) from the top surface to the bottom of the sheet. Use a closed-skive construction, commonly known as a down skive, wherever possible. This is required where the lining is a combination of hard-face stock and soft cushion. Open-skived splices may be used when specified by the lining manufacturer.

11.3.6 Prior to vulcanization (see 11.4) inspect all lined surfaces for blisters (trapped air), pulls, or lifted edges at seams and surface defects. After lining, also check any special dimensional tolerances required.

11.3.7 The scope of this procedure covers the calibration of the equipment and the use of the equipment to determine if there are leaks and their location on sheet linings. Spark test all areas for "pinhole" leaks using a high voltage spark tester adjusted and used as in 11.8.3.2.

11.3.8 It is essential that personnel be instructed in the application procedures to be adopted when entering rubber-lined vessels. A clearance certificate shall always be obtained from the appropriate authority before doing so. The following points should be observed:

11.3.8.1 Personnel shall not wear studded boots or other footwear likely to cause damage. Rubber-soled shoes are to be preferred.

11.3.8.2 In cases where solid deposits have to be removed the use of metal spades or other tools is to be avoided. Wooden or lined implements shall be used.

11.3.8.3 The ends of ladders or scaffolding likely to come in contact with the rubber lining should be covered in such a way that damage is avoided. Swinging air lines or hoses can also puncture rubber linings. Metallic ends shall therefore be covered to prevent this occurring.

11.3.8.4 In large ebonite-lined vessels precautions to avoid successive flexing should be taken and walkways laid if necessary.

11.3.9 Joints

11.3.9.1 Overlap bevel joints as shown in Fig. 1 shall be used when joining separate sheets of unvulcanized rubber. The total contacting surface between the sheets shall be a minimum of four times the sheet thickness but shall not exceed 32 mm at any point.

Where applicable, overlaps shall follow the direction of the liquid flow.

11.3.9.2 When the total lining thickness is built up from more than one layer, only the joints in the top layer shall be of the overlap bevel type, the under layers being flush jointed as shown in Fig. 2. The relatively weak flush joint Fig. 3 is applied when the lining is used as a base for chemical-resistant brick lining. Joints in the different layers shall be staggered.

Joints between rubber pipe linings and the rubber on the flange facing shall not protrude so as to restrict the bore of the pipe or to prevent efficient sealing between the flange faces of adjacent lengths.

11.3.9.3 All scarf joints shall be closely inspected. Any separation of the joint shall be investigated (see Fig. 6). If the extent of the separation is small then the rubber shall be ground back. If the separation of the rubber is extensive then the joint and rubber adjacent to the joint shall be removed and replaced.

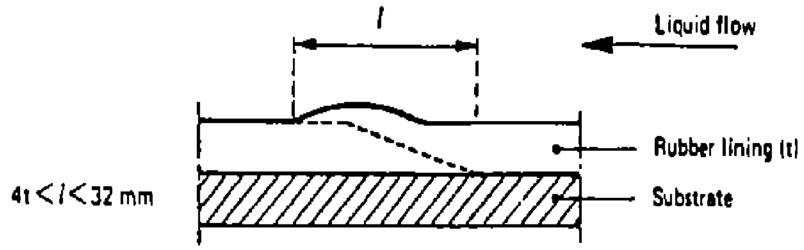
11.3.10 Gaskets

To prevent the gasket and lining bonding together the rubber flange facing shall be lightly rubbed with colloidal graphite.

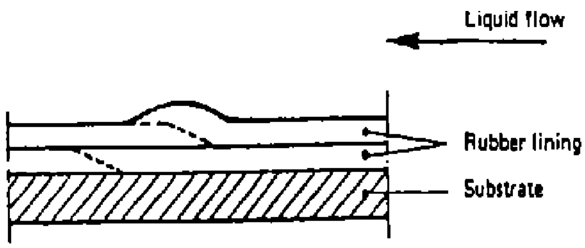
11.3.11 Flanges

Rubber lining on pipe flange connections shall be as shown in Fig. 4. The flanges for vessels are shown in Fig. 5.

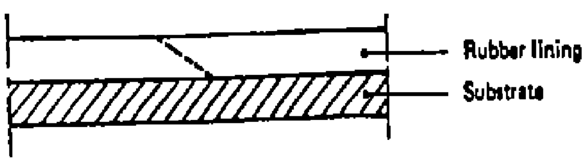
ACCEPTABLE JOINTS IN RUBBER LINING
(Figs. 1, 2 and 3)



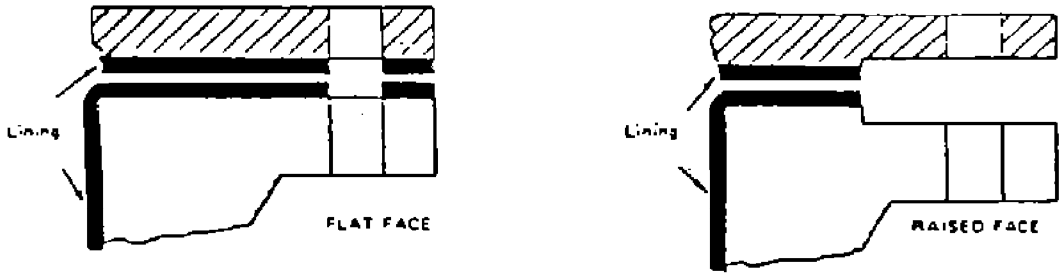
OVERLAP BEVEL JOINT (1 LAYER)
Fig. 1



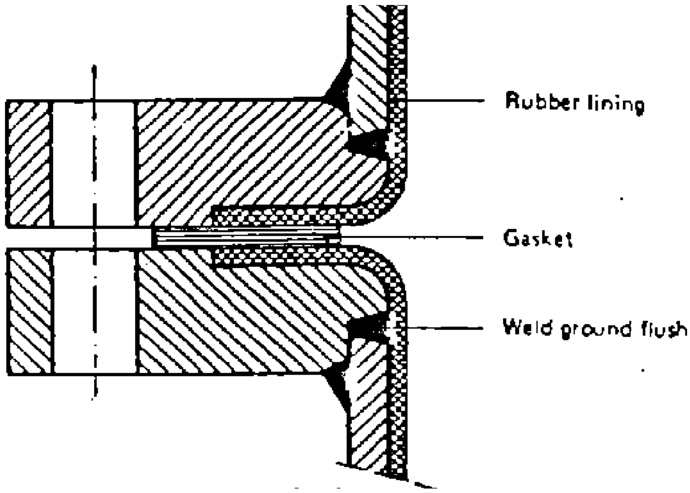
OVERLAP BEVEL JOINT (2 LAYERS)
Fig. 2



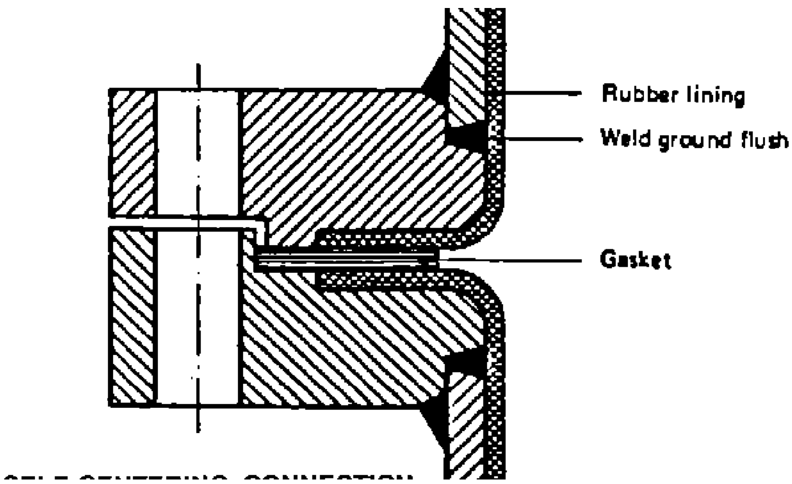
FLUSH JOINT
Fig. 3



RUBBER LINED PIPE FLANGE CONNECTIONS
Fig. 4

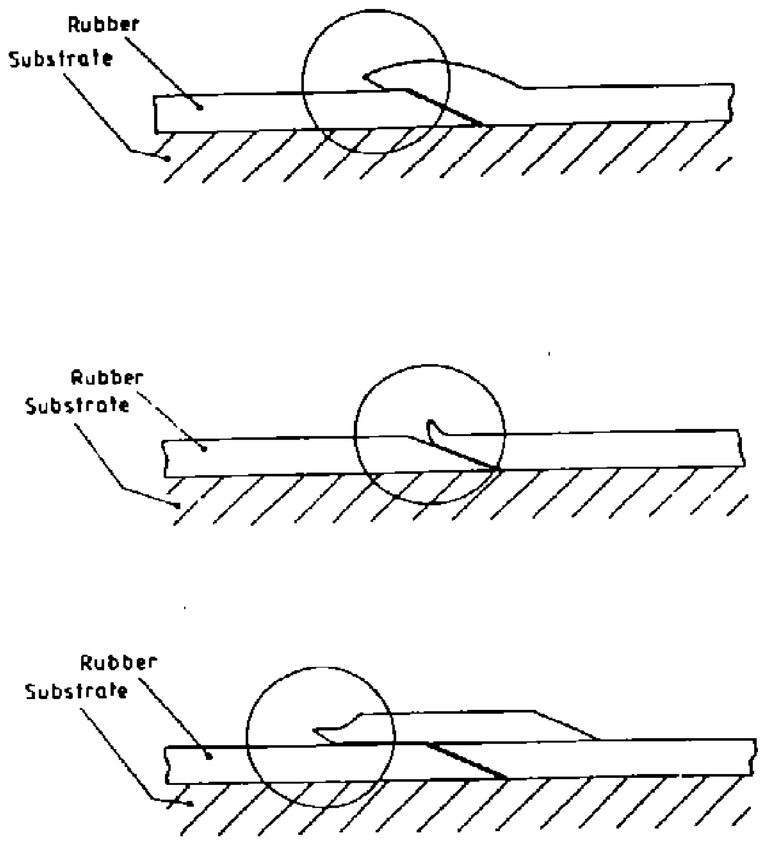


NORMAL CONNECTION
Fig. 5a



SELF-CENTERING CONNECTION
Fig. 5b

RUBBER LINED FLANGED CONNECTIONS FOR VESSELS
Fig. 5



UNACCEPTABLE FAULTS IN JOINTS IN RUBBER LININGS
Fig. 6

11.4 Vulcanizing

Vulcanization of rubber lining shall be carried out in shop or in-situ application as follows:

11.4.1 Shop vulcanization

A typical lining procedure is as follows:

Immediately after preparation of the substrate, an adhesive primer layer is applied. After evaporation of the solvent, and no longer than 96 hours thereafter, the pre-cut unvulcanized rubber sheets are applied. Care is taken to position the sheets accurately without inclusion of air and with joints as detailed in 11.3.9.

The next step is to vulcanize the rubber. This is carried out in an autoclave usually at a pressure of 4-6 bar and a temperature of 140-160°C.

11.4.2 In-situ vulcanization

11.4.2.1 When the equipment to be lined is of such dimensions that it cannot be placed in an autoclave, or there is too high a risk of damaging the shop-applied rubber lining, or the equipment is made from concrete, in-situ lining can be carried out.

11.4.2.2 After surface preparation of the substrate, the unvulcanized sheets are applied similarly as described in 11.3. For the subsequent vulcanization, different heat treatment methods are employed-either steam, hot water or hot air at atmospheric pressure. Alternatively, pre-catalyzed rubber sheets may be used, these cure naturally at ambient temperature. Usually such sheets consist of a completely vulcanized top layer to which a layer of catalyzed, partially vulcanized rubber is laminated. The lining shall not be applied when the temperature of surface is less than 3°C above the dew point of the air in the work area and/or the relative humidity is higher than 80%.

11.4.3 Method of vulcanization

11.4.3.1 General

Vulcanization of the lining shall be carried out by one of the following methods:

a) autoclave vulcanization;
b) using equipment as its own autoclave;
c) steam or hot air vulcanization at ambient pressure;
d) hot water vulcanization; and,
e) self vulcanization at ambient temperature.

Note:

The method employed depends upon the design and size of the equipment. It may be necessary to shield the equipment to reduce heat losses which would otherwise lengthen the duration of vulcanization when using methods (b), (c) or (d).

The duration of vulcanization will depend upon the method used and the composition of the lining material.

With the agreement of the applicator, interruption of vulcanization shall be permitted to detect and repair any faults present. The equipment shall then undergo further heat treatment to complete the vulcanization. An inspection for faults shall be carried out in accordance with Clause 11.8.

11.4.3.2 Autoclave vulcanization

The equipment shall be placed in an autoclave which is then heated to the required temperature and pressure. (Usually at a pressure of 4-6 bar and temperature of 140-160°C.)

11.4.3.3 Using equipment as its own autoclave

With all outlets sealed and a steam trap condensate drain attached to a convenient outlet to ensure continuous removal of condensate, saturated steam shall be injected until the equipment is pressurized to a predetermined pressure.

The pressure shall be within the design pressure limits of the equipment. Precautions shall be taken against failure of the steam supply since, in such cases, condensation can cause a vacuum and collapse the vessel.

11.4.3.4 Steam or hot air vulcanization at ambient pressure

With outlets covered to reduce steam losses and provision made to drain condensate from the equipment, the steam shall be injected until the vulcanization temperature is attained. This temperature shall be maintained for the required time period. Attention is drawn to 11.4.2.2 regarding failure of steam supply.

Note:

Hot air may be used as an alternative to steam in some cases provided that the temperature and heat input can be achieved.

11.4.3.5 Hot water vulcanization

With all outlets below the top flange sealed off and the equipment partially filled with water, steam shall then be injected into the water, raising the water level and temperature. If the water reaches boiling point before the equipment is full, further water shall be added to attain the required level. The temperature shall then be maintained for the required time period while maintaining the water level.

11.4.3.6 Self vulcanization at ambient temperature

Such rubber linings shall be specially designed so that they are capable of vulcanizing under ambient conditions.

Note:

The time to vulcanize is temperature-dependent and at temperatures below 15°C it may be necessary to use supplementary heating in order to reduce vulcanization times to an acceptable period.

11.4.3.7 After vulcanization, inspect all lined surface for blisters, open seams pinholes, lifted edges and surface defects in accordance with Subclause 11.8 and repair all pinholes and other lining defects in accordance with Subclause 11.7.

11.5 Transportation and Storage

11.5.1 Transportation

11.5.1.1 Rubber-lined equipment and piping shall not be transported or assembled if ambient temperature is below or is likely to drop below 0°C. The objects shall be handled with care; hoisting shall be carried out using non-metallic slings. In particular, branches, openings and flange facings shall be protected adequately since these are vulnerable.

11.5.1.2 Lifting shall be arranged so that chains and other lifting aids do not come into contact with lined surfaces.

11.5.1.3 Loose fittings shall not be placed inside lined equipment whilst it is being transported.

11.5.1.4 Responsibility for arranging transport of lined equipment will vary and whoever is responsible (Purchaser, fabricator or applicator) shall instruct the carrier about the precautions in handling.

11.5.2 Storage

11.5.2.1 Lined equipment shall be stored under cover or in a protected compound. when necessary, linings shall be shielded from direct sunlight.

11.5.2.2 All branches, manholes and other openings shall be protected from mechanical damage by using wooden blanks or other suitable material.

11.5.2.3 Between delivery and use, store lined vessels away from direct sunlight, heat, or outdoor seasonal weathering.

11.5.2.4 Flexible-type lining may be stored outdoors, provided the vessels are covered with protective tarpaulins and are not subjected to extreme temperature conditions, such as below 0°C or above 49°C. Avoid sudden changes in temperature. Tanks stored or used in the outdoors may be painted a light color on the outside to reflect heat.

11.5.2.5 To ensure protection, store semi-hard and especially bone-hard type lined equipment in a way that does not allow it to be subjected to extremely cold climatic conditions. If this occurs, thermal stress and expansion may introduce cracking.

11.5.2.6 Rubber-lined equipment may also be protected for extended periods of time by storing the tank partially filled with a diluted solution. When recommended by the rubber lining manufacturer, a 5% sulfuric acid, 5% sodium carbonate solution, or a weak salt solution make ideal storage media to help keep the lining flexible, to minimize expansion and contraction, and to keep the air (ozone) from prematurely deteriorating the lining surface. Do not permit the liquid contained within to freeze.

11.5.2.7 Shelter large rubber-lined equipment that cannot be filled with a solution under a suitable structure to protect it from the direct rays and heat of the sun. Provide sufficient air space between the tank and covering to allow for circulation.

11.5.2.8 For small tanks that can be stored inside, cover any open tops and outlets with plywood, or other suitable material and store them away from steam coils or other high-temperature sources.

11.5.2.9 Inspect any stored vessel prior to being put into service.

11.5.2.10 Do not carry on any welding nor any other activity requiring intense heat in the vicinity of a lined tank.

11.5.2.11 When tanks might be stored outside, take care to ensure good weatherability of the paint. Primer paints are not designed to withstand prolonged atmospheric weather conditions.

11.5.2.12 It is essential that the contractor and/or Purchaser issues instructions to those responsible for installation on the handling procedures and special reference is made to the need to wear soft clean footwear when entering lined equipment and the need to protect lined surfaces from ladders and scaffold poles.

11.6 Installation of Rubber Lined Parts

11.6.1 During the installation of rubber-lined equipment, care shall be taken to avoid damage of the rubber lining. Due attention shall be paid to the susceptibility of linings to collapse when subjected to vacuum and to the risk of damage by local overheating.

11.6.2 Properly applied rubber linings will resist vacuum in the order of 130 m bar absolute. Shop-vulcanized rubber linings have in general a better resistance to vacuum than in-situ vulcanized ones.

11.6.3 Rubber-lined equipment and piping is installed in a way which is similar to that of carbon steel equipment. No welding is allowed on lined equipment and piping, nor shall they be used as a welding ground.

11.6.4 For connecting rubber-lined equipment and piping, only flanged connections may be used. The rubber-lined flange facings shall not be damaged.

11.6.5 Rubber lined piping is used only in above ground installation.

11.6.6 If the equipment to be lined is located out of doors it will be necessary, in certain latitudes and seasons, to protect the equipment from the weather and to provide the heat necessary to maintain a temperature above 15°C. In any event, the equipment must be properly protected against rain and in warm weather from direct exposure to the sun. A satisfactory installation cannot be made if conditions are such as to induce condensation on surfaces prior to cementing and lining. Nor can lining be properly cured unless equipment is protected against excessive heat loss during cure.

11.7 Repair of Lining

11.7.1 General

Repair of damaged rubber linings shall only be carried out by the contractor after consultation with, and the agreement of the Company.

Repairs can be carried out in-situ or at contractor's work using an autoclave for vulcanization. The repaired area shall be checked for adhesion, thickness, hardness and continuity in accordance with 11.8. The quality of the repairs shall be certified by the contractor and approved by Company's inspector.

11.7.2 Spot repair

The total amount of shop repairs allowable in equipment shall not be more than 100 cm² per square meter of lined surface. No lining repairs are allowed in piping, on flange facings or on nozzle necks of equipment.

11.7.2.1 The damaged rubber is cut away, the exposed edges of the lining are beveled and the surface is roughened. Dependent on the size of the damage and the service conditions, repairs of equipment can be made as (11.7.2.2 to 11.7.2.4 inclusive).

11.7.2.2 Damage in non-critical services (to be defined by the Purchaser)

For vessel linings not in direct contact with the process liquid, a vulcanized rubber sheet, cut to fit the spot to be repaired, is glued with an appropriate adhesive. A hot-air device can be used to make the sheet sufficiently flexible for handling.

Alternatively, if the chemical resistance is not impaired, repairs can be carried out with cements based on synthetic resins, such as epoxy or phenol formaldehyde.

11.7.2.3 Minor damage in critical services

For vessel linings in direct contact with the process liquid, an unvulcanized rubber sheet, cut to fit the spot to be repaired, is glued with an appropriate adhesive.

Subsequently heat, equivalent to the normal vulcanizing conditions, is applied by means of pressing a heating element against the rubber.

Areas to be repaired should not be greater than the heating surface of this element.

Alternatively, if chemical resistance is not impaired, repairs can be carried out with a glass-fibre reinforced epoxy resin system cured with hot air in order to yield optimum properties, or with a phenol formaldehyde-based cement.

11.7.2.4 Major damage in critical services

Most rubber lining manufacturers have a method utilizing a hot water vulcanizing or self-vulcanizing type of rubber for repairing large areas in contact with the process fluid. such rubber compounds have been modified with respect to their accelerator system so that vulcanizing at 90°C or at ambient temperature is possible.

The above procedures can also be followed for repairs of equipment, which has been in service. However, the defective and adjacent lining shall be thoroughly neutralized, cleaned and dried.

Note:

The minor and major damages in critical services shall be specified in scope of work.

11.7.3 Complete repair

11.7.3.1 Providing that previously used plant and equipment is structurally sound and that it has not been subjected to extensive corrosion, relining is normally possible. It is, however, particularly important that the lining contractor shall inspect such items and agree that they are in a suitable condition for him to undertake the work.

11.7.3.2 When it is necessary to replace a rubber lining in existing equipment the old lining will have to be removed by one of the following methods.

11.7.3.2.1 Burning

Most rubbers may be removed by this procedure but although effective it is subject to certain disadvantages.

a) Metal structures may warp as a result of the heat generated.

b) Noxious or toxic fumes will be generated and in the case of ebonites and the essentially non-combustible polychloroprene these will be particularly objectionable and may constitute a health hazard.

It is essential therefore that care be taken to ensure that anti-pollution laws are not infringed by this procedure.

11.7.3.2.2 Heating

This is a more acceptable alternative to burning and involves raising the temperature by externally heating the equipment so that the bond to the metal is weakened. The heating process is followed by mechanical removal of the rubber.

11.7.3.2.3 Mechanical removal

The most effective method in instances where adhesion to the metal is still good, is to cut through the rubber so that it is divided into narrow strips. These can then be most readily removed by application of a mechanical chisel to the rubber/metal interface.

11.7.3.3 After removal of the old lining the metal surface shall be prepared in the normal way to produce Sa 2½. Inspection to check the vessel's mechanical suitability for the duty should, if necessary, be also carried out at this stage.

11.7.3.4 When the old lining has been removed and inspection has confirmed that the item is mechanically sound and in a suitable condition for relining, the standard procedures outlined in this Standard shall be followed.

However, if there is any reason to suppose that there has been any impregnation of the metal by chemicals, it is sound practice to sweat the metal in live steam before shot-blasting.

Where noticeable corrosion has occurred relining should be avoided.

11.8 Inspection and Tests

11.8.1 General

Before proceeding the applicator shall ensure that all materials to be used in the lining process are visually examined and where appropriate, physically and practically tested to confirm that they are in an acceptable condition. For the unvulcanized rubber sheeting this shall include:

11.8.1.1 Visual examination to ensure that it has no imperfection which could significantly affect the performance of the finished vulcanized lining.

11.8.1.2 Visual and physical examination to ensure that it has been prepared in accordance with Sub-clause 11.2.2 and that the actual thickness is within ±10% of the specified thickness.

11.8.1.3 A test to ensure that the sample taken from each roll achieves the correct hardness when vulcanized in accordance with the customary practice of the applicator.

11.8.2 Visual appearance of the lining

11.8.2.1 Inspection for visible defects shall be carried out over the entire surface of the lining in a good light, attention being paid to any areas of mechanical damage, cuts, blisters, lack of adhesion and poor jointing.

11.8.2.2 If the applicator finds a defect prior to vulcanization it shall be removed and the area overlaid with unvulcanized rubber of the same type as the original unvulcanized rubber on to which it is bonded. After subsequent vulcanization the area concerned shall be considered identical to a lap joint or seam and thus fully acceptable.

11.8.2.3 All scarf joints shall be closely inspected as specified in 11.3.9.3.

11.8.2.4 To repair defects found after vulcanization, the surface of the lining local to the defect shall be prepared by abrading. Adhesive and a patch of unvulcanized rubber both of the same type as used for the lining shall then be applied. The size of this patch shall not be greater than 25 mm in any direction beyond the defect.

The patch shall then be vulcanized. After rectification, the repaired area shall be tested for pinholes. Minor wrinkles and surface markings which have no significant effect on the performance of the lining shall be acceptable under the responsibility of Purchaser and/or contractor.

Note:

After vulcanization defects such as blisters, blow holes, small cracks or scuffed areas in the lining may be found. when such faults are discovered after vulcanization the defect may be patched.

11.8.3 Tests

11.8.3.1 Hardness test

11.8.3.1.1 The extent of vulcanization shall be checked by a hardness test. If actual hardness levels measured indicate that further vulcanization is required the lining shall be retested after such vulcanization.

11.8.3.1.2 The hardness of a rubber is a property indicative of its chemical resistance and mechanical strength.

The hardness is determined by measuring the penetration of a specified indentor under a certain load. Various types of indentors and loads are used. In general, it is common to express hardness in Durometer A or Durometer D readings in accordance with ASTM D 2240 or BS 2719.

11.8.3.1.3 A chart indicating an approximate comparison of hardness values as measured with different instruments is given in Appendix C.

Typical hardness values for the different rubbers used for lining purposes indicated in IPS-E-TP-350 Clause 11.4.

11.8.3.1.4 The hardness shall conform to the value specified on the requisition within a tolerance of ±5°. A minimum of three reading per square meter shall be taken.

11.8.3.2 Continuity of lining (high frequency spark test)

11.8.3.2.1 Testing for pinholes and other discontinuities shall be carried out:

- **a)** when the rubber has been applied and before vulcanization;
- **b)** after interrupted vulcanization;
- **c)** after complete vulcanization;
- **d)** after any remedial work.

Before testing begins the surface shall be made dry and free from dirt.

11.8.3.2.2 No sparks shall be produced when the liner, applied on a metallic substrate is tested with a direct-current apparatus approved by the Company using a voltage which is determined by the following formula:

6 (1 + thickness in mm) = kV which shall not exceed 30 kV

11.8.3.2.3 This voltage can be adjusted for high carbon black filled (soft) rubbers to approximately 3 kV per mm thickness (exact voltage to be determined on a test sample).

11.8.3.2.4 Antistatic linings on metallic substrates shall be checked with the "Wet Sponge Test", a low-voltage holiday detector.

11.8.3.2.5 The presence of continuous pores in rubber linings applied on concrete substrates can only be determined visually, unless a conductive layer has been applied to the concrete.

11.8.3.2.6 The probe shall be moved continuously over the surface of the lining at a speed not exceeding 100 mm/s. Applying the spark to one spot for any appreciable length of time shall be avoided.

11.8.3.2.7 Wet sponge testing

In the case of rubber linings which are normally at least 3 mm thick and may contain scarf joints up to 32 mm in length wet sponge testing is not recommended. This is because the time that may be required for the electrolyte to penetrate the hole in the rubber, or a leak in joint may be rather long. By the time the electrolyte reaches the substrate the probe may no longer be in a position to complete the circuit. Furthermore, in some cases when the rubber contains a cut it is possible the electrolyte will not penetrate that cut under the conditions of the test.

11.8.3.3 Bond strength tests

11.8.3.3.1 Non-destructive test

The adhesion between the rubber lining and the substrate shall be homogeneous and without any defect. This may be investigated by lightly tapping the rubber lining with an appropriate wooden hammer. At areas where the adhesion is broken a hollow sound will occur. This is no quantitative test method.

11.8.3.3.2 Destructive test

11.8.3.3.2.1 The bond strength between soft rubber and a substrate with using test samples shall be measured by BS 903: Part A 21-Method B or ASTM D 429 Method B.

11.8.3.3.2.2 Test samples shall consist of pieces of substrate, similar to that used in the manufacture of the equipment, to which has been applied rubber of the same mix and thickness used. For the main lining, for preparation of pieces for test purposes from products, see ASTM D 3182.

11.8.3.3.2.3 There is no quantitative test for measuring the bond strength of hard rubber or ebonite to substrates. A quantitative assessment of the bond can be made by chipping the lining on a test plate with a chisel 25 mm wide when it should be possible to loosen only small pieces of hard rubber or ebonite at each blow.

11.8.3.3.2.4 Minimum load figures for bond strengths obtainable with various types of rubber, vulcanized by different methods shall be as given in Table 3.

TABLE 3 - TEST LOADS FOR ADHESION OF VULCANIZED SOFT RUBBER TO CARBON STEEL AND CONCRETE SUBSTRATES

TYPE OF RUBBER		CARBON STEEL			Concrete
		Pressure Vulcanization	Vulcanization by Hot Water or Steam at Atmospheric Pressure	Self-vulcanization at Ambient Temperature	
		kN/m	kN/m	kN/m	kN/m
Natural or synthetic polyisoprene		3.5	2.7	2.7	1.0
Styrene-butadiene	(SBR)	3.5	2.7	2.7	1.0
Chloroprene Rubber	(CR)	3.5	2.7	2.7	1.0
Butyl Rubber	(IIR)	3.5	2.7	2.7	1.0
Ethylene-propylene Rubber	(EPR)	3.5	2.7	—	1.0
Nitrile Rubber	(NBR)	3.5	2.7	2.7	1.0
Butadiene and/or blends	(BR)	3.5	2.7	—	—
Chlorinated Rubber	(CSM)	2.7	2.7	—	1.0

11.8.3.4 Thickness tests

The thickness of the lining applied on a metallic substrate shall be determined with a suitable thickness meter and shall conform to the specified thickness within a tolerance of ±10% (see IPS-E-TP-350). A minimum of 3 measurements per square meter shall be made. The thickness of the rubber lining applied on concrete or any other non-magnetic surface shall be determined destructively.

11.8.3.5 Pressure/vacuum testing

If appropriate, equipment and piping shall be pressure-tested with water at a pressure equal to the test pressure mentioned in the related design code, and at the maximum allowable service temperature for the particular lining; or alternatively vacuum-tested at 130 m bar absolute at ambient temperature.

These conditions shall be maintained for a period of 1 hour. At the end of the test the lining shall be visually inspected. No blisters, cracks or other surface irregularities shall be permitted. Thereafter the lining shall pass the high-voltage spark test.

11.8.3.6 Other tests

In addition to previous methods, the following test methods applicable in general to vulcanized rubber, shall be utilized as required by the Purchaser:

- Tension test	ASTM D 412
- Aging test	ASTM D 573 and D 865
- Immersion test	ASTM D 471
- Abrasion test	ASTM D 2228
- Chemical resistance test	ASTM D 3491

12. BITUMEN, ASPHALT AND COAL TAR LINING

12.1 General

12.1.1 The Clause 12 specifies requirements for the lining of equipment using bitumen and coal tar.

12.1.2 Bitumen and coal tar materials are suitable for protecting internal surfaces of steel pipes, fittings, vessels and cementitious or brick work equipment (see also ISO 5256).

12.1.3 Bitumen and coal tar base lining are available for hot or cold application.

12.1.4 Cold applied lining consist of liquid solution of bitumen or coal tar in volatile solvent (see IPS-M-TP-105 and IPS-M-TP-230 and IPS-M-TP-285 and IPS-M-TP-280).

12.1.5 Hot applied lining consist of bitumen or coal tar pitch and filler, it is melted before use and applied in molten form (see IPS-M-TP-295 and IPS-M-TP-290).

12.1.6 For certain application as will be specified by the designer, bitumen and coal tar can be reinforced with mineral fillers or to produce heavy consistency products suitable for application by trowel or heavy duty spray (see IPS-M-TP-105 and IPS-M-TP-230).

12.1.7 The Company inspector may stop lining operations when conditions such as 7.1.6.

12.1.8 The lined equipment shall be identified as stated in 8.1.10.

12.1.9 The applicator of the lining shall provide a certificate of inspection and testing when requested, in accordance with 8.1.11.

12.2 Preparation

12.2.1 Preparation of material for use

12.2.1.1 Cold applied lining

Where thinning is necessary, e.g. as a first coat on very porous surfaces, only the manufacturer's recommended thinners shall be used.

12.2.1.2 Hot applied lining

The enamel shall be heated in suitable agitated heating kettles equipped with accurate and easily read recording thermometers. The thermometers will be checked and adjusted by the inspector whenever necessary.

Both solidified and molten enamel shall be maintained moisture and dirt-free at all times prior to, and at the time of, heating and application.

The solidified enamel charge shall be melted and brought up to application temperature. The temperature at which the enamel will be applied shall be in accordance with the recommendations of manufacturer.

Excess enamel remaining in a kettle at the end of any heating shall not be included in a fresh batch in an amount greater than 10 percent of the batch. Kettles shall be emptied and cleaned frequently, as required. The residual material removed in cleaning the kettles shall not be blended with any enamel.

12.2.2 Preparation of surface to be lined

12.2.2.1 Metals

Complete removal of mill scale, heat treatment scale previous coatings and paint, loose dirt, grease, oil, salt, etc., which could be harmful to the adhesion of lining to the steel shall be carried out by surface preparation. The surface preparation shall be according to IPS-C-TP-101.

The preparation shall be carried out to achieve a quality of at least Sa 2½ as in SIS 05 59 00.

Immediately before the application of the lining. The surface shall be free from all trace of abrasive and dust. If metallic surfaces are not to be coated immediately after cleaning, a suitable protective film shall be applied to prevent corrosion.

12.2.2.2 Concrete

Concrete or other non-metallic surfaces shall be clean and free from oil and any dust or powdery material according to IPS-C-TP-101 prior to application of lining.

12.3 Application Methods

12.3.1 General

12.3.1.1 Bitumen and coal tar lining can be applied in the factory or other workplace on each pipe, fitting or vessel.

12.3.1.2 Cold applied bitumen and coal tar lining are readily applied by brush, spray or also by dip process as appropriate by the job. For lining of porous surfaces such as concrete surfaces one coat of primer (see IPS-M-TP-285 and IPS-M-TP-280) shall be applied by brush prior to application of main lining.

12.3.1.3 Hot applied bitumen and coal tar lining can be applied by trowel, spray, rotating or other methods.

12.3.1.4 Considerable skill is required in all methods of application.

12.3.1.5 The material are heated as needed in kettle near the application site.

12.3.1.6 For vertical surfaces the material is daubed on with a stiff brush, covering small rectangular areas with short strokes and overlapping to form a continuous lining.

12.3.1.7 In weld areas the brush strokes should be in the direction of the weld; a second coat should then be applied in the opposite direction.

12.3.1.8 For horizontal surfaces, the material can be poured on and then troweled-out and if unevenness occurs where a smooth surface is required, it may be permissible to play a blow-lamp on to the surface and finish by troweling.

12.3.1.9 For lining of pipe the centrifugal casting method shall be used (see 12.3.6.2).

12.3.1.10 When hot-applied coal tar is used as a protective interior lining of steel water pipelines, the temperature of pipeline water must not exceed 32°C and its flow rate must be sufficient to prevent stagnation.

12.3.2 Selection of process

The lining process shall be appropriate to the type of material selected for the lining according to 12.3.3 to 12.3.7 inclusive.

12.3.3 Cold applied bitumen lining

12.3.3.1 Bitumen or solutions (see IPS-M-TP-285 and IPS-M-TP-280) are readily applied by brush or spray and are often used as priming coats for the heavy duty materials which can be applied hot or cold at the works or on site.

12.3.3.2 When lining the interior of tanks, use a forced air supply to disperse the solvent and prevent residual solvent condensing on the lining and washing off.

12.3.3.3 For lining of metallic surfaces, one or more coats of primer (synthetic primer) shall be followed by at least two coats of bitumen-based lining material to obtain the specified thickness.

12.3.3.4 For lining of cementitious or brick work surfaces, two or more coats of bitumen based solution shall be applied to obtain the specified thickness.

12.3.3.5 For lining of drinking water tanks or citerns two or more coats of solvent base bitumen lining shall be applied to interior surfaces to obtain the specified thickness. The lining material shall meet the requirements of BS 3416 regarding the health hazards.

12.3.4 Hot applied bitumen lining

12.3.4.1 For the lining of metallic surfaces one or more coats of primer (cold applied bitumen primer) shall be followed by hot applied bitumen coatings.

12.3.4.2 The application shall be made by rotating the pipe and introducing the lining material in molten state, or by mat, trowel, or spray to vertical surfaces (e.g. vessels).

12.3.4.3 By agreement between the parties, protection at certain types of joint may be effected by the application of a thick, cold applied bitumen coatings.

12.3.4.4 Hot melt bitumen, when used as a tank bottom covering or as an impervious membrane for acid proof brick floor lining, can be poured and leveled by squeegeeing in successive coats.

12.3.4.5 Porous surfaces such as concrete shall be primed with bitumen primer of IPS-M-TP-285 before application of lining.

12.3.5 Cold applied coal tar lining

12.3.5.1 All the cold applied coal tar linings can be applied by brush, spray or also by dip. Usually only two or three coats are applied to obtain the desired dry film thickness.

12.3.5.2 Drying time between coats will vary between 16 to 96 hours, depending upon the temperature, humidity, and air velocity over the coated surface.

12.3.5.3 The cold applied lining generally require no primer.

12.3.5.4 Cold applied lining require from one day to several weeks for the solvent to evaporate and the film to harden.

12.3.6 Hot applied coal tar lining (see also AWWA C 203)

12.3.6.1 Priming

12.3.6.1.1 All blasted surfaces shall be cleaned from dust and grit and shall be primed immediately following blasting and cleaning.

12.3.6.1.2 The use of coal tar primer that has become fouled with foreign substances or has thickened through evaporation of the solvent oils will not be permitted.

12.3.6.1.3 At the option of the contractor, and acceptance of the Company, the application of the primer shall be by hand brushing, spraying, or other suitable means and shall be in accordance with instruction for application supplied by the manufacturer of the primer.

12.3.6.1.4 Spray-gun apparatus to be used shall include a mechanically agitated pressure pot and an air separator that will remove all oil and free moisture from the air supply.

12.3.6.1.5 Suitable measures shall be taken to protect wet primer from contact with rain, fog, mist, spray, dust, or other foreign matter until completely hardened and enamel applied.

12.3.6.1.6 In cold weather, when the temperature of the steel is below 4°C, or at any time when moisture collects on the steel, the steel shall be warmed to a temperature of approximately 30 to 40°C, which shall be maintained long enough to dry the pipe surface prior to priming. To facilitate spraying and spreading, the primer may be heated and maintained during the application at a temperature of not more than 50°C.

12.3.6.1.7 The minimum and maximum drying times of the primer, or the period between application of primer and application of coal-tar enamel, shall be in accordance with instructions issued by the manufacturer of the primer.

If the enamel is not applied within the allowed maximum time after priming, the part shall be reprimed with an additional light coat of primer or the entire prime coat shall be removed by reblasting and the part reprimed.

12.3.6.1.8 During cold weather, when metal surface temperature is below 4°C, or during rainy or foggy weather, when moisture tends to collect on cold surface, enameling shall be preceded by warming of the primed part. Warming shall be done by any method that will heat the part uniformly to recommended temperature without injury to primer. Steel temperature of the part shall not exceed 70°C.

12.3.6.2 Enameling

The application of the enamel to the internal surface of all pipes other than specials shall be by centrifugal casting by either the trough method (see Note 1) or the retracting-weir or feed-line method (see Note 2).

On odd shapes of flat surfaces. The hot applied coal tar lining is applied over the dry primer by hand daubing in shingle-fashion using a dauber or on horizontal surfaces with a glass mop.

Notes:

1) In trough method the pipe shall be rotated and molten enamel shall be introduced into pipe by a pouring trough extending the full length of the pipe.

2) In retracting weir or feed line method, pipe shall be rotated and molten enamel shall be supplied to the weir or feed line from a reservoir through supply pipes and maintained at application temperature by means of insulation and by the use of suitable methods of heating both reservoir and supply line.

12.3.7 Application of coal-tar enamel to ends of pipe section

12.3.7.1 Pipe sections to be field welded

When pipe sections are to be joined together by field welding, a band that is free of protective materials shall be left on the inside and outside if any surfaces at the ends of the sections. This band shall be of 15 cm width, or as specified in the Company's specifications, to permit the making of field joints without injury to the lining and coating.

12.3.7.2 Pipe sections to be joined with mechanical couplings

When pipe sections are to be joined together with mechanical couplings, band free of protective materials shall be left on the exterior surface if any at the ends of the sections. This band shall be of 15 cm width, or as specified in the Company's specifications, to permit joint make-up. The interior enamel lining shall extend to the pipe end.

12.3.7.3 Bell-and-spigot ends

For bell-and-spigot ends with rubber gasket, the interior enamel lining shall extend from the end of the pipe at the spigot end to the holdback in the bell end. The exterior coating shall extend from the lip of the bell to the holdback on the spigot end. The exposed steel surfaces on the inside of the bell and the outside of the spigot end shall be given a coating of synthetic primer to a dry film thickness of 0.06 mm ±0.01 mm.

12.3.7.4 Miscellaneous joints

For joints other than those specified in this Standard, the length of pipe to be left bare at the ends shall be in accordance with the Company's specifications.

12.4 Drying

12.4.1 Cold applied lining

Typical drying times for cold applied lining containing fast curing solvent can vary considerably. However, recommendation of the manufacturer shall be followed as to curing times.

12.4.2 Hot applied lining

Water used for chilling the enamel lining following centrifugal casting shall not be applied until the enamel has hardened sufficiently to prevent water marks.

12.5 Transportation

The lined equipment shall be handled so as to cause damage neither to the bevels nor the lining and coating if any.

During transport of part to the lined works storage site, all appropriate precautions shall be taken to avoid damage to the part and lining and coating if any.

12.6 Installation

Installation shall be in accordance with 7.8.1

12.7 Repair of Lining

12.7.1 Lining material used shall be compatible with the previously applied lining.

12.7.2 Damaged and non-adherent lining shall be removed before effecting a repair.

12.7.3 After surface preparing and priming exposed surfaces, the lining shall be built up, pore-free, to the full thickness by troweling or swabbing molten lining material, followed by smoothing to the original contour of the bore. Careful warming of the metal and edges of the existing lining may be necessary to achieve satisfactory adhesion in hot-applied enamels.

12.8 Inspection and Test Methods

12.8.1 Inspection and testing shall be carried out by contractor.

The contractor shall be responsible for ensuring compliance with the requirements to be met by the lining as specified as follow:

12.8.2 Lining thickness (see IPS-E-TP-350)

The lining thickness shall be measured employing a non-destructive method permitting determination of the lining thickness with an uncertainty of measurement not greater than 10%.

12.8.3 Adhesion

Assessment of the adhesion shall only be made at a pipe or vessel wall temperature of at least +10°C. Parallel incisions shall be made in the lining using a knife. Following this, attempts shall be made to lift the strips from the pipe or vessel in order to determine the adhesive strength of the lining. The assessment can only ever be qualitative.

12.8.4 Lining continuity (see also Clause 19)

12.8.4.1 The contractor shall electrically inspect all interior lining applied or repaired by hand daubing and subjected to traffic or personnel entering the pipe or vessel, or that otherwise exhibit any evidence of physical damage. Any defect in the coating and lining shall be satisfactorily repaired at the expense of the contractor.

12.8.4.2 The inspection, to be carried out on each part, is intended to reveal imperfections in the lining, but is not intended to test the resistance to electrical breakdown of a lining free from such imperfections.

12.8.4.3 The primary input wattage shall be no higher than 20 w, and the minimum pulses at crest voltage shall be 20/s. The operating voltage of the detector in no case shall exceed 15000 V.

12.8.4.4 During measurement, the electrodes (e.g. metal brushes) shall be in close contact with the lining surface, since any air gap would falsify the results. The existence of imperfections is indicated by the sound of a spark-over or by the signals emitted by the instrument.

13. GLASS AND PORCELAIN LINING

13.1 General

13.1.1 This Clause 13 of standard specifies requirements for the lining of equipment using glass and porcelain lining materials.

13.1.2 Glass linings are applied to equipment fabricated in steel, cast iron or stainless steel.

13.1.3 Porcelain enamels are applied to fabricated sheet steel and cast iron in two coat of ground-coat and cover-coat. For aluminum, neither ground coats nor adherence-promoting oxides are required. Single-coat system are used for most application.

13.1.4 Method of application for porcelain and glass lining are wet or dry process. (see also NACE-6H-160).

13.1.5 Requirements for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350.

13.1.6 The Company inspector may stop lining operations when conditions such as 7.1.6.

13.1.7 The lined equipment shall be identified as stated in 8.1.10.

13.1.8 The applicator of the lining shall provide a certificate of inspection and testing when requested, in accordance with 8.1.11.

13.2 Preparation

13.2.1 Preparation of material for use

13.2.1.1 The glass frit is prepared for use in glass lining process in two form: "Slip" and "Dust".

13.2.1.2 To prepare slip the frit is ground in porcelain lined ball mills together with specific amounts of water and such suspending agent as clay. After a period of grinding, a slurry results. This slurry is composed of finely ground glass held in suspension by the clay. By the proper use of water and electrolytes, the specific gravity and viscosity are adjusted to obtain the necessary flow and spraying properties.

13.2.1.3 Dust is prepared by dry grinding the frit in a ball mill to the required fineness.

13.2.2 Preparation of surface to be lined

After the metal has been fabricated and is ready for glassing, it shall be placed in the furnace, brought up to a temperature of about 730-900°C (Normalizing).

After normalizing the metal shall be cleaned and blasted with sand abrasives to Sa 2½ in accordance with IPS-C-TP-101.

13.3 Application Methods

13.3.1 General

13.3.1.1 Glass material after preparation shall be applied in two different coat (Ground and Cover coat) over fabricated sheet steel and cast iron and stainless steel.

13.3.1.2 "Ground coat" is the first coat of glass which is applied to the metal surface. The ground coat is formulated specifically for the purpose of promoting adherence to the base metal and is usually not a high corrosion resistant glass. All surfaces exposed to view or surfaces which come in contact with corrosive media shall be covered by a continuous ground coat or appropriate enamel layer which shall be smoothly finishes.

13.3.1.3 "Cover coat" enamels are applied over ground coat to improve the appearance and proper ties of the coating. Cover coats can also applied directly to properly prepared decarburized steel and aluminum substrates.

13.3.1.4 Two basic methods are used to apply glass enamels to base metal. These include dry-process (13.3.3) and wet-process (13.3.2) enameling.

The ground coat of glass lining usually be applied with wet-process and cover coat can be applied with one of wet or dry process (see Table 4).

TABLE 4 - APPLICATION METHOD OF GLASS LINING ON METAL

METHOD OF LINING	TYPE OF LINING MATERIAL	BASED METAL	NOTE
1) Wet Process - Slushing (Dipping or Poured) - Spraying	 Glass Slip Glass Slip	 Sheet Steel and Cast Iron Cast Iron	1) For glass lining of sheet steel the ground coat and cover coat shall be applied with wet process 2) For glass lining of cast iron parts, the ground coat shall be applied with wet process and cover coat can be applied by one of wet or dry processes
2) Dry Process	Glass Dust	Cast Iron	

13.3.2 Wet-process

13.3.2.1 The wet-process consists of two methods of lining: slushing method and spraying method (see ISO 2723).

13.3.2.2 Slushing

"Slushing", consists of either dipping the item to be coated into a container of slip or pouring the slip over the metal surface. The dried coating is then fired in a furnace. This method is most suited for intricate shapes and pipe.

13.3.2.3 Spraying

"Spraying" is the method used to coat large vessel and accessories. The slip is sprayed on to a clean metal surface, allowed to dry, and the item is then placed in a furnace and the coating fused down. Subsequent coats of glass are sprayed over the fired glass surface and fused.

13.3.3 Dry-process (hot-dusting)

"Hot-dusting" consists of shifting (powdering) glass dust on to a preheated metal surface that has been ground coated with wet process. The item is immediately replaced in furnace and the glass fused down. The process is repeated on the hot item until the desired thickness of glass is reached. This method is mainly used on cast iron items, such as valves and fittings (see ISO 2724).

13.4 Curing

13.4.1 After the spray-dusted or slushed coating is thoroughly dried, the item is placed in a furnace, brought up to the required firing temperature (recommended by material manufacturer), soaked out, and removed from the furance to cool.

13.4.2 The ground coat is fired at a higher temperature than the cover coat.

13.4.3 Between coats of glass, all radii and rough areas on the lining are ground before applying the next coat.

13.4.4 The heating (firing) procedure used in glassing steel must be carefully controlled and for this reason the design of the equipment must be such that there are no sudden changes in metal thickness, such as in very heavy flanges.

13.5 Transportation

13.5.1 Glass lined equipment

13.5.1.1 During shipment, glass-lined equipment is fastened to skids by means of metal straps or by bolting to shipping legs. It is good practice to keep the equipment on these skids until the vessel has been moved to its final location. Items externally glassed should be shipped completely boxed and properly cushioned. Size permitting, vertical tanks are best handled in the upright position.

13.5.1.2 It is recommended, when hoisting, that a four-leg bridle sling be attached to the skid under the body of the tank. If it is desired to use choker slings, do not hoist an unjacketed vessel using only one sling as this results in too much load concentration on the vessel. In using two choker slings, it is good practice to distribute the load over a large area. An unjacketed tank should be wrapped with 2.5 × 15.2 cm wood lagging on the under half of the tank before applying the choker slings. Larger size vessels are shipped with lifting loops welded on.

13.5.1.3 Under no condition shall a vessel be lifted by attaching slings to drive supports or nozzles.

13.5.2 Glass lined pipe

13.5.2.1 Lined piping shall be handled with due regard to fragility of lining which shall include prevention of shock and excessive loads.

13.5.2.2 The ends of lined piping shall be protected with covers to prevent the entry of foreign matter and the lined surfaces from being damaged.

13.5.2.3 Welding or arc striking directly on lined pipe shall not be allowed.

13.6 Installation

13.6.1 Do not weld on any metal that has been glassed. When welding in the vicinity of a glassed surface, be sure to protect the glass from flying sparks and weld spatter. During welding on jackets and other accessories, precautions must be taken to prevent high local heat import.

13.6.2 Pipe connections to glass lined equipment should be made only after the vessel has been leveled and securely fastened to a foundation. To avoid stress failures in glassed pipe, the pipe must be adequately supported by means of pipe hangers and allowance must be made for expansion of the lines if surface temperature is appreciably above room temperature.

13.6.3 Enough pipe hangers must be provided so that the weight of the pipe and its contents are carried by the hangers rather than on the nozzles of the vessel.

13.6.4 The high firing temperatures, plus the stresses introduced by glass coating, tend to distort nozzles on vessels. Likewise, long lengths of pipe tend to bow. The first step in installing pipe is to rotate the pipe or turn it end to end to find the best fit-up. If the alignment is extremely poor, glass lined wedges or porcelain spacers should be employed. Small misalignments can be compensated for by shimming gaskets.

13.6.5 The tightening of split flanges and bolts should be done carefully, evenly, and by means of a torque wrench. Uneven and excessive tightening can cause the glass to spall off of radii. A glassed flange four bolt or more should be tightened evenly. It should be tightened with alternately, diametrically opposite "1, 3, 2, 4" tightening of the bolts.

13.6.6 A glass surfaced, flat-faced flange shall not be bolted to a raised-face flange because of the hazard of snapping the glassed surface about the fulcrum edge of the raised-face flange.

13.6.7 U-bolts shall not be used on the pipe support. Where U-bands are used. The tightening torque shall be approximately one kg.m.

13.6.8 All glassed flange joints require gaskets. The standard gasket has a combination of hardboard sheet and resilient, semi-hard material enclosed in a Teflon envelope.

13.6.9 Where warpage is such that the joint cannot be easily sealed, the gasket must be built up or shimmed. To properly shim a gasket, the operator should have special instructions as the gasket can easily be damaged.

13.6.10 Where pressures are excessive, shroud rings or metal reinforced gaskets may be installed to keep the gasket from blowing out.

13.6.11 For installation of glass lined water heaters see DIN 4753.

13.7 Repair of Lining

13.7.1 General

Because glassed equipment is unique in its method of fabrication, repair techniques common to other solid materials of construction cannot be used. Repair materials other than glass must be used in such cases, even though they may not have the nearly complete inertness to chemical attack as does the original glass lining. A change in chemical conditions (severe or mild chemical service) may, therefore, require a change in the repair materials within any given chemical process.

13.7.2 Severe chemical service

13.7.2.1 Temporary repairs consist of cements applied directly to the prepared surface in the form of air drying liquids or putty-like mixtures. Only one group of silicate (or ceramic) cements has been found to have sufficient adhesion for this type of repair. Other cements, such as the furan resin, polyesters, etc., have sufficient chemical and/or temperature limitations, but because of their lack of adherence to glass, should be used in connection with a suitable metal. Thus the latter cements involve permanent rather than temporary repairs.

13.7.2.2 For maximum adherence and service-ability, the silicate cements require a 24 hours application time including setting and acid treatment. They are resistant only to strong acids and thus should not be used with dilute acids, water or alkaline solutions. The maximum temperature limitation is in the 175-185°C range.

13.7.2.3 Permanent repairs consist of metal patches in the form of discs, plates, sleeves, caps, boots, etc., held on by means of studs and nuts and separated from the glass by a suitable gasket (usually polytetra-fluorethylene). Some suitable cement is necessary to prevent seepage. The metal selected must be satisfactory for the chemical conditions involved. Materials in current use include:

1) Tantalum
2) Silver
3) "Hastelloy" alloys
4) Zirconium
5) Nickel
6) Titanium
7) Molybdenum, and
8) The stainless steels

The chemical limitations of this second type of repair are necessarily determined by the metal selected. Under the proper mechanical and chemical considerations, such repairs are suitable up to 230°C.

Caution:

Two different metals may set up galvanic cells when immersed in the same continuous electrolyte. Abnormal deterioration of one or both of the metals may result.

13.7.3 Mild chemical service

Temporary repairs with the silicate cements may be used under mild service conditions if the acidic concentration is suitable. The rather long installation period limits the use of this type of repair for mild services except in emergency situations. Since mild service is normally understood to be less than 52°C there is no maximum temperature limit for these cements under mild service conditions.

13.7.3.1 When special techniques are employed, epoxy compounds may be used to repair glass lined equipment under mild service conditions.

13.7.3.2 Permanent repairs for this service are the same as for severe chemical service, except the gasket may not be used. Generally, the less expensive metals are selected. The temperature of this type of repair is limited by the maximum equipment operating temperature which is usually 50°C.

13.8 Inspection and Test Methods

13.8.1 Visual inspection

The visual inspection of all vitreous enameled parts shall be carried out under diffused artificial illumination from daylight fluorenscent tubes of between 30 lumens and 50 lumens per square foot.

The quality of the finish shall comply with the following requirements:

a) Cracks-The lining surface shall contain no cracks.

b) Flaking-The lining shall not have flaked off any lined surfaces.

The quality of the finish may show the following imperfections subject to the conditions stated.

c) Hair lines and strain lines-Hair lines or strain lines of ground coat showing through the top coat with no break or crack in the lining are permitted provided that they do not detract from the general appearance of the appliance.

d) Tears (Beads)-Tears (beads) are permitted provided that they do not detract from the appearance or function of the appliance in service.

e) Runs (Drain lines)-Runs (drain lines) are permitted provided that they do not detract from the appearance or function of the appliance in service.

f) Pinholes-There shall be no holes in the lining surface which can be shown to extend to the base metal. For pinholes which do not penetrate the ground coat, the requirements given in below for specks, shall apply.

g) Blisters-Blisters are permitted provided that due to the particular design or fabrication of the article they are unavoidable, and do not detract from the appearance or function of the appliance in service.

h) Depressions and raised areas-Smooth well covered depressions or raised areas in the enamel surface are permitted provided that they are small and widely spaced.

i) Specks and inclusions-Specks showing on or through the enamel surface are permitted provided that they are not concentrated in one area and are not greater than 0.75 mm in diameter, and provided that they do not detract from the general appearance of the appliance.

j) Orange peel (Ripple)-Orange peel (ripple) is permitted provided that it does not detract from the general appearance of the appliance.

13.8.2 Thickness test

The glass lining thickness shall be measured as specified in DIN 50981.

Measurements shall be made at five different points for each square meter of the inside surface of the vessel. The result shall be stated as the maximum, minimum and average values.

13.8.3 Continuity test (electrostatic test-see ISO 8289)

Proper initial inspection prior to assembling and field inspection after assembling of glass-lined equipment is very important. Visual inspection (see 13.8.1) normally suffices, especially if a satisfactory preventive maintenance schedule is being followed. When unusual circumstances prevail or questionable areas are apparent, the electrostatic inspection shall be used.

20 KV, dc has been set for the value of the test voltage on initial inspection of glass lined chemical equipment. This voltage definitely ensures a minimum sound glass thickness in addition to guaranteeing a continuous glass lining. 5 KV, dc (60 cycle) are used to inspect storage vessels and field inspection of chemical equipment where only a minimum thickness of glass is required.

13.8.4 Resistance to impact strength

Resistance to impact strength shall be tested in accordance with DIN 51155 with spring load of 10 N.

13.8.5 Resistance to abrasion

Resistance to abrasion shall be tested in accordance with BS 1344: Part 4.

13.8.6 Resistance to thermal shock and heat

Resistance of glass lined equipment to thermal shock shall be tested in accordance with BS 1344 Part 1, and resistance to heat shall be tested in accordance with BS 1344: Part 7.

13.8.7 Chemical resistance

Chemical resistance of glass lined equipment shall be tested as follows:

- Resistance to acid:	ISO 2722.
- Resistance to products of combustion containing sulfur compounds:	BS 1344: Part 3.
- Resistance to alkali:	BS 1344: Part 6.
- Resistance to detergent:	BS 1344: Part 5.

13.8.8 Leak test

Leak test for the completed piping shall be conducted by using air or "N^2" gas with following conditions. The hydrostatic pressure test shall not be required.

- Test pressures shall be 1.1 times of the design pressure.
- The test pressure shall be maintained to 10 minutes.

14. CERAMIC LINING

14.1 General

14.1.1 This Clause 14 specifies requirements for the lining of equipment using ceramics.

14.1.2 The ceramic types can be used for lining include: silicates base, oxides base, carbides base, silicides base, phosphate bonded material and cermets.

14.1.3 Ceramic lining applies to equipment and construction fabricated in metal, concrete and brick.

14.1.4 Requirements for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350.

14.1.5 The Company inspector may stop lining operations when conditions such as 7.1.6.

14.1.6 The lined equipment shall be identified as stated in 8.1.10.

14.1.7 The applicator of the lining shall provide a certificate of inspection and testing when requested, as specified in 8.1.11.

14.2 Preparation

14.2.1 Preparation of material for use

14.2.1.1 All material furnished by the contractor shall be of best quality and meet the relevant recognized standards and shall be approved by the Company.

14.2.1.2 To prepare the lining materials for application, follow the instruction provided by the manufacturer.

14.2.2 Preparation of surface to be lined

14.2.2.1 Metallic surfaces

The preparation methods of metallic surfaces for various types of ceramic lining are shown in Table 5. The steel surface shall be prepared to Sa 2½ with a nominal 50-75 µm profile.

The preparation of metallic surfaces prior to ceramic lining shall be according to IPS-C-TP-101.

14.2.2.2 Concrete surfaces

14.2.2.2.1 When working with old acid attacked concrete, all loose and deteriorated concrete shall be removed. The surface shall be firm, hard, and at a minimum pH of 5, and all surfaces shall be brought back to grade and the slopes re-established.

14.2.2.2.2 When working with new concrete, the concrete shall be firm and sound. All structural cracks shall be repaired, and it shall be cured for a minimum of 7 days.

14.2.2.2.3 The concrete shall be cleaned of all oil, grease, and form release compounds by degreasing, water blasting and tool cleaning (see IPS-C-TP-101).

14.2.2.3 Brick surfaces

- The preparation of brick surfaces prior to ceramic lining is according to IPS-C-TP-101.

- All attacked or unsound mortar shall be removed from the joints. Mortar joints shall be cleaned to a depth of at least 13 mm to provide support for the ceramic lining. If the joints cannot be cleaned to this depth, it will be necessary to set longhorn or V-type anchors in the joints.

- Flyash and other contaminants shall be removed by abrasive or water blasting.

14.3 Method of Lining

14.3.1 Ceramic lining on metallic substrate

14.3.1.1 In single layer lining, the ceramic material shall be applied over prepared surfaces. With one or more of the methods of 14.3.1.2 to 14.3.1.6 (see Table 4).

The application procedure for a dual-lining system is basically the same as if each component were being applied separately.

14.3.1.2 Air spraying

The air spray (gunited or shotcreting) method can be used when the configuration of the work permits direct access to all surface area to be lined, it is used for applying a closely controlled thickness of lining to exterior surface only.

14.3.1.3 Dipping

Dipping can be used for all parts including rivets or spot welded assemblies, except for those assemblies in which faying surface would be inadequately covered by the slurry.

14.3.1.4 Flame spraying

Flame-spraying can be applied to workpieces in a wide range of sizes and shapes. The three methods of flame spraying to the substrate surface are combustion flame spraying, plasma-arc flame spraying and detonation-gun spraying.

The first two methods utilize coating materials in powder or rod form; detonation-gun spraying uses only powder materials.

After preparation and prior to ceramic lining, the sprayed metal coating, masking tap, rubber or sheet metal, depending on the severity of the surface roughening operation shall be applied. Sprayed molybdenum or Nickel-Chromium-alloy undercoating can be used in thickness 0.05 to 0.3 mm to provide an optimum physical bond for the ceramic lining.

14.3.1.5 Cementation

Pack cementation, the fluidized-bed process, are two types of cementation processes employed in ceramic lining. These processes are used to produce impervious, oxidation-protective coating for nickel base, cobalt base, and vanadium-base alloys, and refractory metals.

14.3.1.6 Trowel lining

Troweled linings are used for furnace lining, hot-gas ducts, and certain repair patches on other ceramic lining for relatively short service exposure.

Surface roughening is accomplished by Blasting or degreasing, or by attaching reinforcements such as wire mesh, corrugated metal, angular clips or honeycomb structures. Reinforcement usually is required for surface having a finish of less than 6 micron (250 micro-inch).

TABLE 5 - APPLICATION METHODS OF CERAMIC LINING ON METALS

APPLICATION METHOD	TYPE OF LINING MATERIAL	SURFACE PREPARATION OF METALLIC SURFACE
1- Air-spraying	Silicate base phosphate bonded	Degreasing + Blasting pickling
2- Flame spraying: - Combustion flame spraying	Silicate base Silicide base Oxide base Carbide base	Blasting + metallic Spray undercoat
- Plasma arc-flame spraying	Oxide base	"
- Detonation-gun spraying	Carbide base	"
3- Dipping	Silicate base	Degreasing + pickling or blasting
4- Troweling	Oxide base (colloidal) Phosphate bonded Silicate base (soluble)	Degreasing + Blasting
5- Cementation: - Packed cementation	Carbide base Silicate base Silicide base	Power tool cleaning + Degreasing + water blasting
- Fluidized bed cementation	Silicide base	Etching + Blasting

14.3.2 Ceramic lining on concrete substrate

At single-layer lining the ceramic material shall be applied over anchoring system.

A dual-layer lining, the membrane shall be applied to the recommended thickness, ensuring that all studs are completely coated and that the lining is free of pinholes.

14.3.3 Ceramic lining on brick substrate

The preferred method of application in this case is to gunite the material. Guniting allows the material to be applied under pressure, this enabling the material to be packed in to the 13 mm open joints and allowing the system to be supported by the studs or keying into the joints.

14.4 Curing

Methods of curing should be agreed upon by the Purchaser and applicator. The methods of curing are described in 16.4.

14.5 Transportation

Ceramic lined equipment shall always be handled carefully. Minor impact and bending normally have no effect on the lining. The practices are recommended to prevent lining damage during handling are described in 13.5 and 16.5.

14.6 Installation

Installation shall be in accordance with 7.8.1.

14.7 Repair of Lining

Repair of damaged ceramic lining shall only be carried out by the contractor after consultation with, and the agreement of the Company.

The repaired area shall be inspect according to 14.8.

14.8 Inspection and Tests

14.8.1 Visual inspection

Although visual inspection or comparison is of only limited usefulness, many plants prepare samples of lining with surface defects that are known to be deleterious to the protective value and service life of the lining and use these samples as visual comparators.

14.8.2 Continuity of lining

High-temperature test and fluorescent-penetrant test are the test procedure for determining lining continuity and oxidation resistance.

14.8.3 Hardness and structure test

The microscope is a useful tool for observing the structure of lining, and hardness testing gives a direct measure of the interparticle bond strength.

Accepted Vickers hardness values of aluminum oxide deposited by various methods are 600 to 800 for flame-sprayed lining, 700 to 1000 for plasma-sprayed lining and 1000 to 1200 for detonation-gun-sprayed lining.

15. BRICK AND TILE LINING

15.1 General

15.1.1 This Clause 15 specifies requirements for chemical-resistant brick and tile lining for process equipment. This Section does not cover refractory brick lining. (see Clause 17 refractory lining).

15.1.2 The chemical-resistant brick lining is a multi-layer system supported by a shell, consists of an impervious membrane to prevent the corrosive medium reaching the shell, and one or more layers of chemical-resistant brick laid in a chemical-resistant cement.

15.1.3 Brick lining applies to equipment fabricated in metal or concrete.

15.1.4 Requirements for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350.

15.1.5 Extra care is necessary in the operation of brick-lined equipment particularly during start-up and shut-down when its operational limitations should be considered. Depending on the selection criteria it may be sensitive to change of pressure, temperature and acid concentrations which could cause damage or even collapse of the lining.

15.1.6 The Company inspector may stop lining operations when conditions such as 7.1.6.

15.1.7 The lined equipment shall be identified as stated in 8.1.10.

15.1.8 The applicator of the lining shall provide a certificate of inspection and testing in accordance with 8.1.11 when requested.

15.2 Preparation

15.2.1 Preparation of material for use

Bricks and tiles should be stored near the job under the same temperature conditions as the equipment to be brick lined (between 20 and 25°C) for approximately 48 hours before using, to avoid temperature and humidity change during the execution.

The bricks and tiles shall be clean.

15.2.2 Preparation of equipment and surface to be lined

15.2.2.1 Steel

- All equipment shall be hydraulically pressure-tested in accordance with the applicable code to confirm adequate strength and liquid tightness, before the application of membrane and brick lining (at least 48 hours).

- All loose and foreign materials, particularly oil and grease shall be removed. When necessary to remove mill scale, rust or other contaminants, blast cleaning to Sa 2 in accordance with SIS 05 5900 shall be applied. (see IPS-C-TP-101).

- All projections and welds shall be ground smooth, weld spatter removed and all corner welds ground to 4.7 mm minimum radius. The prime coat of the adhesive system (for bonding membrane) shall be applied immediately after blasting to prevent rusting.

15.2.2.2 Concrete

- The concrete equipment shall be water-tested to ensure liquid tightness before commencement of the brick lining.

- Defects, enabling water to enter the vessel shall be repaired, e.g. with synthetic resin injection.

- To avoid air inclusions and to ensure sound attachment of the lining, the concrete substrate shall be free from loose sand, dust, laitance, oil, grease or other contaminants. This can be achieved by means of blast cleaning or mechanical steel brushing; pinholes shall be opened by means of blast cleaning (see C-TP-101).

- The moisture content of the concrete should not exceed 5% by volume. Generally, this may be reached after 28 days hardening and drying. The moisture content of the substrate shall be checked regularly during the installation of the lining. Measuring equipment, which shall be calibrated, and the method of establishing moisture content shall be approved by the Company.

- Concrete surfaces which have been attacked by chemicals shall first be prepared by neutralizing or, if necessary, by local replacement of concrete. Repairs shall be carried out after consultation with the Company's specialist.

- Small defects, up to a depth of approximately 50 mm shall be sealed with a quartz-filled epoxy mortar (composition 75% by volume quartz and 25% by volume resin). Larger repairs shall be carried out with non-shrink cement-based mortars.

- The surface of repaired defects shall be smooth and flush with the surrounding surfaces. The final surfaces shall be smooth and even without any sharp edges. Walls and floor shall not bulge inwards, this could cause the brick lining to break away as a result of uneven expansion during operation.

15.3 Method of Lining

15.3.1 General

15.3.1.1 The design of brick linings shall ensure that the thermal, chemical and mechanical effects of operation do not cause cracks to develop thereby invalidating the lining as a corrosion barrier.

15.3.1.2 The brick laying is to be carried out with care. The only method for inspection and testing of the applied brick lining is by visual examination.

15.3.1.3 Since bricks have to be laid by hand, the dimensions of the equipment to be brick-lined shall allow sufficient room for a man to work inside with reasonable freedom. The minimum free diameter recommended is 600 mm.

15.3.1.4 Linings for large flat surfaces will need to be thicker than curved surfaces, because in the latter case the curvature contributes to the overall strength.

15.3.1.5 It will be necessary to provide supports where the lining cannot be supported by the contour of substrate, except where the mass of the brick lining is low enough to rely on the adhesion of the cement.

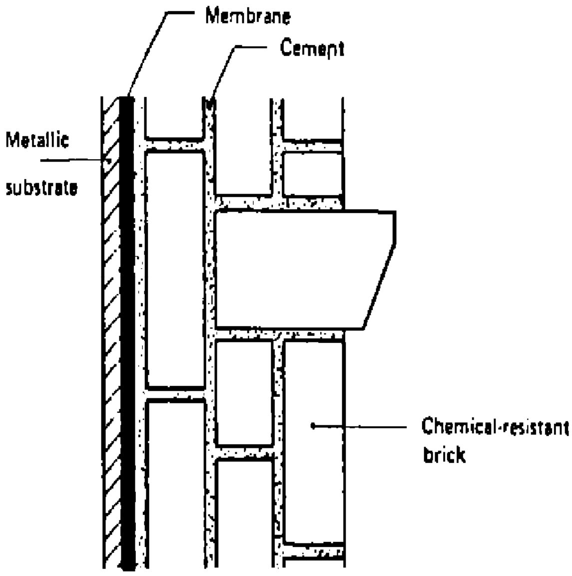
15.3.1.6 Inaccurate shaping of the substrate will cause unexpected compressive stresses and buckling of the brick lining.

15.3.1.7 Stirred vessels or vessels with flat bottoms shall have shaped bottom linings made from straight bricks. The vessel wall lining should not rest on the bottom lining unless more than two layers are applied.

Direct passage to the vessel wall is avoided as much as possible.

15.3.1.8 Internals shall not be supported by the vessel wall through the brick lining. Instead, they shall rest on the brick lining by incorporating special console bricks (see Fig. 7).

Supporting grids for an internal packing bed can be from corrosion-resistant metal or alternatively fabricated in situ from hexagonal ceramic elements jointed together with cement (see Fig. 8).



SUPPORT RING OF PRE-SHAPED BRICK (INTERNAL STRUCTURE)
Fig. 7

15.3.1.9 Metal grids are easily removable. Disadvantages are vulnerability to mechanical damage by shock or concentrated loads, the rather low free passage area and - especially for larger diameters - the low load-bearing capacity.

15.3.1.10 Ceramic element grids can be used for large diameters providing high load-bearing capacities with good free passage areas. Disadvantages are that the vessel needs to be divided into different parts, sometimes requiring extra manholes, and because of the large openings, intermediate layers may be needed, e.g., for stacked rings followed by dumped rings. The necessity to support the gird during construction and hardening of the cement joints also needs to be considered.

Some manufacturers have developed proprietary methods of construction in order to cope with this.

15.3.1.11 Internals independent of the lining, such as inlet pipes, spray nozzles, distribution trays, hold-down trays, etc., shall be installed such that they do not impede thermal movement of the brick layers, either by resting on them or by being locked into the brick lining. They shall be fabricated from material with appropriate chemical, thermal and mechanical properties.

15.3.1.12 The brick lining shall be constructed in such a way that the lining does not tear away from the vessel wall.

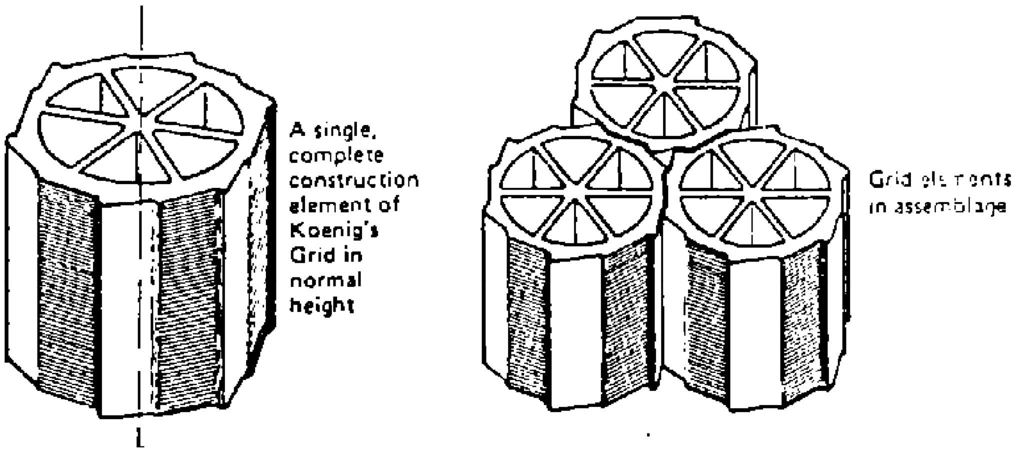
Since the coefficient of thermal expansion of steel is about twice that of the brick lining, the steel shell will tend to expand more than the lining and thus introduce tensile stresses in the lining, an effect which is increased by internal pressure. Since the tensile strength of brick and cement is low, as is the bond strength of cement, cracks will develop unless special precautions are taken (see 15.3.1.13 and 15.3.1.14).

15.3.1.13 With low operating temperatures benefit can be derived from making the lining thicker so that the expansion of the steel shell is equal to that of the outer layer of bricks, or to the average expansion across the brick lining.

15.3.1.14 At higher operating temperatures, tensile stresses may become excessive and a correspondingly thick brick lining would add much to the cost. In practice, good results are being obtained with relatively thin brick linings, because the membrane, which is generally used, has a low heat conductivity which keeps the steel shell temperature low, and it has also a high coefficient of thermal expansion so that it is able to compensate for the difference in thermal expansion between steel shell and brick lining. However, the maximum allowable temperature for the membrane shall not be exceeded.

Note:

A lead membrane is not recommended for this application.



SUPPORT GRIDS ASSEMBLED FROM ELEMENTS
Fig. 8

15.3.1.15 The minimum diameter which can effectively be brick-lined is 600 mm. Smaller diameters for lining shall be prefabricated in short sections and assembled with flanges.

15.3.1.16 The contractor responsible for the brick lining shall ensure before commencement that the specified lining thickness, together with the required final internal dimensions (after lining), can be realized and that the dimensions of the object to be brick-lined are correct.

15.3.1.17 The temperature of equipment to be brick-lined shall be maintained between 18 and 22°C. Higher and lower temperatures will influence the correct curing of the cement. When the equipment to be lined is at a temperature above 22°C, the cement shall be mixed in small quantities in some other location and kept between 15 and 20°C before use. Temperatures which are too high influence the 'pot life' of cement unfavorably.

15.3.1.18 For conditions below 15°C the equipment temperature should be raised, preferably by electric heating to avoid uncontrolled moisture development. Painting of the outside surfaces of equipment with a high-reflecting white coating will reduce the uneven heating effect of the sun. A light-weight shield will reduce the effects of sun, rain and wind on the surface.

15.3.1.19 Condensation is not allowed on the steel or concrete substrate, the membrane and installed layers of the lining. The substrate temperature therefore, shall always be at least 3°C above dew point; relative humidity shall not exceed 85%.

15.3.1.20 The surface temperature and relative humidity of the air shall be controlled by electric heaters and air drying equipment. A daily record of the working conditions should be kept. Cement shall remain free from contact with water and vapor.

15.3.2 Application of lining for metallic equipment

15.3.2.1 Membrane layer application

15.3.2.1.1 General

Membranes shall be continuous, liquid-tight and sufficiently flexible, for which a proven installation procedure and careful application are necessary. The liquid tightness shall be tested after installation; the procedure and test equipment shall be approved by the Company.

When applied on a metal substrate, the membrane can be spark-tested by using a direct electric current which will produce a spark wherever the membrane is not liquid-proof.

The voltage shall not exceed 30 kV and is based on the formula:

6 (1 + thickness in mm) = kV

Anti-static linings on metal substrates shall be inspected with the 'wet sponge test' (a low-voltage holiday detector). For further guidance see Clause 19.

The membranes shall also be visually inspected for air inclusions (blisters), cracks or other imperfections.

15.3.2.1.2 Lead as membrane

For the adhesion of lead to a steel substrate the steel surface shall be lightly tinned with a 0.02 to 0.05 mm thick layer which shall be free from pores. Within 24 hours before application of the tin to obtain good adhesion, dirt, grease and rust shall be removed thoroughly by blast cleaning, or by etching with hydrochloric acid.

The requirements for the installation and testing of lead membrane linings shall be in accordance with DIN 28058. The tightness of the lining shall be verified with the 'sulphuric acid indicator test'. For this purpose the lead surface is primed with a solution of 20% sulphuric acid which is washed away with clean water after 3 hours, if there are pores in the lead lining they will remain filled with the acid solution. If a mixture of water and 'Congo red' having a pH indicator in the range 3 to 5, is then applied and allowed to dry, the pores will show up blue against the red surface.

The minimum thickness of a homogeneous lead lining shall be 6 mm, with a tolerance on thickness of -0 and +25%.

This can be checked with a magnetic layer thickness meter (non-destructive), or by measurement after locally melting the lead (destructive).

Poor adhesion of the lining will reduce the heat conductivity which could cause further detachment of the lead lining due to temperature changes and pressure/vacuum variations during operation. The adhesion shall be ultrasonically tested from the outside (steel) side of the equipment, using examples of both correct bonding and poor adhesion for interpretation.

15.3.2.1.3 Polyisobutylene (thermoplastics) as membrane

The application shall be in accordance with manufacturer's instructions, generally as follows:

Separate polyisobutylene sheets of 3 mm minimum required thickness are joined together by welding to form the membrane. This is attached to the substrate with an adhesive (glue), the separate sheets and the substrate are both coated with the adhesive but the overlap of the sheets to be joined, 30 mm wide approximately, shall be kept free from adhesive.

After about one hour, but within 12 hours depending on temperature and type of adhesive, the sheet of membrane material will be ready for sticking on to the substrate. To avoid air inclusion, the sheets shall be positioned from the center to the sides using a suitable wooden tool to avoid damage; preheating of the sheets will facilitate their installation.

The separate sheets shall then be jointed at the overlap by welding in accordance with the manufacturer's instructions, generally, by roughening with sand paper, cleaning the weld areas with a suitable solvent and welding with hot air welding equipment, the air being directed by a tapered mouth piece at a temperature between 300 and 350°C. When the surfaces become soft they are pressed together with a roller and the seam should almost disappear. Vertical seams shall be welded and rolled downwards to release any remaining solvent.

For severe chemical conditions, the weld seams should be reinforced by welding an additional strip over the completed seam.

For equipment with angular corners the membrane shall be reinforced with a welded, corner-shaped patch, covering a small triangle on all three sides forming the corner, which is stuck and/or welded over the membrane.

Small damaged parts of the membrane can be repaired by welding patches of the same material over the spot. Larger damaged parts of the membrane shall be removed and the substrate prepared after which a new piece can be inserted with adhesive and welded to the surrounding material.

Thermoplastic membranes shall be inspected by spark-testing, or with a wet sponge low-voltage tester (see 19).

Checking adhesion by careful knocking on the surface can be difficult. Therefore testing after installation may be carried out by filling the equipment with water and raising its temperature during a period of 24 hours to 70°C. After draining, imperfections in the adhesion will be seen as blisters or bulges on the surface of the lining.

15.3.2.1.4 Reinforced epoxy as membrane

Glass fibre-reinforced epoxy resin (thermosetting material) shall be used for membrane with the minimum required thickness of 4 mm (see also 10.3.4).

Dosing and mixing of the epoxy resin components and installation of the alternative layers of resin and glass fibre shall be done in accordance with manufacturer's instructions.

The clean prepared substrate surface shall first be primed with the selected epoxy resin, any remaining holes and cracks in concrete surfaces shall be filled with resin.

The laminate is applied 'wet-in-wet', any resin layer that is allowed to cure completely shall be lightly blast-cleaned or roughened with sand paper before the next layer of the laminate is applied. Resin and glass fibre are applied to the surface and the resin is evenly distributed by rolling and pressing, the glass-fibre reinforcement is wetted through completely and air is removed.

The glass fabric reinforcement shall be installed with an overlap of between 25 and 50 mm.

Mixing equipment shall be calibrated for the quantity of components to be mixed; dosing and mixing shall be carefully carried out in accordance with the manufacturer's instructions.

To obtain good adhesion of the membrane to a brick lining, the final and sealing layer of thermosetting resin is treated with silver sand.

15.3.2.1.5 Rubber as membrane

Application of rubber membrane shall be according to Clause 11.

15.3.2.2 Brick and tiles layer application

To prevent damage to the bottom membrane, the brick lining of the bottom shall be finished first. Brick linings in vertical equipment are built up ring upon ring with the bricks placed tightly against the membrane. The brick lining for horizontal equipment should, if practical, be installed with the cylindrical part of the equipment placed in a vertical position.

For horizontal vessels the axial and circumferential joints should both be in line. For vertical equipment vertical joints need not necessarily be in line. For linings consisting of more than one layer of bricks or tiles, the joints of the layers shall be staggered.

Normally the same cement is used for bedding against the membrane and for the axial and circumferential joints. Wedges shall be used for joints which are to be filled later with a different cement. The installation rules are equally applicable for alumina-based acid-resistant bricks and tiles, porcelain tiles, carbon and graphite bricks and special ceramic lining materials.

Joints between the bricks of chemical-resistant brick linings shall be as small as possible to obtain good strength and resistance. The joint space given hereinafter shall be strictly observed particularly when the swelling properties of the cement involved have been determined in the design (see Table 6).

TABLE 6 - JOINTS OF CHEMICAL-RESISTANT BRICK LINING WITH CEMENT

CEMENT	BED JOINTS	AXIAL AND CIRCUMFERENTIAL JOINTS	JOINTS TO BE FILLED AFTERWARDS
Silicate-based cement	5 mm max. × 8 mm	3 mm	7 mm
Synthetic-resin-based cement	5 mm max. × 8 mm	5 mm*	7 mm joint depth 15 mm

*** For prestressed constructions the design instruction for axial joints shall be adhered to.**

Air inclusions in the cement behind or between the bricks shall be prevented. The cement should be placed on the brick being laid as well as on the surface to be lined, and when the same cement is used for bed, axial and circumferential joints, against the side of the installed bricks. The joints are then filled with the positioning of the brick to achieve a homogeneous filling of joints, the surplus cement being removed immediately.

When curing with hot dry air is to be applied, (see 15.4), the curing process for steel vessels can be started during application of the bricks as follows:

The metal wall temperature should be maintained as high as possible i.e., at approximately 35-40°C during the application of the brick lining. To avoid obstruction of the lining work and so as not to influence the pot life of the cement, heat should be applied on the outside of the metal walls. Drying of the bed cement layer shall be controlled so that it does not harden too quickly.

15.3.2.3 Chemical-resistant cement layer

Dosing and mixing of components shall be strictly in accordance with the manufacturer’s instructions. Other procedures could disturb the chemical reactions and curing giving different chemical properties to the cement.

Improvement of the processability of the cement by the application of a modified mixing ratio is allowed only within manufacturer’s limits or with the approval of the Company.

Different types or qualities of cements shall never be mixed. Mixers and tools shall be kept clean and dry to prevent contamination of the cement.

Application of chemical-resistant cements are according to 15.3.3.4.

15.3.3 Application of lining for concrete construction

15.3.3.1 Expansion

Expansion joints are the weakest parts in chemical-resistant brick work and tiling and should therefore preferably be installed outside zones of chemical attack. If this is impossible, it is recommended that they be located so as to minimize the chance of aggressive products permeating them.

At the expansion joint the reinforced concrete shall have a 10 mm wide gap which shall be filled with semi-rigid polyurethane foam, insulation cord, or other appropriate material. The concrete fill applied on top of the concrete to provide the required stop for drainage shall have a gap at the same location and of the same width. This joint shall be sealed with a plastic e.g., polyisobutylene foil or other suitable material. The foil should be adhesive-bonded to the substrate; the adhesive should be a bituminous or rubber type.

The membrane and a layer of bricks or tiles shall then be applied, keeping the joint open. Finally, a rubber or plastic seal shall be fitted with a suitable adhesive in the joint to prevent penetration of liquid.

15.3.3.2 Membranes layer application

Prior to the application of a membrane or a coat of primer, the concrete shall be at least 28 days old, and shall be freed from dust, oil, grease or other contaminants.

Asphaltic bitumen membranes shall be applied to a primed surface, by squeegees or brush until it is smooth even and free from irregularities.

The surface of the membrane shall be sanded for good adhesion of the subsequent cement layer, e.g., by brushing with a solution of bitumen and spreading quartz sand (0.7-1.2 mm grain size) onto the bitumen coating whilst it is still tacky. The minimum Dry Film Thickness (DFT) shall be 20 mm.

The main thermoplastic membrane material is polyisobutylene. It shall be adhesive-bonded to the cleaned concrete surface. The sheet should be joined either by adhesive bonding or welding; vulcanizing is not required. The minimum DFT shall be 3 mm other thermoplastic membranes shall not be used.

Thermosetting membranes: for specific chemical conditions, cold-cured epoxy-resin-based membrane shall be used, if necessary with glass-fibre reinforcement. The clean and rough concrete surface shall be given an epoxy-resin-based primer and within 24 hours after application of the primer. The epoxy resin, and the glass-fibre reinforcement, if any, shall be applied the minimum DFT of this membrane should be 2.5 mm.

It is not allowed to apply an epoxy membrane during rain or at temperatures below 10°C.

15.3.3.3 Brick and tiles layer application

Bricks and tiles shall be clean and dry and should have a temperature of at least 15°C when being applied. If a brick lining has to be applied in winter, provisions shall be taken to protect the area where the brick-laying takes place from cold, rain, snow, etc.

Tiles used for floor, trenches and neutralization pits should be at least 30 mm thick.

For walls in pump houses, etc. The minimum thickness of tiles should be 20 mm.

For narrow joints the bricks or tiles should fit correctly, which requires that they shall be selected at site with regard to their squareness and dimensions.

Vertical parts shall be lined first and then the horizontal parts.

Acid-resistant bricks or tiles shall be applied to pump foundations before the bricks or tiles are laid on the adjoining floors.

15.3.3.4 Cements layer application

The cements shall be mixed in accordance with the supplier's instructions. The tools and mixer shall be clean and dry. Different types of cements shall never be mixed together.

The cements shall not be applied under freezing conditions.

15.3.3.4.1 Hydraulic cements

Hydraulic cements can be used as a bedding mortar (cement/sand ratio usually 1:3 by vol.) for tiles in mildly aggressive conditions. If layers of a hydraulic mortar are applied to make slopes they shall be kept wet during curing (for about one week) to obtain the optimum strength and to avoid hair cracks.

A hydraulic cement which is delivered in paper bags (50 kg) should be worked within 8 hours of opening the bag.

15.3.3.4.2 Silicate cements

Silicate cement may be used as a bedding material, applied on an asphaltic bitumen membrane. The joints between bricks and tiles should then be sealed with a resin-based cement.

Four days after application the brickwork shall be washed with dilute acid, e.g. a 10%-wt solution of hydrochloric acid. This treatment is important, since the alkali hydroxide formed during curing is detrimental too and would eventually destroy the joint.

Silicate cements do not adhere to rubber membranes.

15.3.3.4.3 Cements based on phenol-furfuraldehyde resin

These cements are supplied are supplied as two components, a liquid and a powder, which shall be mixed thoroughly and used immediately.

The cements are used for both embedding and sealing of the joints between bricks and tiles.

The rate of setting and curing of the cement is influenced by temperature. At 15-20°C, the mortar starts to set in about four hours and cures in 1-2 days. At a lower temperature the mortar starts to set and cure at a lower rate.

If the temperature falls below 15°C, consideration may be given to accelerating the curing by heating. However, care should be taken to ensure that the temperature does not exceed 80°C, as otherwise the difference in expansion between the substrate and the top surface may adversely affect adhesion.

In order to give the cement its full chemical resistance, in particular to caustic alkalis, the cement requires a heat treatment at 80°C for 24 hours after it has fully cured. Contact with water or water vapor during curing shall also be avoided. The heating should therefore be carried out using electric heaters.

It is essential that during curing the cement does not come into contact with free alkali, since this alkali would tend to neutralize the acid catalyst. Consequently the concrete floor shall be primed with two coats of a suitable primer when these cements are used as a membrane. The primer shall be in accordance with the resin cement manufacturer's recommendations.

15.3.3.4.4 Cements based on furane resin

In general the properties of furane cement resemble those of the cements based on phenolic resin, but curing at high temperatures to obtain full chemical resistance is not necessary, and they are somewhat easier to apply.

Cements based on furane resin cannot be applied directly to concrete. When a membrane of this cement is to be applied, the concrete shall be pretreated with a primer in accordance with the resin cement manufacturer's instructions.

For application of these cements the same rules apply as for the application of cements based on phenol-furfuraldehyde resin (15.3.3.4.3).

15.3.3.4.5 Cements based on polyester resin

Cements based on unsaturated polyester resin are supplied in the form of a powder and a liquid resin, which should be mixed immediately before use. These cements shall not be mixed or applied under freezing conditions. They are self-curing at 15-20°C, a complete cure at this temperature can be obtained in 24 hours. The curing time and also the pot life are affected by temperature.

Contact with water or water vapor during curing should be avoided.

15.3.3.4.6 Cements based on epoxy resin

These cements are generally supplied as a paste of putty-like consistency together with a liquid curing agent.

After the two components have been mixed the cement cures within one hour at temperatures of 10-30°C. The curing time is affected by temperature.

The cement can be used for continuous floors and for embedding and sealing purposes.

Contact with water or water vapor during curing should be avoided.

15.3.3.5 Joints

The cement layer between the bricks or tiles and the membrane should have a thickness of about 5 mm. The joints between bricks or tiles shall be small as practicable, preferably not more than 3 mm wide. However, wider joints of 5 to 7 mm will be required, e.g. for certain hot-pour jointing materials and when joints between the bricks and tiles are to be sealed. When rejoining may be required after a period of service, the joint shall be made 5 mm wide.

The width of the joints shall be consistent over the full depth of the joint and free from cavities.

15.4 Curing and Prestressing

15.4.1 Chemical-resistant brick linings cannot resist high tensile and bending stresses. Proper curing and prestressing, for steel vessels only, should result in compressive stress in the brick lining while the carbon steel remains under modest tension.

To obtain good chemical resistance the cement should be completely cured. However curing or prestressing treatment shall not commence within 8 days after installation of the brick lining is complete but shall be finished within 6 to 8 weeks after the installation.

15.4.2 Curing with acidic liquid

Curing with acidic liquid is applied for brick linings operating at ambient temperature. Considering the time restraints 15.4.1, the vessel is filled with an acidic liquid (see 15.4.4) and after 3 weeks emptied, water-washed and inspected.

15.4.3 Curing with dry hot air

15.4.3.1 Curing with dry hot air is applied for brick linings operating at conditions up to 80°C and 1 bar.g The curing should preferably begin with application of heat at the installation stage.

15.4.3.2 Considering the time restraints (see 15.4.1) dry hot air is introduced in the bottom of the dry and closed equipment. To control proper curing of the cement, especially during the initial period, direct flame heaters should not be used. The air temperature shall be raised at 5 to 7°C per hour and the pressure simultaneously increased for equipment that will operate under pressure.

15.4.3.3 The final curing condition shall be maintained for 16 hours, followed by a reduction of 3 to 5°C per hour, at the same time reducing the pressure. Care shall be taken that metal wall shrinkage is not less than that of the lining material. When returned to ambient temperature and pressure, the brick lining shall be inspected.

15.4.4 Prestressing with acidic liquid

15.4.4.1 Prestressing with acidic liquid is a wet curing process suitable for brick linings operating above 80°C and 1 bar ga under severe chemical conditions. Considering the time restraints (see 15.4.1) the vessel is either filled with acidic liquid or the liquid is circulated. The liquid is heated to gradually raise the wall temperature up to the operating temperature, while the pressure is raised to the test pressure (see 15.7).

15.4.4.2 Circulating liquids shall thoroughly wet all parts of the brick lining and after maintaining the operating conditions for several hours to cure the cements completely, the temperature and pressure are slowly reduced to ambient (see 15.4.5).

15.4.5 Curing liquids

15.4.5.1 In general diluted acids are used for curing; a solution with a pH value between 2 and 5 is recommended for synthetic-resin-based cements.

15.4.5.2 For silicate-based cement, a 5 to 10% solution of sulphuric acid is suitable; hydrochloric, phosphoric or acetic acid solutions are also acceptable.

15.4.5.3 Solutions of calcium chloride, sodium bisulphite or calcium bisulphite shall not be used for silicate-based cements, since they require washing for the removal of insoluble salts which could react with the lining cement.

15.4.5.4 The curing liquid is brought to the required concentration at ambient temperature in a separate vessel of rubber-lined, thermoplastic or glass-fibre-reinforced plastic material, the liquid is then pumped or circulated to the equipment, see Appendix B.

15.4.5.5 For equipment that will operate under pressure, a curing liquid pressure of 0.5 bar ga is required.

The liquid temperature should be raised at a rate of 5 to 7°C per hour up to the operating temperature with steam injection (direct or via a sparger) or by circulation through a heat exchanger. To limit expansion of the lining during heating, the temperature differential in the equipment shall remain within 15°C. The pressure shall be raised simultaneously with the temperature to reach the required operating pressure at about 100°C.

15.4.5.6 Heating with open steam will raise the pH value with the dilution of the liquid; this shall be corrected by the draining and addition of fresh liquid to keep the pH below 5.

15.4.5.7 The final curing condition shall be maintained for 72 hours, followed by cooling at a rate between 3 to 5°C per hour while gradually reducing the pressure. Care shall be taken that the rate of metal wall shrinkage is not less than that of the lining material. Boiling of the liquid shall be prevented by control of the ratio between pressure, temperature and liquid concentration. After cooling to ambient conditions the vessel shall be left for 3 hours, then after draining and washing the lining shall be inspected.

15.4.5.8 The following data shall be recorded during prestressing and curing:

Temperature

- Liquid in equipment or liquid inlet and outlet temperature.
- Metal wall temperature at 3 representative points.
- Ambient temperature.

Pressure

- Inside the equipment.

Notes:

1) Steam injection direct or via a sparger is in general more economical compared with a heat exchanger circulation system.

2) The lining contractor shall provide a calculation showing the stresses expected during prestressing and curing.

15.5 Transportation

15.5.1 Chemical-resistant bricks and tiles shall be stored adequately protected under dry and cool condition at a relative humidity of 70% maximum and a temperature between 5 and 20°C in a frost-free warehouse. When stored during installation in the open air, the material shall be stacked on wooden pallets and covered with tarpaulins or shrunk or pre film.

15.5.2 To prevent possible cracking, deformation and disbanding caused by shock or vibration to the rather brittle lining materials, the equipment shall not be transported or handled after the brick lining is applied. Equipment to be brick lined shall be properly installed before the lining is applied.

15.5.3 If transport of brick-lined equipment or parts thereof e.g. small vessels, pipe sections, ducting, etc., cannot be avoided, the design and execution shall make allowance for more rigid construction, adequate lifting points additional internal and external supports and temporary studs for rigid fixing during transport. The equipment shall be completely cured and prestressed before handling.

15.5.4 In the case of unforeseen moving of equipment, stiffening rings or structures shall be designed and applied. However welding on lined equipment should be avoided wherever possible.

15.6 Repair of Lining

15.6.1 Repair of lining for metallic substrate

15.6.1.1 To avoid mechanical damage, special protective provision shall be made for clean-out, scaffolding and brick lining repair activities.

15.6.1.2 Nozzles and manholes shall be opened only when required for access, and the required working climate shall be realized.

15.6.1.3 For the execution of local repairs, the remaining lining shall be properly supported when bricks have to be removed. Shocks and vibrations of the surrounding brick lining shall be avoided.

15.6.1.4 Even minor defects of brick linings shall be consistently repaired to prevent spread of the defects to deeper layers of the brick, the membrane and the substrate. This includes the replacement of dissolved or washed out cement from joints.

15.6.1.5 Scraping to sound material and subsequent filling with fresh cement is sufficient when the damage is not too deep. When the erosion nearly equals the thickness of the final brick layer of the lining, the affected area of this layer shall be completely removed and replaced by a new layer to secure the bedding adhesion to other layers.

15.6.1.6 To repair a leak, disbanding, wide cracks, fall-out of bricks or severe spalling, all the affected material shall be removed as far as required to:

- Repair or replace part of the locally affected metal substrate.
- Replace the leaking and affected part of the membrane with a correct weld to sound membrane material.
- Allow replacement of brick lining rejected by the inspector, and to ensure complete and proper bonding to the remaining brick lining.

15.6.1.7 All surfaces of substrate, membrane and brick lining shall be thoroughly cleaned and dried before any replacement work commences. The adhesion between cement and wet or dirty bricks will be significantly lower than with clean and dry bricks.

15.6.1.8 The original brick configuration shall be maintained on replacement. Welding on brick-lined equipment should be avoided, since most membranes will be permanently damaged and the brick lining will be affected. The thermal expansion of the substrate during welding will loosen the brick lining with the possibility of future leakage.

15.6.1.9 If welding cannot be avoided, the brick lining and membrane shall be locally removed up to a minimum distance of 500 mm from the weld. After welding, surface preparation and drying, proper replacement of membrane and brick lining shall follow as previously described.

15.6.2 Repair of lining for concrete substrates

15.6.2.1 Chemical-resistant linings shall be regularly inspected for defects. They shall be carefully treated and protected against damage by traffic loads, impact and impermissible local chemical and thermal attack (steam, leaking flanges, etc.).

Note:

When a defect is detected, repairs shall be carried out immediately in order to prevent serious attack of the concrete substrate.

15.6.2.2 The main defects are spalling of the bricks or tiles, erosion effects, cracks in the lining and degradation of the chemical-resistant lining materials.

15.6.2.3 Spalling of the brick lining might be due to:

- inadequate brick quality, e.g. composition, porosity;
- exposure to exceptional operating conditions, e.g. thermal, chemical or other loads more severe than those foreseen.

15.6.2.4 Local spalling might be due to impact by a falling object. Impact by mechanical load shall always be avoided.

15.6.2.5 Damaged areas or spots shall be repaired by replacement with new material, either of the original quality, or of another quality provided this in wholly compatible with respect to physical and chemical properties, with the adjacent original material.

15.6.2.6 If the effects of erosion or attack by chemicals are slight, the joints can be repaired, by scraping out to sound material and filling with fresh cement. If the depth on the scraped out joint is 75% or more of the thickness of the brick layer, all the cement in the joint shall be removed and replaced, if necessary relaying the bricks.

15.6.2.7 When cracks in the lining are present, they shall be opened completely to establish the condition of the membrane and/or the substrate.

15.6.2.8 Degradation of the lining materials may indicate an excessive chemical attack. The chemical conditions that caused the degradation shall be ascertained.

15.6.2.9 If defects other than those described above are found, the cause of these other defects should be ascertained to avoid further attack of the concrete construction.

15.6.2.10 For repair a sufficient number of bricks shall be taken out to restore the brick lining configuration.

15.7 Inspection

15.7.1 The only method for inspection and testing of applied brick lining is by visual examination.

15.7.2 The equipment shall be inspected by experienced personnel, in accordance with this manual.

Equipment to be assembled from parts shall be checked for correct assembly, before installation of the lining.

15.7.3 Test pressures for brick-lined equipment shall be limited to 10% above the operating pressure, to prevent unacceptable deformations.

15.7.4 Brick-lined equipment shall be inspected at regular intervals observing any local obligations and whenever any leak or product contamination occurs.

15.7.5 The inspection should be restricted to visual observations with consideration of the following:

a) General condition of the brick lining.

b) Color of the bricks.

c) Level of cement in joints; excessive chemical attack, e.g. by fluorides, could reduce the thickness of bricks or tiles which may be indicated by protuberance of the joints.

d) Regular shape of the brick lining; disbanding of bed joints could cause irregularities.

e) All bricks and tiles in proper position, no loose or displaced parts.

f) Cracks; deformation of the equipment due to lack of or improper pretreatment can cause irregularities.

g) Spalling; generally distributed spalling could result from incorrect composition and porosity characteristics of the bricks, or too severe operational conditions caused by frequent temperature or pressure changes. Local spalling could result from direct impact of liquid or vapor jets causing rapid temperature changes, impact and the effect of boiling on the interface level.

h) Cement condition in the joints; erosion, dissolving or washing out, e.g. for silicate-based cements caused by steam, hot water or chemical attack.

i) Lining in and around nozzles and manholes; when design, location, material selection, installation, special treatment and operation are correctly done only minor repairs should be expected.

j) When disbonding and spalling of bricks are noticed, this should be further investigated by careful hammer testing.

15.7.6 If by visual inspection or hammer testing, defects are demonstrated, e.g., leakages, disbonding, wide cracks, missing bricks, severe spalling, material reduction or open joints, a further thorough examination is necessary. This may require locally opening up the brick lining dependent on the severity of the damage.

15.7.7 Specialist's advice based on visual inspection, hammer testing and further examination including laboratory analysis shall decide whether the damage could be the result of material selection, materials supplied, design of equipment and/or lining, specification, protection of materials during storage and installation, curing or operation.

15.7.8 There may be other considerations, such as local conditions, factors in inspection or operating reports, etc., that may help the specialist to decide on the type and extent of any repairs that may be required.

15.8 Start-up and Operation

15.8.1 Brick-lined equipment shall only be operated after:

- complete curing of the cement;
- required prestressing is completed;
- release and approval by inspector.

15.8.2 The equipment shall be brought into service very gradually by slowly increasing the temperature and pressure up to the operation condition. The same careful handling is required when the equipment is taken out of operation. Temperature stresses caused by inexpert handling could destroy the acid-resistant brick lining completely.

15.8.3 Accurately written operating instructions shall be established, based on information to be supplied by the brick lining contractor for equipment with critical limitations of temperature and pressure during start-up and/or operations.

15.8.4 Brick-lined equipment standing idle shall be protected against frost especially for those cases were moisture can reach the lining.

16. CEMENT MORTAR LINING

16.1 General

16.1.1 This Clause 16 specifies requirements for chemical resistant cement-mortar lining for process equipment. This section does not cover refractory cement lining (see 17).

16.1.2 Cement lining applied to equipment fabricated in metal or concrete.

16.1.3 Requirements for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350.

16.1.4 The applicator should exercise diligence to provide uniform linings without thick or thin areas. Adequate and properly spaced hold-downs on the application machinery should be used.

16.1.5 New and used part should be free of mill varnish, oil, paraffin, corrosion products, mill scale, thread lubricant, or any other foreign material when the wet cement mix is introduced for lining.

16.1.6 For more information about cement-mortar lining of water pipe lines, in place or shop applied see AWWA C101/A21.4 and AWWA C205 and AWWA C602.

16.1.7 The Company inspector may stop lining operations when conditions such as 7.1.6.

16.1.8 The lined equipment shall be identified as stated in 8.1.10.

16.1.9 The applicator of the lining shall provide a certificate of inspection and testing in accordance with 8.1.11 when requested.

16.2 Preparation

16.2.1 Preparation of material

16.2.1.1 Mortar for the lining shall be composed of cement, sand, and water that have been well mixed and are of such consistency as to produce a dense, homogeneous lining. Unless otherwise specified by the Purchaser, the mortar may also included admixtures and pozzolanic materials.

16.2.1.2 The approximate proportions of cement and sand in the mortar for the lining shall be 1 part of Portland cement to 1½ parts of sand by volume and proportions of sand to cement shall be not more than 3 parts sand to 1 part cement by weight. The exact proportions shall be determined by the characteristics of the sand used. Pozzolanic material, if used, shall be substituted for a part of the Portland cement in a proportion of approximately 1 part pozzolanic material to 5 parts Portland cement by volume. Admixtures (resin and additives) if added, shall be used in strict compliance with the manufacturer's recommendations.

16.2.1.3 The water content shall be the minimum quantity that produces a workable mixture, with full allowance made for moisture collecting on the interior of the pipe surfaces. Slump tests should be made periodically on freshly mixed mortar immediately prior to the mortar being conveyed to the lining machine. The test shall be made in accordance with ASTM C143. Nominal slumps of cement-mortar mixes for application of lining are indicated in Figs. 9 and 10.

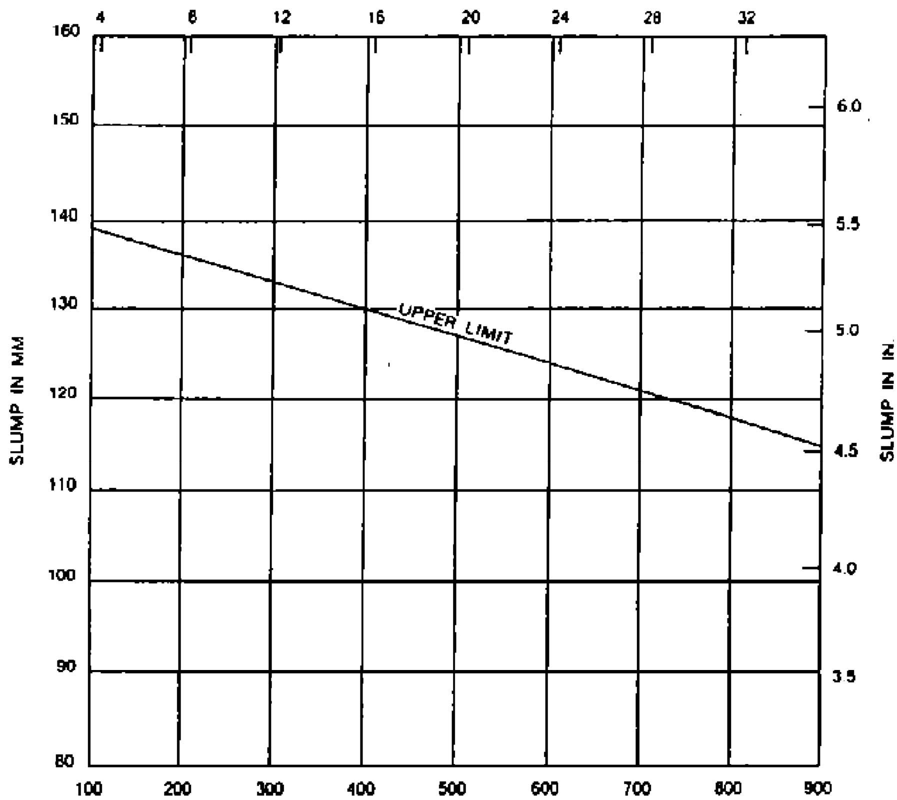
16.2.1.4 Water for mixing mortar shall be clean and free of mud, oil, and injurious amounts of organic material or other deleterious substances. Potable water shall be used when available.

16.2.1.5 Mortar shall be mixed long enough to obtain maximum plasticity. The mortar shall be used before initial set.

16.2.1.6 The soluble Chloride-ion (Cl^-) content of the cement-mortar mix shall not exceed 0.15 percent expressed as a percentage of cement weight.

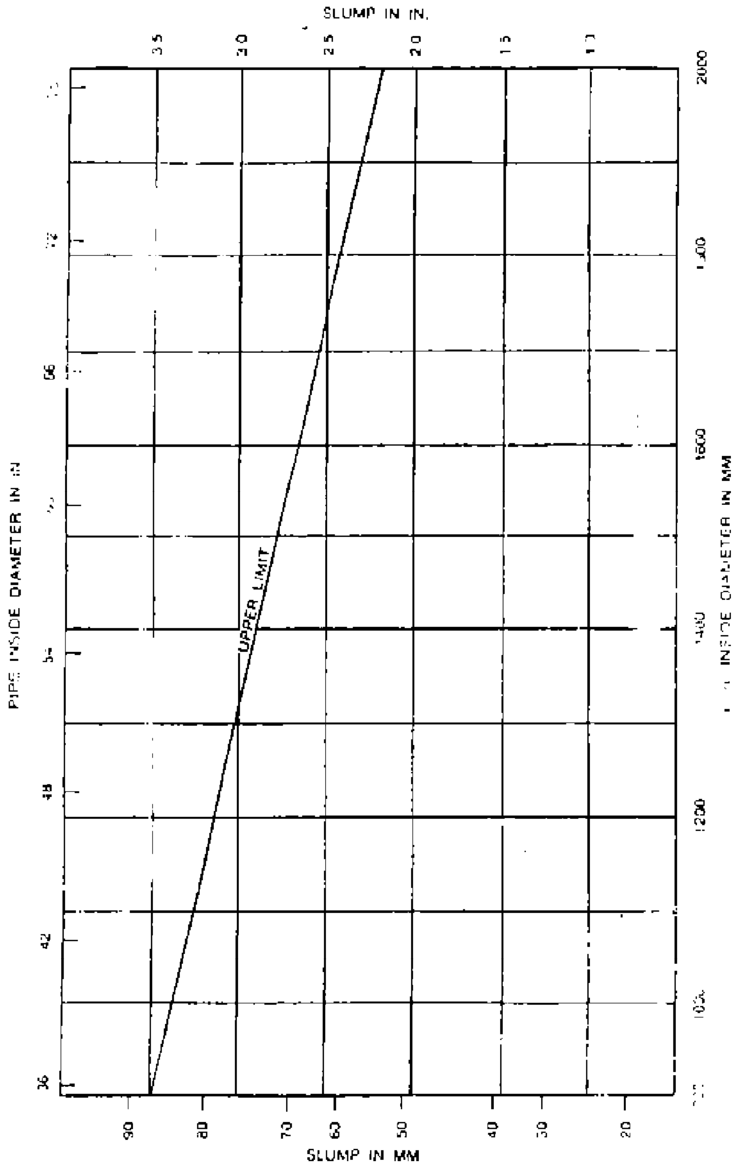
16.2.1.7 The minimum temperature of the wet mix should be maintained at not less than 10°C and the maximum temperature should not exceed 32°C. Do not place cement mix in pipe when the ambient temperature is less than 4°C.

Pipe Inside Diameter in in.



Pipe Inside Diameter in mm

NOMINAL SLUMPS OF CEMENT-MORTAR MIXES FOR APPLICATION OF PIPE LININGS USING PUMP FEED
Fig. 9



SLUMP LIMITS OF CEMENT-MORTAR MIXES FOR APPLICATION OF PIPE LININGS USING MECHANICAL FEED
Fig. 10

16.2.2 Preparation of surfaces to be lined (see also IPS-C-TP-101)

16.2.2.1 The steel surfaces to be cement lined shall be cleaned to remove rust, oil scale and previously applied paint to Sa 2 degree of Swedish Standard SIS 05 59 00 that could interfere with the adherence of the cement mortar.

16.2.2.2 After the interior of the pipe or tubing has been cleaned a visual inspection of each joint is made by the applicator to ensure that no scale, sand, or other foreign matter is left in the pipe, and that the pipe or tubing can be properly cement-lined.

16.2.2.3 The concrete or masonry surfaces to be cement lined shall be cleaned to remove all unsound and loose material by chipping, scarifying, sandblasting or water blastings. Sand blast existing surfaces that do not require chipping to remove paint, oil, grease, and other contaminants, and to provide a roughened surface for proper bonding of shotcrete (see ACI 506 R 85).

16.3 Method of lining

16.3.1 General

16.3.1.1 Cement mortar shall be composed of cement, sand and water, well mixed and of proper consistency to obtain a dense, homogeneous lining that will adhere firmly to the substances surface.

16.3.1.2 Cement-mortar lining shall be applied by spinning, mechanical placement (line traveling), pneumatic process (shotcrete or gunite) and hand troweling.

16.3.1.3 For shop application of cement lining of pipes, centrifugally spinning method shall be used.

For field application of cement lining of pipes mechanical placement (line traveling) shall be used.

16.3.1.4 Vessels, miters, angles, bends, reducers, and other specials shall be lined with mortar by hand troweling, mechanical placement, pneumatic placement.

16.3.1.5 Hand troweling method shall be used in place for lining pipelines where other methods of application is impractical such as sharp bends, or areas closely adjacent to valves.

16.3.1.6 All defects, including but not restricted to sand pockets, voids, oversanded areas, blisters, and cracking as a result of impacts shall be cut out and replaced by hand or pneumatic placement.

16.3.1.7 The lining shall be cured in such a manner as to produce a properly hydrated mortar lining that is hard and durable. The cure may be affected by the application of seal material to the still moist lining.

16.3.2 Pneumatic placement (shotcrete or gunite process)

16.3.2.1 The use of gunite without reinforcement shall be limited to small or confined areas, for gunite thickness not exceeding 20 mm. Details of such installation shall be approved by purchaser.

During guniting operations, the equipment shall be grounded in locations where there is a possibility of flammable materials being present. In addition, protection shall be provided to prevent damage to adjacent structures.

16.3.2.2 The reinforcement shall be placed not less than 13 mm from the surface to be gunited and there shall be not less than 20 mm between the reinforcement and final surface of the gunite. Where the gunite thickness does not permit these requirements, the reinforcement shall be placed midway between the steel surface and the final gunite surface.

16.3.2.3 The reinforcement shall be fastened by welding or by tie wires to anchoring devices welded to the surfaces to be gunited. Such devices may be any combination of rods, clip angles, studs or nuts on edge. Spacing of these points shall be a maximum of 450 mm (18 in.) in both directions.

16.3.2.4 Reinforcement shall be provided in two directions with the following minimum ratio of reinforcement areas to gunite areas in each direction (see also IPS-M-CE-105):

a) Plain bars	0.0030
b) Deformed bars	0.0025
c) Welded wire fabric	0.0020

16.3.2.5 Dampen absorptive substrate surfaces prior to placement of shotcrete to facilitate bond and to reduce the possibility of shrinkage cracking developing from premature loss of the mixing water.

16.3.2.6 Broom or scarify the surface of freshly placed shotcrete to which, after hardening, additional layers of shotcrete are to be bonded. Dampen surface just prior to application of succeeding layers.

16.3.2.7 First, fill with sound material all corners and any area where rebound cannot escape or be blown free. Complete the corners between the web and the flanges of structural steel before application to the flat area.

16.3.2.8 Do not place shotcrete if drying or stiffing of the mix takes place at any time prior to delivery to the nozzle. Do not use rebound or previously expended material in the shotcrete mix.

16.3.2.9 Finishing

Provide one of the following final surfaces finish when specified :

a) broomed;
b) floated;
c) troweled;
d) sponge floated; or
e) flash finish.

Avoid troweling and commencement of moisture curing taken place within a relatively short period after placement of shotcrete.

16.3.3 Mechanical placement for lining of pipeline (line traveling)

16.3.3.1 The lining shall be applied in one course or more by a machine traveling through the pipe and distributing the mortar uniformly across the full section and long radius bends of the pipe. The discharge shall be from the rear of the machine so that the newly applied mortar will not be marked.

16.3.3.2 The rate of travel of the machine and the rate of mortar discharge shall be mechanically regulated to produce a smooth surface and uniform thickness throughout. The mortar shall be densely packed and adhere wherever applied; there shall be no injurious rebound.

16.3.3.3 Procedure at rivets and open joints

In steel pipe 600 mm and larger in diameter, mortar may be applied by hand ahead of the lining machine for uniform thickness over the line of rivet heads. Open joints shall be packed with mortar lining where necessary to provide a smooth surface across the joint. Such mortared areas shall be moist and free of surface checking before proceeding with the machine lining.

16.3.3.4 Finishing

The lining machine shall be provided with attachment for mechanically troweling the mortar. The trowel attachment shall be such that the pressure applied to the lining will be uniform and produce a lining of uniform thickness with a smooth finished surface, free of spiral shoulders.

16.3.4 Spin or centrifugal process (for lining of pipes, shop applied)

16.3.4.1 Straight sections of pipe shall be lined by use of a spinning machine specifically designed and built for the purpose of rotating the pipe section and centrifugally applying cement-mortar linings to the interior of steel pipe.

16.3.4.2 The mortar shall be mixed in batches. The amount of cement and sand entering into each batch shall be measured by weight. The quantity of water entering the mixer shall be measured automatically by an adjustable device, or it shall be otherwise measured to ensure that the correct quantity of water is being added.

16.3.4.3 When required to prevent distortion or vibration during the spinning, each section of pipe shall be suitably braced with external or internal supports appropriate to the equipment.

16.3.4.4 In application of lining by a spinning machine, the entire quantity of mortar required for completion of the lining of the section of pipe shall be placed without interruption.

16.3.4.5 After the mortar has been distributed to a uniform thickness, the rotation speed shall be increased to produce a dense mortar with a smooth surface.

16.3.4.6 Provision shall be made for removal of surplus water by air blowing, tilting of the pipe, or other methods approved by the Purchaser.

16.3.4.7 The application of cement-mortar lining to miters, angles, bends, reducers, and other special sections, the shape of which precludes application by the spinning process, shall be accomplished by mechanical placement, pneumatic placement, or hand application and finished to produce a smooth, dense surface.

16.3.4.8 Reinforcement (see also IPS-M-CE-105)

Wire-fabric reinforcement or ribbon-mesh reinforcement shall be applied to the interior of fittings larger than 610 mm and shall be secured at frequent intervals by tack welding to the pipe, by clips, or by wire. The wires on 50 mm spacing on the 50 mm × 100 mm fabric shall extend circumferentially around the fitting. Repaired areas of machine-applied linings at miters, pipe ends, outlets, and other cuts made in the lining for fabrication of the fitting need not be reinforced if the width of the repair area does not exceed 300 mm. Repairs for widths exceeding 150 mm shall be bonded to the steel and adjacent faces of the lining with a bonding agent.

16.3.5 Hand trawel application for pipeline

16.3.5.1 In pipe 600 mm and larger in diameter in places where machine placing of cement lining is impractical, such as sharp bends, specials, or areas closely adjacent to valves, lining shall be performed by hand. The engineer may permit the correction of any defect by hand application.

16.3.5.2 If necessary areas to be lined shall be moistened with water immediately prior to placing the hand-applied mortar.

16.3.5.3 Steel finishing trowels shall be used for the hand application of cement, except at bends. The outer edges of hand-traweled areas may be brushed in order to reduce the abutting offset.

16.3.5.4 All hand-finishing work in a section of pipeline shall be completed within 24 hours after completion of the machine application of mortar lining to that section.

16.4 Curing of Cement Lining

Methods of curing should be defined by the Company with reference to job requirements. The following methods of steam and atmospheric curing have been found generally successful.

16.4.1 Steam curing

16.4.1.1 Begin steam curing not less than two hours nor more than four hours after final spin. High atmospheric temperatures and low humidities may shorten the time requirements. Low atmospheric temperatures and high humidities may lengthen the time requirements.

16.4.1.2 Leave the lining in the steam curing chamber at 57 to 74°C for not less than 18 hours. The Purchaser may require a longer curing time and should so request.

16.4.1.3 During heating and cooling, do not increase or decrease the temperature of the steam curing chamber at a rate of more than 0.6°C per minute.

16.4.1.4 Place end caps on the cement-lined pipe before placing in the steam chamber. Do not expose the cement-lined pipe for more than 2 hours after spinning without end caps in place.

16.4.1.5 Leave the end caps in place until the pipe is installed in the field system.

16.4.1.6 Keep the cement lining moist and protect it from freezing until delivered to the Purchaser.

16.4.1.7 Keep the cement lining moist following steam cure. The storage time following cure and before installation should be at the discretion of the Company.

16.4.2 Moist (atmospheric) curing

16.4.2.1 Keep the cement lining moist at all times during the curing process.

16.4.2.2 Use airtight end caps to seal the pipe ends to retain moisture in the lining. Do not expose the cement lining for more than 2 hours after spinning without end caps in place. Keep end caps in place until pipe is installed in the field service.

16.4.2.3 Maintain the curing temperature at not less than 10°C for at least 8 days.

16.4.2.4 Atmospheric-temperature-cured cement-lined pipe shall not be transported or installed for at least 8 days after application of the lining.

16.4.3 Membrane curing

Membrane curing, if any, shall consist of the complete encapsulation of the coating by application of curing compound that will retain the moisture of the applied cement lining.

16.5 Transportation

16.5.1 Transportation of equipment

16.5.1.1 Do not drop the equipment on to or off the transporting vehicle.

16.5.1.2 Tie downs shall be used to ensure that the pipe will not shift during shipment. Any tie-down can result in a lining damage, so the pipe shall be properly protected.

16.5.1.3 All impact shall be avoided.

16.5.2 Transportation of lined-pipe

16.5.2.1 Cement lined-pipe shall always be handled carefully. Minor impacts and bending normally have no effect on the lining. The following practices are recommended to prevent lining damage during handling:

- Always keep the air-tight end caps in place. Loss of end caps permits the lining to dry out, which can result in severe cracking of the lining.
- Always load or unload by hand when practical. Whenever loading or unloading.
- Do not drop the pipe onto or off the transporting vehicle.
- Do not roll the pipe onto or off the transporting vehicle in such a manner that it bangs into other pipes.

16.5.2.2 Pipe shall always be supported to avoid undue flexure when being transported. Supports shall be placed every 1.2 m for pipe 152 mm and smaller and every 1.8 m for larger pipe.

Dunnage shall always be placed within 0.6 m of the ends to avoid banging the ends together. When trucking, a flat-bed trailer provides the best support.

16.5.2.3 Pipe that cannot be loaded by hand may be picked up at the midpoint if the ends sag no farther than 0.6 m. If sag exceeds 0.6 m, a 3-point (bar-sling) arrangement shall be used.

16.5.2.4 Tie-downs shall be used to ensure that the pipe will not shift during shipment. Any tie-down can result in a lining damage, so the pipe shall be properly protected.

16.5.2.5 All impacts shall be avoided.

16.5.2.6 Hooks or other devices which insert into the ends of the pipe shall never be used.

16.5.2.7 Lined pipe shall never be dropped after completing a welded joint.

16.5.2.8 Pipe shall never be run over by any vehicle.

16.5.2.9 The pipe shall never be bent to such an extent that the metal is deformed or lining damage will result. Recommended maximum bending is 5 degrees, or 76 mm in 30 m when lowering pipe into a trench or like operation.

16.5.2.10 Number of tiers of lined pipes on each other shall not exceed values of Table 7.

TABLE 7 - NUMBER OF TIERS OF LINED PIPES

NOM. PIPE SIZE		MAX. NUMBER OF TIERS
mm	in.	
50	(2)	10
76	(3)	10
100	(4)	8
152	(6)	6
200	(8)	4
250-400	(10-16)	3

16.6 Installation and Joining

16.6.1 Installation and joining of equipment

The appropriate seal material shall be at joints of cement lined pipes in accordance with 16.6.2.

16.6.2 Installation and joining of lined pipe

16.6.2.1 General

For preventing corrosion damage at joints of cement-lined pipes, the following techniques shall be used as a minimum:

16.6.2.1.1 The lengths of pipe shall first be butted together and checked for alignment and good contact of the cement lining and pipe ends.

16.6.2.1.2 The appropriate seal material shall be applied in accordance with 16.6.3.

16.6.2.1.3 Lines smaller than 100 mm shall be tack-welded at 12 and at 3 or 9 O'clock positions. The first welding pass shall start opposite the chosen second tack weld and continue in the direction of the 6 O'clock position. This is necessary to prevent a gap between the pipe ends opposite the first welding pass. 100 mm and larger pipe should be tack-welded at 4, 8 and 12 O'clock positions.

A slightly different procedure is needed in some cases as explained in 16.6.3.3.

16.6.2.1.4 The pipe shall be joined by the shielded metal-arc welding process. The arc shall not come in direct contact with the cement lining or seal material. Starts and stops shall be staggered so as not to start or stop more than once in the same place. Welding slag shall be cleaned from all weld passes.

Welding materials used shall be in accordance with the current list of approved welding consumables published by Lloyds Register of Shipping, Controls or other internationally acknowledged bodies.

16.6.3 Seal materials

16.6.3.1 Magnesium oxide/graphite/hydraulic cement

Only this compound is suitable for use in welded joints.

The dry compound shall be mixed thoroughly with clean water in a clean container by stirring with a clean welding rod. Pot life of the mixture is approximately one hour.

Only enough compound should be prepared in each batch mixed to last for 45 minutes to one hour. Additional water shall not be used to thin the mixture after it has started to set. The mixing and application container shall be thoroughly washed with clean water before mixing another batch of compound.

The compound can best be applied to the cement at the ends of the pipe by squeezing it from a plastic squeeze-type bottle or applicator. A continuous layer or bead of compound shall be applied to the cement liner on the ends of both lengths of pipe to be welded. Enough shall be used to form a small continuous bead of excess compound in the welding groove when the pipe ends are butted together. Using too much compound will cause a larger bead of excess compound inside the pipe which is unnecessary and wastes material. The compound mixture shall be thin enough to be squeezed through the nozzle of the applicator, but not thin enough to run off the pipe after it is applied.

16.6.3.2 Plastic material

The same procedure should be used as stated in 16.6.3.1, except that a mixing procedure applicable to the material selected shall be used.

Many compounds are available, but several are not resistant to heat. The user shall make sure that the compound selected is suitable for the intended service.

The pot life of most catalytically-cured materials is limited and differs for various compounds.

16.6.3.3 Asbestos gaskets

The pipe ends to be joined should be tack-welded together and the asbestos gasket placed in the 'V' formed. The 'V' should be closed by movement of the pipe lengths and the pipe tack-welded at the top. Line-up clamps should be installed and the welding completed.

The thickness of the gasket shall be 0.8 mm for thin wall pipe and 1.6 mm for heavier wall thicknesses.

The outside diameter of the gasket shall be equal to the inside diameter of the steel pipe minus 1.5-2.5 mm.

The inside diameter of the gasket shall be equal to the inside diameter of the lining, within a tolerance of zero to +1 mm.

16.6.3.4 Caulking

Large-diameter pipe (large enough for a man to go inside) can be caulked at the joint. Numerous compounds are available, but a polysulphide rubber has been the most widely used. The user shall make sure that the compound selected is suitable for the intended service.

16.6.4 Threaded and coupled pipe

For coating of exposed threads many compounds are available. The user shall make sure that the compound selected is suitable for the intended service.

16.6.4.1 Magnesium oxide/hydraulic cement compounds. This compound will lock the joint if include in the make-up portion of the joint.

16.6.4.2 Epoxy materials. These materials will lock the joint if included in the make-up portion of the joint.

16.6.4.3 Polysulphide rubber. This material has been reported as having low resistance to strong H_2S and strong acid environments.

16.6.4.4 Coal-tar epoxy.

16.6.4.5 Coal-tar modified with vegetable pitch.

16.6.4.6 Polyurethane elastomer.

16.6.4.7 Polychloroprene molded and cured inside the coupling or rubber rings have been used to seal the exposed collar area.

16.7 Repair of Lining

16.7.1 All defects, including but not restricted to sand pockets, voids, oversanded areas, blisters, and cracking as a result of impacts, shall be cut out and replaced by hand or pneumatic placement to the same thickness as required for the mortar lining.

16.7.2 In case of water pipeline temperature and shrinkage cracks in the mortar lining less than 1.6 mm in width need not be repaired. Cracks wider than 1.6 mm need not be repaired if it can be demonstrated to the satisfaction of the purchaser that the cracks will heal autogenously under continuous soaking in water. The autogenous healing process may be demonstrated by any procedure that keeps the lining of the pipe continually wet or moist. Pipe used in the demonstration shall be representative of the pipe to be supplied, and water for the moistening of the pipe shall be chemically similar to the water to be carried in the pipeline.

16.7.3 Defective or damaged areas of linings may be patched by cutting out the defective or damaged lining to the metal so that the edges of the lining not removed are perpendicular or slightly undercut. The cut-out area and the adjoining shall be thoroughly wetted, and the mortar applied and troweled smooth with the adjoining lining. After any surface water has evaporated, but while the patch is still moist, it shall be cured as specified in Section 16.6.

16.7.4 For more information about repair procedure of welded steel, cement-lined pipe leak see API-RP 10E Section 9.

16.8 Inspection and Rejection (for Lined Pipe)

16.8.1 General

To ensure good practices of application in order to provide cement lining, the types of inspection that shall be carried out are:

16.8.1.1 Quality control by the applicator during manufacture.

16.8.1.2 Shop inspection by an inspector nominated by the Company to be carried out at the manufacturer's works.

16.8.1.3 Inspection of lined equipment are generally the same as lined-pipe except all lined equipment shall be inspected (see 16.8.2.2).

16.8.2 Inspection during application

The quality control inspector shall check, inspect and test for the following causes of lining failures. Applying inspection methods shall be as described hereafter.

16.8.2.1 Voids

A void is a place in the pipe or equipment where the cement lining is not continuous.

Each pipe shall be inspected immediately after the application by looking through the pipe from each end, (for pipe less than 600 mm ID), and a person to enter (for pipe larger than 600 mm ID), using a strong light on the other end. Voids appear as dark places in the shiny surface of the wet lining. They shall be repaired immediately to obtain their required thickness.

The cured pipe shall be reinspected for voids before acceptance by the Company.

16.8.2.2 Lining thickness

16.8.2.2.1 Cement thickness at and near each end of the pipe shall be determined by internal caliper and measuring scale. Cement thickness near the center of the pipe shall be measured by cutting the pipe and examining the new ends. The number of pipes to be cut shall be agreed upon between applicator and the inspector nominated by the Company.

16.8.2.2.2 Poor lateral distribution of the cement mix can sometimes be detected by looking through the pipe at the fresh spun lining using a strong light at the other end. The appearance of concentric rings indicates poor lateral cement distribution.

16.8.2.3 Sags

If the forces of hoop stress and adhesion in the fresh cement lining are not greater than the force of gravity, the lining sags or pulls away from the pipe surface at some points along the top of the pipe.

Each joint shall be inspected before and after curing by looking through the pipe from each end, using a strong light at the other end. Sags appear as large smooth lumps in the lining at the top of the pipe.

16.8.2.4 Defective ends

The types of end defects include:

- Lining end not located as specified.
- Lining end not perpendicular to longitudinal axis of pipe.
- Lining end not square.
- Lining end chipped or cracked.
- Lining thickness not as specified.
- Threads or welding bevel and land not cleaned of cement.
- Lining separated from steel pipe surface.

Both ends of each joint of cement-lined pipe shall be inspected before and after curing for the defects mentioned above.

Note:

If the ends of the cement-lined pipe are not as specified, it is very difficult to make a corrosion-resistant joint in the pipe. Therefore end defects shall be a major cause for rejection.

Cement-lined pipe is damaged most often at the ends during transportation and handling.

Therefore ends shall also be inspected before the pipe is installed. Any repaired ends shall meet the specification and shall always be reinspected.

16.8.2.5 Foreign material and poor mixing

The quality control inspector shall ensure that the lining plant is operated and maintained so that no foreign material is introduced into the cement lining or its components during handling, mixing, storage or at any other time. He shall also ensure that all components are thoroughly mixed in the correct proportions.

Foreign material or poor mixing are indicated by the appearance of spots or small rough lumps in the fresh lining.

16.8.2.6 Cracks

The detection of cracks and the correct evaluation of the detrimental effect of cracks is the most difficult part of inspection. Unless the pipe is large enough for a man to enter, lining cracks are difficult to see unless viewed from a point perpendicular to the surface of the lining. The best inspection tool consists of a light source and a mirror on the end of a rod which can be inserted into the lined pipe. The inspector can look into the end of the pipe and see the illuminated surface of the lining in the mirror. Under some conditions the cracks in cement lining either 'heal' or do not lead to corrosion of the pipe because of the inherent alkalinity of the cement.

However, if the fluid is corrosive, e.g. salt water, and if pressure surges are present, even hair cracks can cause corrosion failure of the pipe.

Most cracking occurs when the lining is allowed to dry out during curing, transportation and storage. The quality control inspector shall ensure that the lining is still moist after inspection and that air-tight end caps are placed and maintained on the pipe.

The lining of each pipe shall be inspected for cracks after curing, transportation, storage and handling.

16.8.3 Criteria for rejection

Any of the following can be the reason for rejecting the lined part:

- Deviation from lining thickness, end-finish or lining composition requirements.
- Defects in the lining (voids, sags, lumps, water cutting, excessive cracking porosity, softness, etc.)

Note:

The intention in cement lining is to produce a crack-free lining; however, cracking often occurs. If cracks expose steel or weaken the hoop stress of the lining, the pipe should be rejected. Since a limited number of hair cracks can be tolerated in certain cement-lined pipe applications, the acceptance or rejection of pipe with a cracked lining shall be left to the discretion of the inspector nominated by the Company.

- Separation of the cement from the substrate surface.
- Damage to pipe ends or equipment edge.

17. REFRACTORY LINING

17.1 General

17.1.1 This Clause 17 specifies requirements for refractory brick or refractory concrete lining for process equipment.

17.1.2 Refractory lining applied to equipment fabricated in metals.

17.1.3 Requirements for design and fabrication of the equipment, the state of preparation necessary for the surface to be lined and thickness of lining shall be according to IPS-E-TP-350, Clause 15.

17.1.4 The Company inspector may stop lining operations when conditions such as 7.1.6.

17.1.5 The lined equipment shall be identified as stated in 8.1.10.

17.1.6 The applicator of the lining shall provide a certificate of inspection and testing in accordance with 8.1.11 when requested.

17.2 Preparation

17.2.1 Preparation of material for use

17.2.1.1 Storage of refractory cement materials (see Note)

17.2.1.1.1 When not properly stored the factory-prepared dry mix may absorb moisture, which will cause setting. Such material will contain lumps, and shall be discarded.

17.2.1.1.2 If the stored mix becomes hot, the rate of moisture absorption will accelerate upon cooling, the mix shall therefore always be stored in a cool and dry atmosphere.

17.2.1.1.3 If bags containing dry mix are stored in the open air (allowed for a maximum of two days only). They shall always be placed on a ventilated platform, off the ground and protected by a covering, e.g. a tarpaulin and so arranged that water cannot come into contact with any of the bags. Care shall also be taken to avoid the possibility of ground moisture causing a high humidity underneath the covering.

17.2.1.1.4 Materials shall not be piled directly on the ground or floor. Pallets and/or planking must be used.

17.2.1.1.5 If the dry mix has been stored for more than 6 months, its quality shall be checked before use. In general checking of the bulk density and compressive strength will be sufficient.

Note:

For storage of refractory bricks see 15.5.1.

17.2.1.2 Mixing

17.2.1.2.1 Water for mixing the refractory shall be cool, free of impurities, and from a chemical stand point good enough to drink.

17.2.1.2.2 Mixing with water should preferably be carried out in a mixing machine such as a paddle-type mixer which empties itself completely on discharge. The duration of machine mixing shall be kept to the minimum necessary for thorough mixing, and is usually a matter of three to four minutes. Prolonged mixing shall be avoided.

17.2.1.2.3 Mixers should be clean and free of old mortar, Portland cement, lime, and dirt, to avoid contamination of the castable.

17.2.1.2.4 Before commencing, the mixer should be checked for mechanical reliability to prevent breakdown while placement is in progress.

17.2.1.2.5 The size of the batch used for hand mixing shall be limited to a volume that will permit thorough mixing and pouring within 15 minutes from the moment mixing has started, particularly at high ambient temperatures.

17.2.1.2.6 The freshly mixed concrete shall be of a soft puddling consistency so that no tamping is required. Tamping consistencies may be used on some work, such as on sleep slopes, to eliminate the cost of form work.

17.2.1.2.7 It should be borne in mind that the use of excessive amounts of mixing water will reduce cold (unfired) strength and will cause excessive shrinkage.

17.2.1.2.8 During cold weather the water temperature shall not be less than 5°C.

17.2.2 Preparation of surface to be lined

Surface to be lined shall be thoroughly sand blasted with sharp, abrasive sand or wire brushed to remove all unbounded scale, slag, rust, and other foreign materials. All sand blasting dust shall be removed before applying lining material.

Standard "commercial blast cleaning" practices shall be followed, and finish shall be to Swedish Standard SIS 05 59 00 grade Sa 2 (see also IPS-C-TP-101).

17.3 Application Methods

17.3.1 General

17.3.1.1 During application special care shall be taken that all irregular areas and corners are completely filled and that voids or air pockets are precluded. If any surface finish is required, the surface should simply be leveled off with a screed or a wood float. The surface shall not be troweled to a slick finish, e.g. with a steel trowel.

17.3.1.2 During cold weather the concrete and the surface to which it will be applied shall be kept at a temperature above 5°C both during application and curing. This shall be accomplished by providing an enclosure in which a temperature above 5°C is maintained during mixing, application and curing. Linings containing water shall be protected against freezing; however, live steam shall not be used for this purpose.

17.3.1.3 Expansion joints in the lining shall in general be provided every 1.5 to 2.0 mm horizontal and vertical direction.

Straight through joints filled with ceramic fiber board or ceramic fiber blanket (see BS 6466) should be acceptable where local experience has shown them to be satisfactory. Ceramic fiber blanket shall be compressed to around 60% of its nominal thickness and contained in a compressed state in e.g. an expanded metal cage. Straight-through joints are not recommended for unshielded walls or roofs of the radiant sections. In linings of steel stacks the carving of horizontal shrink slits 1 mm wide and 1/5th of the lining thickness deep should be carried out at distances of approximately 2.0 m.

17.3.2 Refractory brick lining

Application method for refractory brick lining is the same as chemical resistance brick lining. For refractory brick lining, refractory bricks are used in conjunction with refractory concrete (17.3.3).

17.3.3 Refractory cement lining

Application of refractory cement lining may be either by casting or gunning (shotcreting) either in place or be prelining. For gunning with a dry gun 30% in excess of design quality calculated shall be required and for casting 10%.

17.3.3.1 Refractory casting methods

17.3.3.1.1 Casting in a horizontal position-Casting in a horizontal position permits easy inspection and requires neither skilled labor nor any special equipment. This method can only be used for new work; its interference with steel structural work as well as the special care required while lifting and assembling the lined sections or panels are serious drawbacks.

Sufficient space will be required for handling the sections or panels, see Figs. 11 and 12.

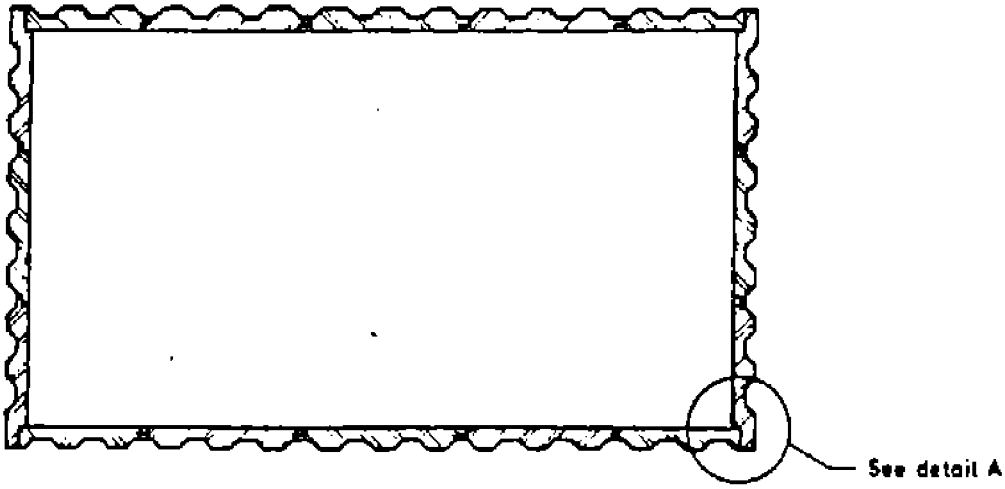
17.3.3.1.2 Casting in a vertical position-The application of this method shall be restricted to minor repairs and to those cases where gunning or horizontal casting is not feasible.

The method requires shuttering, which shall be a maximum of 500 mm high, see Fig. 13. The shuttering shall be made reasonably water-tight and the inside surfaces shall be sufficiently oiled, but without excess.

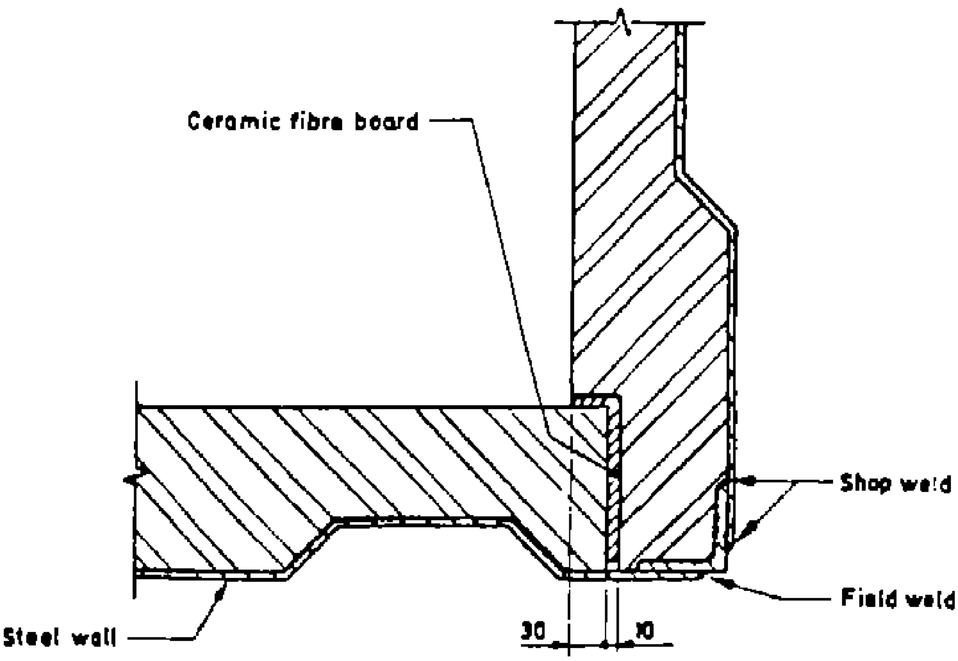
Note:

Dry wooden shuttering may need a treatment to prevent the absorption of mixing water from the fresh concrete.

The concrete shall be cast evenly along the length of the shuttering and consolidated in order to obtain a homogeneous composition. Skilled labor and close supervision shall be imperative.



Cross section of lined and assembled panels

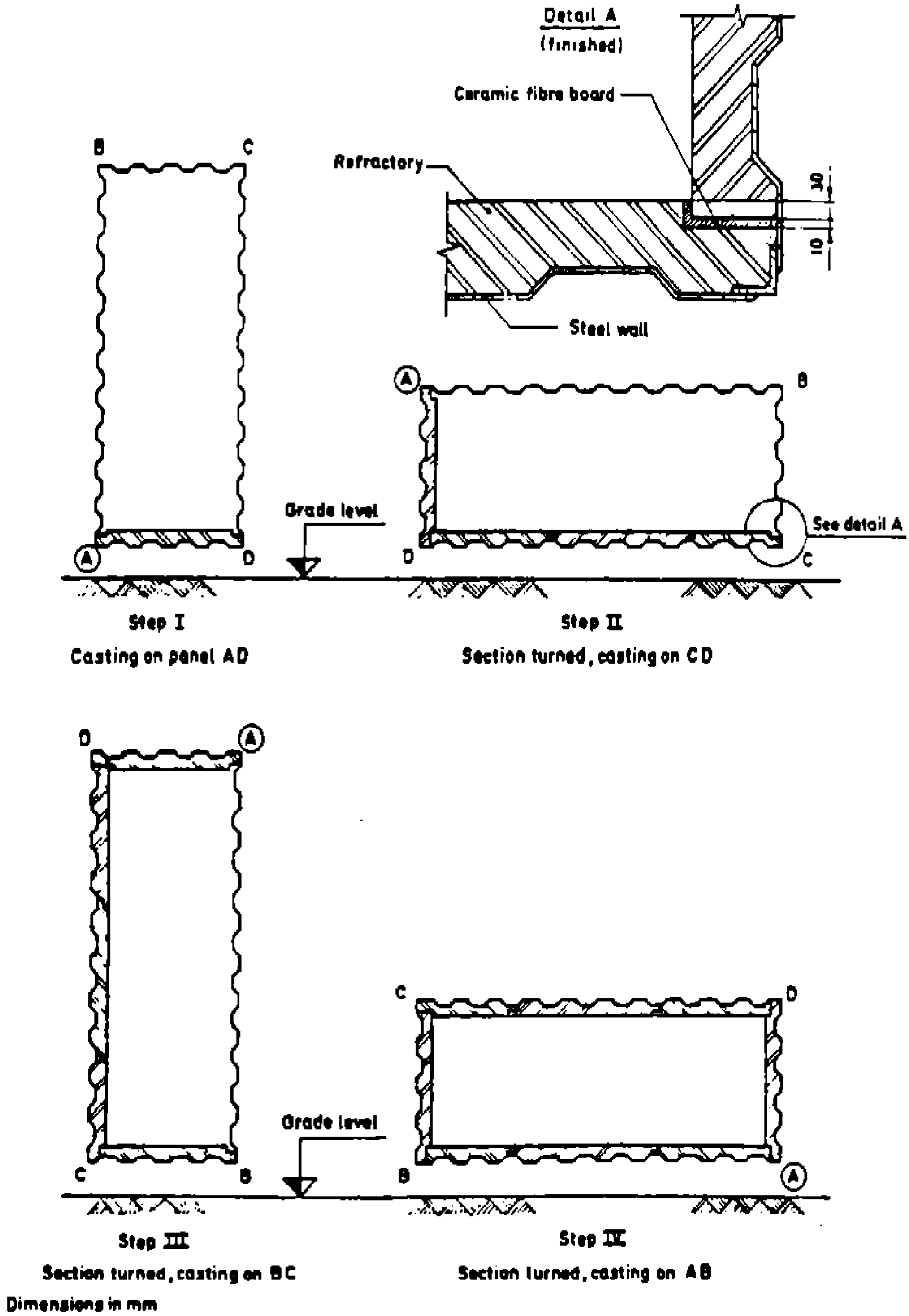


Detail A

Dimensions in mm.

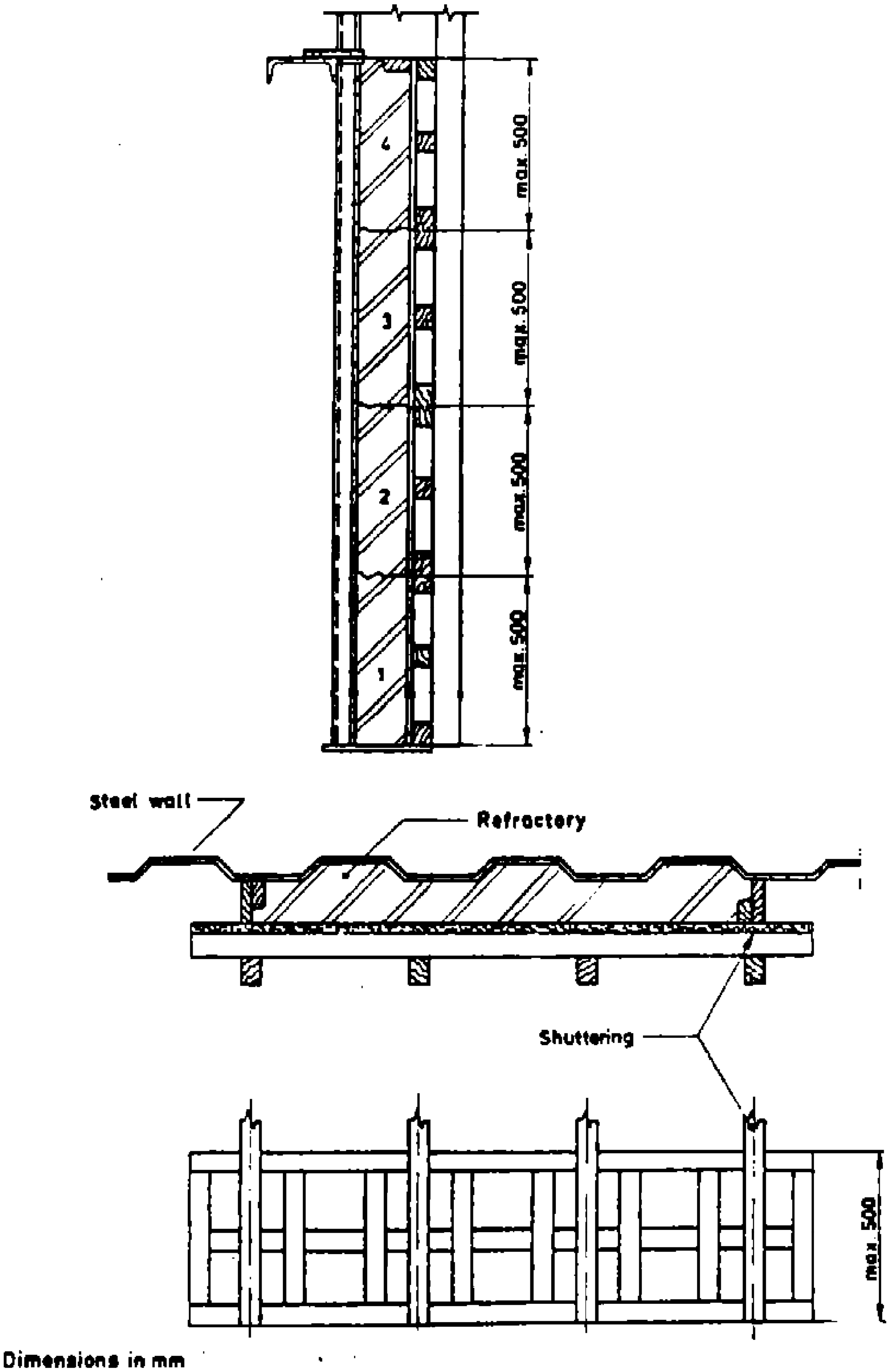
HORIZONTAL CASTING ON SEPARATE PANELS AT GROUND LEVEL AND SUBSEQUENT ASSEMBLY (ANCHORING NOT SHOWN)

Fig. 11



HORIZONTAL CASTING INSIDE PRE-ASSEMBLED PANELS (ANCHORING NOT SHOWN)

Fig. 12



VERTICAL CASTING OF REFRACTORY
(ANCHORING NOT SHOWN)
Fig. 13

17.3.3.1.3 Forms (shuttering) for casting

Both wood and metal forms used for casting hydraulic setting castable refractories should be rigid and strong to prevent movement due to the pressures and loads that develop during placement. The forms should be coated with acid free oil or "parting compound" to prevent wood forms from absorbing water from the castable and to allow the form, metal or wood, to part easily when the forms are removed.

Forms for casting tubular lines or stacks may be tubular collapsible steel, or tubular concrete forms, such as "sono-voids", which are constructed of heavy cardboard and water proofed on the outside diameter.

The refractory contractor shall be responsible for furnishing accurately made forms, suitable for the work being handled. All form designs shall be submitted in complete detail for approval by Company and the Contractor.

Wooden or cardboard forms are to be carefully removed after castable has set, under no circumstances are these forms to be burned off, because in so doing, high temperatures are "flashed" on the face of the still "green" castable, usually resulting in damage to the face of the lining or even the entire lining.

17.3.3.1.4 Casting process

Pour refractory behind forms using funnels and sheet metal tubes as required.

Cast refractory shall be applied in a manner which will minimize material segregation. All material shall be thoroughly worked into place and air bubbles expelled within 15 minutes from the moment when mixing started.

Each batch from the mixer shall be so placed that the full thickness of the lining will be reached, using temporary weirs as necessary. On no account shall another layer be added later to complete the lining.

Once application has started it shall proceed without interruption until the entire lining of the part concerned has been completed. If an unavoidable interruption does occur, the wet edge of the lining shall be cut back at right angle to the surface to give an edge of full thickness. All material ahead of the cut shall be removed and discarded.

If any surface finish is required, the surface should simply be leveled off with a screed or a wood float. The surface shall not be troweled to a slick finish, e.g. with a steel trowel.

To make certain that refractory is placed free of voids use magnetic vibrators or ram rod. Do not excessively vibrate or ram, but agitate only sufficiently to assure good flow. Care must be taken not to vibrate or ram after initial set occurs, which is approximately 15 to 20 minutes after mixing.

17.3.3.2 Refractory gunning method

a) Gunning (shotcreting) should normally be done with a dry gun. The addition of the correct quantity of water in the dry mix at the spray gun and the even mixing of the concrete are completely dependent on the skill and the attentiveness of the gun crew. Skilled labor and close supervision shall be imperative.

b) This method shall be employed after erection of the steel structure is finished, it is suitable for applying linings in horizontal, vertical and overhead positions.

c) Once gunning has started the application of the lining shall be continuous until the whole lining or section is completed.

d) Work shall always proceed along the wet edge of the band just finished, and reach full lining thickness as quickly as possible before proceeding to another panel. Vertical walls shall be gunned in horizontal bands, working upwards from the bottom of the area to be lined.

e) In those cases where the size of the unit precludes successive band placement before initial setting has taken place, or where the gunning will be interrupted for more than 10 minutes, the working edge shall be cut back to full thickness at right angle to the steel wall. All material ahead of the cut shall be removed and discarded.

f) On jobs where the gunning of the lining will not be a continuous operation, the day's work shall not be terminated until a unit or section is finished, which means that the work shall cease only at natural stopping points of complete sub-sections.

g) The tolerance of the lining thickness in gunning method shall be ±5 mm.

h) Sections of the lining below their minimum thickness shall be cut out entirely and replaced. At no stage shall additional material be placed over previously applied material to build up the required thickness.

i) Where trimming will be necessary it shall be done by edge cutting with a trowel; surface smoothing by trowel shall be avoided.

j) Only qualified personnel thoroughly familiar and experienced with pneumatic application of refractory concrete shall be employed for this work.

k) Make certain all gunning equipment is in first class condition and has been thoroughly cleaned before gunning operations.

l) Gun nozzles shall be suitable for handling the refractory material being applied, and spare nozzles or repair parts shall be on hand for immediate use. Hose lengths between gunning machine and equipment being lined shall be as short as possible. Excessive length of hose is more vulnerable to plugging and more material is lost in cleaning.

m) All tools, mixing equipment, and water storage vessels shall be kept clean and free from contaminating materials such as Portland cement, lime, sodium silicate, and the like, before starting the gunning operation. Contamination will affect setting and strength.

n) Refractory materials shall not be applied in freezing or excessively hot weather unless precautions are taken to maintain refractory, steel, and mixing equipment at as close to an ambient temperature of 15°C as possible during mixing, application, and for a minimum of 24 hours thereafter. No admixtures of any kind, nor live steam, shall be used for this purpose.

o) The specified thickness of lining shall not be obtained by building up the material, nor shall a thickness less than specified be applied and allowed to set (see IPS-E-TP-350).

p) If possible, gunning should be continued until completion of full thickness being applied. When it is necessary to discontinue gunning at an intermediate point for more than 20 minutes, the insulating layer of a dual lining or a monolithic lining shall be cut back immediately to the steel wall with a steel trowel. This cut shall be made at a right angle to the steel wall, this cut back shall be at locations where the full thickness has been applied, all materials beyond the cut shall be discarded. Before gunning is resumed each of these terminated sections must be thoroughly cleaned and wetted in order to damp out any suction.

q) Failure to carry out this latter operation may cause lack of adhesion, cracking, or a powdery surface.

r) Material gunned with either too much or too little water shall be immediately removed, and the area regunned.

s) Rebound material or material which has been removed from plugged gunning machines or hoses shall be discarded and under no circumstances re-used. Rebound material shall not be permitted to accumulate at any point where lining has already been applied. Rebound material which has accumulated in areas to be lined shall be completely removed prior to lining application.

17.4 Curing and Drying

17.4.1 During the curing period the lining shall be kept cool in order to avoid cracking or damage thereof. This can best be accomplished by using a water spray which shall be applied as soon as the surface of the lining is hard enough to permit spraying without washing out the cement.

17.4.2 An indication that spraying can start should normally be obtained when the cement will no longer stick to a wet hand placed lightly on the concrete surface. In hot and dry weather it may be found necessary to start spraying two or three hours after the concrete has been placed. The water spray shall merely consist of a fine mist; a water stream should be avoided.

17.4.3 The horizontal parts of the lining should normally be covered with wet cloths or jute sacks.

17.4.4 Once the water spraying has been started it shall be continued, preferably without interruption, for at least 24 hours. If curing is done in an ambient temperature below 15°C, curing time in excess of 24 hours is required. At no time during the curing period shall the intervals between water spraying be more than 30 minutes.

Note:

A liquid membrane forming compound may be applied as an alternative to curing of the lining by water spray, where local experience has shown this to give good results. The compound shall be applied within 30 min. after the installation of the lining on to the whole of its exposed surface in sufficient thickness to prevent evaporation of water from the lining. The color of the compound shall contrast with the lining to facilitate full coverage.

17.4.5 After curing, the concrete shall be permitted to dry under atmospheric conditions as long as possible, but not less than 24 hours.

17.4.6 After this drying period the insulating refractory concrete shall be inspected and any cracks 1.5 mm wide or more shall be repaired.

17.4.7 When equipment with newly installed linings is put into service (started up), the temperature in the equipment shall be increased gradually to expel excess moisture slowly.

The following heating schedule may serve as a guide:

17.4.7.1 Raise the temperature slowly to 300°C (measured at the flue duct) at a rate of not more than 15°C per hour, and maintain this temperature for about 24 hours. Thereafter raise the temperature to 500°C in not less than 12 hours. Continue to heat to furnace operating temperature at a rate of approx. 50°C per hour.

This heating schedule should be adapted as necessary to provide a compromise if two or more different refractory materials have to be heated up simultaneously.

17.4.7.2 The heating schedule applied shall be registered by temperature recorders in conjunction with the installed thermocouples.

17.5 Transportation

Refractory-lined equipment include piping shall not transported until at least 24 hours after the curing operation has been completed.

Rigging shall be such that flexure and distortion are prevented in order to avoid damage to the lining.

17.6 Installation

For pipes 620 mm and above, weld seams or joints requiring welding after application of lining, leave a 76 mm to 84 mm unlined section each side of seam. After welding and inspection of weld, thoroughly clean the steel shell, apply refractory lining according to 17.3.

17.7 Repair of Lining

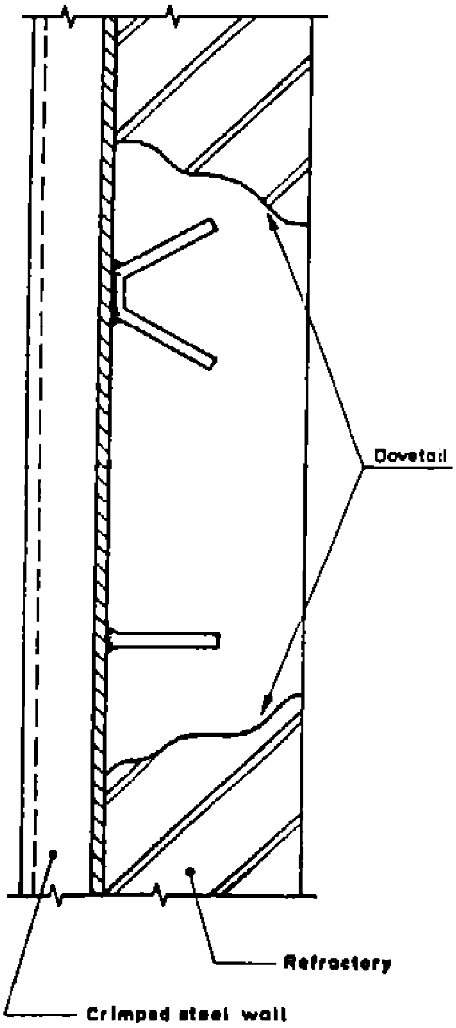
17.7.1 If the lining has to be repaired, the concrete at the damaged area shall be entirely removed down to the steel wall in such a way that a dovetail is obtained, see Fig. 14. Where needed, additional cleats or V-studs should be applied.

17.7.2 Before installing the new lining to a repair area, the area shall be cleaned by blowing with an air hose to remove all loose particles.

17.7.3 The newly exposed concrete surface shall then be thoroughly wetted and lining material of the composition as originally used shall be applied.

17.7.4 Normal curing and drying are again required.

17.7.5 Any voids or dry filled spaces will produce a dull sound. Such spots shall be chiseled out completely to vessel steel wall, and laterally to sound refractory material. The minimum area removed shall be sufficient to expose at least three sluds. The sides of the cut shall be tapered back towards the equipment wall forming a keyed hole to form a stronger patch.



REPAIR OF REFRACTORY
Fig. 14

17.8 Inspection and Test Methods

17.8.1 Prior to refractory lining application, prepare and test the samples in accordance with 17.8.2.

Mixing and application of field application shall not proceed until samples are satisfactory.

After application of lining inspect the part in accordance with 17.8.3.

17.8.2 Pre-application tests (test sample)

17.8.2.1 Sample mixtures shall be made of the refractory to be tested in strict accordance with the applicable refractory specification before proceeding to mix and apply for field installation. Three samples shall be prepared.

17.8.2.2 The sample mix shall be water cured or membrane cured with applicable specification for 114 mm × 114 mm × 65 mm sample.

17.8.2.3 Mixing and application for field installation shall not proceed until samples are satisfactory.

17.8.2.4 Any change in materials or materials supplied from different manufacturer and change in water source shall require new sample mixture testing.

17.8.2.5 Samples shall be prepared in accordance with ASTM C268 and compression tested in accordance with ASTM C93.

17.8.3 Inspection of lined substance

Following initial curing but before drying, test refractory lining by striking with a ball peen machinist's hammer at about 30 cm intervals over the entire surface.

18. SAFETY

18.1 Handling and Applying Lining Material

Organic lining materials should be stored in safe, well ventilated areas where sparks, flames, and the direct rays of the sun can be avoided. Containers should be kept tightly sealed until ready for use. Warning tags should be placed on toxic materials.

Mixing presents many problems. Recommended safety rules for mixing operations include the following:

18.1.1 Use protective gloves.

18.1.2 Keep the face and head away from the mixing container.

18.1.3 Use protective face cream.

18.1.4 Avoid splash and spillage, and inhalation of vapors.

18.1.5 Use eye-protection goggles.

18.1.6 Mix all materials in well-ventilated areas away from sparks and flames.

18.1.7 Use low speed mechanical mixers whenever possible.

18.1.8 Clean up spillage immediately.

18.1.9 Check the temperature limitations of materials being mixed.

Many materials are dangerous at high temperatures.

Protective devices and equipment required for application of lining materials are determined by the type of lining as well as by the environment. The lining manufacturers should provide complete mixing and application instructions, including definite references to safety requirements. Unless definite information regarding explosion and toxicity hazards inherent in the material are provided by the manufacturer, a written request for such data should be made before starting the lining application. Records of previous applications using similar materials should be examined also.

Protective face cream is recommended for all spraying operations. Goggles should be worn wherever possible.

18.2 Health Hazards of Materials

A lining material may be considered a health hazard when its properties are such that it can either directly or indirectly cause injury or incapacitation, either temporary or permanent, from exposure by contact, inhalation, or ingestion.

Degrees of health hazard are ranked according to the probable severity of injury or incapacitation, as follows:

18.2.1 Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment were given. Types of these materials are:

18.2.1.1 Materials which can penetrate ordinary rubber protective clothing.

18.2.1.2 Materials which under normal conditions or under fire conditions give off gases which are extremely toxic or corrosive through inhalation or through contact with or absorption through the skin.

18.2.2 Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment were given. Types of these materials are:

18.2.2.1 Materials giving off highly toxic combustion products.

18.2.2.2 Materials corrosive to living tissue or toxic by skin absorption.

18.2.3 Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical attention is given. Types of these material are:

18.2.3.1 Materials giving off toxic combustion products.

18.2.3.2 Materials giving off highly irritating combustion products.

18.2.3.3 Materials which under either normal conditions or fire conditions give off toxic vapors lacking warning properties.

18.2.4 Materials which on exposure can cause irritation but only minor residual injury even if no treatment is given. Types of these material are:

18.2.4.1 Material which under fire conditions give off irritating combustion products.

18.2.4.2 Materials which cause irritation to the skin without destruction of tissue.

18.2.5 Material which on exposure of fire conditions offer no hazard beyond that of ordinary combustible material.

18.3 Flammability Hazards of Material

A lining material may be considered a flammability hazard when it will burn under normal conditions.

Degrees of hazard are ranked according to the susceptibility of materials to burning, as follows:

18.3.1 Materials which will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature; which are readily dispersed in air; and which will burn. Types of these materials are:

18.3.1.1 Any liquid which is liquid under pressure and having a vapor pressure greater than 1 atmosphere at 38°C.

18.3.1.2 Materials which may form explosive mixtures with air and which are readily dispersed in air, such as mists of flammable or combustible liquid droplets.

18.3.2 Materials that can be ignited under almost all ambient temperature conditions. These materials produce hazardous atmospheres with air under all ambient temperatures and are readily ignited. Types of these materials are:

18.3.2.1 Materials having a flash point of 38°C (100°F) or below and having a vapor pressure not greater than 1 atmosphere (14.7 psia) at 38°C (100°F).

18.3.2.2 Materials which ignite spontaneously when exposed to air.

18.3.3 Materials that must be moderately heated or exposed to relatively high ambient temperature before ignition can occur. Materials of this type are those having a flash point above 38°C (100°F) but not greater than 93°C (200°F).

18.3.4 Materials that must be preheated before ignition can occur. These materials are those that will support combustion for five minutes or less at 815°C (1500°F).

18.3.5 Incombustible materials.

18.4 Toxicity of Materials (see Tables 8 and 9)

18.4.1 Virtually all solvent solution linings are highly flammable in liquid form, and vapors released in the process of application are explosive in nature if concentrated in sufficient volume in closed or restricted areas. Even vapors from ordinary enamels and oil paints may be accumulated in such density as to result in explosive reaction if a source of ignition is present. Generally speaking, however, solvents used in solvent solution coatings are more volatile and dangerous than those used in conventional paints or linings.

18.4.2 A wide variety of solvents are used in the formulation of many linings now available. These include, but are not limited to, the ketone group which includes such solvents as acetone, Methyl Ethyl Ketone (MEK), Methyl Isobutyl Ketone (MIBK), Ethyl Amyl Ketone (EAK), cyclohexane, and others; the hydrocarbons group of toluol, toluene, xylol, xylene, and others. In many instances the ketones act as the solvents which hold the resins in solution; the hydrocarbons are used primarily as diluents to control the viscosity or flow qualities of the lining. Most linings have a combination of solvents from each group. The epoxy and synthetic rubber linings use mostly solvents of the hydrocarbons group although ketones may be used in limited quantities.

18.4.3 All of these solvents are highly flammable and should be handled with the greatest of care.

Solvents, as well as other components of many modern solution linings, present other hazards which must be guarded against at all times. Solvents of all groups are toxic to varying degrees and may cause serious effects to those working with them unless appropriate precautions are taken. Excessive breathing of concentrated solvent vapors may cause dizziness or nausea, excessive drying or irritation of the mucous membranes, and, in rare cases, allergic reactions on the skin.

18.4.4 The epoxides used in epoxy linings and compounds are particularly irritating to the skin, and some persons are seriously affected by allergic reactions if proper hygiene is not practiced while these materials are in use. Common reactions include swelling around the eyes or lips, rashes of the skin, etc. Some epoxy linings have polyamides as curing agents that react much like a mild acid on tender mucous membranes.

18.4.5 Mist and spray of lead based paints may be dangerous if these vapors are inhaled. These minute particles of lead may cause lead poisoning if exposure is not avoided. Good personal hygiene is necessary to control ingestion of lead from contamination by cigarettes or food.

18.4.6 The following basic safety precautions should govern the use of all linings:

18.4.6.1 Always provide adequate ventilation.

18.4.6.2 Guard against fire, flames, and sparks, and do not smoke while working.

18.4.6.3 Avoid breathing of vapors or spray mist.

18.4.6.4 Use protective skin cream and other protective equipment.

18.4.6.5 Practice good personal hygiene.

TABLE 8 - THRESHOLD LIMIT VALUES FOR COMMONLY-USED SOLVENTS

SOLVENT	MAC[1)]	FLASH POINT DEG °C[2)]
Acetone	1000	-17.8
Benzene	25	-11.1
n-Butanol	100	28.9
Butyl Cellosolve	50	60
Carbon Tetrachloride[3)]	10	None
Cyclohexane	400	-17.2
Ethylene Dichloride	100	13.3
Ethanol	1000	12.8
Gasoline	500	7.2
Methanol	200	11.1
Naptha, Coal Tar	200	37.8-43
Naptha, Petroleum	500	<-17.3
Perchloroethylene	200	None
Isopropanol	400	11.7
Stoddard Solvent	500	37.8-43
Toluene	200	4.4
Trichloroethylene	100	None
Turpentine	100	35
Xylene	200	17.2

1) Maximum allowance concentration of vapor in air (or hygienic standard) in parts per million by volume for breathing during continuing eight hour working day. These figures should be used as guides for evaluating exposures, and are subject to change when better information is available. (American Conference of Governmental Hygienists).

2) TAG closed-cup tester: From "Flammable Liquids and Gases," National Fire Codes, Vol. 1.

3) Because of cumulative health hazard, use of this cleaning solvent is not recommended.

TABLE 9 - THRESHOLD LIMIT VALUES FOR FUMES, MISTS, DUSTS

HAZARD		MAC[1)]
Lead		0.2
Dust (no free Silica)		50.0
Silica:		
High, above	50% free SiO_2	5.0
Medium,	5-50% free SiO_2	20.0
Low, below	5% free SiO_2	50.0
Total Dusts below	5% free SiO_2	50.0
Chromic Acids and Chromates as CrO_3		0.1

1) Maximum allowable concentration (or hygienic standards), milligrams per cubic meter of air for breathing during continuing eight hour working day.

19. LINING CONTINUITY AND TESTS

19.1 Discontinuity Definitions

19.1.1 A lining discontinuity is any point or area at which a lining film does not cover or hide the substrate of the lining film and which usually will be penetrated by the exposure medium.

19.1.2 Holidays, skips and misses are gross discontinuities caused by faulty workmanship. By common usage in the industrial lining field, the term "holidays" has become synonymous with discontinuities.

19.1.3 Pores, voids, fish-eyes, pits, and pinholes are names of various types of small cavities or holes in a lining film, all of which are discontinuities which usually will be penetrated by the exposure medium. These are commonly acknowledged to be caused by (a) application short-comings, (b) imperfections of the substrate surface, (c) a contaminant in the lining film, (d) a contaminant on the substrate, (e) too rapid release of solvents or products of reaction such as water, or (f) a short coming of the film forming properties of the lining material.

Blisters are faults of the lining film caused by too rapid release of solvents or products of reaction or entrapped air. Blisters often will occur after the applied lining has been exposed to high temperatures. Blisters may or may not become discontinuities, as defined above.

19.1.4 All discontinuities or latent discontinuities (those which may develop later during service) are to be avoided.

19.2 Descriptive Terminology

The degrees of continuity are termed as Conditions "A", "B" and "C".

19.2.1 Condition "A" - pinhole free

The applied lining film shall be absolutely continuous.

19.2.2 Condition "B" - relatively pinhole free

The applied film shall contain only a negligible number of points of minor discontinuity. No more than two points of discontinuity should occur within an area having a radius of 15 cm as measured from a point of discontinuity (pinhole). No gross discontinuity (larger than pin point size) shall be allowed.

19.2.3 Condition "C" - commercially continuous

The applied film should contain only a minor number of points of discontinuity. No more than two points of discontinuity shall occur within an area having a radius of 15 cm as measured from a point of discontinuity (pinhole). No more than 40% of the total number of allowable points of discontinuity shall occur within any one area equal to 25% of the total area being lined.

19.2.4 Total allowable number of discontinuity points for all specified thicknesses of linings in all three conditions defined above are given in Table 10.

TABLE 10 - TOTAL NUMBER OF ALLOWABLE POINTS OF DISCONTINUITY

SURFACE AREA BEING LINED sq.m	COND. "A" PINHOLE FREE	COND. "B" RELATIVELY PINHOLE FREE	COND. "C" COMMERCIALLY CONTINUOUS
0.9	0	1	5
0.9 - 4.5	0	2	10
4.5 - 9	0	5	20
9 - 45	0	10	30
45 - 90	0	15	50
90 - 450	0	25	75

19.3 Allowable Discontinuities Related

Unless specified otherwise by the Company the degree of continuity of the linings shall be condition A.

19.4 Use of Continuity Tests

19.4.1 The ideal time to test a lining film for continuity is at that time during application when most of the solvents and reaction products have been released from the film but before the film has acquired a degree of cure that will hinder proper correction of any faults that may be located during inspection. With high bake cured lining, the most practical time for performing tests would appear to be just before the final bake or just before application of the last coat. However, testing just before the final bake adds to the cost because another heating and drying operation is necessary to harden the lining film to allow for traffic contact (walking on the surface by the inspectors). Whether made before the final bake or before application of the last coat, testing will not always assure that the lining film quality will remain the same after the final bake has been completed.

19.4.2 Most chemically converted linings are more readily touched-up than are high bake cured lining and thus can be tested after completion of the cure. Some, however, develop such a high degree of chemical resistance that proper adhesion of the touch-up lining to the cured film can not be achieved.

19.4.3 Wet or damp sponge continuity tests shall not be used without having determined that the lining will not be detrimentally affected by water at that stage of the application (see 19.5.2).

The tests and instruments used for continuity testing have definite limitations for quantitative or qualitative determinations as to the number of pinholes existent (see 19.3). In addition, time exposure in service, and abuse of the lining may later expose pinholes or other lining deficiencies. (see 19.3).

19.5 Continuity Testing Equipment

19.5.1 General

The approach to continuity testing is to consider the lining as an electrical insulator and search for holes by trying to make electrical contact to the substrate through the lining. There are two main methods of searching:

19.5.1.1 Wet sponge testing which consists of a wet sponge soaked in an electrolyte as one probe of a low-voltage circuit, the other being the earth return.

19.5.1.2 Spark testing in which a discharge from a high-frequency source or a direct current spark is used to find the fault.

19.5.2 Wet sponge testing

19.5.2.1 The instruments used for this type of testing are quite simple. Normally there are two circuits powered by low-voltage batteries. The primary circuit carries two probes, one of which is connected to the metal substrate. The second is connected to a sponge that is soaked in a 3% solution of electrolyte to which a small amount of a wetting agent has been added. The sponge is passed over the lining. If the lining contains a pinhole or some other form of discontinuity, the electrolyte penetrates the defect to the metal substrate, current flows in the primary circuit which triggers the secondary circuit and the alarm operates.

19.5.2.2 The sensitivity of this type of instrument depends upon the resistance below which current can be detected in the primary circuit. The voltage at which the instrument operates is not an important factor. The resistivity of 3% sodium chloride solution (a commonly used electrolyte) is less than 100 Ω cm. the resistivity of tap water is about 1000 Ω cm. Therefore it is important that sponges are soaked in an electrolyte.

19.5.2.3 It is a simple matter to calculate the minimum diameter of hole that can be detected in a given thickness of lining for a specific sensitivity of instrument. If an instrument has a sensitivity of 10^6 Ω, current will be detected in the primary circuit if the resistance is less than 10^6 Ω. Taking the resistivity of the electrolyte as 100 Ω cm, then it will be possible to find a hole approximately 15 μm in diameter in a lining 200 μm thick.

19.5.2.4 If the instrument is of the right sensitivity, a hole 1 μm in diameter will be found providing that the hole fills with electrolyte. It is not possible with this type of instrument to find a hole that is so small as to be of no significance, because if the electrolyte can penetrate then so can a corrodant. In fact, with conditions of varying temperature and pressure in service, the working conditions can be more searching than the test. However, it is possible to produce an instrument that is too sensitive. For example, if the primary circuit of an instrument will operate up to a resistance of 500 MΩ, then it is possible to demonstrate in humid conditions that if the operator using a probe touches the metal substrate, he will trigger the alarm. Furthermore, if a defect is found, unless all traces of moisture are removed from the surrounding lining, then sufficient current will track and the instrument will indicate holes that are not present. In practice instruments with a sensitivity up to 1 MΩ have been found to be satisfactory.

19.5.2.5 Some instruments are available that give a varying signal according to resistance. This means that the signal has to be interpreted. It is preferable that the instrument responds on a "go" or "no go" basis.

19.5.2.6 The sensitivity of the test instrument will be declared by the Company. There has been evidence in the past that similar models of instrument vary considerably in sensitivity. Therefore, a certificate of performance should be available for individual instruments.

19.5.2.7 Instruments of the wet sponge type can be used for testing a wide range of linings but they are not considered suitable for use with some partially cured resin linings.

19.5.2.8 It should be remembered that before attempting to repair defects found by wet sponge testing it is necessary to remove traces of electrolyte and dry the lining.

19.6 Spark Testing

19.6.1 General

There are two types of spark testing equipment in general use:

a) high frequently with an a.c. source;
b) direct current (high voltage).

The mode of operation of the two types is quite different.

19.6.1.1 High-frequency test equipment

In these instruments a Tesla coil is used to generate a high-frequency discharge. Models are available that operate on supply voltages of 240 V, 110 V or 50 V. The voltages at which they discharge can be varied between 5000 V and 50000 V. Normally output is controlled but the actual output cannot be recorded on a meter. However, it is possible to measure the voltage for any set position of the control by the method laid down in BS 358, namely measuring the gap the spark will jump between 20 mm diameter spheres. The voltage of the discharge does vary but the peak voltage for any setting of the instrument will not be exceeded.

The instruments have a single electrode. When the electrode is held on or close to the lined surface, there is a corona discharge. When a fault is present, the discharge concentrates at that point and the fault is readily identified. It is possible to survey a large area very quickly with quite a small probe. When linings are being examined it is possible, for ease of operating, to use an extended probe so that a band for example 150 mm wide, can be examined in one sweep. Tests have shown that the risk of damage by high-frequency spark testing is remote if the time the probe is allowed to dwell on any one place is short. Breakdown of a lining by spark testing is by erosion until a critical thickness is reached. During the time that the surface of a lining is exposed to a spark in test conditions the material lost by spark erosion is negligible. The only time the critical thickness of a lining is likely to be reached is when there is a bubble in the lining and that bubble has a thin skin. Such imperfections are undesirable.

19.6.2 Direct current spark testers

This type of instrument may be powered by mains or a rechargeable battery. The output voltage varies with the make but a common range is 1000 V to 20000 V. Most instruments do have a voltage control and a built-in voltmeter and this is the model recommended for use. In the case of models operating from a battery the operator should check frequently that full output voltage is available. Batteries need recharging at frequent intervals.

With d.c. instruments it is necessary to have an earth return. Unlike the high frequency instrument there is only a discharge when the electrode is close enough to a defect for the d.c. spark to bridge the gap to earth. When contact is made, the spark can be seen but most instruments of this type incorporate an audio signal. The energy of the spark from a d.c. instrument is greater than that from a high-frequency instrument and it is possible for defects to be enlarged by the action of the spark.

19.6.3 Testing

Whichever type of instrument is selected for continuity testing, it is absolutely essential that the whole of the lining is surveyed. The spark from a high-frequency tester ionizes the air and the spark from such a source will jump a much larger gap than is the case with d.c. sparks. It is particularly important that electrodes used with d.c. instruments conform to the surface contour otherwise defects may be missed. It may be difficult to meet this requirement when using very wide probes. It is essential that inspectors have an understanding of how the instruments work and the need to survey the linings in a controlled fashion.

Because of the need to ensure that continuity testing is carried out to the required standard, it is preferable that the test work is done by a person other than the operator(s) who applied the lining.

19.6.4 For more information about electrical inspection see NACE RP 0274-74.

Note:

For detection continuity of liquid or sheet lining applied to concrete substrates see ASTM D4787-88 and NACE 6F 166.

APPENDICES

APPENDIX A
APPLICATION OF RUBBER SHEET LINING IN PIPE

A.1 All surfaces to be lined shall be prepared in accordance with IPS-E-TP-350, "lining" Clause 10.

A.2 Cementing

A.2.1 Apply one coat of primer as soon as possible after blasting to prevent oxidation. Apply additional coats of primer, intermediate, or tie adhesives as specified by the manufacturer.

A.2.2 Allow sufficient drying time between coats so the coat being applied does not lift up the preceding coat.

A.3 Lining Application

A.3.1 Flat sheet

Whenever calendered or extruded flat sheet lining is supplied, the tube should be formed by using longitudinal skived butt splice(s). The spliced tube's outside circumference should be slightly smaller than the inside circumference of the pipe to be lined.

A.3.2 Extruded tube

Whenever unvulcanized extruded seamless elastomer tubes are supplied, the tubes should have a slightly smaller outside circumference than the inside circumference of the pipe to be lined.

A.3.3 Bleeder strings

Apply twisted multifilament string or yarn lengthwise in two to four locations, to allow for proper gas venting between lining and pipe.

Note:

Use of bleeder strings is optional with applicator.

A.3.4 Enclose the tube in a fabric liner and attach a tow rope. Pull tube into pipe with a slow constant pull.

Note:

The fabric liner facilitates the positioning of the tube in the pipe and prevents premature bonding.

A.3.5 Tube inflation

A.3.5.1 Small and medium diameter pipe

Remove fabric liner and expand elastomer tube against the pipe wall by using pressurized air. A mechanical extension and flange arrangement may be used for the pipe ends so that a minimum of 10 psig internal pressure can be maintained in the expanded tube for at least 5 min.

(to be continued)

APPENDIX A (continued)

A.3.5.2 Large diameter pipe

Pipe too large to feasibly line by inflating a tube and large enough to allow personnel to enter should be rubber lined in the same manner as tanks or duct work. "Bleeder strings" may be used, at applicator's option, to facilitate the escape of gases during cure.

A.3.6 Remove extension and flare excess stock over flange face and trim flush.

A.3.7 Apply a covering to full face of flange. Skive inside diameter of flange stock to slightly less than the inside diameter of lining and stitch firmly to tube stock. On larger sized pipe, the flange stock may be lapped into the pipe lining instead of the skive used on smaller pipe. Rubber shall be removed from bolt holes after cure by means of a knife, reamer, or other suitable tool.

A.3.8 Curing

Cure rubber lined pipe as specified by rubber lining manufacturer.

A.3.9 Inspection and testing

Lining inspection and spark test in accordance with Clause 6. Special equipment is usually required so spark tester can reach all areas inside long lengths of pipe.

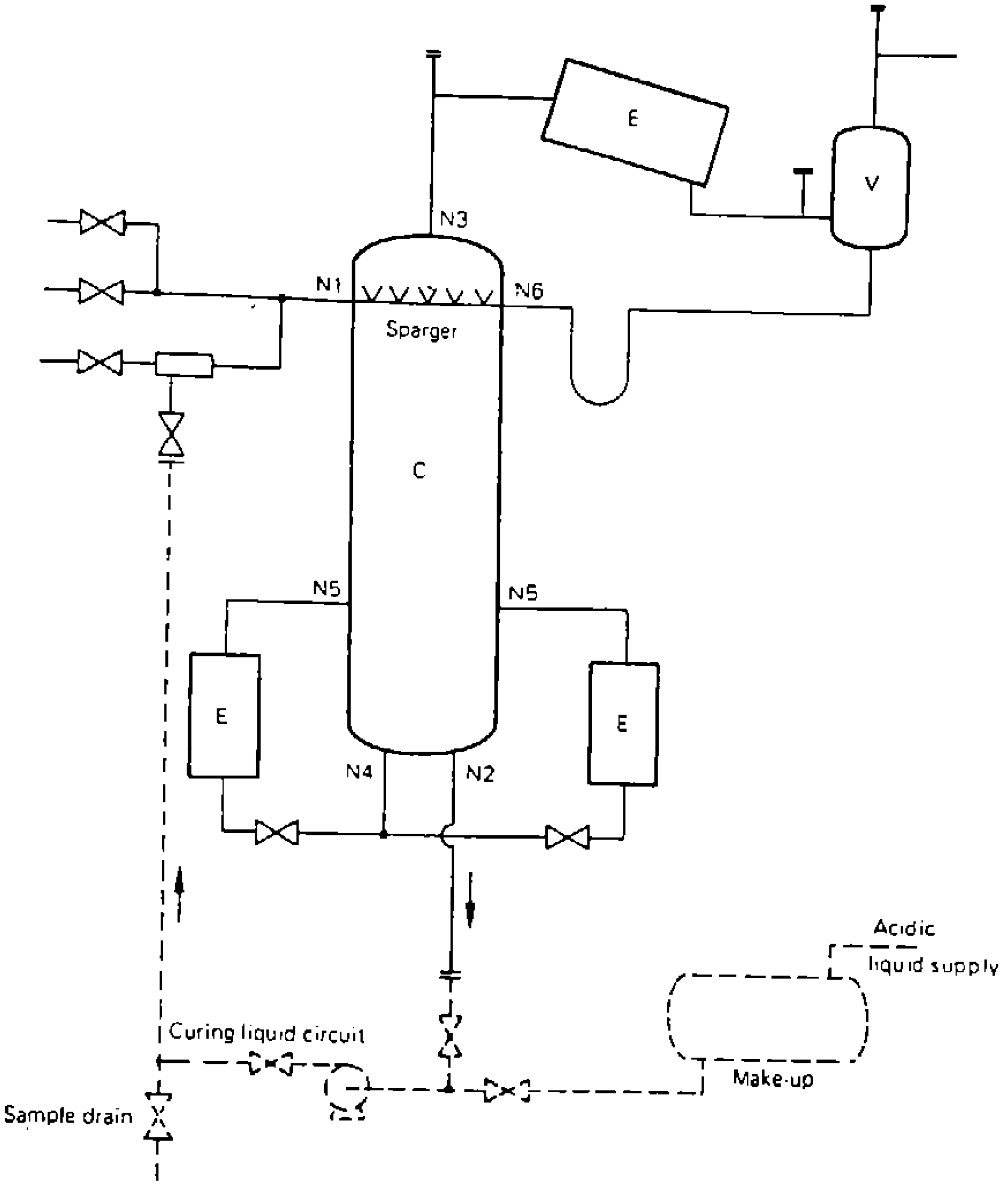
A.3.10 Identification and protection

Identify each piece by stamping on a ground area so numbers will remain visible as follows: "Rubber Lined-Do Not Cut or Weld".

Protect lining on flange faces during shipment or storage by covering with plywood or other suitable material.

APPENDIX B
CURING OF BRICK LINING WITH ACIDIC LIQUID

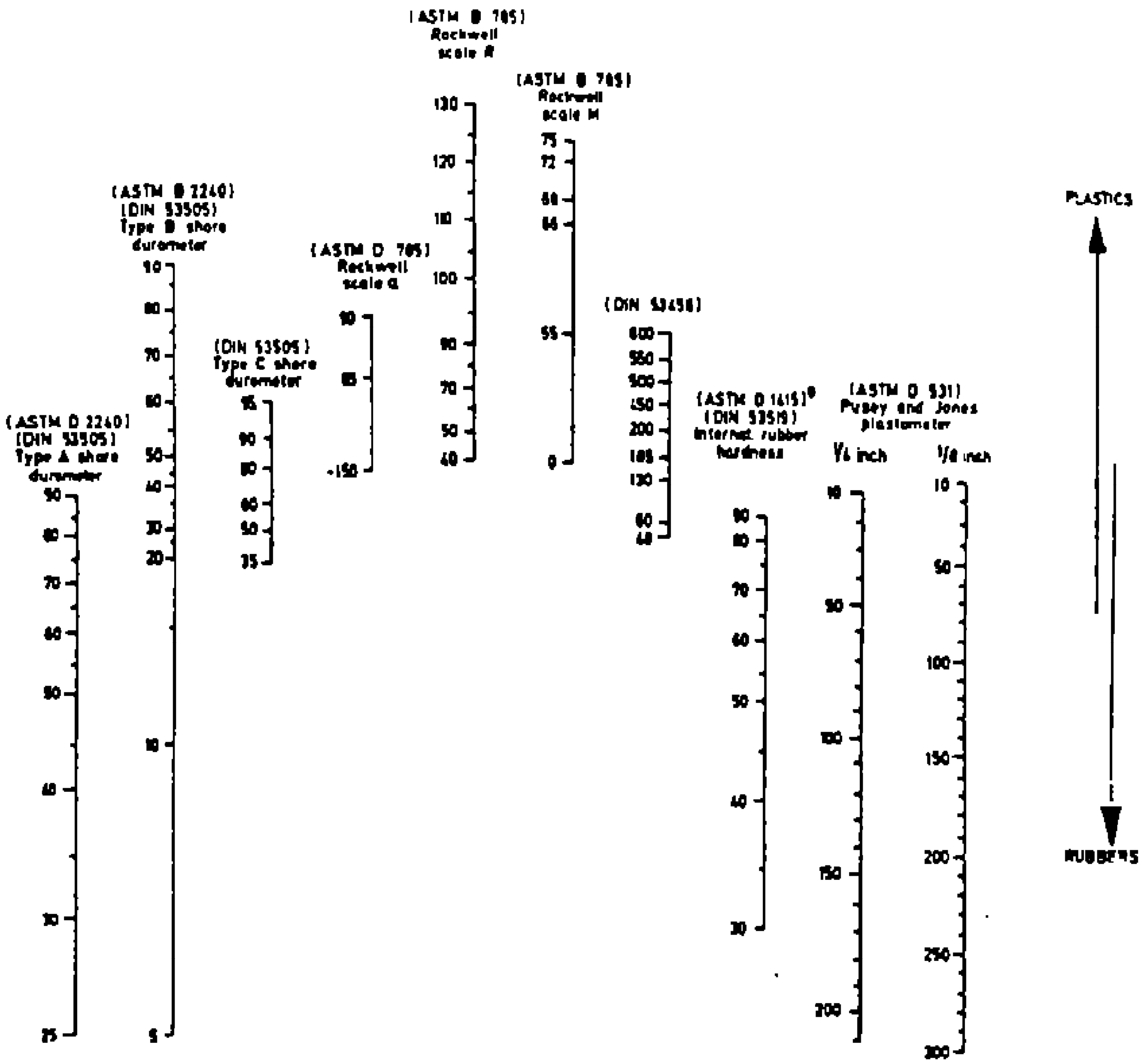
Typical Example for Curing the Brick Lining Installed in a Column



Note:

The circulation of the acidic liquid to the steam sparger is maintained by a pump. Heat is supplied as steam to the sparger. The acidic liquid is prepared at ambient temperature in a separate vessel (not shown).
To spray the acidic liquid against the equipment wall a spray pipe is installed in nozzle N1.

APPENDIX C
HARDNESS COMPARISON CHART



Comparable to BS 903: Part A26.

Note:

Equivalent hardness readings lie on the same horizontal line.
The hardness comparison is not accurate.
An indication of the hardness of plastics is also given.

APPENDIX D
CURING OF TANK LINING

D.1 General

D.1.1 Intent of this Appendix is to give heating equipment requirements, methods and control equipment to obtain drying and curing of tank lining materials.

This Appendix is limited to interior tank lining of the dispersion or solvent solution type (i.e. backing, chemically converted and air dried) where resistance to immersion is the primary factor.

D.1.2 Only three basic types of lining materials are considered.

The first type is air dried materials (vinyl's, vinyl copolymers, vinylidene chloride, etc.), the second type is chemically converted materials (catalyzed epoxies, catalyzed phenolics, catalyzed furanes and combinations of these), and the third is baking type materials (high baked phenolics, phenolic epoxies and urethanes).

All three of these types of materials must be heated before they are placed in service to insure optimum chemical and permeation resistance. Only the extent and degree of heating varies with each type.

D.2 Reasons for Heating Lining Materials

D.2.1 The basic reasons for heating each of the three types of lining materials discussed here are given below for each type:

D.2.2 Air Dried Type

To remove volatile solvent (or vehicle in case of emulsions) from lining to insure optimum film density and to increase chemical and permeation resistance. Also to remove solvent or vehicle from the vessel so that curing process can proceed, to prevent solvent wash and to decrease or eliminate residual odor.

D.2.3 Chemically converted type

To remove volatile solvent and products of polymerization from lining and tank and to accelerate and assure complete polymerization or cure, to obtain maximum chemical and permeation resistance.

D.2.4 Baking type

To remove volatile solvent and products of polymerization from lining and tank and to accomplish polymerization or cure to obtain chemical and permeation resistance.

D.2.5 In each case, one reason for heating is to remove volatile solvent or water not only from the lining but also from the vessel. Unless removed from the tank during the heating process, a portion of the solvent or water will be re-absorbed into the lining material and the heating process will have been all but wasted. Severe examples of this are called solvent wash, a redilution of the lining material especially prevalent with thermo-plastic materials.

D.2.6 Therefore, when heating is mentioned in this report, a type of heating is meant which utilizes a high volume of air circulation over the surface of the film and maximum air change in the tank itself.

(to be continued)

APPENDIX D (continued)

D.3 Heating Equipment

D.3.1 Many types of heating units are available capable of giving a high volume 1.4 to 3.76 m^3/s (3000 to 8000 cfm) of hot air. They fall into one of four categories: gas fired, oil fired, steam or electric.

D.3.2 Each of these categories can be subdivided into direct or indirect fired. To prevent intercoat contamination as well as surface dirt and possible degradation of lining film, indirect fired (eliminating products of combustion) heating is preferred. Indirect fired is appreciably less efficient. The sizable heat loss usually prohibits indirect fire for higher temperature bakes (above 120°C or above even 66°C in large vessels). When direct fired units must be used, considerable effort should be made to provide as clean heating air as possible. Direct fired oil heaters are dirty compared to most direct fired gas heaters. Sources of gas vary as to combustion products, and the gas-air combustion mixture must be adjusted carefully for cleanest flame.

D.3.3 For heating to a metal temperature of 82 to 93°C (as in the force drying or force curing of air dried or chemically converted lining materials and some between coat drying of high baked materials) a high volume, low temperature rise, indirect fired unit normally is preferred. Steam operated units generally are adequate; however, gas or oil fired units can be used effectively. Steam, gas or oil fired units are preferred in the field or on large tanks; the electric as well as the gas and oil fired for oven type cures (when heating or baking of the applied lining is accomplished by placing the entire tank in a high volume, hot air oven).

D.4 Method of Heating

D.4.1 There are no definitive rules as to a precise method of heating. Each heating project must be engineered beforehand to determine three points:

D.4.1.1 What the metal temperature must be and how long it should be held to accomplish removal of solvent or water from the film.

D.4.1.2 What the metal temperature must be and how long it should be held to complete polymerization in the case of the chemically converted or baking type materials.

D.4.1.3 The amount of air circulation required or frequency of air change required to remove the solvent or moisture from the tank.

D.4.2 After these three points are established, it is necessary to determine what equipment will be required, where to place it, how to obtain a uniform distribution of heat and air circulation over the surface of the lining, how to obtain a uniform metal temperature with no hot or cold spots and whether or not insulation is necessary or how much and of what type.

D.4.3 Influencing each of these is the "capacity" of each lining material to take heat. This capacity must be determined from the volatility and boiling point of each solvent or blend of solvents in the material. This allows the time-temperature scale to be determined for the coating system. Excessive heat or rate of heat application can result in solvent entrapment or entrapment of polymerization products with resultant blistering or boiling of the finished film. Often this blistering or boiling is not readily observable but causes a marked increase in permeability of the film and is thus detrimental to proper performance.

D.4.4 The following factors are significant in determining the method of heating, equipment to be used and time-temperature rates to achieve proper cure:

D.4.4.1 Tank location (inside a building as opposed to exposed to the weather).

D.4.4.2 Tank supports (steel saddles or on sand base) and the amount of heat that will thus be lost.

(to be continued)

APPENDIX D (continued)

D.4.4.3 Atmospheric conditions (hot or cold, still air or moving air).

D.4.4.4 Tank dimensions.

D.4.4.5 Tank construction (internal baffles that might interfere with circulation and various metal masses in the same tank).

D.4.4.6 Hazardous conditions (explosive fumes in area).

D.4.4.7 Whether tank is insulated already and type used.

D.4.4.8 Accessibility for blowers and heaters.

D.4.4.9 Filter losses in dirty atmosphere.

D.4.5 The problem of designing a permanent, large capacity oven for minimum temperature variation throughout is great. Complications arise when it is necessary to have a large volume of air movement or air change coupled with the necessity of having to accomplish this without knowing specifically the size of the piece or pieces to be heated and without knowing the mass of metal involved.

D.4.6 The design problem is great for an oven when the type and degree of insulation can be specified and fixed and when it is possible to use necessary ducting, baffles, outlets and fans to circulate the heated air as well as for removing the cooler air. Design problems are even greater when it is necessary to heat a mass of metal such as a tank by introducing the heated air through a restricted and fixed number of openings without the help of internal baffles, ducting and fans.

D.4.7 There is little or no correlation between air temperature and metal temperature during the heating of a tank because primary concern for proper curing is the minimum lining temperature. For all practical purposes, the exterior metal temperature and the minimum lining temperature are identical. Therefore, when a temperature is mentioned in connection with the curing of a lining material, it should be in reference to metal temperature alone.

D.4.8 In addition to the minimum lining or metal temperature, concern also must be given to a maximum metal temperature. Over-heating can be as detrimental as under-heating or under-curing. Over-heating of air dried and some chemically converted coatings are difficult to detect by physical inspection. The baking type coatings, short of charring, are less sensitive and certainly have many more failures from under-bake than from over-bake. Unfortunately, this temperature range between the maximum and minimum limits often is small.

D.4.9 An effort was made to develop an empirical formula for computing heater capacities required to obtain varying metal temperatures in various size tanks, but the task has been abandoned because of the many uncontrollable variables that prevent correlation between test results and field experience.

D.4.10 The factors necessary to complete proper curing of linings are based primarily on knowledge and skills derived from experience. The factors include proper calory capacity, proper heater design, method, type and degree of insulation required, ways and means of setting up ducting and curing time. These still must be considered an art rather than a science and are found principally with those few organization specializing in the application of the three types of tank lining materials discussed in this report.

D.5 Temperature Controls

D.5.1 The controls required to assure that the necessary minimum metal temperature is obtained and that the maximum temperature is not exceeded at any given spot in the tank consist mainly of surface temperature measuring devices such as controller-pyrometers on the heater, surface contact pyrometers, surface thermometers, temperature indicating crayons and thermocouples connected to direct reading potentiometers.

(to be continued)

APPENDIX D (continued)

D.5.2 Recorders in connection with these instruments would be advantageous. Physical proof would be available after completion of the heating cycle to show that maximum temperatures were not exceeded and that minimum temperature was obtained and held for the specified period. However these records would be of little value because they would record the temperature of a few isolated points rather than the entire surface. The use of recorders, therefore, would increase the coat of the applied lining. Such recorders would be another expensive piece of equipment that would have to be amortized against each tank lining project without giving much benefit.

D.5.3 The only value of surface temperature measuring devices is to assist the applicator performing the heating or curing operation in determining when minimum temperatures are obtained and when an area is approaching the maximum temperature permissible. As these readings are obtained, he must take whatever action his skill indicates is necessary. He must know, by experience, where the critical areas are in any given tank (where the greatest heat loss will be, thus the area with the lowest temperature, or where the hot spots will be). He must check these areas constantly during the entire heating operation. Insufficient attention to this phase of the operation or a mistake in judgment could cause complete failure, requiring the applicator to remove the lining and start over again.

D.6 Testing and Inspection

D.6.1 Determining whether or not the cure or force dry has been accomplished on an applied lining material by test methods is almost impossible. Therefore, considerable emphasis must be placed on proper engineering of the heating operations and on the controls used during the heating process. Spasmodic work is being done to develop hardness test standards for the three types of materials, but to date there has been no success reported.

D.6.2 Three simple tests are outlined below that can be made during final inspection of a lining to determine whether or not the material is free of solvent, cured and ready for service.

D.6.3 Air dried lining materials

If the air dried type lining has been properly heated with high volume hot air for sufficient time, there should be little or no solvent odor in the case of solvent based materials. There should be no excessive humidity in the case of water base materials.

D.6.4 Chemically converted materials

If the chemically converted lining has been heated properly at a high enough temperature and with sufficient air volume for the proper length of time, the lining should be polymerized completely with little or no solvent odor present. The lining material should be hard and solid.

If the lining has been sufficiently cured, a solvent soaked rag rubbed on the surface should not soften the lining or remove any coloring. However, this test is meaningless because many films pass this test only to be proved severely under-cured later in service. More conclusive indication can be obtained by rubbing the lining with fine sandpaper. If the lining is properly cured, the sandpaper should not gum up. This test, however, is far from being foolproof.

D.6.5 Baking type materials

If the baking type lining has been properly heated for the correct period of time, it should be polymerized completely with little or no solvent odor present. In most cases, a change in appearance or color occurs although this may be only minor and difficult to observe.

Some applicators have successfully used prepared color comparison strips for each phase of the color change that occurs during the curing of this type lining. A good indication can be obtained by comparing the lining being cured with the appropriate strip. With experience, this technique can become a valuable guide.