

PETRONAS TECHNICAL STANDARDS

TECHNICAL SPECIFICATION

BITUMINOUS ENAMEL COATING OF STEEL LINEPIPE

PTS 31.40.30.33

OCTOBER 2011



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This revision of PTS **31.40.30.33 – Bituminous Enamel Coating of Steel Linepipe (October 2011, Revision 1)** has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS **31.40.30.33 (October 2001)** will be removed from PTS binder / e-repository from herein onwards.

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PREFACE

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The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, it is expected of them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the owner.

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1 INTRODUCTION

1.1 SCOPE

This PTS specifies the minimum requirements and the test procedures for the factory application of hot-applied, external, bituminous enamel coating to linepipe and includes the material, application, inspection, repair, handling and storage requirements. Bituminous enamel coatings may be based on conventional "oxidised bitumen" or "modified bitumen".

Bituminous enamel coatings may be used for the corrosion protection of subsea steel pipelines that are to be concrete weight-coated and for buried landfall sections of a pipeline.

Oxidised bitumen enamel is suitable for use when the design temperature of a subsea pipeline does not exceed 70 °C. It may also be used for buried landfall sections of a pipeline provided that the pipeline temperature does not exceed 60 °C. It is suitable for use at temperatures down to -10 °C.

Modified bitumen enamel is suitable for use when the design temperature of the line does not exceed 90 °C. *For pipeline design temperature of 80°C and above, manufacturer shall submit qualification records including the long term (>10,000 hours) thermal degradation of critical coating properties associated with high operating temperatures for Principal approval.* Modified bitumen enamel is suitable for use at temperatures down to -20 °C.

Bituminous enamel coatings are not suitable for pipelines that pass through locations that have been or are likely to be contaminated by fuel spillages, e.g. aviation fuel. Bituminous enamel coatings are not suitable for pipelines that are to be laid by reelbarge.

This PTS is based on the European Standard EN 10300.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as described in PTS 00.00.05.05).

This PTS is intended for use in onshore and offshore pipelines.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with respect to safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible

1.3 DEFINITIONS

1.3.1 General definitions

The Contractor is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility.

The Principal may undertake all or part of the duties of the Contractor.

The Manufacturer/Supplier is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The Principal is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word shall indicates a requirement.

The word should indicates a recommendation.

1.3.2 Specific definitions

Coating Contractor	The party ultimately responsible for the coating operation, which may include supply of coating materials, application of the coating, and transport of uncoated and coated linepipe as specified in the relevant contract. The Coating Contractor may be the Coating Applicator, the Linepipe Manufacturer or the Pipeline Construction Contractor.
Coating Manufacturer	The party that manufactures or supplies materials, equipment and/or services to perform the duties specified by the Coating Contractor.
Coating Applicator	The party that applies the bituminous enamel coating system in the coating plant.
Batch	The amount of materials produced during one uninterrupted production run of maximum 8 hours under constant production conditions.
Shift	A set of pipes coated in one production run of which the beginning and end coincide with a change in personnel. In the context of the quality control procedures of this PTS, the maximum duration of a shift is 10 hours.
Primer	A material applied as a thin film to metal in order to ensure adhesion of the subsequent protective coating.
Bitumen	A very viscous liquid or a 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 colour and possesses waterproofing and adhesive properties. It is obtained by refinery processes from petroleum.
Oxidised bitumen	Bitumen which has been rheologically changed by the action of blowing air through it.
Modified bitumen	Bitumen which has been rheologically changed by the addition of a polymer or polymers.
Inert filler	Finely divided mineral powder, which is not hygroscopic, is not electrically conductive, and does not react with other ingredients of the coating material or with the environment in which it will be used.

Bituminous enamel	A coating material which comprises oxidised or modified bitumen and filler (formerly also called "asphalt enamel").
Non-woven glass fabric	A continuous sheet of randomly arranged glass fibres in an open porous structure bonded by a suitable resin and reinforced by continuous longitudinal glass yarns.
Woven glass fabric	A regular woven glass fabric made from glass yarns held together by a binder.
Composite glass fabric	One layer of glass fibre tissue and one layer of woven or lock welded glass mesh held together by a binder.
Composite polyester/glass fabric	A woven polyester/glass mesh with a layer of glass fibre tissue held together by a binder.
Innerwrap	An inert porous reinforcement which is intended to be saturated and buried within the bituminous enamel coating in order to improve its mechanical performance.
Outerwrap	A continuous sheet of reinforced glass fibre fabric or glass fibre/polyester composite fabric impregnated by a suitable bituminous material which is compatible with the bituminous. The process that allows bitumen enamel to pass through the outerwrap to form a mechanical bond between glass fabric and the enamel.

1.4 ABBREVIATIONS

DFT	Dry film thickness
IR	Infra-red
HSE	Health, Safety and Environment
WFT	Wet film thickness

1.5 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section is shown in brackets. Other documents referenced in this PTS are listed in [\(9\)](#).

2 GENERAL INFORMATION

2.1 COATING SYSTEM DESCRIPTION

The bituminous enamel coating system described in this PTS shall comprise a number of layers or components as follows:

1. a primer: which must be compatible with the bituminous enamel coating;
2. an enamel: comprising a bitumen containing an inert filler;
3. innerwrap: reinforcing glass fabric wrap (oxidised bituminous enamel only);
4. outerwrap: glass or composite fabric wrap impregnated with oxidised bitumen;
5. solar protection: weather-resistant material to protect the coating from sunlight;
6. other: in special cases (for example, for onshore use due to the nature of backfill material or for offshore use) additional mechanical protection or a concrete weight coat may be applied by agreement. The type and grade of outerwrap may be influenced by the presence or absence of the additional mechanical protection.

With suitable surface preparation and application techniques, this coating system shall produce coating properties required for the intended installation and operating conditions of the pipeline see (5.2) and (5.7).

2.2 INFORMATION TO BE SUBMITTED BY THE PRINCIPAL

The Principal shall submit all technical information to the Coating Contractor regarding the project, in particular the installation and operating conditions.

This information shall include as a minimum:

1. project name;
2. the type of coating required;
3. the minimum and maximum operating temperature of the pipeline;
4. the pipeline diameter and wall thickness including minimum required wall thickness;
5. the applicable linepipe specification;
6. the geographical area (offshore/onshore);
7. expected ambient temperatures during installation;
8. installation method;
9. soil and backfill conditions for land pipelines;
10. seabed trenching, laying and burial conditions for sub-sea pipelines;
11. subsequent coatings to be applied (e.g. weight coating);
12. requirements for temporary protection of pipe ends;
13. type(s) of cathodic protection.

The Principal shall indicate whether, and to what extent, he intends to witness coating application and quality control.

2.3 INFORMATION TO BE SUBMITTED BY THE COATING CONTRACTOR

The Coating Contractor shall submit all data specified in (2.3.1), (2.3.2) and, if required by the Principal, (2.4).

2.3.1 System identification

The Coating Contractor shall submit all necessary details to identify the coating system, which shall include:

1. system designation or trade name;
2. name of Manufacturers of the primer, bitumen enamel, inner and outer wraps;
3. nominal total coating thickness;
4. recommended Coating Applicators;
5. relevant international and national coating standard approvals;
6. approvals for previous projects for PETRONAS Group Companies;
7. recommended storage and shelf life of coating materials;
8. HSE data sheets.

2.3.2 Coating system application

2.3.2.1 Coating plant

The Coating Contractor shall submit to the Principal details of the coating plant, including:

1. layout diagram of the coating plant and pipe routing scheme;
2. general description of the equipment available to carry out the coating process;
3. details of process control and inspection equipment, required for the coating process such as temperature control, thickness control, holiday testers, laboratory equipment;
4. details of the pipe handling and transport equipment and procedures;
5. quality assurance and control procedures.

2.3.2.2 Coating process

The Coating Contractor shall submit to the Principal information on the required coating process. The information shall include:

1. description of the coating process;
2. pipe cleaning procedure and pipe surface preparation;
3. pipe heating and temperature control;
4. method of bituminous enamel application;
5. minimum and maximum coating application temperature;
6. coating repair procedures.

2.4 ACCEPTANCE BY THE PRINCIPAL OF THE PROPOSED COATING SYSTEM

The Coating Contractor shall show that samples of the proposed coating system applied on pipes of the same material and nominal wall thickness as the pipes to be coated under the contract will meet the requirements of this PTS as defined in (5.2) and (5.7).

With the approval of the Principal, tests carried out in accordance with other coating standards may be used insofar as their procedures are the same as or more stringent than the procedures in this PTS. Such information shall include full reports on test procedures and results and be signed by the laboratory representatives.

Based on the information provided, the Principal may require the proposed coating system to be qualified via a pre-production trial. The results of this pre-production trial shall be reported to the Principal 2 (two) weeks before the scheduled start of production.

3 COATING SYSTEM REQUIREMENTS

3.1 GENERAL

The coating system shall be suitable for the installation and operating conditions of the pipeline as specified by the Principal (2.2).

Any modification of a proposed coating system shall require the Contractor to submit the technical properties of the modified system to the Principal, prior to application of the modified coating system.

3.2 COATING MATERIALS

3.2.1 Primer

All primer shall be supplied in sealed containers with the following information clearly marked on the container:

1. name of Manufacturer;
2. material designation;
3. date of manufacture;
4. batch number/letter(s);
5. relevant manufacturing standard (e.g. *BS EN 10300*).

Any primer without the required identification shall be rejected and replaced with approved material.

The primer shall be fast drying, it shall be compatible with the bituminous enamel coating to be used by the Coating Contractor, and it shall be supplied by the Coating Manufacturer of the bitumen.

Material that is not traceable to satisfactory test certificates shall not be used.

3.2.1.1 Primer for oxidized bitumen enamel

Primers for use with oxidized bitumen shall contain chlorinated rubber, plasticiser, and when required, colouring pigment, together with solvents needed to give a consistency suitable for application by spray, brush or other approved method. The primer shall conform to the requirements of Table 1 in section 5.2.2.

3.2.1.2 Primer for modified bitumen enamel

Primers for use with modified bitumen shall contain hydrocarbon resin, plasticiser, and when required, colouring pigment, together with solvents needed to give a consistency suitable for application by spray, brush or other approved method. The primer shall conform to the requirements of Table 1 in section 5.2.2.

3.2.2 Inert filler

The inert filler shall be physically and chemically stable at the maximum application temperature of the coating material. Powdered slate and talc are typical examples of suitable filler types.

The inert filler shall be supplied dry in bulk or in sacks and shall be accompanied by documentation detailing the Manufacturer's name, material designation, date of manufacture and batch number.

3.2.3 Bituminous enamels

The bituminous enamel shall comprise either oxidised or modified bitumen with inert filler. Bituminous enamel may be supplied either hot in bulk or cold in drums or kegs. Supplies shall be accompanied by a delivery note clearly marked with the Manufacturer's name, material designation, date of manufacture and batch number.

3.2.4 Innerwrap (oxidised bitumen only)

The innerwrap shall be a non-woven glass fibre tissue that comprises a continuous sheet of randomly arranged glass fibres in an open porous structure bonded by a suitable resin and shall be reinforced by continuous longitudinal glass yarns that are spaced evenly across the width. It shall have a uniform appearance and be undamaged. It shall be compatible with the bituminous enamel coating material with which it is used and it shall have a texture such that it may be embedded completely within the coating material.

All innerwrap shall be supplied in sealed polyethylene bags and shall be clearly marked with the Manufacturer's name, material designation, date of manufacture and batch number.

3.2.5 Outerwrap

The outerwrap shall be a continuous sheet of reinforced glass fibre for oxidised bitumen or glass fibre/polyester composite fabric for modified bitumen impregnated by a suitable bituminous material that is compatible with the bituminous enamel coating.

The outerwrap shall have a uniform porosity to allow air and fumes to escape and to allow the hot coating to bleed through to ensure fusion of the outerwrap within the outer surface. All outerwrap shall be supplied in sealed polyethylene bags and shall be clearly marked with the Manufacturer's name, material designation, date of manufacture and batch number.

When unrolled at ambient temperature, the successive layers of outerwrap shall not stick to each other.

3.2.6 Sample retention

A 1 kg sample shall be taken from each batch of enamel. Samples shall be marked and stored by the Coating Applicator under conditions such that the enamel does not deteriorate. The Principal may request tests on these samples up to one year after delivery of the last coated pipe of the order.

4 COATING OPERATIONS

4.1 PIPE SURFACE PREPARATION

The pipes shall be inspected for surface contamination prior to blast-cleaning. Oil, grease and other contaminants shall be removed by a suitable solvent (e.g. Xylene) or detergent. Salt contamination, chemical cleaning agents and remaining detergents shall be washed off using potable water. The pipe surface shall be dry before blast-cleaning.

End plugs shall be placed inside ends of the pipe to prevent the inclusion of blasting abrasives.

All pipes shall be washed with potable water before blast-cleaning and pre-heated to a minimum of 30 °C in order to remove moisture and to prevent contamination of the abrasive media.

The pipe surface shall be cleaned of mill scale, rust and other foreign matter by blast-cleaning to achieve a minimum surface cleanliness of Sa 2 ½ in accordance with ISO 8501-1. The grade of abrasive shall give a blast peak-to-trough profile of $(75 \pm 25) \mu\text{m}$. During blast cleaning, the pipe surface temperature shall be at least 3 °C above the ambient dew point. The residual chloride salt content on blast cleaned steel pipes shall be measured once for every 100 pipes. The pipes with salt content higher than 30 mg/m² shall be re-blasted. The residual salt content on steel pipe surfaces shall be measured either by Elcometer 130 SCM 400 salt contaminator meter or other method approved by the Principal.

Abrasives shall be stored in dry condition and only dry abrasive shall be used. For carbon steel pipes the abrasive shall be steel grit or a mixture of steel grit and shot. The abrasive shall be kept free from dust, salts and other impurities. The abrasive shall be checked for salt contamination twice per shift. The salt contamination of the abrasive can be checked by conductivity measurement. The conductivity of the abrasive material extract shall be below 50 $\mu\text{mho/cm}$.

For stainless steel pipes, stainless steel or non-ferrous abrasives shall be used for blast-cleaning.

The use of sand is not permitted.

Before coating, the pipe surface shall be cleaned of all dust and foreign matter using clean, dry, oil-free, compressed air or vacuum cleaning.

To prevent dust and grit contamination of primed and coated surfaces, blast-cleaning shall not be done in areas close to coating operations.

Any pipe which has been rejected, repaired and subsequently re-accepted by the Principal under the provisions of section (5.4) and (5.5) and has not been coated within 4 hours of blast-cleaning shall be re-blasted.

Any pipe not meeting the specified surface preparation standard shall be re-cleaned as described above.

4.2 COATING APPLICATION

4.2.1 General

Blast-cleaned pipes shall be coated before showing any visible rust stains, otherwise pipes shall be blast cleaned again.

The application of the coating shall be in accordance with the Coating Manufacturer's application procedures.

The pipes and components shall be preheated so that the steel temperature is between 30 °C and 50 °C when the primer is applied. During coating the bevelled ends of the pipes and the pipe bore shall be protected against mechanical damage and from contamination with coating material.

Each pipe end shall be left uncoated over a length of 250 mm $\pm$ 15 mm unless otherwise specified.

The bevelled ends of uncoated pipe ends shall be protected by an end cap for transit.

4.2.2 Priming

The primer shall be applied to a dust-free, clean, dry, prepared surface and shall be applied in accordance with the primer Manufacturer's recommendations.

The primer, applied at the wet or dry film thickness specified by the Coating Manufacturer, shall be uniform and continuous. The wet or dry film thickness shall be measured on four pipes per shift (see Table 5). The primer shall be free from runs, drips, sags, holidays and bare areas. Bare areas may be primed by roller application of primer.

Pipes not primed correctly shall be re-cleaned and re-primed in accordance with this PTS.

Pipes on which the primer has deteriorated, or become contaminated, shall be rejected and the rejected pipes shall be re-cleaned and re-primed in accordance with this PTS.

4.2.3 Enamel preparation

The hot bituminous enamel shall be stored in approved containers and shall be maintained at a storage temperature recommended by the Coating Manufacturer, to avoid settlement and/or partial solidification.

All storage containers shall be fitted with mechanical agitators, which shall continuously agitate the bituminous enamel. At no time shall hot bituminous enamel be stored without agitation for a period of time in excess of 30 min.

Bituminous enamel that has been heated in excess of the Manufacturer's recommendations or has been held at application temperature for over 6 hours shall be rejected and replaced.

Bituminous enamel shall be used as supplied on a first-in, first-out basis. Delivery dates for each batch shall be recorded and shall be available for inspection.

All application kettles shall be equipped with screens to exclude foreign materials that may cause coating flaws. Care shall be exercised to ensure there is no mixing of material from different sources or of different grades.

4.2.4 Enamel application

Enamel application shall commence within 4 hours of the start of primer application. The primed surface shall be dry and free from surface contamination prior to enamel application.

The primed steel surface shall be at a temperature in accordance with the Coating Manufacturer's recommendations, but at least 3 °C above the dewpoint temperature.

A stripe of the linepipe bituminous enamel shall be applied to the linepipe weld seam(s) after priming, and before enamel coating, in order to ensure that the minimum coating thickness is achieved over the weld. The stripe is applied using an automatic weld seam applicator which extrudes hot enamel onto the weld in a stripe approximately 5 cm wide by 2 mm thick along the length of the weld.

The enamel shall be applied at a temperature in accordance with the Coating Manufacturer's recommendations. The enamel shall flow evenly onto the pipe and be free from any solid particles that may cause irregularities in flow.

The oxidised and modified bitumen enamels shall be applied as follows:

4.2.4.1 Oxidised bitumen enamel application

An even coating of enamel shall be applied by flood coating in parallel with equipment for spirally wrapping the innerwrap and outerwrap under controlled tension.

Two layers of innerwrap shall be applied in a uniform spiral manner with a minimum overlap of 12 mm. Where a thin enamel layer is used one innerwrap may be applied by agreement. The flood coat of enamel shall have the innerwraps pulled in and the outerwrap pulled on immediately following flood coating. The innerwraps shall not touch the surface of the pipe and shall be embedded in the middle 50 % of the enamel thickness. Sufficient enamel shall penetrate the glass fibre reinforcement to ensure proper wet-out.

The entire coating system thickness shall be between 5.5 mm and 7.5 mm on the pipe body. The coating thickness on the weld shall be at least 4 mm.

The outerwrap shall be pulled onto the enamel and be well bonded with some bleed through of enamel occurring. Wraps shall be wrinkle-free with minimum overlap of 12 mm.

4.2.4.2 Modified bitumen enamel application

Due to their higher viscosities, modified bitumen enamels are not suitable for flood coating and are applied by an extrusion process. An even coating of enamel shall be applied by extrusion coating with equipment for spirally wrapping the outerwrap under controlled tension.

The extruded enamel shall be applied prior to the outerwrap. The outerwrap shall be pulled onto the enamel and be well bonded with bleed through of enamel occurring. The outerwrap shall be wrinkle-free with an overlap of at least 12 mm. The entire coating system shall have a thickness of at least 4 mm over the weld and pipe body.

4.2.5 Solar protection

A weather-resistant solar protection coating shall be applied to all the coated surfaces of pipes, after inspection and testing and prior to stockpiling. The solar protective coating shall not contain Portland cement or similar products or substances, which are considered detrimental to the outerwrap, bituminous enamel or to the concrete weight coating.

The solar protective coating is typically whitewash or water emulsion latex as described in AWWA C203-02 sections 4.3.8, and applied in accordance with sections 4.4.1.2. and 4.7. Other protective coatings may also be used by agreement with the Principal.

5 QUALITY CONTROL

5.1 GENERAL

The Coating Applicator shall carry out the quality control activities needed to ensure that the final product complies with the requirements of this PTS.

The identity of the pipe under test and the results of the tests detailed below shall be recorded.

Records of all quality control test results shall be kept in accordance with (7).

5.2 COATING MATERIALS

5.2.1 Selection

Guidelines for the selection of the different grades of bitumen enamels and outerwraps are given in Appendix A.

5.2.2 Primer

Each batch of primer shall comply with the requirements given in Table 1 when tested by the methods specified and, when dry, shall provide an adequate bond between the metal and subsequent coating, in accordance with the appropriate performance requirements given in (5.7.7).

Table 1 Requirements of primer for oxidised and modified bitumen enamel

Characteristics	Primer Specification	Test Method
Flow time (Flow cup No. 4 at 23 °C), seconds	35 to 60	ISO 2431
Flash point (Abel closed cup), minimum °C	23	ISO 13736
Residual non-volatile matter, at 105 °C to 110 °C for 3 hours, % mass, minimum	25	ISO 3251

5.2.3 Inert filler

The fillers, graded in accordance with ISO 2591-1, Subclause 7.3, shall meet the following requirements:

passing 90 µm: more than 93 % by mass

passing 250 µm: more than 99 % by mass

5.2.4 Bituminous enamels

Bituminous enamel coating materials, in combination with a primer as appropriate, shall comply with the requirements for the appropriate grade given in Tables 2a and 2b.

Table 2a Acceptance criteria for enamel material properties

Property	Oxidised bitumen			Modified bitumen		Test Method	Frequency
	Grade a	Grade b	Grade c	Grade d	Grade e		
Filler content by ignition, mass fraction (%)	25 to 35	25 to 35	45 to 55	20 to 30	25 to 35	BS EN 10300 Annex K	Each production batch
Density at 25 °C, g/cm ³	1.2 to 1.4	1.2 to 1.4	1.4 to 1.65	1.1 to 1.3	1.2 to 1.4	BS EN 10300 Annex L	Each production batch
Softening point (ring and ball), °C	100 to 120	110 to 130	120 to 150	115 to 135	130 to 160	EN 1427	Each production Batch
Penetration at 25 °C, 10 ⁻¹ mm	10 to 20	5 to 17	5 to 15	10 to 30	5 to 17	EN 1426	Each production batch
Flash point (Cleveland open cup), minimum °C	250	260	260	260	260	ISO 2592	Each production batch

Table 2b Acceptance criteria for enamel performance properties

Property		Oxidised bitumen			Modified bitumen		Test Method	Frequency
		Grade a	Grade b	Grade c	Grade d	Grade e		
Sag	Maximum, mm 60 °C, 24 hours 75 °C, 24 hours 80 °C, 24 hours 90 °C, 24 hours	1.5	1.5	1.5	1.5	1.5	BS EN 10300 Annex D	Every 5000 tonnes or monthly (whichever is more frequent)
Impact	Disbonded area, maximum, mm ² 0 °C 25 °C -10 °C	15,000	6,500	6,500	6,500	6,500	BS EN 10300 Annex E	Every 1000 tonnes or weekly (whichever is more frequent), sampling batchwise only i.e. not composite testing
Peel	Initial and delayed, maximum, mm 30 °C 40 °C 50 °C 60 °C	3.0 3.0 3.0 3.0	3.0 3.0 3.0 3.0	3.0 3.0 3.0 3.0			BS EN 10300 Annex F (F.4.1 for oxidized bituminous enamel coating)	Every 1000 tonnes or weekly (whichever is more frequent), sampling batchwise only i.e. not composite testing
Peel	Initial an delayed, minimum, N/mm 30 °C 40 °C 50 °C 60 °C				4.0 2.5 1.5 1.0	4.0 2.5 1.5 1.0	BS EN 10300 Annex F (F.4.2 for modified bituminous coating) see note † below	Every 1000 tonnes or weekly (whichever is more frequent), sampling batchwise only i.e. not composite testing

Property	Oxidised bitumen			Modified bitumen		Test Method	Frequency
Bend minimum, mm 0 °C -10 °C	20	15	10	20	15	BS EN 10300 Annex G	Every 5000 tonnes or monthly (whichever is more frequent)
Cathodic disbonding, (20 ± 5) °C, 28 days, maximum, mm	10	10	10	7	7	BS 4164 Appendix M	Every 5000 tonnes or monthly (whichever is more frequent)
† In accordance with paragraph 5.7.7.2, the bond shall satisfy the peak force gauge reading at the temperature indicated in this table							

5.2.5 Innerwrap (oxidised bituminous enamel only)

The glass shall be of Hydrolytic Class 3 quality as a minimum when tested in accordance with ISO 719. The innerwrap shall comply with the requirements of Table 3.

Table 3 Acceptance criteria for Innerwrap

Characteristics	Unit	Specification	Test Method
Mass per unit area	g/m ²	50 ± 3	ISO 5256 Method R
Loss of mass on ignition, maximum	%	20	ISO 5256 Method R
Tensile strength - longitudinal (R ₁₀), minimum - transverse (R ₁₀), minimum	Newton/50 mm Newton/50 mm	150 50	ISO 5256 Method S
Thickness, minimum	mm	0.33	EN 1849-1
Average reinforcement spacing, maximum	mm	30	ISO 5256 Method Q
Porosity	Pa	6 to 19	ASTM D 737

5.2.6 Outerwrap

The outerwrap shall have a uniform appearance free from holes, slits and other visible faults. The reinforcement yarns shall be spaced evenly across the width. The outerwrap shall meet the following requirements in Table 4.

Table 4 Acceptance criteria for Outerwrap

Characteristic	Unit	Type of outerwrap (see Appendix A)						Test Method
		for oxidised bitumen				for modified bitumen		
		A	B	C	D	E	F	
		non-woven glass fibre tissue	non-woven glass fibre tissue	woven glass fibre	composite glass fibre	composite glass/ polyester fibre	composite glass/ polyester fibre	
Mass per unit area of carrier before impregnation, minimum	g/m ²	50	80	170	90	70	110	BS EN 10300 Annex M
After impregnation with enamel								
Thickness, minimum	mm	0.6	0.76	0.76	0.76	0.5	0.6	EN 1849-1 ^a
Mass per unit area, minimum	g/m ²	450	550	250	500	450	450	BS EN 10300 Annex M
Tensile strength minimum, - longitudinal	Newtons/50 mm	300	300	800	700	400	800	EN 12311-1 modified as in Annex N of BS EN 10300
- transverse	Newtons/50 mm	150	230	800	700	200	800	

5.3 AMBIENT CONDITIONS

The Coating Applicator shall measure the ambient conditions throughout each shift in accordance with ASTM E 337 and shall keep records of prevailing temperature, humidity and dewpoint temperature. If the conditions are such that the linepipe surface temperature is not a minimum of 3 °C above the dewpoint temperature, then the production process shall be suspended until the required conditions are met.

5.4 INSPECTION BEFORE BLAST-CLEANING

Before surface preparation starts, each pipe shall be visually examined for dents, laps, defective bevels and other defects to avoid the coating of unserviceable pipes. Defective pipes shall be removed from the coating line for repair or, if repair is not possible, the pipes shall be rejected.

The pipe surface shall be visually checked for contamination with oil and/or grease. Contaminated pipe surfaces shall be re-prepared (4.1).

5.5 INSPECTION AFTER BLAST-CLEANING

Immediately after blast-cleaning, the complete metal surface of each pipe shall be inspected for surface cleanliness, all remaining weld spatter and irregularities shall be removed from the pipe surface by chiselling and/or grinding, and the edges shall be smoothed or rendered flush. After any grinding or mechanical repairs the remaining wall thickness shall be checked and compared with the minimum requirements of the linepipe specification. Pipes not meeting the minimum wall thickness shall be rejected. Any treated surface with an area larger than 50 cm² shall be re-blasted to the required cleanliness and roughness as specified below.

The surface roughness of the first five pipes following each change of blast-cleaning material and each subsequent twentieth pipe shall be measured. The surface finish after blast-cleaning (4.1) shall be inspected by visual comparison according to the following International Standards:

Surface cleanliness: ISO 8501-1.

Surface profile: ISO 8503-2.

The surface profile comparator shall comply with ISO 8503-1 and shall be calibrated before every unit of production in accordance with ISO 8503-3 or ISO 8503-4.

Pipes which do not comply with these requirements shall be blast-cleaned again to obtain the surface cleanliness and roughness requirements.

Repairs to the pipe shall be made using a procedure agreed with the Principal.

5.6 INSPECTION AFTER PRIMING

The wet or dry film thickness of the primer shall be measured in accordance with the respective ISO 2808 methods 6 or 7b on four pipes per shift.

5.7 COATING PROPERTIES

5.7.1 Testing

The minimum quality control tests to be performed on coated pipe are summarised in Table 5.

5.7.2 Visual appearance

Each coated pipe shall be visually checked for imperfections and irregularities of the coating, cleanliness of the pipe ends and damage of the bevelled ends.

The coating shall be of uniform appearance and free from any wrinkling, pinholes, voids, laminations, holidays, dry wrap and contamination and shall be completely bonded to the pipe surface. Uncoated pipe ends shall be clean and free of primer, bituminous enamel, solar protection and/or foreign material.

Pipes that do not comply with the requirements shall be marked and removed from the coating line for repair or recoating. If subsequent pipes do not comply with the requirements, the coating process shall be checked or stopped to remove the cause of the problem.

Damaged bevels shall be repaired using an agreed procedure.

5.7.3 Enamel coating thickness

Each coated pipe shall be checked for coating thickness.

A film thickness gauge of the magnetic or electro-magnetic type shall be used to measure the coating thickness of each pipe (including coating over the weld where applicable) at five equidistant points along the pipe length to ensure compliance with the minimum thickness requirement (4.2.4). The instrument shall be calibrated at least twice daily.

Pipes that do not comply with the requirements shall be marked and removed from the coating line for repair or recoating. If subsequent pipes do not comply with the requirements, the coating process shall be checked or stopped to remove the cause of the problem.

Pipes having a coating of insufficient thickness shall not be repaired by overcoating.

5.7.4 Distribution of innerwrap (oxidised bitumen only)

One pipe in twenty shall be sampled immediately after coating. The samples shall be examined in cross-section to determine the distribution of the innerwraps within the enamel.

At the quarter, half and three quarter positions along the length of the pipe a sample 100 mm x 150 mm in size shall be taken. One sample shall be taken along the longitudinal weld. The samples shall be examined in cross-section to ascertain the distribution of the innerwraps through the enamel.

The innerwraps shall be completely embedded within the middle 50 % of the enamel thickness and shall be visually separate from each other. If any of the three samples taken does not comply with these requirements, then the coating shall be stripped and the pipe shall be re-coated.

5.7.5 Void detection

On one pipe in every 20 pipes coated and along the weld where applicable, the coating shall be rung out by means of tapping with a blunt instrument to detect voids. All areas exhibiting defects shall be repaired in accordance with the qualified repair procedure (6).

5.7.6 Holiday detection

A holiday test shall be performed on each coated pipe to check for the absence of holidays.

A low-amperage, adjustable voltage pulse type holiday detector having an audible and visual alarm shall be used. The scanning electrode shall consist of a metal brush or coil spring, fitting the diameter of the coated pipe. The earth connection shall be made directly on the pipe. The test voltage shall be set at between 18 kV and 22 kV and shall be calibrated at least twice per shift using a high-voltage meter. The electrode shall be moved over the pipe surface with a speed of not more than 0.3 m/s. The whole of the pipe surface shall be covered by the test.

The coating shall be free from holidays.

Holidays caused by metal surface defects shall require the removal of the defect by grinding or filing of the defect prior to application of the repair material. No repairs shall be made that violate the applicable linepipe specification. Under no circumstances shall a steel defect be overcoated with repair material.

All holidays detected shall be repaired in accordance with the qualified repair procedure (6).

5.7.7 Adhesion

Adhesion testing shall be carried out between 4 h and 24 h after coating has taken place on one pipe in every twenty. Three adhesion tests as described in (5.7.7.1) or (5.7.7.2), shall be carried out on the selected pipe. After testing the coating shall be repaired in accordance with the qualified repair procedure (6).

If any of the three adhesion tests fail to meet the acceptance criteria, the pipe shall be marked and removed from the coating line for repair or re-coating. If subsequent pipes do not comply with the requirements, the coating process shall be checked or stopped to remove the cause of the problem.

5.7.7.1 Oxidised bitumen enamel

The pipe coating and steel surface shall be between 10 °C and 25 °C. By means of a heated sharp blade, two cuts shall be made in the coating 20 mm apart, 150 mm in length. The two cuts shall be joined by another cut on one end only. A flat spatula of the correct width shall be inserted at the bottom of the cuts and an attempt made to lift the coating from the pipe surface. Once sufficient coating has been lifted, the coating shall be gripped between the thumb and the spatula blade, and an attempt made to peel the coating from the pipe surface. The bond shall be considered satisfactory if the coating does not exhibit adhesive failure between the primer and the enamel but only exhibits failure within the enamel and the maximum peel length is 3 mm before the coating breaks.

5.7.7.2 Modified bitumen enamel

The pipe coating and steel surface shall be between 10 °C and 25 °C. By means of a heated sharp blade, two cuts shall be made in the coating 20 mm apart, 150 mm in length.

The two cuts shall be joined by another cut on one end only. A flat spatula of the correct width shall be inserted at the bottom of the cuts and the coating shall be lifted from the pipe surface. Once sufficient coating has been lifted, a hand-held tensometer with digital readout, peak force indication and a minimum capacity of 200 N incorporating a wedge grip shall be used to clamp the coating at its interface with the steel. Applying an even, steady force the coating shall be pulled at 90° to the steel surface. When either the coating begins to detach from the primer surface or when the strip breaks, the tension is immediately released and the peak value is read from the tensometer gauge.

The bond shall be considered satisfactory if the peak force gauge reading for the 20 mm wide strip is greater than 80 N (i.e. 40 N/cm).

5.8 NON-CONFORMANCE PROCEDURE

If the coated pipe selected for and subjected to the above tests (5.7) shows defects/failures which give cause for rejection, then the three pipes preceding and following this pipe shall also be tested. These six pipes shall be subjected to the test procedures described above. If further defects/failures are detected then the entire production for that shift shall be checked and examined. Further testing shall involve inspection and examination similar to that carried out on the original rejected test pipe(s).

If in any total production batch the rejection rate is higher than 10 %, the whole batch shall be rejected and the cause of the failures ascertained. No pipes shall be dispatched from the coating yard before the quality control results have been approved by the Principal. In addition, the Coating Applicator may be required to stop production and carry out a full investigation into the source of the problem; he shall submit the results to the Principal before receiving permission from the Principal to recommence production.

5.9 TRACEABILITY OF PIPES AND COATING

The Coating Applicator shall ensure that individual pipes are fully traceable during and after the coating process. If the serial number of the pipe as given in the pipe mill is removed or obliterated, then it shall be reapplied. The Coating Applicator's own serial number shall be indicated on the pipe and records shall be kept to identify the sequence and time of coating and the batch of bituminous enamel used for each pipe.

Table 5 Minimum quality control requirements for bituminous enamel pipeline coatings

Materials or property	Section	Test method	Frequency	Acceptance criteria
Primer	(3.2.1)	Table 1	each batch	(5.2.2)
Filler	(3.2.2)	(5.2.3)	each batch	(5.2.3)
Enamel	(3.2.3)	Table 2a/2b	each batch	(5.2.4)
Fabric wraps	(3.2.4)	Table 3	each batch	(5.2.5)
	(3.2.5)	Table 4	each batch	(5.2.6)
Coating operations and coating system				
Ambient conditions	(5.3)	ASTM E 337	every 2 hours	(5.3)
Surface condition before blasting	(4.1)	Visual	each pipe	(4.1), (5.4)
Cleanliness of blasted surface	(4.1)	(5.5)	each pipe	(4.1), (5.5)
Residual salt level on blasted surface	(4.1)	Elcometer 130 SCM 400	Each 100 th pipe	< 3 µg/cm ²
Surface profile	(4.1)	(5.5)	4 pipes per shift	(4.1), (5.5)
Primer thickness	(4.2.2)	DFT – ISO 2808 Method No. 7B WFT – ISO 2808 Method No. 6	4 pipes per shift	(4.2.2)
Pipe surface temperature before surface preparation	(4.1)	Surface contact or IR thermometer	each 5 th pipe	(4.1)
Pipe surface temperature before priming	(4.2)	Surface contact or IR thermometer	each 5 th pipe	(4.2)
Visual appearance of coating	(5.7.2)	visual	each pipe	(5.7.2)
Coating system thickness	(4.2.4)	(5.7.3)	each pipe	(5.7.2)
Distribution of innerwrap	(4.2.4.1)	(5.7.4)	one pipe per 20	(5.7.3)
Void detection	(5.7.5)	(5.7.5)	one pipe per 20	Subject to repair criterion (6)
Holiday detection	(5.7.6)	(5.7.6)	each pipe	Subject to repair criterion (6)
Adhesion	(5.7.7)	(5.7.7)	one pipe per 20 (minimum one pipe per day)	(5.7.7)
Pipe ends	(4.2)	Visual (5.7.2)	each pipe	(5.7.2)

6 COATING REPAIR

The Coating Contractor shall submit detailed procedures for coating repairs. These procedures shall contain as a minimum:

1. repair of surface defects;
2. repair of holidays and small defects;
3. repair of damage due to quality control testing;
4. removal of rejected coating and cleaning the pipe to the required standard for re-coating;
5. testing to prove the effectiveness of the repairs.

The maximum total surface area per pipe that may be repaired is 0.1 % of the coated pipe surface area. Pipes requiring larger total repairs shall be re-coated.

Pipes having insufficient coating thickness shall not be repaired by overcoating. Records shall be kept of all repaired pipes and shall include the repair and test details.

7 DOCUMENTATION

The Coating Contractor shall keep accurate records of all relevant data of the coating process, materials and coating performance.

This documentation shall include:

1. copies of the coating system information (2.3);
2. copies of qualification information as required in (2.4);
3. serial numbers of all pipes (5.9) as given by the Linepipe Manufacturer (e.g. by copies of the pipe mill data sheets);
4. copies of the coating materials' data including Manufacturer's name, material designation, date of manufacture and batch number (3.2);
5. bitumen enamel samples retained (3.2.6);
6. copies of, or reference to, all procedures for coating of the pipes (4);
7. the batch numbers of the coating materials applied to each pipe, the day and time of loading of each batch;
8. the order of coating, the day and shift of coating of each pipe;
9. serial numbers of rejected pipes and the reason for rejection;
10. the results of all quality control testing (5);
11. names and signatures of the persons responsible for the coating process and quality control;
12. repair records (6).

This documentation shall be submitted to the Principal after completion of the coating works together with the calibration certificates of the testing and inspection instruments.

8 HANDLING, STORAGE AND TRANSPORT OF BARE AND COATED PIPE

8.1 GENERAL

The Coating Contractor shall take receipt of the pipes, delivered by the linepipe Manufacturer, and shall keep a record of the serial numbers of the delivered pipes. Upon receipt, the pipes shall be inspected for transport damage or other defects. Damaged pipes shall be separately stored and reported to the Principal. Repairs shall only be carried out after approval by the Principal.

8.2 HANDLING OF PIPE

The Coating Contractor shall ensure that coated pipes and components are handled without causing damage to the ends of the pipes or to the coating. The use of steel ropes, steel slings or any lifting equipment that could damage the coating and the pipe ends shall be prohibited.

Pipes shall be handled by means of end hooks or by flat slings, which cradle the pipe, and other lifting equipment such as spreader bars, beams, hoists and cranes.

Pipes shall at all times be handled in a way that prevents damage to and contamination of the surface of the coating. Hooks and slings shall be designed to prevent damage to the surface, coating or bevelled ends. If skids are used these shall be wide and padded to prevent damage. Bare cables, chains, hooks, metal bars or narrow skids shall not be permitted to come into contact with coated and wrapped surfaces.

Walking on coated and wrapped pipes shall not be permitted. Any damage to the pipe or coating caused by handling shall be repaired as outlined in this PTS.

Lifting trucks or front-end loaders shall have soft padded forks or grips to prevent damage to pipes or pipe coating.

Coated pipes shall not be rolled or dragged over the ground.

Pipes shall not be lifted in bundles without prior approval by the Principal. When more than one pipe is lifted, separate slings or hooks shall be used for each pipe and coated pipes shall be provided with soft padding between the pipes.

For handling of stainless steel pipes, handling and transport equipment and conveyors shall be padded to prevent contact with carbon steel.

8.3 TRANSPORT OF PIPE

During transportation to the storage area at the coating factory, the coater shall take all relevant precautions to avoid damage to the pipes and components and to the coating.

Coated pipes shall be prepared for transport or shipment in accordance with API RP 5L1, or API RP 5LW, whichever is applicable. During transportation, pipes shall be stacked and secured so as to prevent movement, abrasion and/or peening.

8.4 STORAGE OF PIPE

Storage of the coated pipes shall be such that the coating does not deteriorate. In particular, stacks of pipes which are intended to be stored for a long period shall be protected from the action of ultraviolet light on the coating (4.2.5).

Pipes shall be stored in designated areas. Pipes shall not be stored with other consignments or pipes for other contracts.

Pipes shall be stacked only to such height that damage or deformation to the pipes due to the weight of other pipes shall not occur. Coated pipes shall be stacked only to such height that no damage to the coating occurs.

Pipe supports shall be spaced so that no bending of pipes occurs. Pipe supports shall be made of soft padded wooden bolsters or sand rows, free of stones, covered with plastic sheets. The pipe surface shall be at least 150 mm clear from the soil.

Piles of pipe shall be secured by wooden wedges or ground pins, provided with adequate padding to prevent coating damage, and of sufficient size to prevent collapse of the piles. Coated pipes shall be stacked using soft separators such as rubber pads, or tyre tread.

When stored outdoors, pipes shall be placed at a small angle to allow drainage of any rainwater from the inside of the pipes.

8.5 LOADING OF PIPE

Loading of coated pipes and components at the factory shall be undertaken so that no damage is caused to the coating.

9 REFERENCES

In this PTS, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

PETRONAS STANDARDS

PTS publications and standard specifications PTS 00.00.05.05

AMERICAN STANDARDS

Recommended practice for railroad transportation of linepipe API RP 5L1

Recommended practice for transportation of linepipe on barges and marine vessels API RP 5LW

Issued by:
American Petroleum Institute
Publications and Distribution Section
1220 L Street Northwest
Washington DC 20005
USA

Porosity of glass fabric ASTM D 737

Standard test method for measuring humidity with a psychrometer (the measurement of wet- and dry- bulb temperatures) ASTM E 337

Issued by:
American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103 1187
USA

Coal-tar protective coatings and linings for steel water pipelines –enamel and tape – hot applied AWWA C203-02

Issued by:
American Water Works Association
6666 West Quincy Ave.
Denver, CO 80235
USA

BRITISH STANDARDS

Steel tubes and fittings for onshore and offshore pipelines — Bituminous hot applied materials for external coating BS EN 10300

Issued by:
European Committee for Standardisation
Rue de Stassart, 36
B-1050 Brussels
Belgium BS 4164

Coal-tar-based hot applied coating materials for protecting iron and steel, including suitable primers where required

Issued by:
British Standards Institute
389 Chiswick High Road
London W4 4AL
U.K.

EUROPEAN STANDARDS

Bitumen and bituminous binders – Determination of softening point – ring and ball method	EN 1427
Bitumen and bituminous binders – Determination of needle penetration	EN 1426
Flexible sheets for waterproofing. Part 1: Bitumen sheets for roof waterproofing. Determination of thickness and mass per unit area	EN 1849-1

NOTE: Copies can also be obtained from National Standards Organizations

INTERNATIONAL STANDARDS

Glass - Hydrolytic resistance of glass grains at 98 °C - Method of test and classification	ISO 719
Paints and varnishes - Determination of flow time by use of flow cups	ISO 2431
Test sieving. Part 1: Methods using test sieves of woven cloth and perforated metal plate	ISO 2591-1
Petroleum products – Determination of flash and fire points - Cleveland open cup method	ISO 2592
Paints and varnishes - Determination of film thickness	ISO 2808
Paints and varnishes – Determination of non-volatile matter of paints, varnishes and binders for paints and varnishes	ISO 3251
Steel pipes and fittings for buried or submerged pipelines - External and internal coating by bitumen or coal tar derived materials	ISO 5256
Preparation of steel substrates before application of paints and related products - visual assessment of surface cleanliness. Part 1: rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings	ISO 8501-1
Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates	ISO 8503
Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces	ISO 8503-1
Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel - Comparator procedure	ISO 8503-2
Part 3: Methods for the calibration of ISO surface profile comparators and for the determination of surface profile - Focusing microscope procedure	ISO 8503-3
Part 4: Methods for the calibration of ISO surface profile comparators and for the determination of surface profile - Stylus instrument procedure	ISO 8503-4
Petroleum products and other liquids - Determination of flash point - Abel closed cup method	ISO 13736

Issued by:
International Organisation for Standardisation
1, Rue de Varembe
CH-1211 Geneva 20
Switzerland.

NOTE: Copies can also be obtained from National Standards Organizations

APPENDIX A GUIDELINES FOR THE USE OF COATING MATERIALS

A.1 Oxidised Bitumen Enamel Coating

Oxidised bitumen enamels are applied externally by flood coating. In general, grades of higher softening point and lower penetration are intended for use under higher service temperature conditions. Typical in-service temperatures for the grades are:

Oxidised bitumen enamel	Design temperature range	Comment
Grade a	-10 to +60 °C	Suitable at normal and lower than normal ambient temperatures in temperate climates.
Grade b	-10 to +70 °C	Suitable at ambient temperatures in both temperate and hotter climates.
Grade c	-10 to +70 °C	Suitable for use at ambient temperatures in tropical climates.

A.2 Modified Bitumen Enamel Coating

Due to their higher viscosity, modified bitumen enamels are not suitable for flood coating and are applied by an extrusion process. Composite glass/polyester outerwraps are normally applied only to modified bitumen coating materials

In general, grades of higher softening point or lower penetration are intended for use under higher temperature conditions. Typical in-service temperatures for the grades are:

Modified bitumen enamel	Design temperature range	Comment
Grade d	-20 to +80 °C	Suitable for use in cold and temperate climates. Can be used in cooler tropical climates with suitable care.
Grade e	-20 to +90°C	Suitable for use in all climatic conditions. For use on hot lines.

A.3 Outerwrap

The type of outerwrap specified depends on the environmental conditions around the pipeline. The objective is to provide a mechanical protection against external influences, such as soil stress, stones and pipe movement. All types of outerwrap are suitable for use under a concrete weight coat in submarine conditions. The more flexible glass/polyester outerwrap is used with modified bitumen enamel.

Typically, the stronger the outerwrap the greater the reinforcement and protection it offers. However, the stronger the outerwrap the more expensive it is. Selection of the right outerwrap is a balance between performance and cost. Where the enamel coating is to be protected by a concrete weight coat, it is usual to specify a light duty outerwrap.

Type A:	suitable for normal conditions
Type B:	suitable for protection in higher stressed conditions
Type C:	an extra strong woven material for use in high stress conditions
Type D:	an extra strong lock-welded material for use in high stress conditions
Type E:	a strong composite material for use with modified bitumen enamel under normal conditions
Type F:	a heavier duty composite material for use with modified bitumen enamel under high stress conditions