ENGINEERING STANDARD

FOR

PROTECTIVE COATINGS

FOR

BURIED AND SUBMERGED

STEEL STRUCTURES

CONTENTS :

PAGE No.

0. INTRODUCTION

The main task of protective coatings is to prevent or control external corrosion of buried or submerged steel structures. The coating isolates metal from contact with surrounding environments. Since a perfect coating cannot be assured, cathodic protection is used in conjunction with the coating system to provide the first line of defense against corrosion. And since a properly selected and applied coating should provide 99% of the protection required, it is of utmost importance to know the advantages and disadvantages of available coatings. The right coating material properly used will make all other aspects of corrosion control relatively easy. The number of coating systems available necessitates careful analysis of the many desired properties for an effective pipe coating.

Therefore optimum selection and proper application of protective coatings is of engineering importance. During extended period of time a protective coating deteriorates as a result of contact with moisture, oxygen, chemicals fluctuating temperatures, abrasion, pressure and many other possible factors proper and timely maintenance is required to get the optimum performance from a protective coating.

Meanwhile, selection and application of maintenance coating is more complicated than for initial construction.

Climatic conditions, chemical exposure, available time, budget, health and safety, grade of surface preparation have serious influence on the planning of optimum design coating. To select the best coating system to fit the environment or soil condition. Knowledge of operating and installation conditions is the beginning of the process. Steel source and job location may limit the coatings available to each project. Selection of a quality applicator is the most important consideration and frequently is the most neglected. Following coating and applicator selection, inspection at the coating mill and especially on the job site during construction will go far in assuring that a high quality pipe coating system has been installed.

1. SCOPE

1.1 This Engineering Standard covers the minimum requirements for the design and selection of coating systems for external protection of pipes, storage tanks and piling systems to be buried or submerged in water.

1.2 The contents of this Standard define the essential requirements for surface preparation, selection of coating systems and repair of coating defects.

1.3 The standard is intended for corrosion protection of steel structures of oil and gas and petrochemical industries including refineries, chemical and petrochemical plants, gas plants, oil exploration and production units.

1.4 It does not cover pipelines requiring thermal insulation and casing protection.

1.5 Coating of stainless steel, galvanized steel and non-ferrous alloys under external corrosive condition is subject to approval of company design engineer.

1.6 In addition, the internal protection of piping systems for water supply and internal protection of water or chemical storage-tanks are excluded from this standard, and the reference is made to IPS-E-TP-350.

1.7 This Engineering Standard does not supersede cathodic protection application for piping systems and steel structures at burial or submersible conditions.

1.8 Detailed instructions for applying a specific coating are not included , since they are furnished by IPS-C-TP-274.

1.9 Although this Engineering Standard shall submit proper guidelines for selection of proper materials, but decisions on coatings shall not be left to the casual attention of inexperienced personnel.

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.

AS (AUSTRALIAN STANDARD)

AS 1518	"Extruden High-Density Polyethylene Protective Coating for Pipes"
AS 2043	"Coal Tar and Synthetic (Fast Dry) Primers for Steel Pipes"
AS 2046	"Code of Practice for the Coating and Lining of Steel Pipes with Coal Tar Primer/Enamel Systems"
AS 2518	"Fusion-Bonded Low-Density Polyethylene Coating for Pipes and Fittings"

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

D 5	"Test Method for Penetration of Bituminous Materials"
D 427	"Test Method for Shrinkage Factors of Soils"
D 785	"Test Method for Rockwell Hardness of Plastic and Electrical Insulating"
D 2240	"Test Method for Rubber Property-Durometer Hardness"
G 8	"Test Method for Cathodic Disbonding of Pipeline Coatings"
G 13	"Test Method for Impact Resistance of Pipeline Coating (Limestone Prob Test)"
G 19	"Test Method for Disbonding Characteristics of Pipeline Coating by Direct Soil Burial"

AWWA (AMERICAN WATER WORKS ASSOCIATION)

AWWA C205	"Cement-Mortar Protective Lining and Coating for Steel Water Pipe 4 Inch and Larger-Shop Applied"
AWWA C213	"Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines"
AWWA C215	"Extruded Polyolefin Coatings for the Exterior of Steel Water Pipelines"

DIN (DEUTSCHES INSTITUTE FÜR NORMUNG)

DIN 30670	"Polyethylene Sheathing of Steel Tubes and Steel Shapes and Fittings"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-TP-350	"Lining"
IPS-E-TP-820	"Electrochemical Protection (Cathodic & Anodic)"
IPS-C-TP-101	"Surface Preparation"
IPS-C-TP-274	"Protective Coatings"
IPS-G-TP-335	"Three Layer Polyethylene Coating Systems"
IPS-M-TP-105	"Bitumen Mastic"
IPS-M-TP-275	"Fast Drying Synthetic Primer"
IPS-M-TP-280	"Coal Tar Primer (Cold Applied)"
IPS-M-TP-285	"Bitumen Primer (Cold Applied)"
IPS-M-TP-290	"Coal Tar Enamel (Hot Applied)"
IPS-M-TP-295	"Bitumen Enamel (Hot Applied)"
IPS-M-TP-300	"Glass Fiber Matt For Inner Wrap"
IPS-M-TP-305	"Coal Tar Impregnated Glass Fiber Matte for Outer Wrap"
IPS-M-TP-306	"Bitumen Impregnated Glass Fiber Matte for Outer Wrap"
IPS-M-TP-310	"Cold Applied Laminated Plastic Tape for Inner Layer"
IPS-M-TP-311	"Cold Applied Laminated Plastic Tape for Outer Layer"
IPS-M-TP-313	"Hand Applied Laminated Tape Suitable for Cold Applied Coating Systems"
IPS-M-TP-314	"Hand Applied Laminated Suitable for Hot Applied Coating Systems"
IPS-M-TP-315	"Perforated Plastic Tape Over Wrap for Rockshield"
IPS-M-TP-316	"Plastic Grid for Rockshield (Sheet)"
IPS-M-TP-317	"Petrolatum Impregnated Tape & Its Primer"
IPS-M-TP-318	"Wrap & Heat Shrinkable Sleeve"
IPS-M-TP-321	"Primer for Use with Cold Applied Plastic Tape"
IPS-M-TP-322	"Primer for Use with Hand Applied Laminated Tape Suitable for Cold Applied Coating Systems"
IPS-M-TP-323	"Primer for Use with Hand Applied Laminated Tape Suitable"

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO 3233/BS 3900 Part A10	"Paint and Varnishes-Determination of Volume of Dry Coating (Non Volatile Matter) Obtained from a Given Volume of Liquid Coating"

SIS (SWEDISH STANDARD)

SIS 05 5900	"Pictorial Surface Preparation Standards for Painting Steel Surfaces"

3. DEFINITIONS AND TERMINOLOGY

For the purposes of this Standard the following definitions apply:

Adhesive

A substance capable of holding materials together by surface attachment.

Bitumen

A very viscous liquid or solid, consisting of hydrocarbons and their derivatives, which is soluble in carbon disulphide or trichloroethylene. It is substantially non-volatile and softens gradually when heated. It is black or brown in color and possesses waterproofing and adhesive properties. It is obtained by refinery processes from petroleum.

Cathodic protection

A technique to reduce the corrosion rate of a metal surface by making it a cathode of an electrochemical cell.

Consolidate soil

When a soil is subjected to an increase in pressure due to loading at the ground surface, a re-adjustment in the soil structure occurs. The volume of space between the soil particles decreases and the soil tends so settle or consolidate over time.

Coal tar epoxy coating

Coating in which binder or vehicle is a combination of coal tar with epoxy resin.

Corrosion protection

Corrosion protection is the separation of the metallic material from the attacking medium by paint or coating.

Disbondment

The loss of the bond between a coating and the surface coated.

Enamel

The enamel is composed of a specially processed coal tar pitch or bitumen combined with an inert mineral filler.

Engineer

The person, firm, or employee representing the purchaser for adequacy of design and quality assurance.

Environment

The circumstances, acts, or conditions to which a steel pipeline is subjected.

Epoxy resin

Cross-linking resins based on the reactivity of the epoxide group. One common type is the resin made from epichlorhydrin and bisphenol A. Aliphatic polyols such as glycerol may be used instead of the aromatic bisphenol A or bisphenol F.

Hot applied

Of such a consistency at ambient temperature that heating is required before application.

Inert filler

Finely divided mineral powder or inorganic fiber which is not substantially hygroscopic, not electrically conducting and does not react with other ingredients of the coating material or with the environment in which it will be used.

Immersed

Is defined as permanent immersion such as submerged structures, offshore drilling rigs, etc.

Ionic transport

Corrosion of a metal is an electrochemical reaction between the metal and its environment, which results in wastage of metal. Thus corrosion is a combination of chemical effect of transported ions of corrosive environment to the metal surface with an associated of electrical energy (corrosion current).

Top coat (finish)

The paint intended to be the last coat applied in a coating system; usually applied over a primer, or intermediate coat.

4. UNITS

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

5. FIELD OF APPLICATION

This Engineering Standard deals generally with the following structures to be coated and mainly with buried and submerged steel pipes.

5.1 Types of Pipes to be Coated

The types of pipe to which this Standard is applicable, include both welded and seamless pipes of non-alloy steel used for the conveyance of gas and fluids.

5.2 Types of Fittings to be Coated

The types of fittings to which this Standard is applicable are mainly Bends, Tees Reducers and Collars.

5.3 Valves and Insulating Joints

The standard is applicable to all buried valves and insulating joints.

5.4 Storage Tanks

Any storage tanks which shall be externally coated and to be buried underground or submerged in water.

In all cases the storage tank shall considered as a pipe which is closed at both ends, requiring external protective coating at overall surfaces.

6. THE NEED FOR STANDARD

Many materials passes the basic properties required for control of corrosion, but only a limited numbers meet the overall needs for protection of buried, submerged or over ground steel structures against, corrosion.

7. PURPOSE OF COATING

Coatings prevent corrosion of buried and submerged structures ways, as follows:

a) They inhibit corrosion by providing an adhesive film with a high resistance to ionic transport.
b) They reduce the current requirements for cathodic protection by providing an electrically insulating film.
c) They assist in the uniform distribution of cathodic protection current.

Although high costs are involved with the initial coating procedure, the application of coatings will lead to a considerable reduction in cathodic protection power consumption.

Coatings are considered to be an integral part of any cathodic protection system. In most situations, coatings provide the main thrust of any corrosion protection system, with cathodic protection providing back-up corrosion protection of the structure at points where failure of the coating, or damage to the coating, has occurred.

Note:

In compact structures, many combinations of coating systems are used. In-situ repairability should be a significant factor in the selection of the coating system.

8. COATINGS AND CATHODIC PROTECTION (see also IPS-E-TP-820)

8.1 Influence of Coatings on Cathodic Protection Current Requirements

Although it is technically possible to protect bare (buried or immersed) steel structures and pipelines by applying cathodic protection only, it is seldom desirable to do so because of the cost of providing the large current required and, often the difficulty of arranging anodes so as to give, a uniform current distribution. A good coating of high insulating value greatly reduces the current required to maintain the steel at the required steel-to-soil potential and also provides a more uniform spread of current from the anodes. A protective coating should therefore always be applied to any buried and immersed structure or pipeline which is to be cathodically protected.

8.2 Influence of Cathodic Protection on Coatings

8.2.1 The current required to protect a structure or pipeline is approximately proportional to the area of bare steel (see Table 1). Theoretically, therefore, cathodic protection should be unnecessary when the steelwork is perfectly coated. In practice, coatings are often damaged in transport or during laying, or may contain imperfections such as pinholes. Even in low-corrosivity soils the slightest discontinuity in the protective coating may result in severe local corrosion, so that when corrosive conditions exist even coated structures or pipelines shall be given cathodic protection.

8.2.2 Pipeline coatings of bitumen, coal tar or epoxy coal tar type are never much affected by properly applied cathodic protection. However, a potential more negative than -2.0 V with reference to a copper/copper sulphate electrode may damage the coating by causing hydrogen evolution on the steel surface.

8.2.3 Cathodic protection of painted or metal sprayed and painted structures should be considered carefully because oil-based paints may be saponified by the alkalinity developing at the cathodically protected surface; sprayed aluminum or zinc may be attacked in a similar way. The surface potential shall therefore be maintained as closely as possible to the value needed for protection, and over-protection avoided.

8.2.4 Recommended ’off ’- potential limits for underground coatings (to Cu/$CuSO_4$ half-cell) are:

Epoxy powder fusion-bonded	- 1.5 V	Epoxy coal tar (not included in this Standard)	- 1.5 V
Hot applied enamel (coal tar and bitumen)	- 2.0 V	Polyethylene (2 layers)	- 1.0 V
Plastic tape	- 1.5 V	Polyethylene (3 layers)	

9. COATING DESIGN

9.1 Desirable Characteristics of a Coating

9.1.1 Effective electrical insulator

Since soil and salt corrosion is an electrochemical process, a pipe coating has to stop the current by isolating the structure from the environment.

9.1.2 Ease of application

The coating material must be suitable and properly applied to be effective. Many excellent pipe coatings require exacting application procedures that are difficult to maintain. Consistent quality may be obtained with a coating system that is least affected by variables. Coating application specifications and good construction practice combined with proper inspection contribute to the quality of the finished coating system.

9.1.3 Applicable to piping with a minimum of defects

This characteristic correlates with ease of application. No coating is perfect, and that is why cathodic protection is required.

9.1.4 Adhesion to metal surface

Coating adhesion is important to eliminate water migration between the metal substrate and the pipe coating. The coating adhesion assures permanence and ability to withstand handling during installation without losing effectiveness.

9.1.5 Resist development of holidays

Once the coating is buried, two areas that may destroy or degrade coatings are soil stress and environmental contaminants. Soil stress, brought about in certain soils that are alternately wet and dry, creates tremendous forces that may split or cause thin areas. Adhesion, cohesion, and tensile strength are important properties to evaluate in order to minimize this problem. The coating’s resistance to chemicals, hydrocarbons, and acidic or alkaline conditions has to be known in order to evaluate performance in known contaminated soils.

9.1.6 Handling, storage and installation

The ability of a coating to withstand damage is a function of its impact, abrasion, and ductile properties. Pipe coatings are subjected to a great deal of handling from application to backfill. While precautionary measures of proper handling, shipping, and stockpiling are recommended, coatings vary in their ability to resist damage. Outside storage requires resistance to ultraviolet rays and temperature changes. These properties must be evaluated to assure proper performance.

9.1.7 Constant electrical resistivity

Since corrosion is an electrochemical reaction, a coating with a high electrical resistance over the life of the system is important. The percentage of initial resistance drop is not as indicative of the pipe coating quality as the overall level of electrical resistivity.

9.1.8 Resistant to disbonding

Since most pipelines are eventually cathodically protected, it is necessary for the coating to withstand cathodic disbondment. The amount of cathodic protection is directly proportional to the quality and integrity of the coating. Considering interference and stray current problems, this becomes a most important requirement. Cathodic protection does two things. First, it drives water through a coating that would ordinarily resist penetration. It also may produce hydrogen at the metal surface where current reaches it, and the hydrogen breaks the bond between the coating and melt surface. No coating is completely resistant to damage by cathodic protection, but it is very important to choose a coating that minimizes these effects. The ASTM G8 test for cathodic disbonding of pipeline coatings, commonly known as the salt crack test, measured a coating’s resistance to damage by cathodic protection.

9.1.9 Ease of repair

Recognizing that some damage may occur and that the weld area must be field coated, compatible field materials are required to make repairs and complete the coating after welding. Manufacturers’ recommendations should be followed. Variables in conditions influence selection of materials.

All nine of these characteristics are important when evaluating the selection of a pipe coating.

The following factors should also be considered when selecting a pipe coating:

9.1.10 Type of soil or backfill

Soil conditions and backfill influence the coating system selected and thickness specified.

Soils are rated by their shrink-swell factor (soil stress). High shrink-swell soils can damage conventional coatings. Ideally, trenches should be free of projections and rocks, permitting the coating to bear on a smooth surface. When backfilling, rocks and debris should not strike the pipe coating. The following ASTM tests are recommended to measure resistance to penetration of the pipe coating if set on stones in the trench: ASTM D 785, "Method of Test for Rockwell Hardness of Plastics and Electrical Insulating Materials", ASTM D 5, "Method of Test for Penetration of Bituminous Materials", and ASTM D 2240, "Method of Test for Indention Hardness of Rubber and Plastics by Means of a Durometer".

The following ASTM tests are recommended to measure the resistance against damage by rock in back fill: ASTM G 13, "Limestone Drop Test" and ASTM G 19, "Falling Weight Test". Soil stresses on pipe coatings may be evaluated by ASTM D 427, "Method of Test for Shrinkage Factory of Soils".

9.1.11 Accessibility of pipeline

When a pipeline is inaccessible or in a marine environment, the best system should be selected with less emphasis on initial cost. Experience under similar conditions for at least five years or well-designed laboratory tests on new products are the best criteria for coating selection.

9.1.12 Operating temperature of piping

Surface temperature and environmental conditions must be considered, because, once buried, a coating experiences a wet heat condition, which is more detrimental than dry heat and harms coating effectiveness. A modified disbondment test, ASTM G 8 Cathodic Disbonding of Pipeline Coatings, determines resistance to elevated temperatures.

9.1.13 Ambient temperatures during construction and installation

Temperatures during construction and installation are often more critical than operating temperatures. For instance, some thermoplastic systems such as mastics, tapes, or enamels may become brittle in freezing temperatures (polyethylene coating systems, however, have been field bent at -40°C). Above recommended operating temperatures, thermoplastic systems may cold flow. Extra care in handling, transport and storage is needed under extreme conditions.

9.1.14 Geographical and physical location

Pipe source and coating plant location often determine the coating or are a cost factor in selection. Severe environments, such as river crossings, pipe inside casings, exceptionally corrosive soils, high soil stress areas and rocky conditions require special consideration. On large projects in remote areas, the economics may favor a railhead or field coating site.

9.1.15 Handling and storage of coated pipe

Handling, shipping and stockpiling are important in the selection process. Some coatings require special handling and padding. All require careful handling.

Most underground coatings are not designed for above ground use and are affected by excessive above-ground storage. Coal tar and asphalt enamel and mastic coatings are protected from ultraviolet deterioration by whitewash (see 12.1.2.5.1) or craft paper. In polyethylene, the addition of 2.5 percent carbon black is the most satisfactory deterrent. Stock should be rotated, first-in, first-out, to minimize the potential problem. Long-term storage requirements could determine coating selection.

9.1.16 Costs

Evaluation of pipe coating properties with the above considerations assists in selection. The most misunderstood factor is "costs". In pipe coating economics the end has to justify the means. The added cost of coatings and cathodic protection has to pay for itself through reduced operating costs and longer life. "True" protection costs include not only initial costs of coating and cathodic protection but also installation, joint coatings and repairs. Field engineering and facilities to correct possible damage to other underground facilities may add costs, possibly outweighing initial costs of the pipe coating.

9.1.17 Current Density Requirements

9.1.17.1 The current density required to protect a buried structure is depend on the type and performance of the coating used. Table 1 gives a minimum design value for new construction projects. The current density values in Table 1 are to be related to the total pipeline surface area and take into account coating deterioration during the refereed life of the pipeline.

It is assumed that pipeline construction is carried out in a manner to avoid coating damage during construction and operation.

TABLE 1 - DESIGN CURRENT DENSITIES FOR DIFFERENT PIPELINE COATINGS (OPERATING TEMPERATURE UP TO 30°C)

COATING TYPE	PIPELINE LIFE (YEARS)		
	0 - 5	5 - 15	15 - 30
	CURRENT DENSITY (mA/m²)		
Asphalt bitumen and coal tar, 6 mm Asphalt mastic	0.040	0.100	0.200
Fusion bonded epoxy Liquid epoxy Coal tar epoxy	0.010	0.020	0.05
Polyethylene Polypropylene	0.002	0.005	0.010
Plastic tape (laminated)	0.040	0.100	0.200

Note:

The current densities given in Table 1 already include the current requirements due to the expected coating breakdown during the pipeline life.

9.1.17.2 For protection of pipelines with elevated operating temperatures the minimum design current densities given in Table 1 shall be increased by 25% per 10°C rise in temperature above 30°C.

9.2 General Requirements

9.2.1 Some typical properties of known coating systems. Table 2 gives typical properties for coating.

TABLE 2 - TYPICAL PROPERTIES OF REPRESENTATIVE COATING SYSTEMS FOR COMPACT STRUCTURES

COATING SYSTEM*	COATING SITE	EASE OF ON-SITE APPLICATION	STRUCTURE PRETREAT-MENT (FOR STEEL)	COATING THICK-NESS mm	SUSCEPTIBILITY TO DAMAGE FROM		
					SOIL♣ STRESSES	CATHODIC DISBONDMENT	IMPACT
Coal tar enamel	Field (over-the-ditch) yard	Difficult	Wire brush or blast ϒ	3 to 6	Medium	Medium	Medium
Extruded polyethylene	Shop	—	Blast	2.5 to 3.5	Low	Low	Medium
Fusion bonded polyethylene	Shop	—	Blast	2.5 to 3.5	Low	Low	Low
Fusion bond epoxy	Site and shop	Difficult	Blast	0.35 to 0.45	Low	Low	Low
Asphalt enamel	Field and yard	Medium	Wire brush or blast ϒ	3 to 6	Medium	Medium	Medium
PVC, poly-ethylene backed laminated tape	Field	Easy	Wire brush or blast ϒ	1.5 to 3.0	High	Medium	High
Petrolatum tapes	Field	Easy highly conformable	Wire brush ϒ	3 to 6	High	Not applicable	Medium
Heat shrink sleeves	Field	Medium	Blast	1.0 to 3.0	Low	Medium	Medium
Coal tar epoxy	Field and yard	Medium	Blast	0.3 to 0.6	Low	Medium	Medium

*** Metalliferous primers should not be used in coating systems for structures requiring cathodic protection.**

♣ Properties resulting from soils which produce stresses, e.g. clay.

ϒ It is good practice to blast clean surfaces prior to coating application to ensure maximum adhesion. Wire brush pretreatment, which may leave millscale on a steel surface, may leave the structure in a condition susceptible to stress-corrosion cracking, and is inferior to blast-cleaned surfaces.

§ Used on site welded joints. Difficult to repair.

Note:

The properties tabulated above relate only to the basic standard coating for each system. Coating performance can vary substantially from these values, and is dependent on the characteristics of the actual system used.

10. COATING SCHEDULE

10.1 Type of Coatings

With reference to previous considerations only the following types of coatings is been selected for the purpose of this engineering standard. Among which the desired coating system(s) shall be selected in accordance with the following sections for a particular underground and/or submerged structures including offshore risers and piling systems.

10.1.1 Bitumenous coatings (see 12.1)

Bitumenous coatings include of coal tar and bitumen (asphalt) enamels which are applied in the molten state. These coatings are applied in field or in site.

10.1.2 Extruded polyethylene coatings (see 12.2)

There are two systems available, one is polyethylene sleeve shrunk over a hot applied asphalt mastic adhesive.

The first is a dual extrusion where an butyl adhesive is extruded onto the blast-cleaned pipe followed by multiple fused layers of polyethylene. The second is a three layers, includes multi-stage process where an epoxy powder primer is sprayed onto the hot blast-cleaned pipe followed by a fused copolymer adhesive and then by multiple fused layers of polyethylene. The latter utilizes multiple extruders in a proprietary method, which obtains maximum bond with minimum stress. These coatings are applied in factory.

10.1.3 Fusion bonded epoxy powder coatings (see 12.3)

Fusion bonded epoxy coatings are applied to preheated pipe surfaces of 204 to 260°C with or without primers. These coating shall be applied in factory.

10.1.4 Plastic tape (see 12.4)

Prefabricated, cold applied plastic tapes are normally applied as a three-layer system consisting of primer, corrosion preventive tape (inner layer), and a mechanical protective tape (outer layer).

These coating are generally applied in field.

10.1.5 Concrete coating (see 12.5)

Cement mortar coating are usually used for cast-iron pipes and for shielded areas where cathodic protection can not be used effectively. It is relatively expensive but results in a strong, long-lived coating for speciality applications.

Concrete coating are used as negative buoyancy and armour protection over ordinary coatings in marine environments.

For field joint coating (see 10.5.4).

10.2 Characteristics of Specified Coatings

Followings are the main characteristics of desired coatings special characteristics of these coatings are described in each individual sections.

The conventional coating to be used on a line pipe shall be determined regarding the following coating properties.

10.2.1 Bitumenous enamel (asphalt and coal tar)

a) Chemically inert.
b) Highly moisture resistant for coal tar but less for bitumen.
c) Very good electrical resistivity.
d) Brittle at low temperatures; sags at high temperatures.
e) Both yard and over the ditch coating possible.
f) Dangerous fumes result from necessary high application temperatures of coal tar.
g) Service temperature range from -10 to 70°C depending on type (see 12.1.4.2).

10.2.2 Extruded coatings

a) Good chemical resistance.
b) Low water absorption.
c) Extremely good electrical resistivity.
d) Flexible.
e) Plant application only.
f) Service temperature range from -40 to 80°C.

10.2.3 Fusion bonded epoxy

a) Extremely good chemical resistance.
b) Polyamide-catalyzed epoxies have better water resistance than amide or amine-adduct cured epoxy.
c) Extremely good electrical resistivity.
d) Flexible.
e) Plant application only.
f) High impact and abrasion strength.
g) Excellent adhesion to steel.
h) Electrical deposition method of application. Only sure prevention of pinholes and voids in coating.
i) Service temperature range from -70 to 120°C.

10.2.4 Plastic tape

a) Good chemical resistance.
b) Good electrical resistivity.
c) Both yard and over the ditch application possible.
d) Low impact and abrasion strength.
e) Subject to pressure deformation from rocky backfill, and damage during transportation from plant to field.
f) Poor resistance to aromatic hydrocarbons.
g) Service temperature range from -20 to 55°C depending on type.

10.3 Factors Affecting the Design of Pipeline Coating

Main factors influencing the design of pipeline coatings are as follows:

10.3.1 Diameter and length of pipe.

10.3.2 Service temperature of the pipe internal media.

10.3.3 Pressure and frequency of expansions contractions.

10.3.4 Soil resistivity, soil analysis and soil stress potential.

10.3.5 Statistical condition of pipeline route and right of way.

10.3.6 Availability of materials and cost.

10.3.7 Limitation of access to work.

10.3.8 Repair access and frequency of prospected repair.

10.3.9 Condition of manpower requirement at site.

10.3.10 Transport and handling of the pipe sections.

10.3.11 Availability of electricity beside the pipeline for permanent impressed current-cathodic protection installation.

10.3.12 Provision of access equipment.

10.3.13 Special safety and security regulation which limit the coating design.

10.3.14 Protection condition of adjacent pipeline.

10.4 Selection of Coating to be Used

10.4.1 The coating selected for a specific application ideally shall be that coating which will still have the lowest applied cost per meter of pipe and have the desirable characteristics of good electrical and mechanical strength and long term stability under the environmental conditions and cathodic protection. In order to select optimum coating system following factors shall be considered.

10.4.1.1 Function

a) What is the main function of the structure?
b) What are the second functions of the structure?

10.4.1.2 Life

a) For how long is it required to fulfill this function?
b) What is the life to first maintenance? (It may not be possible to decide this until further questions have been answered?)

10.4.1.3 Environments

a) What is the general environment at the site of the structure?
b) What localized effects exist or are to expected?
c) Is the structure buried or immersed?
d) Is the structure immersed in sea water or buried in sea bed?
e) Is sulfate reducing bacteria present?
f) Are other type of bacteria’s present?
g) Is existing of soil stress probable?
h) What other factors may affect the structure (e.g. surface temperature and abrasion, service temperature and fluctuation, service pressure and fluctuation)?

10.4.1.4 Special properties

What special properties are required of the coating (e.g. coefficient of friction)?

10.4.1.5 Health and safety

a) Are any problems to be taken into account during initial treatment?
b) Are any problems to be taken into account during maintenance treatment?

10.4.1.6 Tolerance

Does the coating need to be tolerant of:

a) Indifferent surface preparation.
b) Departures from specification.
c) Indifferent application techniques

10.4.1.7 Coating systems

a) What coating systems are suitable?
b) Are these systems readily available?
c) Are the system elements mutually compatible?
d) Which facilities shall be required?

10.4.1.8 Coating facilities

a) Are the coating facilities readily available:

- for factory application?
- for site application?
- for field application?

b) Do they cover all sizes and shapes of fabrication?
c) Do they permit speedy application?
d) Do the facilities permit work to adequate standards?

10.4.1.9 Compatibility with engineering and metallurgical features

a) Is the design and jointing of the structure compatible with the preferred coating technique?

b) Does surface preparation (blasting) or application of coating affect the mechanical properties of the steel in any way that matters?

c) Is the system compatible with cathodic protection?

10.4.1.10 Delays

What delays should be allowed between:

a) fabrication and first protective coating;
b) application of primer and coating;
c) application of coating and installation;
d) final coating and repair.

10.4.1.11 Transport, storage and handling

How well does the coating withstand:

a) excessive or careless handling;
b) abrasion and impact;
c) early stacking;
d) exposure to sea water during transit;
e) exposure to sun light?

10.4.1.12 Experience

a) What is known of the consistent performance of the coating?

10.4.1.13 Export/import

a) What special precautions should be taken when the steelwork is exported or imported?

10.4.1.14 Maintenance

a) Is the deterioration of the coating rapid and serious if maintenance is delayed?
b) What access is there going to be for effective maintenance?
c) What is the possibility of effective maintenance?

10.4.1.15 Costs

a) What are the approximate costs of:

1) the basic system;
2) any additional items;
3) transport;
4) access?

b) What are the approximate costs of maintenance?

10.4.1.16 Cathodic protection

a) Is there specific need for restricting cathodic protection current to absolute minimum? For example, locations where cathodic protection current sources can be installed may be limited and widely spaced necessitating the best practicable current distribution.

b) Is the electricity available beside the structure for impressed current cathodic protection systems to be installed?

c) Is there any restrictions for impressed current systems (e.g. lack of electricity, location, etc.).

d) Is there any restrictions regarding soil resistivity availability of galvanic anodes, etc.?

10.4.1.17 Access

Will all or part of the structure be installed where not readily accessible (such as river crossings, swampland installations, submarine locations and other similar situations)?

10.4.2 Each coating system considered shall be evaluated carefully in terms of the preceding items. All application and performance characteristics of each coating must be determined, particularly with respect to limitations beyond which good performance cannot be expected.

A relatively simple coating system may be fully adequate if, for instance, a pipeline is to be installed in a rock-free soil not subject so soil stress; if application and installation conditions are to be reasonably dry and not subject to extremes of temperature; if pipeline operating temperature is not to be appreciably above soil temperature; and if pipeline accessibility is reasonable with no unusual limitations on cathodic protection installations. Typically, a single layer standard pipeline enamel with felt wrapper or pipeline plastic tapes could do an excellent job.

On the other hand, a coating as mentioned above might not be satisfactory under adverse conditions. Under rocky conditions, a coating system that will resist impact damage and penetration by steady pressure should be specified. If soil stress is a problem, materials that will resist distortion and "plucking-off" under such conditions should be used. If ambient temperatures are extreme, materials that will not become embrittled and crack at low temperature should be used. If high temperatures are the problem, a material should be selected that will not soften and be easily damaged during handling. If the pipeline, once installed, will be essentially inaccessible for maintenance work, the best coating available may be essential.

The choice between the use of yard coated pipe and over-the-ditch coating procedures is largely economic. Factors involved include location of the coating plant with respect to the pipeline right-of-way (which will influence shipping costs and whether the pipeline project is large enough to justify the cost of using over-the-ditch coating equipment. The cost of over-the-ditch coating can vary considerably with the type of coating being used as some materials require more equipment and larger crews than others. With some coating materials, establishment of centrally-located "railhead" field coating plants may be justified on large Projects. In any event, the choice is best based on a cost analysis for the particular type of project being planned.

10.4.3 Coating selection criteria

In summing up this subject the following criteria shall be used in selecting the coating system as a minimum:

10.4.3.1 Resistance to deterioration when exposed to corrosive media.

10.4.3.2 High dielectric resistance.

10.4.3.3 Resistance to moisture transfer and penetration.

10.4.3.4 Applicable with a minimum of defects.

10.4.3.5 Resistant to bacteria, microbial growth and vegetable roats.

10.4.3.6 Good adhesion to metallic surfaces.

10.4.3.7 Resistance to mechanical damage during handling, storage, and installation.

10.4.3.8 Resistance to cathodic disbonding.

10.4.3.9 Ease of repair.

10.4.3.10 Retention of physical properties with time.

10.4.3.11 Conditions during shipping, storage construction, and installation.

10.4.3.12 State of the art in the application of coatings.

10.4.3.13 The level of inspection and quality control during coating application.

10.4.3.14 Cost and availability.

10.4.3.15 Service-proven experience.

10.4.3.16 Low water-absorption.

10.4.3.17 Compatibility with the type of cathodic protection to be applied to the system in case of submarine pipes.

10.4.3.18 Compatibility with the system operating temperature.

10.4.3.19 Sufficient ductility to minimize detrimental craching.

10.4.3.20 Resistance to future deterioration in submerged environment.

10.4.4 Field joint coatings

10.4.4.1 Coated pipe sections connected by welding and/or mechanical coupling by means of valves or other underground appurtenances will be considered field joints. Coating of field joints must be equal to or better than the coating on the pipeline and shall be compatible with main coating.

10.4.4.2 Where materials requiring primer are used, the primer may be hand applied in a uniform coat. Curing or drying time must be in accordance with manufacturer's specification.

10.4.4.3 Coating materials must be applied substantially free of voids, wrinkles, and air or gas entrapment. This may require the use of materials that will conform to the shape or irregular appurtenances, such as valves. Petrolatum tape coating (IPS-M-TP-317) shall be used for irregular shops such as bare valves and fittings when applicable.

10.4.4.4 A new coating must overlap and adhere to existing material. The overlap must be sufficient to allow for shrinkage of both new and existing coating (e.g. 10 cm on each side).

10.4.4.5 When hand applied tape (IPS-M-TP-314 or IPS-M-TP-313 as with which is compatible) is selected for field joints it shall be used with 50 percent overlap on its own.

10.4.4.6 Field joints coating systems selected shall be suitable for field application. It shall be fast and easily applicable and shall not require special attention for application and field storage.

10.4.4.7 Types of field joint coatings

With yard-applied coatings, the coating of many field joints has to be carefully selected and applied with sufficient overlap to ensure that the whole length of the pipeline is correctly protected. For the protection of the joint a variety of suitable joint coverings is available. The recommend systems are as in Table 3.

10.4.4.8 Bellow ground unburied valves shall be coated with asphalt mastic (IPS-M-TP-105) to a minimum thickness of 3.5 mm.

TABLE 3 - LIST OF PREFERRED MATERIALS FOR COATING WELDED JOINTS

<table>
<tr><th rowspan="2">TYPE</th><th colspan="2" rowspan="2">POSSIBLE COMBINATIONS OF DIFFERENT TYPES OF COATING EACH SIDE OF WELD</th><th colspan="2">CHOICE OF COATING</th></tr>
<tr><th>1st Choice</th><th>2nd Choice</th></tr>
<tr><td>A</td><td>Fusion bonded epoxy</td><td>Fusion bonded epoxy</td><td>Fusion bonded epoxy
(see IPS-G-TP-335)</td><td>Two component
liquid epoxy</td></tr>
<tr><td>B</td><td>Two-component
liquid epoxy (if any)</td><td>Two-component
liquid epoxy (if any)</td><td rowspan="2">Two-component liquid epoxy</td><td rowspan="5">Hand applied laminated tape with 50% overlap
(IPS-M-TP-314)
(First choice for types F and H)</td></tr>
<tr><td>C</td><td>Fusion bonded epoxy</td><td>Two-component
liquid epoxy (if any)</td></tr>
<tr><td>D</td><td>Coal tar or bitumen enamel</td><td>Two-component
liquid epoxy</td><td rowspan="3">Two-component liquid epoxy
Overlap sealed with hand applied laminated tape
(IPS-M-TP-314)</td></tr>
<tr><td>E</td><td>Coal tar or bitumen enamel</td><td>Two-component
liquid epoxy (if any)</td></tr>
<tr><td>F</td><td>Coal tar or bitumen enamel</td><td>Coal tar or bitumen enamel</td></tr>
<tr><td>G</td><td>Polyethylene plastic tape</td><td>Fusion bonded epoxy</td><td rowspan="4">Heat shrinkable tape
IPS-M-TP-318</td><td rowspan="4">Cold applied laminated tape with self-adhesive tape overwrap
IPS-M-TP-313</td></tr>
<tr><td>H</td><td>Coal tar or bitumen enamel</td><td>Polyethylene</td></tr>
<tr><td>I</td><td>Polyethylene</td><td>Multi-component liquid
(if any)</td></tr>
<tr><td>J</td><td>Polyethylene</td><td>Polyethylene</td></tr>
</table>

Notes:

1) Bare or painted pipe or fittings shall be coated with hand applied tape (IPS-M-TP-313) before the relevant butt joint coating is applied)

2) When the butt weld to be coated is on a pipeline that will operate at less than 30% SMYS (specified minimum yield strength) and less than 20°C, the use of joint coatings other than those detailed in this Table may be considered.

3) Polyethylen is referred to both 2 and 3 layers polyethylene coatings.

4) In case where the operation temperature of the pipeline is about 80°C then the special heat shrinkable tape with multi-component liquid epoxy primer shall be used. Materials specification shall be approved by company and the field application of materials shall be in accordance with manufacturer instructions.

11. COATING APPLICATION

11.1 The external coating shall be applied according to IPS-C-TP-274.

The procedure is normally to include:

- Handling and treatment of coating materials.
- Surface preparation.
- Temperatures, air humidity and time lags between steps in the coating process.
- Testing methods, with reference to IPS-C-TP-274.
- Acceptance criteria.
- Repair procedure following attachment of cathodic protection cables, padeyes. etc.
- Handling, transport of coated pipes.
- Quality control and inspection.
- Coating repair.
- Reporting procedure.

11.2 Status of Coating

The quality control reports shall include the followings:

- Acceptance criteria according to the coating specification.
- Surface preparation data.
- Temperature and humidity measurements.
- Number of coats and total dry film thickness.
- Adhesion data.
- Holiday detection.
- Information on the location of reinforcement in the coating.

A preproduction test is to be carried out at the coating yard in order to demonstrate that the coating can be adequately applied under the prevailing conditions.

11.3 Field Joint Coating

Field joint coating should be applied according to an approved procedure of similar nature as described in IPS-C-TP-274.

The field joint coating should be compatible with the pipe coating. (see 10.5.4).

11.4 Repair & Rejection

Criteria for acceptance, repair and rejection of coating before burial or submersion of pipe are to be stated. Repair methods for damaged coating under field conditions is described in IPS C-TP-274.

11.5 Surface Preparation

The steel surface to be coated shall, at the time of application of the coating, be dry and free from all contaminants (such as previous coatings, paint, loose dirt, grease, oil, salt, etc.) which could be harmful to the surface preparation or to the adhesion of the coating to the steel.

The surface of steel shall be prepared in accordance with IPS-C-TP-101. The prepared surface shall be Sa 2½ to SIS 055900 for all the coating systems specified in this Engineering Standard.

Note:

Surface preparation for coating of field joints and repair shall be in accordance with IPS-C-TP-274.

12. DESCRIPTION OF COATING SYSTEMS

12.1 Bitumenous Coatings

12.1.1 General

12.1.1.1 Enamels are formulated from coal tar pitches or petroleum asphalts hot applied (blown bitumen) and have been widely used as protective coatings for many years. Coal tar and asphalt enamels are available in various grades. These enamels are the corrosion coating, combined with glass wool to obtain mechanical strength for handling. These materials shall meet requirements of relevant IPS-M-TP-290 and 295 Enamel Coatings have been the workhorse coatings of the industry and provide efficient long life corrosion protection.

12.1.1.2 Bitumenous coating systems may be used within a service temperature range of -10 to 70°C (see 12.1.1.8). When temperatures fall below 4°C, precautions should be taken to prevent cracking and disbonding during field installation. Enamels are affected by ultraviolet rays and should be protected by craft paper or whitewash (see 12.1.2.5.1). Enamels also are affected by hydrocarbons. A barrier coat is recommended when contamination exists. This coating can be used on all sizes of pipe.

12.1.1.3 Enamel coatings are low-cost coatings whose protective properties depend on film thickness.

12.1.1.4 Enamel coatings have good resistance to dilute acids and alkalis, salt solutions and water, but are not resistant to vegetable oils, hydrocarbons and other solvents. They may become brittle in cold weather and soften in hot weather. Enamel coated articles shall not be stacked (see also Table 4).

12.1.1.5 Enamel coatings are not suitable for above ground structure and piping and shall only be used for underground and subsea structures and pipelines.

12.1.1.6 The coatings may be applied in a coating yard or over-the-ditch as appropriate by the job. The designer shall specify the method of application. Coating at a yard is likely to produce the best results, assuming that proper control is exercised and that subsequent transport, handling and joint coating are carried out with care.

12.1.1.7 The cost of materials for hot-applied coatings is usually relatively low, whereas the cost of application is relatively high.

12.1.1.8 These coatings should in general not be used for buried pipelines and structures if the operating temperature is above 60°C, or above 70°C in case of subsea pipeline unless special enamel coating is specified (see 12.1.4).

12.1.1.9 Enamel coatings are widely used for submarine pipelines alone or under the concrete weight coating. (enamel coating thickness shall be 6 mm minimum).

12.1.1.10 Bitumenous enamel glass fiber reinforced coatings shall be used for coating linepipes and networks buried in normal soil, except when the soil is contaminated with hydrocarbons or other solvents (see Table 4), or when the temperature of the pipeline contents exceeds 50°C when the pipeline is buried in consolidated fill.

12.1.1.11 Recently, coal tar enamel use for buried pipes and structures has declined for the following reasons:

- Reduced suppliers.
- Environmental and health hazard regulations.
- Increased acceptance of other coatings such as extruded polyethylene and fusion bonded epoxy coatings.

12.1.2 Description of bitumenous coating system

The bitumenous coating system consists of:

12.1.2.1 A cold applied primer coat which shall be selected in conjunction with the bitumen or coal tar derived coating material with which it shall be compatible.

Coal tar primer (IPS-M-TP-280) or bitumen primer (IPS-M-TP-285) shall be used with coal tar enamel or bitumen enamel respectively and is only suitable for site or yard application. Fast-drying synthetic primer (IPS-M-TP-275) can be used both with coat tar and bitumen enamel and is suitable for site application as well as for field or ditch application. The primer shall apply at the thickness specified by the manufacturer with reference to relevant IPS standard for each primer.

12.1.2.2 One or more coats of bitumenous coal tar enamel (IPS-M-TP-290) or bitumen enamel (IPS-M-TP-295) build up to form the thickness required for the type of protection. (see 12.1.2.7.2)*.

12.1.2.3 One or more reinforcements of glass fiber mat (IPS-M-TP-300) as inner wrap, embedded in each protective layer.

12.1.2.4 One protective layer of coal tar or bitumen saturated fiber glass mat (IPS-M-TP-305 or M-TP-306 with which it is compatible) as outer wrap.

12.1.2.5 One solar protective layer, in case of coal tar enamel, with following formula as white wash to prevent excessive heating of the coating by solar radiation:

12.1.2.5.1 White wash formula

All white wash to be used shall be mixed as follows:

- Ingredients

White wash ingredients shall include 190 liters water, 3.8 liters boiled linseed oil, 68 kg processed quicklime, and 4.5 kg salt.

- Mixture

Add salt to water, then add quicklime and linseed oil slowly and simultaneously, and mix thoroughly, allow mixture to stand for not less than three days before it is used.

12.1.2.6 In certain special cases (for example, nature of backfill, rocky area, environmental temperature or working temperature (about +50°C) an additional mechanical protections as rockshield (IPS-M-TP-316 or IPS-M-TP-315 as will be defined by the designer) under the concrete weigh coating and concrete slabs or rockshield may be specified by the designer with reference to the job requirements.

12.1.2.7 Type of coating system

Two types of coating system are generally specified for Bituminous coating as follows:

*** For each 4 mm enamel thickness only and layer of inner wrap shall be specified.**

12.1.2.7.1 Single coat system consists of:

- One coat of primer.
- One coat of Bituminous enamel.
- One wrap of glass fiber inner wrap.
- One wrap of glass fiber outer wrap.

12.1.2.7.2 Double coat system consists of:

- One coat of primer.
- One coat of Bituminous enamel.
- One wrap of glass fiber inner wrap.
- One coat of Bituminous enamel.
- One wrap of glass fiber outer wrap.

12.1.2.8 Single coat system usually used for field (over-the-ditch) coating application and double coat system for yard application.

12.1.3 Characteristic of coal tar and bitumen enamels

12.1.3.1 Table 4 gives a comparison of Bitumen Enamel (Asphalt) characteristics with coal tar Enamel.

TABLE 4 - COMPARISON OF BITUMEN ENAMEL (ASPHALT) CHARACTERISTICS WITH COAL TAR ENAMEL

USE OF RESISTANT COATINGS	COAL TAR ENAMEL (HOT APPLIED)	BITUMEN ENAMEL (HOT APPLIED)
Temperature resistance	Poor	Poor
Abrasion resistance	Fair	Fair
Bacteria & fungus resistance	Good	Poor
Chemical resistance	Good	Good
Hardness	Fair	Poor
Acid-oxidizing	NR	NR
Nonoxidizing	Good	Good
Organic	NR	NR
Alkali	Good	Good
Salts: Oxidizing	NR	NR
Nonoxidizing	Sea water OK	Sea water OK
Solvent: Aliphatic	NR	NR
Aromatic	NR	NR
Oxygenated	NR	NR
water:	Excellent	Good
Moisture permeability	Low	Fair
Petroleum products	Good	NR
Flexibility	Good	Good
Root penetration	Good	Poor
Soil resistance	Excellent	Excellent
Weather & Uv light resistant	NR	Good
Principal hazard-application	Coal tar fumes	

NR = Not Resistant

12.1.3.2 The hardness of the coal tar is better than asphalt enamel, but weatherability of the asphalt is better than the coal tar, however, proper asphalt enamel can be used for underground waterlines and gas pipelines, but coal tar for oil processing areas and oil and gas pipelines.

12.1.3.3 Despite of bitumen, coal tar enamel due to polynuclear carcinogen hydrocarbon compound is toxic to vegetable and sea animals therefore, it is good coating for pipelines in seabeds and forest environment and wooden right of way.

12.1.4 Temperature limitation (the application and service temperatures)

12.1.4.1 Application temperature

For application of enamel coatings by flooding or other means, the temperature of the coating material shall be such that the viscosity is controlled to give the thickness of coating required, and not so high as to cause excessive fuming. No grade of material should be heated above the maximum application temperature given in Table 5.

12.1.4.2 Service temperature

In general, materials of higher softening point or lower penetration are intended for use under higher temperature conditions coal tar service (operating) temperature requirements are achieved by modifying the combined materials with various plasticizers. Grade 105/15 or bitumen grade a at normal and lower than normal ambient temperatures in temperature climates.

Coal tar grade 105/8 and bitumen grade b are suitable at ambient temperatures in both low temperate and hotter climates coal tar grade 120/5 shall be designed for use at elevated service temperatures up to 70°C, or up to 115°C in the case of off-shore pipelines when an additional concrete antibuoyancy coating material is used. Under these conditions a degree of hardening will occur early in use. The manufacturer of the product should be consulted as to its suitability under particular conditions.

TABLE 5 - APPLICATION TEMPERATURE

GRADE OF COATING MATERIAL		MAXIMUM APPLICATION TEMPERATURE	SERVICE TEMPERATURE
COAL TAR	BITUMEN		
To IPS-M-TP-290	To IPS-M-TP-295	°C	°C
105/15	a	250	See Notes
105/8	b	250	"
120/5	c	260	"

Notes:

1) For service temperature-higher and lower than normal (0-35°C) only synthetic primer (IPS-M-TP-275) shall be used.

2) Bitumen enamel grade C can be used for service temperature zero to 60°C and coal tar enamel grade 120/5 can be used for service temperature zero to 80°C for buried structures or up to 115°C in the case of off-shore pipelines when an additional concrete weigh coating is used.

12.1.5 Application and inspection procedure

12.1.5.1 Surface preparation shall be by blast cleaning to SIS 05 5900 grade Sa 2½ proceeded by removal of surface contamination. The surface preparation shall be in accordance with IPS-C-TP-101.

12.1.5.2 The prepared surface shall be primed with appropriate primer (for field coating application only synthetic primers shall be used). The primer shall be applied at the rate recommended by the manufacturer, with reference to relevant IPS standard for specified primer, and shall be subject to his recommended maximum and minimum rates. It shall be allowed to dry to a uniform film free from bubbles and discontinuities.

12.1.5.3 The primed surface shall be enamel coated only within the time limits recommended by the manufacturer and shall be free from dust, moisture and other contaminants before flood coating.

12.1.5.4 The flood coating of enamel shall be applied in an approved machine, also equipped for spiral wrapping of the inner and outer wrap.

12.1.5.5 The first flood coat of enamel shall have the inner wrap pulled in so that it does not touch the surface of the steel pipe and is embedded in the middle 50% of the enamel thickness; the second flood coat shall have the outer wrap pulled on and securely bonded, without wrinkles, to the enamel. The two flood coats may be combined if approved by the Company. Each wrap shall overlap by not less than 25 mm (1 inch).

12.1.5.6 The enamel shall be applied at a temperature not exceeding that specified in 12.1.4. It shall be melted in a boiler fitted with mechanical agitators and shall be continuously stirred. All other aspects of enamel handling, melting and application shall be as specified in IPS-C-TP-274.

12.1.5.7 The coating shall terminate 250 mm (10 inch) or cut back 100 mm up to size DN 500 mm and 150 mm for sizes over DN 500 mm from each end of each length of pipe and be neatly trimmed to a 45° bevel.

12.1.5.8 The finished thickness of the coating shall average 5 mm (3/16 inch) with a minimum of 4 mm (5/32 inch) and a maximum of 6 mm (¼ inch). The minimum thickness over seam or spiral welds may be relaxed to 3 mm (1/8 inch) provided that the coating satisfies holiday detection requirements.

12.1.5.9 After inspection and repair of defects, the coating shall be covered with weather-resistant whitewash (12.1.2.5.1) or similar approved solar protection coating if the coating is applied at site.

12.1.5.10 Coated pipe shall be suitably marked to identify the grade of enamel employed.

12.1.5.11 For either field or yard application of coating the procedures outlined in 12.4.4 shall be followed.

12.1.5.12 Inspection shall include the following points (see also IPS-C-TP-274):

a) Monitoring the particle size, cleanliness and mix of the blast cleaning media.
b) Visual checks in good light, after blast cleaning, of the pipe surface for steel defects and occluded grit.
c) Control of temperature and freedom from moisture of the pipe surface before priming and before flood coating.
d) The enamel melting and application temperatures.
e) The location of the inner wrap in the thickness of the enamel.
f) The adhesion of the coating to the pipe and to the outer wrap.
g) Overall holiday detection, including testing of repairs, as required in IPS-C-TP-274.
h) The adhesion or bond test shall be as required in IPS-C-TP-274.

12.1.6 Handling and stacking

12.1.6.1 All coated pipe shall be handled and transported according to IPS-C-TP-274. The contractor shall ensure that pipe is not handled under unsuitable temperature conditions.

12.1.6.2 Stacking of coated pipe shall be limited to such a height that neither flattening nor indentation of the coating occurs (see IPS-C-TP-274).

12.1.7 Field repair, joints and fittings

- Field coating repair and coating of joints, fittings and specials sections shall be performed by using hand applied laminated tape IPS-M-TP-314 and it's primer IPS-M-TP-323. The tape shall be wrapped with 50% overlap.

- For irregular shapes such as valves and fittings which are buried petrolatum tape (IPS-M-TP-317) shall be used.

For bellow ground unburied valves shall be coated with asphalt mastic (IPS-M-TP-105) to a minimum thickness of 3.5 mm.

12.1.8 Standard coating materials

The standard coating materials used shall be as follows:

12.1.8.1 Primer

- Synthetic primer IPS-M-TP-275.
- Bitumen primer IPS-M-TP-285.
- Coal tar primer IPS-M-TP-280.

12.1.8.2 Enamel

- Hot-applied bitumen enamel IPS-M-TP-295.
- Hot-applied coal tar enamel IPS-M-TP-290.

12.1.8.3 Inner wrap IPS-M-TP-300

12.1.8.4 Outer wrap IPS-M-TP-305

12.1.8.5 Rock shield IPS-M-TP-316

12.1.8.6 Hand applied tape coating:

- Hand applied plastic tape IPS-M-TP-314.
- Primer IPS-M-TP-323.

12.1.9 Cathodic protection characteristics

12.1.9.1 Bituminous coatings have good electrical resistance and need rather low cathodic protection current (see Table 1). Recommend design current density for 15-30 years service life is 200 micro ampers per square meter of external pipe surface.

12.1.9.2 These coatings are more resistance to cathodic disbonding than other coatings.

12.1.9.3 Recommend "off" potential limits for underground coating (to $Cu/CuSO_4$ half-cell) is -2 volts.

12.2 Extruded Polyethylene Coating

12.2.1 General

12.2.1.1 Extruded polyethylene coating have been available since 1956. Its growth and acceptance has been remarkable. Initial problems of stress cracking and shrinkage have been minimized by better quality and grade of high molecular weight polyethylene resins.

12.2.1.2 There are two systems available for coating of line pipes. One is an extruded polyethylene sleeve, shrunk over a primed pipe by cross head extruded method. The other is a dual extrusion (side extrusion method) where a butyl adhesive (soft primer) or polyethylene copolymer (hard primer) is extruded onto the blast-cleaned pipe followed by multiple fused layers of polyethylene. The later utilizes multiple extruders in a proprietary method, which obtains maximum bond with minimum stress.

12.2.1.3 In both methods the pipe is normally preheated to between 120 and 180°C, depending on the type of adhesive primer.

12.2.1.4 The sleeve type is available on 130 mm through 610 mm (½ inch through 24 inch) pipe, while the dual extrusion is presently available on 63.5 mm through 260 mm (2½ inch through 103 inch) pipe.

The accepted standard to which pipe is coated with these types of polyethylene coatings is DIN 30670.

12.2.1.5 Improved adhesion and cathodic disbonding resistance can be achieved by priming the pipe surface first with an epoxy-based layer on top of which the adhesive layer and polyethylene coating is being applied. This new-generation 3-layer corrosion protection system 3-layer polyethylene coating shall be according to IPS-C-TP-335.

12.2.2 Characteristic of polyethylene coatings

12.2.2.1 Polyethylene coatings are durable and their penetration and impact resistance are better than the resistance of hot applied (asphalt or coal tar enamel) coatings are therefore less prone to mechanical damage during transport, handling, storage and laying. They also exhibit a high electrical resistance which allows of low cathodic protection current requirements throughout long years of service (see Table 1).

12.2.2.2 Pigmenting the material with carbon black has eliminated earlier ultra-violet degradation problems resulting from long exposure to sunlight.

12.2.2.3 Polyethylene coatings are not recommended for pipelines operating above 65 and 80°C (depending on the grade of polyethylene).

12.2.2.4 Polyethylene coatings have a field's good bendability (1.9° per pipe diameter length at -40°C).

12.2.2.5 Swelling may occur in hydrocarbon environments.

12.2.2.6 These coatings are applied only in the yard at a thickness which depends on the pipe diameter (see Table 6).

TABLE 6 - MINIMUM THICKNESS FOR POLYETHYLENE COATINGS

DIAMETER OF PIPE (mm)	MINIMUM THICKNESS, mm	
	STANDARD	REINFORCED
Up to 250	2.0	2.5
250 to 500	2.2	3.0
500 to 800	2.5	3.5
800 and over	3.0	3.5

12.2.2.7 For other characteristic of this coating system see 10.3.2.

12.2.3 Application procedure

12.2.3.1 Both crosshead and side extrusion procedures preheat bare pipe prior to blast cleaning to SIS 050590 grade Sa 2½ with the sleeve type coating, the adhesive undercoating is applied by flood-coating the hot material over the pipe before it passes through an adjustable wiper ring that controls thickness. After adhesive primer is applied, the pipe passes through the center of the crosshead die where polyethylene is extruded in a cone shape around the undercoating and pipe. Immediately the polyethylene is water quenched to shrink it around the undercoating and pipe. Following electrical inspection, pipe ends are trimmed for cut back, and the coated pipe is stock piled.

12.2.3.2 In the dual extrusion (side extrusion) system, the blast cleaned pipe is rotated at a calibrated rate. The first of two extruders applies a film of adhesive primer (soft or hard) of predetermined width and thickness, fusing the film to the rotating pipe in two layers. White the primer is still molten, high molecular weight polyethylene is applied from the second extruder in multiple layers of a predetermined thickness, producing a bonded coating 2 to 3.5 mm thick. Water quenching, electrical inspection, thickness measurement, visual inspection and cut back is completed prior to stocking.

12.2.3.3 For polyethylene copolymer adhesive the system requires high temperature (200°C) for application of adhesive primer.

12.2.3.4 In 3-layer polyethylene coating the side extrusion system equipped with an electrostatic spray gun to allow a powder epoxy primer to be applied to the cleaned pipe prior to application of adhesive primer. See IPS-G-TP-335.

12.2.3.5 Application of 3-layer polyethylene coating shall be according to IPS-G-TP-335.

12.2.4 Handling and stacking

All coated pipes shall be handled and stored at coating factory in accordance with IPS-G-TP-335 and handled, transported and stored for installation according to IPS-C-TP-274 and IPS-G-TP-335.

12.2.5 Field joints and specials

12.2.5.1 Field joints and specials shall be coated either by polyethylene shrink tape or sleeve (IPS-M-TP-318) or cold-applied tape (IPS-M-TP-313) to be applied with 50% overlap over it's primer (IPS-M-TP-322).

12.2.5.2 Polyethylene shrink tapes and sleeves have the advantages and disadvantages over conventional cold-applied tape. Their advantages are self-tensioning, and resistant to direct sunlight. Their disadvantages are:

- They require a source of heat (a flame torch) for application which is major disadvantage.
- Field construction crews must be skilled to apply the heat shrink tape and sleeve properly.
- Their application is slow and time consuming.
- They are more expensive.

12.2.5.3 For irregular shapes such as valves and fittings which are buried petrolatum tape (IPS-M-TP-317) shall be used.

12.2.6 Cathodic protection characteristic

12.2.6.1 Due to high electrical resistance the coatings need low cathodic protection current throughout long years of service.

12.2.6.2 Recommended design current density for 15-30 years service life is 10 micro amper per square meter of external pipe surface.

12.2.6.3 Recommended "off"-potential limits for underground coatings (to $Cu/CuSO_4$ half-cell) is -1.0 Volt.

12.3 Fusion Bonded Epoxy Coating (FBE)

12.3.1 General

12.3.1.1 Fusion bonded powder epoxy coating was introduced in 1959 and have been commercially available since 1961.

12.3.1.2 This coating is a thin-film coating and can be applied on small and larger diameter pipes (19 to 1600 mm).

12.3.1.3 The fusion-bonded powder epoxy coating have good mechanical and physical properties and may be used above or below ground. On above-ground installations, to eliminate chalking and to maximize service life, topcoat with a urethane paint system. Of all the pipe coating systems the fusion-bonded epoxy resin system is the most resistant to hydrocarbons, acids, and alkalies.

12.3.1.4 Perhaps the main advantage of fusion-bonded powder epoxy coating is that because they cannot cover up apparent steel defects due to their lack of thickness, they permit excellent inspection of the steel surface before and after coating.

12.3.1.5 The number of holidays that occur is a function of the surface condition and thickness of the coating increasing the thickness of the applied coating will minimize the holidays.

12.3.1.6 This coating is widely used for land-based pipelines operating at elevated temperatures.

12.3.2 Characteristic of coating

12.3.2.1 Despite its low film thickness (350-450 μm) the fusion-bonded epoxy coating displays many desirable characteristics or properties not fully found in any of the traditional pipe coating systems. For example, this system is tough, has great flexibility and provides good adhesion to the steel pipe along with extremely good chemical resistance.

12.3.2.2 In view of its high dielectrical strength, very small quantities of current for complete cathodic protection are required (see 12.3.7.2).

12.3.2.3 An extra benefit from epoxy pipe coating not easily achieved with other coating systems is the ability to withstand a relatively high temperature of approximately 100°C for an extended length of time without damage, provided the environment is dry. Some epoxy thin-film systems can even withstand wet environments at this elevated temperature.

It is current group practice to specify this type of coating for land-based pipelines operating at temperatures 65°C.

12.3.2.4 A shortcoming of the coating system is its increased sensitivity to sharp impact damage, which requires careful attention during transportation, field handling and pipe laying. Fortunately, impact damage does not normally cause disbonding outside of the damage area and can be readily repaired by hot-melt or with liquid epoxy resins.

12.3.2.5 Experience has shown that proper surface preparation prior to the application of the epoxy resin powder is of extreme importance with this coating. To obtain a satisfactory coating it is furthermore absolutely necessary that good quality control during the application process is strictly adhered to.

12.3.2.6 Fusion bonded epoxy coating should only be ordered against detailed specifications covering both the epoxy resin materials and their application.

12.3.2.7 Fusion bonded epoxy coating shall be in accordance with ANSI/AWWA C213.

12.3.2.8 The coating shall be applied to a minimum thickness of 350 microns and a maximum of 450 microns coating applied outside these limits shall be rejected and reprocessed.

12.3.2.9 For other characteristics of this coating system see 10.2.3.

12.3.3 Application and inspection procedure

12.3.3.1 The coating is plant-applied by applying epoxy resin powder by means of multiple electrostatics guns on to a blast cleaned (to Sa 2½ to SIS 505900) and preheated pipe (approximately 230-240°C).

12.3.3.2 The pipe surface shall be free from protective oil, lacquer or mill primer. The pipe surface shall also be as free as possible from scabe, silvers, laminations and similar defects.

12.3.3.3 The pipe surface shall be blast cleaned. The cleaning media shall be selected to achieve a surface profile of 40-80 microns. The appropriate blend of shot and grit to achieve this profile is necessary. The surface preparation shall be in accordance with IPS-C-TP-101.

12.3.3.4 The application and inspection procedure shall be according to IPS-C-TP-274.

12.3.4 Coating materials

The powder epoxy used shall be in accordance with ANSI/AWWA C215.

12.3.5 Handling and stacking

12.3.5.1 All coated pipes shall be handled and stored of coating factory in accordance with IPS-C-TP-274 and ANSI/AWWA C215.

12.3.5.2 A short coming of the coating system is its increased sensitivity to sharp impact damage, which requires careful attention during transportation, field handling and pipe laying.

12.3.5.3 Transportation, field handling and storing for installation shall be in accordance with IPS-C-TP-274.

12.3.6 Field joints and fittings

12.3.6.1 Pipe joints and fittings shall be coated by hot-melt or with liquid epoxy resins. The materials shall be in accordance with ANSI/AWWA C215.

12.3.6.2 Field joint coating and repair shall be in accordance with IPS-C-TP-274.

12.3.7 Cathodic protection characteristics

12.3.7.1 Due to high electrical resistance the coating needs rather low cathodic protection current throughout long years of service.

12.3.7.2 Recommended design current density for 15-30 years service life is 50 $\mu A/m^2$ of external pipe surface.

12.3.7.3 Recommended "off"-potential limits for underground coating (to $Cu/CuSO_4$ half-cell) is -1.5 Volts.

12.4 Plastic Tape Coating System

12.4.1 General

12.4.1.1 Cold-applied plastic tape coating system are applied as a three-layer system consisting of primer, corrosion preventive tape (inner layer) and a mechanical protective tape (outer layer). This system is recommended for temperatures up to 57°C. This temperature is a limitation for normal tape available, but there are special tape systems available for temperatures up to 93°C which are not covered in this Standard.

12.4.1.2 The primer's function is to provide a bonding medium between the pipe surface and the adhesive or sealant on the inner layer. For standard specification of primer see IPS-M-TP-321.

12.4.1.3 The inner layer tape consist of a plastic backing and adhesive. This layer protect against corrosion, so it has to provide a high electrical resistivity and low moisture absorption and permeability, along with an effective bond to the primed steel. For standard specification see IPS-M-TP-310.

12.4.1.4 The outer layer tape consists of a plastic film and an adhesive of the same types of materials used in the inner layer tape. The purpose of the outer layer tape is to provide mechanical protection to the inner layer tape, and also to be resistant to the elements during outdoor storage. For standard specification see IPS-M-TP-311.

12.4.2 Characteristic of coating system

12.4.2.1 Three-layer coating system is applied for normal construction conditions. This coating system is applied cold to a prepared pipe surface.

12.4.2.2 The coating can be applied by hand to small diameter pipes and small pipe sections, but it shall normally be applied by machine.

12.4.2.3 The coating can be easily applied in field.

12.4.2.4 The coating is suitable for operation temperature from -34 to 57°C.

12.4.2.5 For other characteristic of the coating system see 10.2.4.

12.4.3 Description of coating system

The coating system consists of:

12.4.3.1 One primer coat which shall be properly applied. The material specification shall be in accordance with IPS-M-TP-321.

12.4.3.2 One protective layer (inner wrap) which shall be applied to the primed steel pipe. Material specification shall be in accordance with IPS-M-TP-310.

12.4.3.3 One mechanical protective layer (outer wrap) to be applied over protective layer. Material specification shall be in accordance with IPS-M-TP-311. The spiral overlap of each layer shall be one inch.

12.4.4 Application and inspection procedure

12.4.4.1 Surface preparation

Prior to application of primer the pipe shall be prepared to Sa 2½ according to SIS 505900 by blast cleaning. Surface preparation shall be in accordance with IPS-C-TP-101.

12.4.4.2 Field application of coating

In this procedure the pipe is welded together beside the canal then the surface preparation, priming and wrapping is performed continuously over the ditch. The coating is inspected simultaneously and the approved coated pipeline will be buried.

12.4.4.3 Yard and field application of coating

In this procedure the pipes are surface cleaned and primed at yard. The primed pipes are transported to the field, jointed, cleaned from contaminations, reprimed wrapped, inspected and buried as in 12.4.4.2.

The application and inspection procedures of coating shall be in accordance with IPS-C-TP-274.

12.4.4.4 Field repair and fittings

Field coating repairs and coating of fittings and special sections shall be performed using hand applied laminated tape IPS-M-TP-312 and its primer IPS-M-TP-322. The tape shall be wrapped with 50% overlap.

12.4.5 Chathodic protection characteristics

12.4.5.1 Due to good electrical resistance the coating needs rather low cathodic protection current (see Table 1).

Recommended design current density for 15-30 years service life is 200 micro amper per square meter of external pipe surface.

12.4.5.2 Although plastic tape coatings have certain advantages and are relatively easy to apply, many problems have arisen with this system in practice. One major drawback of tapes is their sensitivity to disbonding, particularly at the overlaps. as a result of which cathodic protection currents are easily shielded, rendering the cathodic protection system ineffective so that corrosion can proceed unabated. As a consequence, the use of tape coatings shall be limited to the special cases where other coatings can not be selected for the reason(s) stated in 7.5.

12.4.5.3 Recommended "off "-potential limits for underground coating (to $Cu/CuSO_4$ half-cell) is -1.5 Volts.

12.5 Concrete

12.5.1 General

12.5.1.1 Mortar lining and coating has the longest history of protecting steel or wrought iron coating and cast iron from corrosion. When steel is encased in concrete, a protective iron oxide film forms. As long as the alkalinity is maintained and the concrete is impermeable to chlorides and oxygen, corrosion protection is obtained. See IPS-C-TP-274 and/or AWWA C205 for a detailed reference on concrete coatings.

12.5.1.2 Today, concrete as corrosion coating is limited to internal lining (see IPS-E-TP-350). The external application is applied over a corrosion coating for armor protection and negative bouyancy in marine environments. A continuous reinforced concrete coating has proved to be the most effectively controlled method.

12.5.1.3 Materials including water, sand, and/or heavy aggregate and cement are mixed in the application plant. The materials are conveyed by belt to the throwing heads where controlled-speed belt/brushes throw the mixture on-to the coated pipe surface. The rotating pipe is moved past the throwing heads to receive the specified thickness of concrete. Simultaneously, the galvanized wire reinforcement is applied with an overlap. To increase tensile strength and to improve impact resistance, additional layers of wire of steel fibers may be specified. Welded wire cages are another alternate method of reinforcement. Other application methods include forming or molding of concrete in place or applying it to the pipe by means of a plastic film.

12.5.2 Concrete weight coatings

12.5.2.1 Concrete weight coatings are normally applied to offshore pipelines, river crossings and marsh lines to maintain the lateral and vertical stability of the pipeline. The amount of concrete is determined by the calculated required submerged weight of the pipeline, also called negative buoyancy.

12.5.2.2 Most frequently the concrete is applied by the impingement method over an anti-corrosion coating of asphalt or coal-tar enamel. This design has demonstrated good short and long-term characteristics.

Combined with properly selected tensioners on a lay barge this design has also been successfully installed offshore in many areas.

12.5.2.3 There must not be any electrical contact between the pipe and the reinforcement, as this may make subsequent cathodic protection of the pipe difficult or even impossible.

12.5.2.4 Application methods for concrete coatings other than by impingement are being developed to resolve problems resulting from weight coating application over FBE anticorrosion coating. Current experience with these applications is limited.

13. COATING OF SUBSEA PIPELINES

13.1 Subsea pipelines are defined as those lines which are laid in or on the seabed. It covers requirements for coating against corrosion the external surfaces of pipelines that are welded and joint coated on a lay barge, followed by pipe laying over the stringer. It also covers pipelines laid by reel barge or by pulling into the sea or across creeks, estuaries, rivers or canals.

13.2 The coatings that may be used on subsea pipelines are specified in Section 12.

All coatings on such subsea pipelines shall be compatible with concrete or bituminous weight coating and with normal levels of cathodic protection, with the protective potential no more negative than minus 1.30 Volts measured against a silver/silver chloride half cell.

13.3 For weight coating see 12.5.

13.4 Hot-applied coal tar enamel glass fiber reinforced (see 12.1) shall be used for coating subsea pipelines which may or may not be weight coated. It shall not be used when:

a) The temperature of the pipeline contents exceeds 70°C (160°F) (see 13.5).
b) The pipeline is to be laid from a reel (see 13.5).
c) The pipeline is to be laid by pulling or placing and is not to be concrete weight coated. See 13.6.

13.5 Epoxy powder coating shall be used when one or both of the following conditions apply:

a) The temperature of the pipeline contents is too high for coal tar enamel but does not exceed 95°C (200°F). This includes pipeline risers.

b) The pipeline is to be laid from a reel.

13.6 Pipelines which are laid by pulling or placing and are not concrete weight coated (this includes prefabricated spool pieces), shall be coated with epoxy powder.

13.7 Plastic tape coating shall not be used for subsea pipelines.

13.8 When designing coating for subsea pipelines the following important factors shall be considered:

13.8.1 Concrete slippage

For submarine applications some coatings, e.g. fusion bonded epoxy, polyethylene, polypropylene will normally need an intermediate coating to provide increased friction to avoid slippage between concrete and coating during pipelaying.

For laybarges with a single tensioner, precautions may be needed to avoid breakage and slippage of the concrete at the ends of the pipe. This might be achieved with temporary infill blocks or could involve stronger longitudinal reinforcing wire. (Any dimensional irregularities at the end of the coating, e.g. "bell ends", will exacerbate this problem.)

The exposed end portion of anti-corrosion coating may become too short or even disappear if slippage does occur.

13.8.2 Anti-corrosion coating damage

An intermediate "barrier" layer may be needed to prevent damage from the concrete impingement process.

13.8.3 Choice of anti-corrosion coating

There are normally many factors involved in the choice of coating for a particular pipeline. The above two potential problem areas may need to be taken into account in this choice.

13.8.4 Pipe dimensions and stiffness

Pipes with large diameter/wall thickness (D/t) ratios have a tendency to become oval when loaded externally and may also buckle at the field joint area when the concrete coated pipes are installed.

Large concrete thicknesses can be the cause of ovalization.