

Materials and Qualification Procedures for Ships

Book L

Procedure 15-1

Approval Scheme for Firms undertaking Thermal Spraying Processes

Revision 1, Sept 2013

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Approval Scheme for Firms undertaking Thermal Spraying Processes

1 Introduction

1.1 Application for approval

1.1.1 In order that consideration may be given to approval of a firm undertaking thermal spray coating on components subject to LR classification, the local Surveyors are to submit a report to Materials and NDE Department, giving the information listed in Section 2 and the results of approval tests carried out under their survey.

1.1.2 Approved works will be subject to periodic inspection (see Procedure 1-1)

1.2 Scope

1.2.1 This procedure outlines the method of approving firms undertaking thermal spraying on components subject to LR classification.

1.2.2 Thermal spraying processes are widely used for the application of protective coatings during original manufacture of items and also for the refurbishment of components during overhaul.

1.2.3 LR will consider thermal spraying for surfacing applications to improve resistance to wear and corrosion, and to restore worn or inaccurately machined parts to original dimensions. Approval is based, however, on the condition that no dependence is placed on the coating for tensile or torsional strength and that machined preparations do not reduce dimensions below Rule requirements.

1.2.4 Typical applications for which thermal spraying will be considered are given in the appendix.

1.3 Range of approval

1.3.1 Separate approval is required for each of the following process categories:

- a) Flame or arc spraying zinc, aluminium and their alloys for corrosion protection, anti-slip and permanent identification applications.
- b) Flame or arc spraying for engineering purposes.
- c) Plasma spraying for engineering purposes.
- d) HVOF spraying for engineering purposes.

1.3.2 Additionally, for categories (b), (c) and (d) above, each application will require procedure approval. Procedure approval can be used to gain process approval.

1.3.3 With the exception of applications restricted by Note 6 in Appendix 1, an approved procedure can be used for other components of the same type, e.g. a procedure approved for thermal spraying the outer diameter of a cylinder liner for cavitation/corrosion protection can be used on other cylinder liners of similar geometry for the same purpose.

1.3.4 Procedures that have been developed by original equipment and consumable suppliers or company research centres, and approved by LR can be used by other firms/sites, provided they can provide evidence that they have been authorised to use the procedure by the originator. Such authorisation should include evidence of adequate training.

1.4 Related Rules

1.4.1 LR's Rules and Regulations for the Classification of Ships (hereinafter referred to as the Rules for Ships).

1.4.2 LR's Rules for the Manufacture, Testing and Certification of Materials (hereinafter referred to as the Rules for Materials).

2 Information required for approval

2.1 The firm is to supply the following information:

- a) Name and address and brief statement of background indicating whether the firm is new or long established and experience in thermal spraying.
- b) Types of thermal spray processes for which approval is sought.
- c) Details of facilities available, including equipment for surface preparation, spray equipment and machining facilities.
- d) Details of operator training. Operators should have completed formal training and undertaken approval testing in accordance with ISO 14918 or equivalent.
- e) Technical data sheets for the materials to be used for thermal spraying.
- f) Detailed process procedures for each type of component to be sprayed. These should include as a minimum:
 - i) Unique procedure reference number.
 - ii) Part description.
 - iii) Sketches showing area to be sprayed. These should include details of blend out of sprayed area.
 - iv) Substrate material and condition - grade, heat treatment, etc.
 - v) Reason for thermal spraying, coating function etc.
 - vi) Details of thermal spraying equipment to be used, bond coat material (if applicable) and coating material type, trade name/number.
 - vii) Details of substrate preparation, pre-cleaning, blast process, type and size of grit, blasting pressure, masking materials, maximum delay before coating etc.
 - viii) Details of spraying procedure, masking for spraying, gun to work piece distance, rotation speed of work piece, traverse rate of gun, gun fixing method, powder/wire feed rate, types of gases, gas consumption, pre-heat temperature, maximum temperature of work piece, bond coat thickness (if applicable), coating thickness inclusive of any finishing allowance, auxiliary cooling.
 - ix) When applicable, details of sealing coat type and method of application.

- x) Details of any post spraying machining operations.
 - g) Details of quality control checks carried out on batches of powders.
- 2.2** LR are to be advised of any proposed changes to approved procedures. If the changes affect any of the items listed in paragraph 3.1, f); vi), vii), viii) and ix) above, they should be submitted to Materials and NDE Department who will determine if re-qualification is required.

3.0 Approval tests

3.1 Approval of a firm for a particular thermal spraying process will normally be undertaken in conjunction with approval of a specific application procedure.

3.2 The attending Surveyor should witness work piece preparation and spraying operations.

3.3 The tests required for approval are dependant on the thermal spraying process and are detailed below:

3.3.1 Flame or arc spraying zinc, aluminium and their alloys for corrosion protection, anti-slip and permanent identification applications.

3.3.1.1 A test piece according to fig. 1 of rolled 150 mm equal angle section, 8 mm thick at minimum and 500 mm long is to be prepared and sprayed over both internal faces of the section in accordance with the parameters of the procedure under evaluation.

3.3.1.2 The thickness of the coating is to be measured in at least six places on each coated surface. The results should confirm that the coating thickness meets the minimum requirements of the procedure and is of uniform thickness.

3.3.1.3 The coating is to be visually examined. This should show a uniform texture and freedom from lumps, dust inclusions, blisters, lifting and spalling.

3.3.1.4 An adhesion test is to be performed in accordance with BS EN 22063.

3.3.2 Flame or arc spraying for engineering purposes.

3.3.2.1 A cylindrical test piece according to fig. 2 is to be prepared and sprayed over the reduced diameter central portion in accordance with the parameters of the procedure under evaluation. Sufficient material shall be sprayed to allow the deposit to be machined, by an appropriate technique, to the original 75 mm diameter.

3.3.2.2 The thickness of the coating is to be measured in at least four places along the test piece. The coating thickness should be uniform and not exceed 1.0 mm.

3.3.2.3 The coating is to be visually examined. This should show a uniform matt texture and freedom from lumps, dust inclusions, cracks, blisters, lifting and spalling.

3.3.2.4 After visual inspection the test piece is to be machined to 75 mm diameter to confirm that adequate coating thickness had been applied, and that the coating cleans up over the entire surface. The machined surface is to be inspected for over-heating, excessive porosity, cracks, and detachment.

3.3.2.5 An adhesion test is to be performed in accordance with BS EN 582 or ASTM C 633 using six test pieces and the results shall be consistent within 20% of the highest value and conform to stated bond strength values for the coating being used.

3.3.3 Plasma spraying for engineering purposes.

3.3.3.1 For metals and metal alloy coatings a cylindrical test piece according to fig. 3 is to be prepared and sprayed over the reduced diameter central portion in accordance with the parameters of the procedure under evaluation. Sufficient material shall be sprayed to allow the deposit to be machined, by an appropriate technique, to the original 50 mm diameter.

3.3.3.2 For metal based carbides/carbides and ceramic coatings a tubular test piece according to fig. 4 is to be prepared and sprayed over the full length in accordance with the parameters of the procedure under evaluation.

3.3.3.3 The thickness of the coating is to be measured in at least four places along the test piece. The coating thickness should be uniform and not exceed specification requirements.

3.3.3.4 The coating is to be visually examined. This should show a uniform texture and freedom from lumps, dust inclusions, cracks, blisters, lifting and spalling.

3.3.3.5 After visual inspection, the test piece is to be machined to confirm that adequate coating thickness had been applied, and that the coating cleans up over the entire surface. The machined surface is to be inspected for over-heating, excessive porosity, cracks, and detachment.

3.3.3.6 An adhesion test is to be performed in accordance with BS EN 582 or ASTM C 633 using six test pieces and the results shall be consistent within 20% of the highest value and conform to stated bond strength values for the coating being used.

3.3.3.7 For metal based carbides/carbides and ceramic coatings, samples are to be prepared for metallographic examination and micro hardness testing. Hardness values are to comply with the appropriate technical data sheet. Metallographic examination should confirm total absence of transverse cracks, delamination, substrate - coating interface voids and other deleterious defects. Porosity levels should be within the limits specified on the powder data sheet.

3.3.4 HVOF spraying for engineering purposes.

- 3.3.4.1 A tubular test piece according to fig. 4 is to be prepared and sprayed over the full length in accordance with the parameters of the procedure under evaluation.
 - 3.3.4.2 The thickness of the coating is to be measured in at least four places along the test piece. The coating thickness should be uniform and not exceed specification requirements.
 - 3.3.4.3 The coating is to be visually examined. This should show a uniform texture and freedom from lumps, dust inclusions, cracks, blisters, lifting and spalling.
 - 3.3.4.4 After visual inspection, the test piece is to be machined to confirm that adequate coating thickness had been applied, and that the coating cleans up over the entire surface. The machined surface is to be inspected for over-heating, excessive porosity, cracks, and detachment.
 - 3.3.4.5 An adhesion test is to be performed in accordance with BS EN 582 or ASTM C 633 using six test pieces and the results shall be consistent within 20% of the highest value and conform to stated bond strength values for the coating being used.
 - 3.3.4.6 Samples are to be prepared for metallographic examination and micro hardness testing. Hardness values are to comply with the appropriate technical data sheet. Metallographic examination should confirm total absence of transverse cracks, delamination, substrate - coating interface voids and other deleterious defects. Porosity levels should be within the limits specified on the powder data sheet.
- 3.4 Surveyors should witness all stages in the thermal spraying of at least two typical machinery components. This should include dimensional checks before and after spraying and careful visual examination after final machining which, if possible, should be supplemented by liquid penetrant testing.

4.0 Production tests

4.1 In order to assess production coating quality appropriately dimensioned test pieces of the same material are to be sprayed with the component and are to be subjected to the following tests:

- a) Visual examination (aided if required, by low magnification eyepiece).
- b) Bend tests: The specimen is to be bent, with the coating in tension, through an angle of 180°, over a former of a diameter not exceeding eight times the thickness of the specimen substrate thickness. Bending should be completed within two to five seconds. Cracks in the coating parallel to the axis of the bend are acceptable, provided the coating does not peel off the base material unless within 1.5 mm of the edges, exclusively on the bent part.
- c) Metallographic examination (plasma and HVOF coatings only): Examination should confirm the total absence of transverse cracks, delamination, substrate - coating interface voids and other deleterious defects. Levels of porosity and oxide content should be reported.
- d) Hardness tests (where appropriate).

4.2 Thermal spray coated components should be subjected to the following examinations:

- a) Visual examination after spraying and after final machining.
- b) Liquid penetrant examination after machining.

5.0 Additional tests

5.1 Depending on the application of the coating one or more of the following additional tests may be required:

5.1.1 Fatigue tests

5.1.1.1 Where it is proposed to carry out repairs to components which are subject to alternating bending stresses, rotating bending fatigue tests will be required to confirm that the proposed coating does not adversely affect the fatigue strength of the parent material.

5.1.1.2 It is not possible to predict directly the fatigue performance of large machine components from the results of laboratory tests on small specimens, due to size effects, and the testing described below can only be used as an indicator of the possible affect the thermal coating has on the fatigue strength.

5.1.1.3 Testing should be undertaken in accordance with BS 3518 - "Methods of fatigue testing, Part 2 - Rotating bending fatigue tests." Parallel test pieces with two-point loading in accordance with BS 3518, Part 2, fig. 4 should be used.

5.1.1.4 The minimum diameter of the test specimen in way of the sprayed area should be as large as possible, taking into account the strength of the parent material and load capacity of the test machine. The parallel portion should be of sufficient length to include both end blend-outs of the coating.

5.1.1.5 A minimum of three polished and three sprayed test specimens should be tested for each base material.

5.1.1.6 The stress level for all tests should be such that the polished specimens break at between 1×10^5 and 2×10^5 cycles.

5.1.1.7 Previously published fatigue test data may, if appropriate, be accepted in lieu of testing, at the discretion of Materials and NDE Department.

5.1.2 Wear tests

5.1.2.1 Where it is proposed to carry out repairs to components which are subject to abrasive wear, tests will be required to verify that the proposed coating has wear resistance equivalent to or better than the original material.

5.1.2.2 Testing should be in accordance with a recognised standard, such as ASTM G65 - "Measuring abrasion using the dry sand/rubber wheel apparatus".

5.1.2.3 Previously published wear test data may, if appropriate, be accepted in lieu of testing, at the discretion of Materials and NDE Department.

5.1.3 Corrosion tests

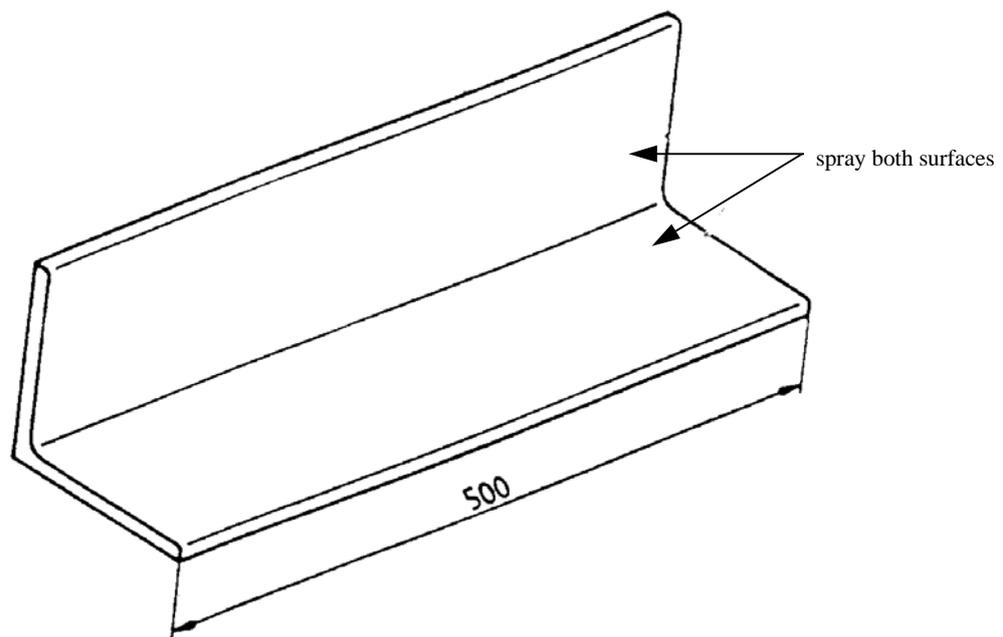
5.1.3.1 Where it is proposed to carry out repairs to components which are subject to corrosion, tests will be required to verify that the proposed coating has corrosion resistance equivalent to or better than the original material.

5.1.3.2 Testing should be in accordance with a recognised standard, such as ASTM B117 - "Standard practice for operating salt spray (fog) apparatus," ASTM G85 - "Standard practice for modified salt spray (fog) testing," or BS 7479 - "Method for salt spray corrosion tests in artificial atmospheres."

5.1.3.3 Previously published corrosion test data may, if appropriate, be accepted in lieu of testing, at the discretion of Materials and NDE Department.

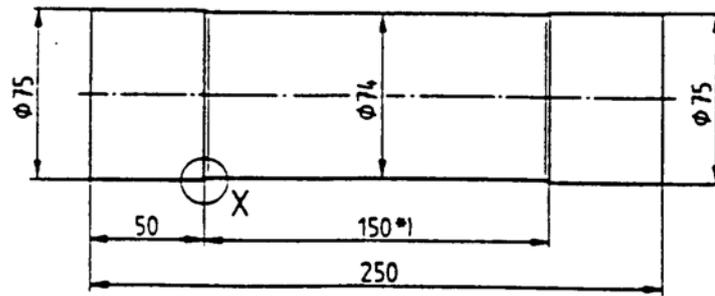
6.0 Continuation of approval

- 6.1 The initial approval certificate will have a validity of three years.
- 6.2 For the validity to be extended for a further three years, the Surveyors should undertake a periodic inspection in accordance with MQPS Procedure 1-1.
- 6.3 Firms undertaking thermal spraying should keep a record of all applications and this record is to be reviewed at the time of survey.
- 6.4 In the event that products have not been sprayed during the six months prior to expiry of the validity of a certificate, the Surveyors are to witness tests on at least one component and submit the results with their periodic inspection report.



dimensions in mm, tolerances + 0.05 mm

Figure 1: Test piece for flame or arc spraying of Al/Zn and their alloys



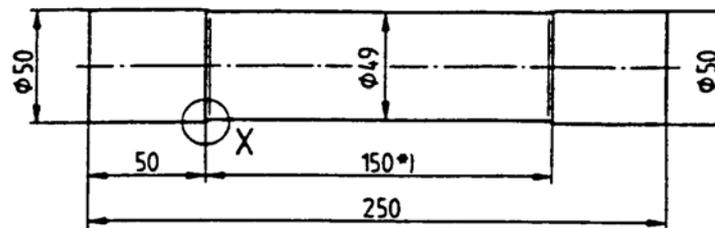
X

*) spray over this area



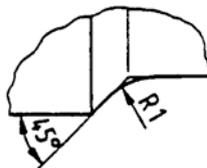
dimensions in mm, tolerances ± 0.05 mm

Figure 2: Test piece for flame or arc spraying of metals and alloys



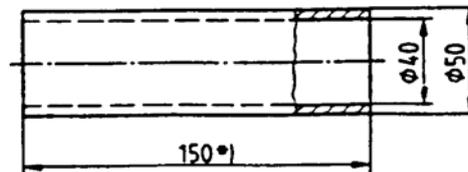
X

*) spray over this area



dimensions in mm, tolerances ± 0.05 mm

Figure 3: Test piece for plasma spraying metals and alloys



*) spray over this area

dimensions in mm, tolerances + 0.05 mm

Figure 4: Test piece for plasma spraying of ceramics, plasma spraying of metal based carbides/carbides, HVOF spraying of metals and alloys or HVOF spraying of metal based carbides

Appendix 1 Typical thermal spray coating applications

Generic Applications	Coating Function	Typical Applications	Notes
Smooth surfaces	Provide a non-skid surface for personnel, equipment and aircraft	Ladders, decks, helicopter pads, walkways	
Unmarked surfaces	Provide permanent identification	Identification pads, (tail hook, landing gear, etc.)	
Surfaces subject to atmospheric and immersion corrosion	Resist salt atmosphere or immersion corrosion	Hull and superstructure surfaces	
Surfaces subject to heat and oxidation	Rebuild and provide subsequent protection from: - oxidation at high temperature - gaseous corrosion at high temperature	Exhaust mufflers, pipes and silencers. Hot gas ducts, chimneys, burners. Exhaust valve cages, Exhaust valve stems	1 1
Surfaces impacted by hard particles	Rebuild machinery components and subsequently resist erosive wear	Exhaust fans, Exhaust valve cages	1 1
Liquid/metal surfaces	Rebuild machinery components and subsequently resist surface cavitation damage	Cylinder liners (external surfaces)	1
Metallic surfaces sliding against each other under pressure	Rebuild machinery components and subsequently resist adhesive wear	Babbit bearings Crankshafts Cylinder liners (bore surfaces) Fuel pump rotors Pinion gear journals Piston guides Rudder stock Tail shaft end bearing Turbocharger rotor shaft journals	1,2 1,2,3,4,5,6,7 1,2,3,6,7 1,5 1,3,4,6,7 1,5 1,5 1,3,5,6 1,4,5,7

Generic Applications	Coating Function	Typical Applications	Notes
Mating surfaces where no motion between them is intended	Rebuild machinery components and subsequently resist fretting	Connecting rod (L/E & S/E bores) Cylinder head / block mating faces Cylinder liner (mounting surfaces) Flange mating faces Flywheel (location diameter) Main bearing saddles Manifold mating areas Tail shaft (coupling diameter)	1,3,5,6 1 1 1 1,5,6 1,5,6 1 1,3,5,6
Mating surfaces, one of which has hard projections or where hard particles are in relative motion to a wear surface	Rebuild machinery components and subsequently resist abrasive wear	Circulating pump shafts Guide bars Impeller shafts Pump seals Pump shafts Pump sleeves	1,5 1,5 1,5 1,5 1,5 1,5

- Notes:
1. To be carried out to specifically approved procedures
 2. Approved for auxiliary machinery only
 3. Owner's consent required
 4. Spray coating to be kept clear of stress concentrations at fillet radii
 5. Approval restricted to Plasma and HVOF processes only
 6. Each application subject to separate approval
 7. OEM approval required.