

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

(CORE)

TECHNICAL SPECIFICATION

THERMAL SPRAY COATINGS OF ALUMINIUM AND 85/15 ZINC/ALUMINIUM ALLOY

PTS 30.48.40.31

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This revision of PTS 30.48.40.31 – Thermal Spray Coatings of Aluminium and 85/15 Zinc/Aluminium Alloy (**December 2010**) has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards.

The previous version of this PTS **30.48.40.31 (May 2004)** will be removed from PTS binder / e-repository from herein onwards.

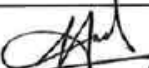
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PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication, of PETRONAS OPU/Divisions.

They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPUs 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.

The right to use PTS rests with three categories of users:

- 1) PETRONAS and its affiliates.
- 2) Other parties who are authorised to use PTS subject to appropriate contractual arrangements.
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) and 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

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1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the application of thermal spray coatings, of such quality as to last for 25 years prior to first maintenance, to onshore and offshore structures, equipment and piping etc. under atmospheric conditions and beneath insulation. Thermal spray coatings may also be used on immersed and buried surfaces, equipment and structures. The following coating systems are included in this PTS:

- Aluminium;
- Zinc-Aluminium (85/15);
- Duplex coating system: Zinc-Aluminium (85/15) + Topcoat.

All three systems, when applied in the manner and to the requirements specified by this PTS, are equivalent for use under atmospheric conditions.

This PTS is a revision of the PTS of the same number dated August 2005; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to PETRONAS companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants and exploration and production facilities as well as distribution storage PTSots and installations.

When PTSs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

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 regard to the 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, the objective being to obtain agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies coating materials, equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that 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 **Coating Contractor** is the party that applies the thermal spray coatings.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Bend test	180° bending of a sample on a mandrel.
Companion coupon	Rectangular steel coupon, prepared for qualification of thermal spray coating materials and coated concurrently with the workpiece for quality control and inspection.
CUI	Corrosion under insulation.
Dew point	The temperature of a given air/water-vapour mixture at which, under atmospheric pressure, condensation starts.
Feather	Smooth tapered transition between thermal spray coating and the adjacent non-coated surface
Holding period	Time between the completion of the final surface blasting and completion of the thermal spraying.
Overspray	The portion of the thermal spray PTSosit that is not PTSosited on the desired area of the workpiece.
Rust bloom	Discoloration indicating the beginning of rusting, bleeding through the interconnecting pores of the thermal spray coating.
Sealer	A thin paint coating, about 40 µm thick, that is absorbed into the pores of the thermal spray coating and seals the coating surface.
Shift	Production run of which the beginning and end coincide with a change in personnel.
Soluble salt contaminants	Water-soluble salts, such as chlorides and sulphates, which contaminate the steel surface and cause rust bloom and premature coating failure.
Thermal spray	Application of metallic coating by means of arc- or flamespray equipment.
Topcoat	Paint coat applied over a sealed thermal spray coating.
TSA	Thermally Sprayed Aluminium.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced by this PTS are listed in (10).

1.5 CHANGES FROM THE PREVIOUS EDITION

This PTS is a revision of the PTS of the same number dated August 2005. The following are the main, non-editorial changes.

Section	Change
General	- QA/QC better aligned with PTS 30.48.00.31-P - Added: Zinc/aluminium (85/15) alloy and Duplex coating - Increased alignment with ISO standards.
1.	Extended application: TSA for CUI, increased maximum TSA service temperature.
2.	Added: Section on applications and limitations Added: Table on risks and safety measures.
3.	Revised: more prescriptive material specifications for thermal spray coating, sealer, and topcoat.
4.	Revised: More prescriptive requirements for surface preparation. Better aligned with requirements of offshore coating in PTS 30.48.00.31-P
5.	Revised: More prescriptive requirements for qualification of thermal sprayers, and coating materials.
6.	Revised: More prescriptive requirements for quality assurance and quality control for thermal spray coatings, including sealers, and topcoats. Better aligned with requirements of PTS 30.48.00.31-P Added Figure showing bend test arrangement and pass/fail samples.
7.	Revised: More prescriptive requirements for coating application.
8.	Revised: More prescriptive requirements for coating repair. Added: Section on field welds

2. APPLICATIONS, LIMITATIONS AND SAFETY CONSIDERATIONS

2.1 APPLICATIONS AND LIMITATIONS

Thermal spray coatings specified in this PTS shall be applied by arc or flame spraying, using a solid metal wire. Powder consumables, high velocity oxy-fuel (HVOF) and plasma techniques shall not be used.

Thermal spray aluminium (TSA) and zinc/aluminium (85/15) alloy coatings provide both a barrier and cathodic protection to the steel substrate.

Thermal spray Aluminium (TSA) and Zinc-Aluminium (85/15) coatings shall not be used in acidic or caustic environments; the acceptable range is pH 4 to 8.

TSA coatings only shall be used to protect stainless steel against chloride stress corrosion cracking.

TSA coatings only shall be used for protection against corrosion under insulation (CUI).

The maximum service temperature for TSA coatings shall be 590 °C under dry conditions, and 200 °C under wet, or immersed conditions.

Thermal spray aluminium coating shall not be sealed when applied:

- (i) to immersed components;
- (ii) under insulation (to protect against CUI); or
- (iii) to buried components (e.g. buried piping).

The maximum atmospheric service temperature for zinc/aluminium (85/15) alloy coating shall be 300 °C under dry conditions, and 60 °C under wet, immersed, or buried (e.g. pipe) conditions. Zinc/aluminium (85/15) alloy coating shall not be used under insulation (CUI).

Thermal spray zinc/aluminium (85/15) alloy coating shall not be sealed when applied:

- (i) to immersed components, and
- (ii) buried components (e.g. buried piping).

Thermal spray zinc/aluminium (85/15) alloy coating shall not be used for coating stainless steel.

The maximum atmospheric service temperature for coated zinc/aluminium (85/15) alloy, the so-called "duplex system" shall be 120 °C. The duplex system shall not be used for immersed or buried applications.

2.2 SAFETY

2.2.1 General

Thermal spray coatings may involve the use of hazardous materials, operations, and equipment. However, this PTS does not address all of the potential safety concerns associated with their use.

It is the responsibility of the Contractor and/or Applicator to establish appropriate safety and health requirements, and determine any regulatory requirements or limitations prior to use.

Safe working is of the greatest importance particularly in confined spaces such as tanks and vessels.

All personnel shall be provided with approved personnel protection, e.g. protective clothing, safety glasses, safety shoes, hard hats, goggles, respirators, earplugs, fresh-air-fed hood and any other necessary safety equipment. All safety equipment shall be maintained in good working condition.

Adequate warning signs shall be prominently displayed at all access points to areas where abrasive blasting and thermal spraying is in progress.

Thermal spraying is a safe process when performed by an Applicator who follows the recommended precautionary measures, has a proper understanding of thermal spraying practices, has knowledge and skill, and exercises care in using thermal spray equipment.

2.2.2 Hazardous components

Potential thermal spray hazards include exposure to flame, heat, vapours, (metal) dust, fumes, gases, noise, (from the spray gun) and arc ultraviolet (UV) radiation. Additionally, improperly used thermal spray equipment can create potential fire and explosion hazards from the fuel and carrier gases and a potential electrical shock hazard from the electrical and electronic equipment and charged wire spools. To minimize hazards, adequate safety precautions shall be followed. Thermal sprayers shall comply with the procedures in the safety regulations, the Manufacturer's technical manuals, and the material safety data sheets.

2.2.3 Safety measures

Risk factors, consequences, and recommended safety measures for thermal spray coatings shall include as a minimum the following:

Source	Risk	Safety measures
Heat from spray gun Flame from spray gun	Burn injuries Fire	Wear non-flammable, heat-resistant clothing, in compliance with ISO 14877.
Noise from spray gun	Ear damage	Wear suitable ear protectors
UV-exposure from arc spray	Irritation / damage of eyes	Wear dark (welder's) glasses
Metal (spray) dust	Irritation of airways / lungs Fire Dust explosions	Wear hood with forced air supply Water shall not be used; Use dry sand, or Class D fire-extinguisher; Regular cleaning of floor and equipment to remove metal spray dust (good housekeeping).
Heavy weight of gun	Overstraining muscles	Regular job rotation during spraying

3. MATERIALS

3.1 THERMAL SPRAY COATING

For application of thermal spray coating in accordance with this PTS, the chemical composition of the metallic wire material used shall meet the following requirements:

- aluminium shall be in accordance with ISO 209, Grade 1350 or Grade 1100. Grade 1100 should be used for application under insulation;
- zinc/aluminium alloy shall be in accordance with ISO 14919, Grade ZnAl15.

Zinc/aluminium alloy shall not be applied on stainless steel.

TSA coated surfaces shall not be in direct contact with carbon steel, e.g. TSA coated pipe and steel support. A non-metallic layer, e.g. PTFE, or elastomer strip should be used to avoid direct contact between a TSA coated surface and its steel counterpart.

3.2 SEALER

Sealers are designed to fill the porosity of the thermal spray coating, and not to build film thickness.

The sealer shall have sufficiently low viscosity to penetrate into the pores and seal the surface of the thermal spray coating. The dry-film thickness (DFT) of the sealer should not exceed 40 µm.

TSA coating shall not be sealed when applied:

- To components that are to be immersed (e.g. in seawater);
- Under insulation (to protect against CUI);
- To components (e.g. piping) that are to be buried.

Thermal spray Zinc/aluminium (85/15) alloy coating shall not be sealed when applied:

- To components that are to be immersed (e.g. in seawater);
- To components (e.g. piping) that are to be buried.

TSA and zinc/aluminium (85/15) alloy coatings may be sealed when used under atmospheric conditions, e.g. to prevent fouling of the surface, or when a particular decorative finish, or safety colors are required.

The following sealer materials shall be used:

- Epoxy: to a maximum temperature of 120 °C;
- Silicone: to a maximum temperature of 450 °C.

3.3 TOP COAT

Topcoats applied on thermal spray coating shall be chemically compatible with the sealer and shall be applied according to the instructions of the paint Manufacturer.

TSA and zinc/aluminium (85/15) alloy coatings may be topcoated when used under atmospheric conditions, and when a finishing colour is required, e.g. for safety markings, visual appearance, etc. The following coating system shall be used:

- Epoxy sealer, maximum DFT 40 µm;
- Aliphatic polyurethane topcoat, maximum DFT 40 µm.

For the Zinc/aluminium (85/15) Duplex system, the following coating system shall be applied:

- Epoxy sealer;
- Epoxy mid-coat;
- Aliphatic polyurethane topcoat.

The organic coating system applied over the zinc/aluminium (85/15) thermal sprayed system shall be qualified as for coating system FC2-N as specified by PTS 30.48.00.31-P., except that the organic coating system shall have a minimum thickness of 200 µm (7.7).

4. SURFACE PREPARATION

4.1 GENERAL

All edges to be coated shall be ground to a minimum radius of 2 mm. Flame cut areas and weld spatter shall be ground flush.

Cleaning of surfaces shall be done by dry blast cleaning, in accordance with ISO 8504-2.

Fabrication should be complete before surface preparation begins.

Alternative surface preparation, such as power tool cleaning, grinding, etc., shall not be performed.

Stainless steel surfaces shall not be treated with carbon steel cleaning tools or tools previously used on carbon steel.

4.2 CLEANING

Prior to the blast cleaning and/or thermal spraying, the surface shall be free of any contamination and any excessive rust scale shall be removed. Salt contamination of parts that have been stored in and exposed to the open air should be removed prior to blast cleaning. Salt contamination shall be assessed as specified in (6.6.4).

If emulsion or detergent type degreasers or Teepol/fresh water solutions are used, this treatment shall be followed by copious rinsing with fresh and clean potable water or pressure water/steam wash. All degreasers shall be proven to be biologically degradable.

All welded areas and appurtenances shall be given special attention for removal of welding flux in crevices. Welding spatter, slivers, de-laminations and underlying mill scale not removed during fabrication and exposed before and during blast cleaning operations shall be removed by the best mechanical means. Edges shall be smoothed or rendered flush.

Where rectification has been necessary on blast-cleaned surfaces, the areas shall be pre-cleaned as initially specified.

For the treatment of stainless steels, attention shall be given to the level of free halides in materials to be used.

4.3 ABRASIVE BLAST CLEANING

4.3.1 General

Blast cleaned steel surfaces shall not be touched by bare hands.

If the surface being cleaned lies adjacent to a coated surface, the blast cleaning shall overlap the coated surface by at least 50 mm. The edges of the existing coating system shall be feathered (7.6.2). The remainder of the existing coated surface shall be properly protected with shields or screens to prevent any over blast damage.

No acid washes, cleaning solvents or other chemical treatments shall be used on metal surfaces after they have been blast cleaned. This restriction includes inhibitive washes intended to prevent rusting.

Where rectification has been necessary on blast-cleaned surfaces, the areas shall be re-blasted to minimum Sa 2½, in accordance with ISO 8501-1.

4.3.2 Abrasives

Abrasives for blast-cleaning steels shall be in accordance with Table 1. Test methods shall be in accordance with the tests specified in ISO 11127. Each batch of abrasive shall be tested to check that the abrasive meets the requirements as specified in the relevant ISO standard.

The conductivity of abrasives to be used for stainless steels shall be a maximum of 150 µS/cm. The Principal shall approve the use of alternative abrasive materials.

The abrasives shall be free from oil, grease, moisture, chloride contamination etc.

For blasting stainless steel, non-(free)iron containing abrasive shall be used, e.g. Garnet, coal slag, or aluminium oxide.

Abrasives shall be supplied with certification documentation traceable to batches of material.

Table 1 Abrasives specification

Type	Generic Name	Characteristics	Standard
Metallic	Iron grit	> 1.7 % carbon	ISO 11124-2
	Steel grit	0.8 % to 1.2 % carbon	ISO 11124-3
Natural mineral	Staurolite	Iron/aluminium silicate	ISO 11126-9
	Garnet	Calcium iron silicate	ISO 11126-10
Synthetic mineral	Coal slag	Aluminium silicate	ISO 11126-4
	Aluminum oxide	Crystalline corundum	ISO 11126-7

4.3.3 Surface finish

At the time of application of the thermal spray coating, the surface finish shall be minimum Sa 2½, in accordance with ISO 8501-1.

4.3.4 Surface roughness

The surface roughness shall be measured by means of replica tape, in accordance with ISO 8503-5. Other, proprietary testing techniques may be used, as agreed by the Principal.

The surface roughness for thermal spray coatings shall be between 75 µm and 110 µm, in accordance with ISO 8503-5. The surface shall have a sharp angular profile, and shot shall not be used.

5. QUALIFICATION

5.1 GENERAL

Individual thermal sprayers, both for manual and mechanised application techniques, shall be qualified in compliance with ISO 14918. The qualification tests, as specified in ISO 14918, Annex B.1 and B.9, shall be witnessed and certified by an independent third party authority, to be agreed by the Principal.

The coating repair methods proposed by the Contractor shall also be qualified, in compliance with this PTS.

Before a thermal spray coating can be applied, the Contractor shall submit the following information to the Principal:

- Abrasives - name of product and Manufacturer, mesh size, cleanliness report;
- Blasting and thermal spray equipment - type and name of the Manufacturer;
- Spray material - name of Manufacturer, wire size, chemical composition;
- Sealer and topcoat - name of product and Manufacturer.

5.2 QUALIFICATION TESTS

In addition to the ISO 14918 requirements, additional qualification tests shall be performed, and shall be witnessed and certified by an independent Third Party authority, to be agreed by the Principal.

5.2.1 Test coupons

For the test coupons, the same type of steel shall be used as for the actual component, or structure to be coated. Surface preparation, coating material, spray technique, coating thickness, etc., shall comply with this PTS.

5.2.2 Bend test

Each thermal sprayer shall prepare and spray a minimum of three companion bend test coupons (dimensions 150 mm x 50 mm, thickness 1.8 mm). The thermal spray bend test coupons shall not be sealed or topcoated.

The bend test entails bending at least three thermal spray coated steel coupons through 180° on a 13 mm diameter steel mandrel.

Should any one of the bend tests fail the acceptance criteria specified in Table 2, the thermal sprayer may make one additional attempt to qualify by spraying and testing a further 3 coupons. Should any one these fail, the sprayer shall be deemed to have failed the qualification test.

5.2.3 Adhesion test

Each thermal sprayer shall prepare and spray one test panel, thickness 6 mm, with a minimum surface area of approximately 1 m². The coated surface shall not be sealed or topcoated.

The adhesion strength between the thermal spray coating and the steel substrate shall be measured by means of a portable, self-aligning, hydraulic controlled adhesion tester in accordance with ISO 4624. The adhesive between the dolly and the thermal spray coating shall be an epoxy.

A minimum of three pull-off adhesion tests shall be conducted. Should any one of the pull off adhesion tests fail the acceptance criteria, specified in Table 2, the thermal sprayer may make one additional attempt to qualify by spraying and testing a further panel. Should any one of the subsequent pull-off adhesion tests fail, the sprayer shall be deemed to have failed the qualification test.

5.2.4 Sealer

If a sealer is specified, then following completion of the pull-off adhesion tests, the test panel used shall be sealed with the same sealer material that is to be used for the thermal sprayed component or structure, and which shall comply with this PTS.

The sealed surface area of the thermal spray coated test panel shall be examined by means of a microscope with minimum 10x magnification. The sealed surface shall show 100 % coverage, and no open pores shall be present at the surface.

5.2.5 Duplex coating system

The organic coating system applied over the zinc/aluminium (85/15) thermal sprayed system as part of the duplex coating system shall be qualified as coating system FC2-N as required by Section 2.2 and 3.2 of PTS 30.48.00.31-P. except that the organic coating system shall have a minimum thickness of 200 µm (7.7).

5.3 SUMMARY OF QUALIFICATION TESTS AND ACCEPTANCE CRITERIA

Table 2 Qualification test requirements for thermal sprayer and coating material

Property	Test method	Measurements	Acceptance criteria
ISO Qualification	ISO 14918, Annex B.1 and B.9	Thickness, visual, adhesion	Full compliance with ISO 14918
Coating surface	Visual inspection (6.8) ISO 14918	100 % of surface	Uniform appearance, no blisters, bare patches, defects, or non-adhering coating
Coating Thickness	ISO 2808 (7.7)	At least 5, at random	Minimum 250 µm
Coating Adhesion	ISO 4624 (6.10)	At least 3, at random	> 7 MPa (single measurement)
Overall quality	Bend test (6.11)	At least 3	Minor cracks, with no coating lifting or spalling, see Figure 1.
Sealer	Visual inspection (6.8)	100 % of surface	100% coverage, no open pores present at the surface
Duplex coating	PTS 30.48.00.31-P.	PTS 30.48.00.31-P.	Full compliance with PTS 30.48.00.31-P.

6. QUALITY ASSURANCE AND CONTROL

6.1 GENERAL

The Principal or its Representative shall have the right to inspect, check or review, at all times, any or all of the activities, equipment, inspection equipment or product designated for the work. All parts of the work shall be accessible for this purpose.

An independent third party authority to be agreed by the Principal shall carry out regular quality checks. However, in no way does this relieve the Contractor of any responsibility with respect to the quality of the coating work.

The Principal's Representative assigned to the coating application work shall be given at least four hours' notice of any change in the schedule of the coating activities.

Whenever any section is to be assembled that will prevent subsequent inspection of an area, the Principal's Representative shall be notified in time, so that inspection and repair activities can be carried out before proceeding with the assembly.

Both the applicator and the Manufacturer of the coating materials shall implement a quality management system in accordance with ISO 9001.

6.2 RESPONSIBILITY OF COATING CONTRACTOR

The Coating Contractor is responsible for the quality of the work, which shall be performed in accordance with this PTS, and all other relevant documents such as site regulations, safety rules and requirements, product data sheets, referenced standards and codes.

The Contractor shall be fully responsible for all Quality Assurance and Control activities.

The Contractor shall schedule a pre-job meeting to ensure that job and quality requirements are fully understood. Attendees shall include a representative of the Principal, the Contractor's job superintendent, the Coating Contractor, his coating supervisor and the Contractor's coating inspector.

For all coating work, the Contractor shall submit appropriate work plans and a quality plan for implementing the requirements of this PTS for review by the Principal. The quality plan shall fully reflect the requirements of this PTS.

Unless otherwise agreed, the Contractor shall supply all the weather protection, scaffolding and any other equipment necessary to ensure that the work is carried out in accordance with this PTS and the agreed programme. This includes, for example, heating and air-drying equipment.

The Coating Contractor shall protect all equipment, structures and any other areas from mechanical damage, environmental damage, blockage or obstruction, or damage, caused by the coating work.

Copies of this PTS, the work plans and the quality plan shall be made available to the coating Contractor's representative at the site and the Contractor shall be familiar with their contents.

6.3 QUALITY PLAN

The quality plan of the Coating Contractor shall comply with ISO 14922-1 and ISO 14922-2.

Before commencing any work, a written project-specific quality plan shall be submitted to the Principal for approval. This plan shall include:

- a) A sequence for the various activities in relation to the total work to be done;
- b) Detailed scope of the work to be done including, per item or area, the required surface preparation and coating system to be applied;

- c) Full details of the blast and thermal spray equipment including, where appropriate: dehydration, temperature, any other environmental control measures, methods of access, etc.;
- d) Details of coating materials used, including datasheets, certificates;
- e) Details of the personnel involved in the work together with a clear definition of their responsibilities and lines of communication;
- f) Detailed procedures and plans for testing and inspection including the methods and equipment to be used and the frequency of their application and acceptance criteria;
- g) Details documenting the essential steps in achieving quality;
- h) Dew point determination table;
- i) Calibration methods of the inspection equipment;
- j) Qualification of abrasive blasting and thermal spraying personnel.

Following review and approval by the Principal, the project quality plan may be updated and revised during the work, as and when required. All revisions shall be submitted to the Principal for approval prior to being included in the quality plan.

6.4 QUALITY RECORDS

The coating Contractor or Applicator shall keep and submit to the Principal accurate records of all relevant data of the surface preparation, spray process, sealer and topcoat materials.

The documentation shall include as a minimum:

- Record of contract / design review;
- Surface preparation – abrasive material type and size, cleanliness of abrasive, compressed air cleanliness, surface cleanliness, surface profile;
- Material certification;
- Thermal spraying procedure specification;
- Thermal spraying procedure approval test records;
- Thermal sprayer approval certification;
- Pre and post treatment and procedures specification records;
- Dimensional reports, including coating thickness;
- Records of repairs or new thermal spraying.

Quality records shall be submitted to the Principal after completion of the coating work together with the calibration certificates of the testing and measuring instruments. Quality records shall be retained for a minimum period of 5 years.

6.5 INSPECTION PERSONNEL AND EQUIPMENT

All inspection personnel shall be individually certified by a recognized Accreditation / Inspection Agency, e.g. NACE, Lloyds, DNV, TÜV or Velosi, to be agreed by the Principal.

The Contractor shall provide and use all inspection equipment necessary to ensure that the specified conditions and quality requirements are achieved.

6.6 SURFACE PREPARATION

6.6.1 General

Cleaned surfaces shall be examined for traces of oil, grease or other contamination and tested for the presence of soluble salts. If present, contaminants shall be removed by solvent washing or for salts, by water washing or steam cleaning, and the affected areas re-blasted. The illuminance for examination shall be at least 500 lx.

6.6.2 Surface finish

At the time of application of the thermal spray coating, the surface finish shall be minimum Sa 2½, in accordance with ISO 8501-1.

6.6.3 Surface roughness

Checks on surface roughness shall be made at least once per 100 m² of prepared surface, with a minimum of three measurements per day per shift.

The surface roughness shall be measured by means of replica tape, in accordance with ISO 8503-5. Other, proprietary (field) testing techniques may be used, as agreed by the Principal.

The surface roughness for thermal spray coatings shall be between 75 µm and 110 µm, in accordance with ISO 8503-5. The surface shall have a sharp angular profile, and shot shall not be used.

6.6.4 Residual salt contamination

The maximum total allowable soluble salts level on the surface shall not exceed 20 mg/m², and shall be measured in accordance with ISO 8502-6 and ISO 8502-9. Other, proprietary field-testing techniques may be used if agreed by the Principal.

The level of salts shall be tested at least once per 100 m² of prepared surface, with a minimum of three measurements per day per shift.

6.6.5 Surface dust

The dust level on the blast-cleaned surface at the time of coating shall not exceed quantity-rating 1 in accordance with ISO 8502-3.

Dust levels shall be checked at least once per 100 m² of prepared surface, with a minimum of three measurements per day per shift.

6.7 DEW POINT AND RELATIVE HUMIDITY

No thermal spray coating work shall be carried out when the temperature of the steel surfaces is less than 3 °C above dew point of the surrounding air, or the relative humidity of the air is greater than 85 %. Dew point determination shall be in accordance with ISO 8502-4.

6.8 COATING APPEARANCE

The thermal spray coating shall be free from defects such as blisters, spatter, cracks, loose particles, areas with bare substrate steel, etc., when examined with a microscope with 10x or higher magnification.

Sealer visual inspection shall be performed for every 50 m² of manually sprayed, and for every 100 m² of mechanised sprayed coating. The sealed surface shall show 100 % coverage, and no open pores shall be present at the surface, when examined with 10x or higher magnification.

6.9 COATING THICKNESS

Spot checks shall be carried out during thermal spraying of the coating to ensure that the specified coating thickness is being maintained, and the thickness shall be measured by means of a thickness meter based on eddy-current or electromagnetic techniques, in accordance with ISO 2808, methods 7B (magnetic-flux), 7C (magnetic-induction) or 7D (Eddy-current). The coating thickness gauge shall be calibrated daily.

For flat surfaces, coating thickness measurements shall be taken along a straight line. The average value of five readings taken in a line at 25 mm intervals shall be determined.

Thickness measurements shall be taken and recorded at a minimum of one (1) per m² of coated surface.

For complex geometries, a spot measurement shall be taken. Thickness is determined by the average value of five readings taken on a local area of approximately 10 cm².

For the acceptance of an inspected area the following thickness criteria shall apply:

- Local thickness of the thermal sprayed coating shall not be lower than 90 % of the specified minimum thickness (7.7);
- Local thickness of the thermal sprayed coating, e.g. at corners, shall be maximum 2 x the specified minimum thickness.

If the thermal spray coating local thickness is less than 90 % of the specified minimum value (7.7), the thermal sprayer shall apply additional layers to meet the thickness requirement.

If the local thickness is greater than the specified maximum value, the Principal shall be notified for resolution of this discrepancy. The pull-off adhesion test may be performed on a coating with excessive thickness to check its integrity.

Any unacceptable applied thermal spray coating shall be blasted off and a new coating applied, in compliance with this PTS.

The thermal sprayer shall record all areas with coating thickness outside the specified minimum or maximum value.

6.10 ADHESION STRENGTH

The adhesion strength between the thermal spray coating and the steel substrate shall be measured by means of a portable, self-aligning, hydraulic controlled adhesion tester in accordance with ISO 4624. In all cases, adhesion tests shall be performed directly on the work piece.

The adhesive between the dolly and the thermal spray coating shall be an epoxy.

The pull-off adhesion strength for thermal spray coating shall be minimum 7 MPa for any single measurement. Pull-off adhesion tests shall be performed at least once per 100 m² of prepared surface, with a minimum of three measurements per sprayer per shift. If one of the three measurements falls below the minimum specified value of 7 MPa, but not lower than 6.3 MPa, the coating shall be accepted.

If any one value is less than 6.3 MPa or if two or more readings are below 7MPa, the thermal sprayed surface shall be blasted off and a new coating applied, starting from the location where the last acceptable pull-off strength was measured.

Spots damaged by the adhesion tests shall be repaired in accordance with the coating Contractor's qualified repair procedures and the requirements of this PTS.

6.11 BEND TEST

During the thermal spray operation, steel companion coupons shall be used to monitor the quality of the thermal spray coating.

The bend test entails bending at least three steel coupons (dimensions 150 mm x 50 mm, thickness 1.8 mm), through 180° on a 13 mm diameter steel mandrel.

For the test coupons, the same type of steel shall be used as for the actual component or structure to be coated. Surface preparation, coating material, spray technique, coating thickness, etc., shall comply with this PTS.

Three companion coupons shall be abrasive blasted and sprayed to the specified minimum thickness (7.7), and a minimum of three bend tests shall be performed once per 100 m² of thermal sprayed surface, with a minimum of three bend tests per day per shift, and/or after any change in parameter settings of the spray apparatus. The thermal sprayed coupons for the bend test shall not be sealed, or topcoated.

Typical bend test arrangement, visual appearance of pass and fail samples and acceptance criteria are shown in Figure 1.

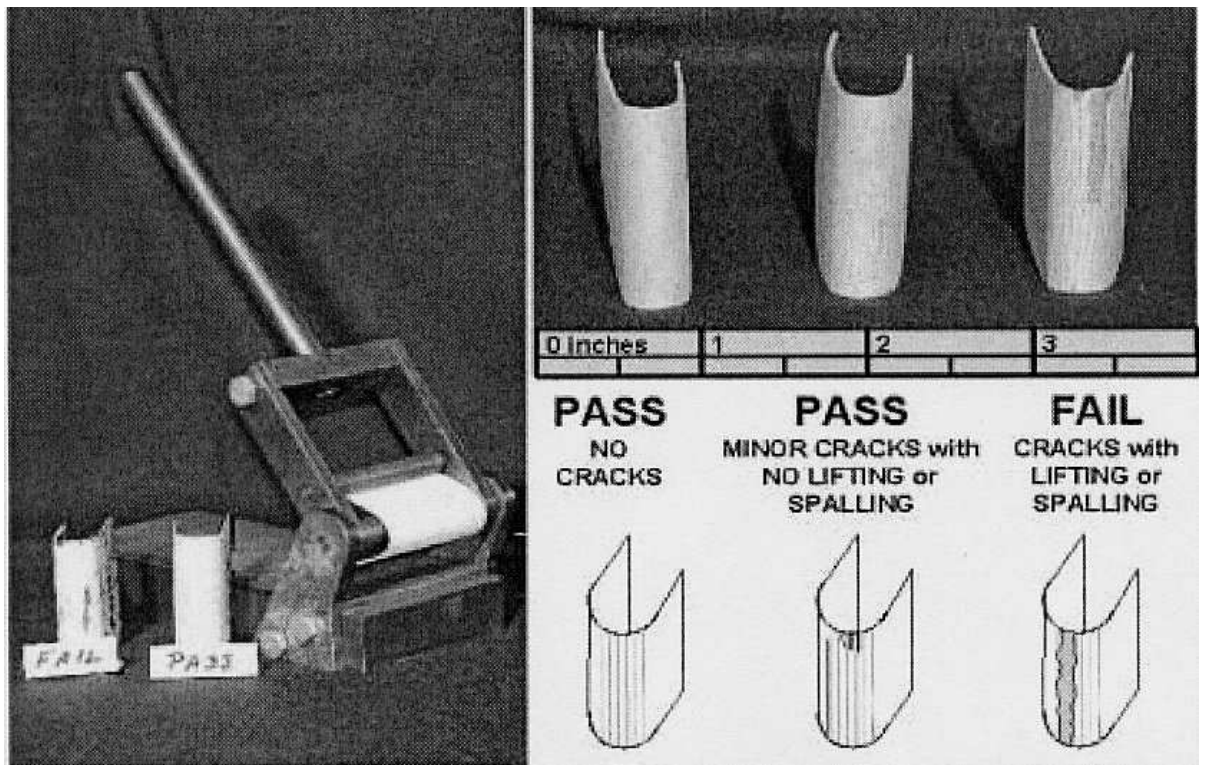


Figure 1 - Bend test arrangement : visual appearance and acceptance criteria for pass and fail samples

If the bend test is failed, the thermal spray operation shall be stopped, and corrective action shall be taken before thermal spraying is continued.

6.12 FINAL INSPECTION

As part of the Quality Assurance (QA), a final inspection shall be conducted prior to acceptance of the thermal spray coating work. This final inspection shall include a visual check of the appearance and overblast of the coating work, and checks on total thickness of coating system, when completed.

The Contractor and the Principal shall both be represented and they shall sign an agreed acceptance form as part of the warranty agreement.

As part of the acceptance procedure, the Contractor shall prepare a report including the following:

General

- Name of the Contractor / Applicator and the responsible personnel.
- Scope of work.
- Dates when work was carried out.
- Copies of the work and quality plan.
- Deviations from this PTS and the quality plan.

Inspection equipment

- Type and calibration of instruments used.

Surface preparation:

- Condition of surface before preparation.
- Checks of surface cleaning as specified in this PTS.

Coating application

- Information on coating materials being applied (i.e. spray material, sealer, topcoat, etc.)
- Checks of coating application as specified in this PTS.
- Check on thickness of the applied coating.

Inspection reports

- Copy of the inspection reports of the Contractor.
- Inspection reports from an independent third party.
- Qualification and production test results.

7. COATING APPLICATION

When personnel are working in confined spaces, adequate ventilation and spark-proof lighting shall be provided.

7.1 BLASTERS AND THERMAL SPRAYERS

Blasters and thermal sprayers working on every coating job should be certified in accordance with a scheme approved by the Principal. A certified foreman should supervise the blasters and thermal sprayers. Before any work is commenced or a contract is awarded, the certificates should be submitted to the Principal. Certifying bodies shall comply with ISO/IEC 17024, or other Standards, to be agreed by the Principal.

Thermal sprayers and coating materials shall be approved by qualification tests in accordance with this PTS. All records of approval shall be maintained up to date.

7.2 EQUIPMENT

7.2.1 General

The Contractor shall demonstrate that the blasting and spraying equipment to be used is in good condition and well maintained. Blasting and thermal spray equipment shall fully comply with any local and/or regional regulations.

7.2.2 Blasting equipment

The compressed air shall be free of water and oil. Adequate separators and traps shall be provided, installed in the coolest part of the system. The presence of oil and water shall be determined in accordance with ASTM D 4285 at least two (2) times per twelve (12) hours and following every compressor start-up. The air discharge temperature shall not exceed 100 °C.

Blasting nozzles shall be replaced when the specified minimum blast pressure, surface cleanliness and surface profile can no longer be achieved.

Blasting equipment, its operators and the object being blasted shall be properly earthed to prevent the occurrence of electrostatic discharges.

Abrasive blast cleaning equipment shall be of an intrinsically safe construction and equipped with a remote shut-off valve triggered by the release of a dead man's handle at the blasting nozzle.

If air-operated equipment is used, the operator's hood or headgear shall be positive pressure fed by clean, cool air supplied through a filter, to prevent blast cleaning residues from being inhaled.

7.2.3 Thermal spray equipment

Thermal-spray equipment shall be set up, calibrated, and operated according to the instructions and technical manuals of the Manufacturer or thermal spray Applicator.

The thermal-spray equipment's spray-parameter set-up shall be validated with a bend test (6.11) at the beginning of each shift or crew change. The Principal shall receive a copy of the spray parameters set-up.

7.3 ACCESS

All surfaces of the structure that have to be coated shall be visible and within reach of the operator by a safe method. Personnel involved in surface preparation, coating application, and inspection shall be able to move safely and easily on all parts of the structure in conditions of good lighting.

Scaffolding shall be constructed in accordance with local regulations and the requirements of the Principal.

Surfaces which are to be blasted and coated should be sufficiently accessible to allow the operator adequate space to work in.

7.4 HOLDING PERIOD

Time between blasting of the steel surface and thermal spraying shall be no greater than four (4) hours. If the holding period exceeds 4 hours, the surface shall again be cleaned and abrasive blasted in compliance with this PTS.

7.5 MASKING

Areas not to be covered by thermal spray coating shall be protected by masking. Self-bonding tapes, hardwood, rubber, silicone rubber, or metallic masks should be used. Precautions shall be taken to ensure that the masking material does not contaminate the surface to be sprayed.

7.6 THERMAL SPRAYING

No thermal spray coating work shall be carried out when the temperatures of the steel surfaces is less than 3 °C above dew point of the surrounding air, or the relative humidity of the air is greater than 85 %. Dew point determination shall be in accordance with ISO 8502-4.

Before starting, and during flame spraying, the surface to be coated shall be warm enough to prevent moisture (present in flame) to condense on the substrate. If condensation on the substrate occurs, the surface should be preheated up to maximum 60 °C. In any case, oxidation of the surface during preheating shall be avoided.

The spray equipment shall be operated in accordance with the Manufacturer's instructions and thermal sprayer's procedures.

7.6.1 Rust bloom

If rust bloom, blistering or a degraded coating appears at any time during thermal spraying, the following procedure shall apply:

- Stop spraying;
- Mark the rejected sprayed area;
- Re-prepare the rejected areas to the requirements of (6.6).

7.6.2 Feathering

The edges of the existing thermal spray coating shall be feathered by abrasive blasting to provide a 50 mm to 75 mm overlap with the newly applied thermal spray coating.

7.7 COATING THICKNESS

Thickness of the coating systems shall be:

- Aluminium (TSA): minimum 250 µm;
- Zinc-Aluminium (85/15): minimum 250 µm;
- Sealer coat: maximum DFT 40 µm;
- Topcoat:
 - Epoxy sealer: maximum DFT 40 µm;
 - Aliphatic polyurethane finish coat: maximum DFT 50 µm;

- Duplex coating
 - Zinc-Aluminium (85/15) primer coat: minimum 150 µm;
 - Epoxy sealer: maximum DFT 40 µm;
 - Epoxy barrier coat: minimum DFT 110 µm;
 - Aliphatic polyurethane finish coat: maximum DFT 50 µm;

The coating thickness shall be measured by means of a thickness meter based on eddy-current or electromagnetic techniques, in accordance with ISO 2808, methods 7B (magnetic-flux), 7C (magnetic-induction) or 7D (Eddy-current).

7.8 SEALER AND TOPCOAT

Sealer, thinners (to lower viscosity of sealer), and topcoats (paint) shall be supplied in unopened, clearly identified containers. Handling, mixing and storage of sealer, thinner, and coating materials shall be in accordance with the coating Manufacturer's specifications. Sealers and coating shall meet the local restrictions on volatile organic compound (VOC) content.

Sealers and top coating (paint) should be applied within maximum six (6) hours after thermal spraying. If a sealer or top coat cannot be applied within six hours, application may still be acceptable subject to the condition that it shall be verified (by visual inspection) that the thermal spray coating has not been contaminated, has no rust bloom, and that the thermal spray coating is dust-free (by means of a clear cellophane tape, in compliance with ISO 8502-3).

8. COATING REPAIR

8.1 GENERAL

The applicator shall produce a coating repair procedure, to be agreed by the Principal. Only qualified coating repair methods shall be used, in compliance with this PTS.

If the thermal spray coating has been damaged and bare substrate metal is observed, the coating shall be repaired, including the local (repair) application of a new sealer, and/or topcoat, if applicable.

The damaged area shall be pre-cleaned, followed by local blast cleaning to a minimum of Sa 2.5, in compliance with this PTS.

Edges of the remaining existing coating system shall be feathered (7.6.2) by abrasive blasting, and the remainder of the adjacent coated surface shall be properly protected

Local (repair) application of thermal spray coating shall be in compliance with this PTS, including local (repair) application of new sealer and topcoat.

If the thermal spray coating only shows local surface damage, the area shall be pre-cleaned, followed by local sweep blasting. The adjacent coated surface shall be properly protected (masking). The locally restored thermal spray coating, including sealer / top coat, shall meet the minimum thickness requirements (7.7).

Arc-spray coating shall not be applied on existing flame-sprayed coating because of the risk of coating delamination damage. However, flame-sprayed coating applied on existing arc-sprayed coating is acceptable.

If only the sealer or topcoat has been damaged, the surface shall be prepared by abrasion with medium coarse abrasive paper until a clean bright surface is visible. Edges of the remaining coating at the location of the repair shall be feathered. The re-applied sealer / topcoat system shall be compatible with the existing coating system.

8.2 FIELD WELDS

Weld spatter shall be ground flush.

Prior to the blast cleaning and/or thermal spraying, the surface at the field weld to be coated shall be free of any contamination and any excessive rust scale shall be removed.

Cleaning of the field weld surface shall be done by dry blast cleaning, to at-least Sa 2.5, in accordance with ISO 8501-1.

The surface roughness for thermal spray (field weld) coating shall be between 75 µm and 110 µm, in accordance with ISO 8503-5. The surface shall have a sharp angular profile, and shot shall not be used.

Edges of the remaining existing coating system shall be feathered (7.6.2) by abrasive blasting, and the remainder of the adjacent coated surface shall be properly protected.

Surface preparation and coating application for field welds shall comply with this PTS.

Arc-spray coating shall not be applied on existing flame-sprayed coating because of the risk of coating delamination damage. However, flame-spray coating applied on existing arc-sprayed coating is acceptable.

9. STORAGE AND HANDLING

For coated components, canvas or nylon slings shall be used for lifting, and wooden, rubber or plastic blocks shall be applied during transportation. Coated objects, pipes, etc. shall be stored and handled in such a manner as to prevent damage.

To avoid damage of the coating, the Contractor shall supply all the necessary protection when storing coated components in the open air prior to construction.

10. REFERENCES

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

NOTES: 1. Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto;

PETRONAS STANDARDS

Protective coatings for offshore facilities PTS 70.48.11.30

AMERICAN STANDARDS

Standard test method for indicating oil or water in compressed air ASTM D 4285

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INTERNATIONAL STANDARDS

Aluminium and aluminium alloys – Chemical composition	ISO 209
Paints and Varnishes – Determination of Film Thickness	ISO 2808
Paints and varnishes – Pull-off test for adhesion	ISO 4624
Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness	ISO 8501-1
Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 3: Assessment of dust on steel surfaces prepared for painting (pressure-sensitive tape method)	ISO 8502-3
Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 4: Guidance on the estimation of the probability of condensation prior to paint application	ISO 8502-4
Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 6: Extraction of soluble contaminants for analysis – The Bresle method	ISO 8502-6
Preparation of steel substrates before application of paints and related products – Tests for the assessment of surface cleanliness – Part 9: Field method for the conductometric determination of water-soluble salts	ISO 8502-9
Preparation of steel substrates before application of paints and related products – Surface roughness characteristics of blast-cleaning steel substrates – Part 5: Replica tape method for the determination of the surface profile	ISO 8503-5
Preparation of steel substrates before application of paints and related products – Surface preparation methods – Part 2: Abrasive blast-cleaning	ISO 8504-2
Quality management systems – Requirements	ISO 9001

Preparation of steel substrates before application of paints and related products – Specifications for metallic blast-cleaning abrasives – Part 2: Chilled-iron grit	ISO 11124-2
Preparation of steel substrates before application of paints and related products – Specifications for metallic blast-cleaning abrasives – Part 3: High-carbon cast-steel shot and grit	ISO 11124-3
Preparation of steel substrates before application of paints and related products – Specifications for Non-metallic blast-cleaning abrasives – Part 4: Coal furnace slag	ISO 11126-4
Preparation of steel substrates before application of paints and related products – Specifications for non-metallic blast-cleaning abrasives – Part 7: Fused aluminium oxide	ISO 11126-7
Preparation of steel substrates before application of paints and related products – Specifications for non-metallic blast-cleaning abrasives – Part 9: Staurolite	ISO 11126-9
Preparation of steel substrates before application of paints and related products – Specifications for non-metallic blast-cleaning abrasives – Part 10: Almandite garnet	ISO 11126-10
Preparation of steel substrates before application of paints and related products Test methods for non-metallic blast-cleaning abrasives	ISO 11127
Protective clothing for abrasive blasting operations using granular abrasives	ISO 14877
Thermal spraying – Approval testing of thermal sprayers	ISO 14918
Thermal spraying – Wires, rods and cords for flame and arc spraying – classification – Technical supply conditions.	ISO 14919
Thermal Spraying – Quality Requirements of Thermally Sprayed Structures – Part 1: Guidance for Selection and Use	ISO 14922-1
Thermal Spraying – Quality Requirements of Thermally Sprayed Structures – Part 2: Comprehensive Quality Requirements	ISO 14922-2
Conformity assessment – General requirements for bodies operating certification of persons	ISO/IEC 17024

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Copies can also be obtained from national standards organizations.