



**External fusion-bonded epoxy coating
for steel pipes**

Botop Steel



This Australian Standard® was prepared by Committee ME-038, Petroleum pipelines. It was approved on behalf of the Council of Standards Australia on 27 JULY 2001. This Standard was published on 01 January 2002.

The following are represented on Committee ME-038:

- Australasian Corrosion Association
- Australian Institute of Petroleum
- Australian Petroleum Production and Exploration Association
- Australian Pipeline Industry Association
- Bureau of Steel Manufacturers
- Cooperative Research Centre for Materials Welding and Joining
- Department of Labour New Zealand
- Department of Minerals and Energy WA
- Department of Mines and Energy NT
- Department of Natural Resources and Environment Vic.
- Department of Natural Resources and Mines Qld
- Gas Association of New Zealand
- Ministry of Energy and Utilities NSW
- Primary Industries and Resources SA
- Australian Gas Association
- Welding Technology Institute of Australia

Additional interests:

- Cathodic Protection Systems
 - Tyco Water Pipelines Research
 - Canusa
 - Brian Martin and Associates
 - Bredero Shaw Australia
 - Socotherm
-

This Standard was issued in draft form for comment as DR 00130.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

Keeping Standards up-to-date

Australian Standards® are living documents that reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about Australian Standards, drafts, amendments and new projects can be found by visiting www.standards.org.au

Standards Australia welcomes suggestions for improvements, and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at mail@standards.org.au, or write to Standards Australia, GPO Box 476, Sydney, NSW 2001.

Australian Standard[®]

**External fusion-bonded epoxy coating
for steel pipes**

Originated as AS 3862—1991.
Second edition jointly revised and designated AS/NZS 3862:2002.
Reissued and redesignated incorporating Amendment No.1 (September 2017)

COPYRIGHT

© Standards Australia Limited

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher, unless otherwise permitted under the Copyright Act 1968.

Published by SAI Global Limited under licence from Standards Australia Limited, GPO Box 476, Sydney, NSW 2001, Australia

ISBN 0 7337 4089 8

PREFACE

A1 | This Standard was prepared by the joint Standards Australia/Standards New Zealand Committee ME-038, Petroleum Pipelines, at the request of manufacturers and users of fusion-bonded epoxy coating for pipes. Amendment No. 1 to this Standard was prepared by the Australian members of this Joint Standards Australia/Standards New Zealand Committee. As a consequence of Amendment No. 1, which is published as an Australian-only amendment, the designation of this Standard has been changed from AS/NZS 3862:2002 to AS 3862:2002.

This Standard incorporates Amendment No. 1 (September 2017). The changes required by the Amendment are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

The objective of this Standard is to provide purchasers and manufacturers of petroleum pipelines with a Standard for the specification of pipeline coatings using external fusion-bonded epoxy.

The fusion-bonded epoxy coating referred to in this Standard is to be applied only to external surfaces of pipes.

Attention is drawn to the fact that this Standard does not purport to satisfy all requirements for pipelines.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

Statements expressed in mandatory terms in notes to figures and tables are deemed to be requirements of this Standard. All other notes are for information and guidance only.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE.....	5
1.2 REFERENCED DOCUMENTS.....	5
1.3 DEFINITIONS.....	6
1.4 PIPE MARKING.....	7
SECTION 2 MATERIAL REQUIREMENTS	
2.1 FUSION-BONDED EPOXY (FBE) POWDER.....	8
2.2 ABRASIVE MATERIALS.....	8
2.3 REPAIR MATERIALS.....	8
SECTION 3 APPLICATION	
3.1 MILL APPLICATION.....	9
3.2 FIELD APPLICATION.....	12
SECTION 4 REPAIRS	
4.1 REPAIRS TO COATINGS IN THE MILL.....	15
4.2 REPAIRS TO FIELD JOINTS AND ADJACENT AREAS.....	15
4.3 REPAIR PROCEDURE.....	15
SECTION 5 STORAGE, HANDLING AND TRANSPORT	
5.1 STORAGE OF POWDER.....	18
5.2 TRANSPORT OF POWDER.....	18
5.3 HANDLING, TRANSPORT AND STORAGE OF PIPES.....	18
5.4 HEALTH AND SAFETY.....	20
SECTION 6 TESTING REQUIREMENTS	
6.1 GENERAL.....	21
6.2 COATING TESTS.....	21
6.3 TESTING OF REPAIRS.....	21
APPENDICES	
A PURCHASING GUIDELINES.....	22
B MEANS FOR DEMONSTRATING COMPLIANCE WITH THIS STANDARD.....	24
C CHEMICAL PRETREATMENT.....	31
D DENSITY OF POWDER.....	32
E GEL TIME OF POWDER.....	34
F PARTICLE SIZE ANALYSIS OF POWDER.....	35
G VOLATILE CONTENT OF POWDER.....	36
H DSC ANALYSIS.....	37
I FOAMING.....	43
J ADHESION OF COATINGS TO STEEL.....	45
K RESISTANCE OF COATING TO IMMERSION IN HOT WATER.....	46
L FLEXIBILITY.....	47
M UNIFORMITY OF HEATING.....	49
N HEAT DECAY PERIOD.....	50

O WATER ABSORPTION OF COATING TEST 51
P THERMAL STABILITY OF COATING TEST 52
Q PREPARATION OF A TEST PANEL AND VISUAL INSPECTION 54
R PREPARATION OF TEST PANELS FOR REPAIR MATERIALS..... 56
S INTERFACIAL CONTAMINATION 58

Botop Steel

STANDARDS AUSTRALIA

Australian Standard

External fusion-bonded epoxy coating for steel pipes

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for external fusion-bonded epoxy (FBE) coating of steel pipes for protection against corrosion. It includes coating in the mill and coating in the field.

NOTES:

- 1 Guidelines to purchasers on information that should be supplied by the purchaser and those variables that should or may be agreed upon at the time of inquiry or order are given in Appendix A.
- 2 Line pipe manufactured in accordance with API 5L may not be suitable for application of FBE coating without requiring additional surface preparation. Surface imperfections in the form of steel slivers, burrs and laminations can cause excessive holidays, resulting in the need for extra surface cleaning, grinding or filing.
- 3 Line pipe manufactured in accordance with API 5L may require a more stringent straightness specification to allow coating in accordance with this Standard.
- 4 Consideration should be given to strain ageing when specifying line-pipe for FBE coating. Guidance is given in Clause 3.1.2, Note 3.

Methods for demonstrating compliance with this Standard are given in Appendix B.

1.2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

- | | |
|--------|--|
| 1199 | Sampling procedures and tables for inspection by attributes |
| 1399 | Guide to AS 1199—Sampling procedures and tables for inspection by attributes |
| 1627 | Metal finishing—Preparation and pre-treatment of surfaces |
| 1627.4 | Part 4: Abrasive blast cleaning |
| 2490 | Sampling procedures and charts for inspection by variables for percent nonconforming |
| 3894 | Site testing of protective coatings |
| 3894.1 | Part 1: Non-conductive coatings—Continuity testing—High voltage ('brush') method |

AS/NZS

- | | |
|--------|---|
| 2243 | Safety in laboratories |
| 2243.2 | Part 2: Chemical aspects |
| 2990 | Quality systems for engineering and construction projects |
| 3894 | Site testing of protective coatings |
| 3894.6 | Part 6: Determination of residual contaminants |

AS/NZS	
ISO 9001	Quality management systems—Requirements
ISO 9004	Quality management systems—Guidelines for performance improvement
HB 18	Guidelines for third-party certification and accreditation
HB 18.28	General rules for a model third-party certification system for products
ASTM	
D 149	Tests for dielectric breakdown voltage and dielectric strength of solid electrical insulating materials at commercial power frequencies
D 257	Tests for D-C resistance or conductance of insulating materials
D 1044	Test for resistance of transparent plastic materials to surface abrasion
D 1653	Test for water vapour permeability of organic coating films
D 1921	Test for particle size (sieve analysis) of plastic materials
D 2370	Test for tensile properties of organic coatings
G 11	Test for effects of outdoor weathering on pipeline coatings
G 14	Test for impact resistance of pipeline coatings (falling weight test)
G 17	Test for penetration resistance of pipeline coatings
G 62	Test methods for holiday detection in pipeline coatings
API RP	
5L	Specification for line pipe
5L1	Recommended practice for railroad transportation of line pipe
5LW	Recommended practice for marine transportation of line pipe

1.3 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

1.3.1 Batch (FBE Powder)

A discrete and continuous manufacturing run.

1.3.2 Bolster

Support for coated pipes during transport and storage.

1.3.3 Coupon

Sample of steel pipe coated with fusion-bonded epoxy and used for laboratory tests.

1.3.4 Drop

Non-homogeneous or partially cured lump of powder deposited on the surface of the coating.

1.3.5 Holiday

A discontinuity of protective coating that exposes the steel to the outside environment.

1.3.6 Lot

A batch or number of batches manufactured within a limited period of time, typically 24 h or less.

1.3.7 Pinhole

A small discontinuity on the surface of the FBE coating which may or may not extend to the steel surface.

1.3.8 Pipe diameter length

Length of pipe measured in diameters of the pipe.

1.3.9 Run or sag

Visible flow of the coating under gravity to produce a significant local variation in film thickness

1.3.10 Rust blooming

Visual detectable colour change on the surface of the pipe due to oxidation, other than as a result of pre-treatment

1.3.11 Shelf life

Characteristic of each material formulation, which is related to storage time, temperature and humidity, which may make it unsuitable for use.

1.3.12 Strain ageing

A change in the properties of steel associated with ageing at elevated temperature subsequent to cold working.

1.3.13 Substrate

The steel pipe surface to which the coating is to be applied.

1.3.14 Surface crater

A localized surface depression produced during coating application, detectable by normal vision.

1.3.15 Test panel

Sample of steel plate coated with fusion-bonded epoxy for laboratory tests.

1.4 PIPE MARKING

Unless otherwise specified by the purchaser, the following information shall be marked a minimum of 0.3 m clear of the ends of the pipe, on each length of coated pipe with a permanent weatherproof marking system:

- (a) Date of coating (year, month, day).
- (b) Coating applicator's name or trademark.
- (c) Nominal coating thickness, in micrometres.
- (d) Pipe specification and steel grade.
- (e) Pipe length, diameter and wall thickness.
- (f) Pipe number (where applicable).

SECTION 2 MATERIAL REQUIREMENTS

2.1 FUSION-BONDED EPOXY (FBE) POWDER

The following requirements apply to the composition and properties of FBE powder:

- (a) FBE powder shall be a pigmented thermosetting material based on cross-linkable epoxy resins as the binder system. It shall not contain tri-mellitic anhydride.
- (b) The components of the formulation shall be melt-compounded in an extrusion process prior to being milled to the final powder form.
- (c) The powder shall be free flowing and able to be fluidized and spray-applied using conventional electrostatic guns.
- (d) When applied to a pre-heated pipe, the powder shall fuse to form a continuous uniform film that will rapidly cure under the action of the residual heat in the pipe.

2.2 ABRASIVE MATERIALS

Abrasive materials shall comply with the requirements of AS 1627.4. They shall be free from contamination and contain less than 100 mg/kg chlorides and less than 0.3% copper.

Abrasives shall be shot or grit, or both, in accordance with AS 1627.4. The particle size shall be such that the blasted steel pipe surface complies with Clause 3.1.1.

Abrasives for use in field joints shall be silica-free non-metallic or metallic materials in accordance with AS 1627.4. The particle size shall be such that the blasted steel pipe joint complies with Clause 3.2.5.

2.3 REPAIR MATERIALS

Materials, which have been subject to environmental conditions that exceed those specified by the manufacturer, including but not limited to shelf life, shall not be used.

All repair materials shall comply with the requirements of this Standard.

The repair material shall be a two-pack epoxy resin or other suitable material that is compatible with the original coating.

SECTION 3 APPLICATION

3.1 MILL APPLICATION

3.1.1 Surface preparation

The following requirements apply to surface preparation:

- (a) All oil, grease, soil, organic and other contaminants shall be thoroughly removed prior to abrasive cleaning. After cleaning, the pipe shall be suitably protected from, and maintained free of, all contaminants.
- (b) Prior to the application of the coating, all rust and mill scale shall be removed from the external surface of the pipe by abrasive blast cleaning in accordance with AS 1627.4.
- (c) Any solvents or detergents used in the pre-cleaning of pipe for spot removal of contaminants shall not leave a residue or coating, either before or after heating, which may adversely affect coating application or performance, or degrade pipe properties.
- (d) Any water used in the pre-cleaning of the pipe surface shall be potable, and shall contain not more than 500 mg/L of total dissolved solids. The water shall not be re-used.
- (e) The pipe shall be preheated prior to abrasive cleaning to a temperature at least 3°C above the dew point. Thermometers used for determination of the dew point shall be calibrated to an accuracy of $\pm 0.5^\circ\text{C}$. All pipe coming from the preheat oven or heating equipment shall be free of all moisture. Damp or wet pipe shall not be abrasive cleaned.
- (f) Where the pipe is coated internally, the internal coating shall be protected from grit blast and impact damage at all times.
- (g) Cleaning of the external pipe surface shall be in accordance with AS 1627.4 and shall be a minimum finish quality of Class 2½ near-white metal.
- (h) After passing through blast cleaning the pipe surface shall be inspected for slivers, scabs, laminations, burrs or bristles of steel, which shall be removed by grinding or filing. The grinding wheel or file used shall not cause contamination of the pipe surface.
- (i) Grinding or filing of individual surface areas greater than 4000 mm² shall not be permitted. All grinding or filing shall be carried out in a manner that produces an even profile on the pipe surface. The total surface area treated on any one pipe shall not exceed 0.1%. The remaining pipe wall thickness shall be not less than 92% of the nominal pipe wall thickness. After surface preparation, the surface profile shall be within the range of 50 µm to 100 µm peak to trough height measured with Press-O-Film replication tape in accordance with Method A of AS 3894.5 or other approved method. The profile shall be slightly angular and not have undercuts.
- (j) Pipe surface shall be monitored for contamination in accordance with AS 3894.6.
- (k) The blast-cleaned surface shall not be contaminated with material that may be detrimental to the coating performance including grit, dust, metal particles, oil, water. In addition, the anchor pattern shall not be scarred or burnished beyond profile limit as specified.

- (l) Tests, in accordance with AS 3894.6 as appropriate, shall be carried out prior to coating application to detect the presence and, where appropriate, concentration of the following:
 - (i) Chloride contamination in excess of 25 mg/m².
 - (ii) Soluble iron corrosion products.
- (m) Pipes with chloride contamination in excess of 25 mg/m² (see Clause 3.1.1(l)(i)) shall be subject to chemical pretreatment and the chloride level shall be retested in accordance with Clause 3.1.1(l).

NOTES:

- 1 Pipes satisfying the requirements of Clause 3.1.1(l) may be subject to chemical pretreatment using either a silicate/chromate conversion coating, a phosphate wash or both.
 - 2 Information on the benefits of chemical pretreatment is provided in Appendix C.
- (n) Where pretreatments are used, deleterious residues shall be removed prior to application of the coating.
 - (o) Any pipe, which is not suitably cleaned in accordance with Clause 3.1.1(l), shall be re-blast cleaned and retested.
 - (p) All pipes shall be coated within 4 h of blast cleaning. Any pipe, which is not coated within 4 h or where rust blooming has occurred, shall be completely re-blast cleaned.

3.1.2 Pre-application heating

The following applies to pre-application heating:

- (a) Pipe for coating shall be uniformly heated in accordance with the manufacturer's specified temperature limits, but shall not exceed 260°C.

NOTES:

- 1 The preferred method of heating is by induction coil or indirect fired oven.
- 2 The optimum range of application temperature depends on the particular powder used and may be narrower than the broad range indicated above. Below the minimum application temperature, adhesion, after the hot water test (Appendix K), and cathodic disbondment resistance (AS 4352) may be reduced.
- 3 Prior strain and subsequent thermal ageing are prerequisites for the appearance of strain ageing in steel. The extent to which steel properties are ultimately affected depends collectively on—
 - (a) the level of applied strain in pipe forming and cold expansion;
 - (b) the subsequent thermal history of the pipe, i.e. coating temperature and time; and
 - (c) steel composition.

The composition of steel may be adjusted to minimize strain ageing effects. However, where a strain-ageing resistant steel is not chosen, an increase in transition temperature may occur as a result of the strains involved in pipe making with a further increase as a result of the heat treatment involved in the coating process.

The purchaser should consult with the pipe supplier to ensure that the pipe will meet the requisite fracture toughness properties after the heat treatment experienced during coating.

- (b) The pipe surface temperature shall be checked and recorded using temperature-indicating crayons or other suitable means. Crayons used to mark the pipe surface shall not cause deleterious effects and their use shall be kept to a minimum. The nominal temperature value of the temperature-indicating crayons shall be checked prior to use. The designated melting range for each batch of temperature-measuring crayons shall be checked, by determining the actual melting range of the crayon using differential scanning calorimetry (DSC).

- (c) The heating operation shall not cause contamination of the prepared surface by combustion products or surface oxidation.

3.1.3 Application of FBE powder

The following requirements apply to the application of FBE powder:

- (a) The powder shall be applied to the pipe surface by an electrostatic spray. The resulting cured film thickness shall be 400 μm min.

NOTES:

- 1 Thicknesses in excess of 600 μm may limit flexibility.
 - 2 The minimum thickness required will depend on the performance of the particular powder being used, pipeline operating conditions, pipeline route terrain and many other factors. Accordingly, minimum coating thickness should be that specified by the purchaser for the particular end use being considered.
- (b) The heating temperature, the curing temperature and curing time shall be consistent with the powder manufacturer's specification for application procedure.
- (c) The coating shall be applied to the external surface of the full length of each pipe except for a cutback of 75 mm to 120 mm at each end. The cutback shall be measured from the bevel shoulder. Any coating applied to the cutback shall be removed.
- (d) Recycled powder is permitted only when collected and processed through a closed system, which controls the ratio of recycled to virgin powder. Sieving equipment of 350 μm or finer and a magnetic particle separator shall be used. The ratio of recycled powder to virgin powder shall not exceed 20%.
- (e) When coating application on a pipe length is discontinuous, the pipe shall be rejected, stripped of its coating and prepared for recoating in accordance with Clause 5.1.
- (f) Powder material on the internal surface of the pipe shall be removed without damaging pipe identification.
- NOTE: Powder material should be prevented from entering the inside of the pipe.
- (g) During the entire coating application, curing and handling, the coating and internal lining shall be protected against physical damage and any contamination that could be deleterious to the coating or internal lining.

3.1.4 Post-curing and cooling

The following applies to post-curing and cooling:

- (a) Post-application heating may be used to complete the curing of the coating. The pipe temperature reached during this process shall not exceed the powder application temperature.

The coated pipe shall not be subjected to a curing temperature in excess of 260°C.

- (b) The pipe shall cool in such a manner as to avoid damage to the newly applied coating.

After completing cure in accordance with the powder manufacturer's recommendations, the pipe may be quenched with running water or forced air cooling to facilitate coating handling, inspection and repairs. This time to quench shall be monitored to ensure compliance with the manufacturer's minimum curing requirements.

3.2 FIELD APPLICATION

3.2.1 Protection of mill-applied coating during pipe welding and cutting operations

Mill-applied coatings shall be protected from welding and flame cutting processes.

During pipe welding, cutting and blast cleaning it is necessary to protect the adjacent coating for a distance of approximately 750 mm each side of the welded joint or cut. This can be achieved by the use of blankets made of fire-resistant material, which will prevent sparks and globules of molten metal from contacting the surface of the mill-applied coating. These blankets are to be secured to the pipe throughout welding, grinding and cutting operations.

3.2.2 Protection of mill-applied coating during pipe pre-heating for welding

In many cases it is necessary to pre-heat the pipeline prior to welding. Damage to the mill-applied coating can occur during this process. The application of flame heating outside the cutback area shall be avoided. Steel temperatures adjacent to the mill-applied coating shall not exceed 260°C.

3.2.3 Pipe weld profile

The profile of the weld capping pass should not contain any irregularities or discontinuities (including surface undercut and lack of fusion on cap) which could affect the integrity of the joint coating.

3.2.4 Procedure trials

Prior to commencement of field coating, procedure trials shall be carried out to determine the following parameters:

- (a) Heating rate.
- (b) Heat profile—temperature variation around the circumference.
- (c) Maximum and minimum temperatures.
- (d) Temperature decay rate.
- (e) Powder application method.
- (f) Powder application rate.
- (g) Number of passes to achieve required thickness.

The above tests shall be carried out under field conditions using field equipment on each diameter and thickness of pipe to be used.

NOTES:

- 1 Where the heating procedure is controlled by time and heat input, the procedure should establish the impact of the substrate temperature on the heating time for situations including the following:
 - (a) Early morning.
 - (b) Wet conditions.
 - (c) Conditions where there is a significant difference between the top and the underside of the pipe that is exposed to full sun.
- 2 The maximum heat input rate should be established to minimize bubbling of the overlap coating.

3.2.5 Surface preparation

All discontinuities, sharp edges, points and slag shall be ground off the weld cap prior to field coating. Surface preparation shall be as follows:

- (a) Prior to abrasive cleaning remove all visible oil, grease, soil, organic and other contaminants in accordance with AS 1627.4.

- (b) Either before or after heating, ensure that solvents or detergents used do not leave an undesirable residue or coating on the pipe.
- (c) If water is used in the precleaning of the pipe surface prior to abrasive blast cleaning, the water shall be potable and shall not contain more than 500 mg/L of total dissolved solids.
- (d) The surface to be coated and the adjacent coating shall be dry prior to the commencement of dry blasting. Direct-flame drying shall not be used for powder application purposes.
- (e) Cleaning of the external pipe surface shall be in accordance with AS 1627.4 and shall be a minimum finish quality of Class 2½ near-white metal, with a surface profile after blasting of between 50 µm and 100 µm as measured in accordance with AS 1627.4.
- (f) Blast-cleaning abrasives shall comply with the requirements of AS 1627.4. Abrasives shall be free of moisture, and any other deleterious materials, and shall contain less than 100 mg/kg chlorides and less than 0.3% copper. Abrasives shall be stored in a clean, dry area.
- (g) The mill-applied coating adjoining the field joint shall be abraded for a minimum distance of 20 mm from the edge of the field joint.
- (h) All field joints shall be coated within 4 h of blast cleaning. Any field joint, which is not coated within 4 h of blast cleaning or where rust blooming has occurred, shall be completely reblasted.
- (i) The blast-cleaned surface shall be monitored for contamination in accordance with AS 3894.6 and the requirements of Clause 3.1.1(k) of this Standard. Where air is used for the removal of contaminants, it shall not further contaminate the surface.

3.2.6 Pre-application heating

The following requirements apply to pre-application heating:

- (a) Field joints for coating shall be uniformly heated in accordance with the manufacturer's specified temperature limits, but shall not exceed 260°C. Uniformity of heating shall be in accordance with Appendix M.

NOTES:

- 1 The preferred method of heating is by induction coil.
- 2 See also Notes to Clause 3.1.2(a).

- (b) The pipe surface temperature shall be checked using temperature-indicating crayons, surface thermometers or other suitable means, and shall be recorded. Crayons used to mark the pipe surface shall not cause deleterious effects and their use shall be kept to a minimum. The nominal temperature value of the temperature-indicating crayons shall be checked prior to use. The designated melting range for each batch of temperature-measuring crayons shall be checked, by determining the actual melting range of the crayon using differential scanning calorimetry (DSC).
- (c) The period of heat-decay between maximum and minimum application temperatures on the field joint surface, prior to completion of coating, shall be checked at least three times per production day or whenever ambient weather conditions change significantly or whenever there is a change in pipe wall thickness or diameter. The application of the coating shall be completed within the heat-decay period as determined by Appendix N.
- (d) Care shall be taken during the heating operation to prevent contamination of the prepared surface by combustion products or excessive oxidation.

- (e) Any mill-applied coating or repaired coating adjacent to the field joint that is damaged or blistered during the heating process shall be repaired. If blistering occurs in the parent coating, a modified heating rate, which does not promote the blistering, shall be determined and used.

NOTE: Blistering may occur in the parent coating if it is heated too rapidly. The problem is intermittent, and is not related to particular FBE powder types, coating thickness, or pipe properties. The cause of the problem is thought to be the rapid escape of absorbed water from the parent coating.

3.2.7 Application of FBE powder

The following applies to the application of FBE powder:

- (a) The powder shall be applied to the pipe surface by spray. The resulting cured film thickness shall be 400 μm min.

NOTE: The minimum thickness required will depend on the performance of the particular powder being used, pipeline operating conditions, pipeline route terrain and many other factors. Accordingly, minimum coating thickness should be that specified by the purchaser for the particular end use being considered.

- (b) The coating shall be applied over the entire bare steel area and with a minimum overlap of 25 mm on the adjacent mill-applied coating. The field-applied coating shall completely cover all mill coating abraded during surface preparation with a minimum overlap of 5 mm on untouched mill-applied coating. The overlap coating shall fuse with the substrate coating for a minimum of 20 mm, when tested with a knife. Additional controls may need to be applied to the preheating rate and duration to achieve this condition.
- (c) Powder application equipment shall be completely cleaned before and after each day's work.

3.2.8 Post-application heating

Post-application heating may be used to complete the curing of the coating.

The coated joint shall not be subject to a curing temperature in excess of 260°C and shall be in accordance with the powder manufacturers' specifications or written instructions.

NOTE: Prolonged elevated temperatures will result in degradation of the coating.

SECTION 4 REPAIRS

4.1 REPAIRS TO COATINGS IN THE MILL

The following applies to repairs to pipe coating in the coating mill:

- (a) All holidays defined in Clause 1.3 detected during final bench testing and in the course of handling the coated pipe in the pipe mill yard shall be repaired in accordance with this Standard, using materials qualified in accordance with Clause 6.2.3 and Table A1, Appendix A.
- (b) The maximum single area to be repaired shall be 0.01 m².
- (c) The maximum total area to be repaired on one joined pipe shall be 0.1% of the total external surface area of the coated length of pipe.
- (d) For any individual pipe length, the number of holidays shall not exceed the rate of 1 per metre of pipe length.
- (e) There shall be no more than 50 repairs on any 10 consecutive pipes.
- (f) Repairs shall be carried out in accordance with Clause 4.3.
- (g) If any of the criteria described in Item (b), (c) or (d) is exceeded, the length of pipe shall be stripped and recoated.
- (h) The repaired area shall be subject to a holiday test in accordance with AS 3894.1.

A1 |

4.2 REPAIRS TO FIELD JOINTS AND ADJACENT AREAS

Field joints and adjacent areas shall be subject to repairs as follows:

- (a) All holidays defined in Clause 3 detected on coated field joints shall be repaired in accordance with Clause 7.3. Visible coating discontinuities not detected electrically shall also be repaired in accordance with this Standard.
- (b) The maximum number of holidays permitted to be repaired in the field joint coating and within 150 mm beyond the junctions of the field joint coating and the original coating shall be—
 - (i) 5 for pipe whose diameter is 273 mm or larger; or
 - (ii) 3 for pipe whose diameter is less than 273 mm.
- (c) If the criterion described in Item (b) is exceeded, the field joint shall be stripped and re-coated in accordance with the requirements of this Standard.
- (d) Repairs shall be carried out in accordance with Clause 4.3.

4.3 REPAIR PROCEDURE

4.3.1 General

Repairs shall be carried out using a two-part epoxy resin material that is qualified in accordance with Clause 6.2.3; or a fusion bonded epoxy applied in accordance with Clause 3.1.3 for major repairs.

4.3.2 Surface preparation

Surface preparation shall be as follows:

- (a) *Defects of maximum dimension in any direction less than 100 mm* Dimension shall be measured after removal of all loose and disbonded coating. All visible oil, grease, organic and other contaminants shall be removed prior to further cleaning.

All holidays shall be abraded back to a clean steel surface using a coarse hand file or abrasive blast cleaning. Preparation shall leave a profile of not less than 50 µm and shall remove all FBE from the surface. All other defects shall be abraded back to sound coating with a minimum of sound parent material being removed.

The edges of the parent or field joint coating shall be feathered. A region of the parent coating approximately 10 mm to 20 mm wide, adjacent to the area to be repaired, shall be abraded with the minimum amount of sound parent material being removed.

All contamination shall be removed from the surface prior to application of repair materials.

- (b) *Defects over 100 mm in any direction* Dimension shall be measured after removal of all loose and disbonded coating. All loose and disbonded coating shall be cut back to sound material. The steel surface shall be cleaned by dry blast cleaning in accordance with AS 1627, Class 2½.

A region of the parent coating approximately 20 mm to 30 mm wide adjacent to the area to be repaired shall be roughened by blasting.

All contamination shall be removed from the surface prior to the application of repair materials.

4.3.3 Mixing of repair materials

The following applies to the mixing of repair materials:

- (a) Each mixing shall include the complete components of a kit provided by the coating manufacturer. There shall be no mixing of part kits.

NOTE: Mixing of components using a dual cartridge gun supplied by the coating manufacturer for this purpose is permitted.

- (b) If required to facilitate curing the two components may be heated to 50°C in a hot water bath prior to mixing.
- (c) The contents of one component shall be added to the other component and mixed. The mixing shall render each of the two components completely homogeneous. The mixing shall be carried out with a clean mixer and clean container. Under no circumstances shall mixing be carried out with a mixer or container on which there are traces of semi-cured material.
- (d) All mixed material shall be used within its pot life as defined by the manufacturer or shall be discarded. Any increase in viscosity of the material is evidence that the material has exceeded its pot life.

4.3.4 Application of repair materials

The following applies to the application of repair materials:

- (a) To facilitate curing the surface may be heated to 50°C prior to application and after application of the coating. Heating may be with hot air, radiant heaters, or propane torch. The surface temperature shall not exceed 50°C. The temperature shall be monitored using temperature-indicating crayons.

NOTE: Any coating damaged by excessive heat shall be removed and repaired. No discoloration of the FBE coating nor the repair material is permitted. There shall be no direct flame impingement onto the repair material.

- (b) The surface to be coated shall remain dry from the commencement of surface preparation until the completion of the application of the coating. Any rust bloom that occurs during the initial or subsequent phases of flame heating shall be removed.
- (c) The repair material shall be applied evenly over the exposed steel surface and onto all profiled FBE linepipe coating. It may be applied by brush, roller or spatula.
- (d) The material shall be applied to a minimum dry film thickness of 1000 µm for any single reading.

4.3.5 Curing of repair materials

The following requirements apply to the curing of repair materials:

- (a) The material shall be allowed to cure to a Durometer D hardness of at least 65 before testing and handling.
- (b) The material shall be free of runs, sags, drips, voids, pinholes, blistering, peeling, loss of adhesion, inadequate film thickness and inadequate cure.
- (c) Any material, that fails any one of the tests in this Section or any one of the tests listed in Table B5 of Appendix B, shall be removed, the surface re-prepared and the coating reapplied.

SECTION 5 STORAGE, HANDLING AND TRANSPORT

5.1 STORAGE OF POWDER

5.1.1 General

The manufacturer's recommendation of storage conditions of the powder shall be followed.

Powders that have been stored beyond the manufacturer's expiry date are considered suitable for use, provided the characteristics remain in accord with Table B1, subject to recertification by the powder manufacturer.

5.1.2 Containers

Prior to use the powder shall be stored in the manufacturer's original container, which shall be marked with the manufacturer's name, batch number, type of powder, storage condition and expiry date.

5.2 TRANSPORT OF POWDER

5.2.1 Containers

Powder shall be transported in sealed containers, which will prevent ingress of water. Where necessary, containers shall be refrigerated to maintain the temperature so that no deterioration of the powder occurs.

Temperature-indicating tags shall be indicative of the manufacturer's recommended storage conditions. The minimum number of temperature-indicating tags that are affixed to powder containers shall be as follows:

- (a) 1 per batch as manufactured.
- (b) 4 per container.
- (c) 1 per truckload, if less than 1 batch.

5.2.2 Damaged containers

The contents of any container that has been damaged to the point where the epoxy resin powder has been exposed to the atmosphere shall be tested for gel time, moisture content and DSC analysis and shall be within specification for each property. Out-of-specification powder shall not be used for coating.

5.3 HANDLING, TRANSPORT AND STORAGE OF PIPES

5.3.1 Handling

Pipes shall be protected from damage to the pipe material, coating and lining during handling. At all times during handling, coated pipes shall be prevented from contacting each other.

NOTE: Where forklifts are used to handle coated pipe, the tynes should be covered with a suitable padding material. Where cranes are used to lift and handle the pipe, tail lines should be secured to each end of the pipe to prevent it coming into contact with obstructions and other pipes, which might cause damage.

Where end hooks are used, they shall not be copper faced. End hooks shall provide bearing on a minimum of one-eighth of the circumference (12.5%). If end hooks are used, a spreader bar shall also be used. The spreader bar and length of sling used with the end-hooks shall be such that the included angle of the slings above the spreader of the crane bar is not more than 120°.

5.3.2 Storage of uncoated pipes

All uncoated pipes shall be stored a minimum of 150 mm clear of the ground in such a manner as will prevent water and dirt from accumulating in the pipe.

When pipes are supported on timbers, the pipe supports shall be placed nominally within 1.5 m of each end of the pipe and at intervals not greater than 5.5 m measured along the pipe.

The bottom layer of pipe in any stack shall be supported on wooden bearers or windrows. Timber bearers shall be nominally 200mm wide, and the ends of each row shall be securely chocked to prevent movement of the pipes in the stack. When pipes are supported on windrows covered with suitable plastic sheeting, the pipe supports shall be placed nominally within 2.5 m of each end of the pipe. For pipes in excess of 12 m length, additional windrows may be required.

The second and subsequent layers of uncoated pipes may be 'nested' on top of the previous layers or alternatively may be stripped with non-padded timber.

The height of pipe stacks shall not exceed requirements of Table 5.1.

TABLE 5.1
PIPE STACK HEIGHT

Outside diameter of pipe, mm	Maximum No. of layers
Up to 219.1	10
273.1 to 323.9	7
355.6 to 508.0	5
589.0 to 864.0	4
Bundled pipe (Bundles separated with timbers)	Maximum No. of bundled layers
Up to 114.3	5
168.3	4

NOTE: Subject to agreement of the purchaser and compliance with API 5LW, greater stacking heights may be permitted for bare pipe.

5.3.3 Storage of coated pipes

Coated pipes shall be stored a minimum of 150 mm clear of the ground in such a manner as to minimize corrosion to the uncoated parts of the pipe and prevent damage to the pipe and the coating. No uncoated section of pipe shall be in contact with the soil.

When pipes are supported on timbers, the pipe supports shall be placed nominally within 1.5 m of each end of the pipe and at intervals not greater than 5.5 m measured along the pipe.

The bottom layer of pipe in any stack shall be supported on wooden bearers or wind-rows. Timber bearers shall be nominally 200 mm wide padded with rubber, felt or similar material, and the ends of each row shall be securely chocked to prevent movement of the pipes in the stack. When pipes are supported on wind-rows covered with suitable plastic sheeting, the pipe supports shall be placed nominally within 2.5 m of each end of the pipe. For pipes in excess of 12 m length, additional wind-rows may be required. Pipe separators shall be used to prevent contact between the coated pipes. A minimum of three separators shall be used for double random pipes, and 5 separators shall be used for triple random lengths.

The second and subsequent layers may be nested on top of previous layers provided that the separators between layers are not compressed sufficiently to allow contact between coated pipes.

Alternatively, for timber stockpiles, the second and subsequent layers may be supported on further rows of timber, 3 timbers for double random pipes, and 4 timbers for triple random lengths. In this case, both the top and bottom of such timber shall be protected with padding to prevent damage to the coating.

A1 | The height of pipe stacks shall not exceed the maximum number of stacking layers for uncoated pipes (see Clause 5.3.2).

NOTE: Exposure of FBE to sunlight can have an adverse affect on the flexibility of the FBE. Damage can occur in less than 12 months exposure and can result in the coated pipe failing the bend test. Exposure to sunlight also reduces the FBE film thickness by chalking. This reduction in thickness may be up to 25 µm per year.

5.3.4 Transport

Where applicable, the transportation of pipe shall be in accordance with API RP 5L1 or API RP 5L5.

Pipes shall be secured to the transport vehicle in a manner that prevents movement of the pipes during transport.

Where pipe is in contact with supports or bolsters and securing devices, the pipe coating shall be protected from damage. All supports or bolsters shall be a minimum of 150 mm wide.

Individual pipes shall be separated with materials such as rubber pads, tyre treads or synthetic rope to prevent contact between pipes. Subsequent layers may be nested or supported by padded or shaped and padded bolsters.

Pipes shall be supported on bolsters. A minimum of three bolsters shall be used for double random pipes, and a minimum of 4 bolsters shall be used for triple random lengths.

Pipes may be transported in bundles provided that the bundle is held together with straps, which will not damage the pipe coating.

The coated pipes shall be protected from stone damage during transport.

5.4 HEALTH AND SAFETY

5.4.1 General

Hazards associated with the handling and application of fusion-bonded epoxy powder and associated materials may be reduced by sound safety procedures.

5.4.2 Handling of powder

The handling of powder shall be in accordance with the requirements of AS 2243.2.

5.4.3 Handling of chromates, phosphates and other hazardous materials

The relevant material safety data sheets shall be consulted for information on safe handling. In general, contact with skin should be avoided and fumes should not be inhaled.

SECTION 6 TESTING REQUIREMENTS

6.1 GENERAL

Means of demonstrating compliance with this Standard are given in Appendix B.

A1

6.2 COATING TESTS

6.2.1 Qualification tests

Tests shall be carried out on panels prepared in accordance with Appendix Q and shall comply with the requirements of Table B1 of Appendix B. These qualification tests are to determine the suitability of the FBE material.

6.2.2 FBE powder compliance tests

FBE powder shall comply with the requirements of Table B2 of Appendix B.

NOTE: Alternatively, the material manufacturer may provide a certificate of compliance, confirming that the powder supplied meets the requirements of Table B2, or a test certificate detailing the test methods used and results which demonstrate equivalent performance.

6.2.3 Repair material qualification test

Test coupons shall be prepared by the method specified in Appendix R and shall comply with the requirements of Table B5 of Appendix B.

6.2.4 Production coating tests

Production coated pipe shall comply with the requirements of Table B3 of Appendix B.

Notwithstanding coated pipe complying with the testing schedule, all coated pipe produced is required to comply with the technical requirements specified in Table B3 of Appendix B. Identification of localized infrequent non-deleterious non-compliances shall not constitute reason for rejection.

6.2.5 Tests of field-applied coating

When tested as specified herein, the coating shall comply with the requirements of Table B4 of Appendix B.

6.3 TESTING OF REPAIRS

All repairs shall be subjected to holiday testing in accordance with Table B5 of Appendix B, after hardening, and shall be examined visually for defects.

APPENDIX A
PURCHASING GUIDELINES
(Informative)

A1 SCOPE

Australian/New Zealand Standards are intended to include the technical provisions necessary for the supply of products referred to in a particular Standard, but do not purport to contain all the necessary provisions of a contract.

In a number of cases, the purchaser is either asked to specify requirements or is given a choice of optional requirements. These are contractual matters to be agreed upon between the purchaser and the manufacturer.

This Appendix contains advice and recommendations on the information to be supplied by the purchaser at the time of enquiry. Its aim is to avoid misunderstandings and to result in the purchaser receiving satisfactory products and service.

A2 INFORMATION TO BE SUPPLIED BY THE PURCHASER

The following information should be supplied by the purchaser:

- (a) Powder qualification tests to be performed.
- (b) Additional tests that are nominated by the purchaser (see Paragraph A4).
- (c) Mill application requirements.
- (d) Field application requirements.
- (e) Maximum operating temperature.
- (f) Other special requirements.

NOTE: Pipe purchasers should consider the inclusion in their pipe specifications a requirement that limits pipe surface imperfections, for which grinding or filing is necessary prior to coating (see Clause 1.1, Notes 3 and 4).

A3 INFORMATION TO BE SUPPLIED BY THE COATING APPLICATOR

The following information should be supplied by the coating applicator:

- (a) A quality assurance manual in accordance with AS 9001
- (b) Name and location of the material manufacturer.
- (c) Physical and chemical properties of the powder.
- (d) Results of differential scanning calorimetry tests on the fusion-bonded epoxy resin powder in the form of a graph and typical of the powder proposed.
- (e) Production rates of pipe coating or field joints.
- (f) Handling, transport and storage methods for powder, uncoated pipe and coated pipe.
- (g) Safety procedures.
- (h) Identification of powder, pipe coating or field joints.
- (i) Material manufacturer's recommended methods of application of powder.

- (j) Set of typical test results for the nominated coating including tests on—
 - (i) cathodic disbonding (see AS 4352);
 - (ii) foaming (see Appendix I);
 - (iii) resistance to immersion in hot water (see Appendix K); and
 - (iv) flexibility (see Appendix L).
- (k) Other special requirements.

A4 MANUFACTURER'S CERTIFICATE

The manufacturer shall, upon request, supply the purchaser with a signed certificate stating that the pipes, fittings, or both, have been manufactured in accordance with the requirements of the purchaser and this Standard.

NOTE: Manufacturers making a statement of compliance with this Australian/New Zealand Standard on a product, packaging, or promotional material related to that product are advised to ensure that such compliance is capable of being verified.

APPENDIX B
MEANS FOR DEMONSTRATING COMPLIANCE WITH THIS STANDARD
(Normative)

B1 SCOPE

This Appendix sets out two means by which compliance with this Standard shall be demonstrated by a manufacturer, as follows:

- (a) The use of a product certification scheme.
- (b) The use of a minimum sampling and testing frequency plan.

B2 RELEVANCE

The relevance of a product certification scheme for FBE-coated pipes is to provide assurance of the quality of product.

B3 PRODUCT CERTIFICATION

The purpose of product certification is to provide independent assurance of the claim by the manufacturer that products comply with this Standard.

The certification scheme shall meet the criteria described in SAI HB 18.28/SANZ HB 18.28 (ISO/IEC Guide 28) in that, as well as full type testing from independently sampled production and subsequent verification of conformance, it requires the manufacturer to maintain effective planning to control production.

The certification scheme serves to indicate that the products consistently conform to the requirements of this Standard.

Product certification shall be conducted by a certification body accredited by the Joint Accreditation System for Australia and New Zealand (JAS-ANZ) or by another certification body that is acceptable to JAS-ANZ.

A1 | The frequency of the sampling and testing plan as detailed in Paragraph B4 shall be used by the certifying body for product compliance auditing. However, where the manufacturer can demonstrate adequate process control to the certifying body, the frequency of sampling and testing nominated in the manufacturer's quality and/or documented procedures shall take precedence for the purpose of product certification.

B4 MINIMUM SAMPLING AND TESTING FREQUENCY PLAN**B4.1 General**

Table B1 sets out the minimum sampling and testing frequency plan for a manufacturer to demonstrate compliance of product(s) to this Standard.

B4.2 Retesting

Should a failure occur on testing coated pipe, retesting shall be carried out in production sequence either side of the rejected coated pipe using a narrowing procedure to establish identification of the cause of the failure and the need for rework or rejection of portions of the production run.

B4.3 Rejection after test

In the event of a quarantined batch being rejected after retesting in accordance with the procedures set out in Paragraph B4.2, it may be subjected to 100% testing for the failed requirement(s), and only those items found to comply may be claimed and/or marked as complying with this Standard.

B5 TEST REQUIREMENTS

Testing shall be undertaken as specified in Section 4 at a frequency not less than that specified in Table B1.

TABLE B1
TYPICAL TESTING SCHEDULE FOR ASSESSMENT OF COMPLIANCE

Characteristic	Requirement	Test Method	Frequency
Density	±4%	Appendix D	At any change in material design or application process
Gel time	±20% for gel time ≤ 20 s ±15% for gel time > 20 s	Appendix E	At any change in material design or application process
Particle size analysis	< 32 µm sieve ±15% < 150 µm sieve ±5%	Appendix F or ASTM D 1921 Method B using sieves specified in Appendix F	At any change in material design or application process
Volatile content	0.50% max. (absolute value)	Appendix G	At any change in material design or application process
DSC Analysis	Glass transition temperature (T_{gi}) ± 4°C Heat of reaction (ΔH) ±15% Peak exothermic temperature (T_p) ±3°C Final glass transition temperature (T_{gr}) ±3°C	Appendix H	At any change in material design or application process
Abrasion resistance	(CS17 wheels, 1000 g load, 1000 cycles) 60mg max.	ASTM D 1044 ASTM D 4060	By agreement between purchaser and supplier
Resistance to penetration	2% (-40°C to 100°C)	ASTM G 17	By agreement between purchaser and supplier
Tensile strength and elongation (free film)	50 MPa min. (4% elongation min.)	ASTM D 2370	By agreement between purchaser and supplier
Dielectric strength (free film)	40 V/µm min.	ASTM D 149	By agreement between purchaser and supplier
Water permeability (free film)	1.5 g.mm/m ² max. in 24 h	ASTM D 1653	By agreement between purchaser and supplier
Water absorption (free film)	4.5% max. at 98°C	Appendix O	By agreement between purchaser and supplier
Volume resistivity	25°C: 1.0 × 10 ¹³ Ω.m min. 100°C: 1.0 × 10 ¹⁰ Ω.m min.	ASTM D 257	By agreement between purchaser and supplier

(continued)

Characteristic	Requirement	Test Method	Frequency
Resistance to weathering	No film degradation other than surface chalking shall occur within 6 months	ASTM G 11	By agreement between purchaser and supplier
Thermal stability (dry cycling)	Adhesion rating ≤ 2 Impact 1.5 J min.	Appendix P	By agreement between purchaser and supplier
Thermal stability (immersion)	Rating ≤ 2 Impact 1.5 J min.	Appendix P	By agreement between purchaser and supplier
Impact resistance	$\leq 550 \mu\text{m} = 1.5 \text{ J}$ $> 550 \mu\text{m} = 3 \text{ J}$ There shall be no holiday	ASTM G 14	At any change in material, design or application process
Flexibility	Min. of 3.75° /pipe diameter for $\leq 600 \mu\text{m}$ coating thickness. No cracking. For greater coating thicknesses, testing to be by agreement between the purchaser and supplier	Appendix L	At any change in material, design or application process
Resistance to hot water	Adhesion rating ≤ 2 after 24 h	Appendix K	At any change in material, design or application process
Resistance to cathodic disbondment	$65 \pm 3^\circ\text{C}$; 48 h test $\leq 6 \text{ mm}$ average radial disbondment $20 \pm 2^\circ\text{C}$; 28 day test. $\leq 7 \text{ mm}$ average radial disbondment. No blistering $65 \pm 3^\circ\text{C}$; 28 day test. $\leq 13 \text{ mm}$ average radial disbondment. No blistering	AS 4352	At any change in material design or application process

TABLE B2
FBE POWDER COMPLIANCE TESTS

Characteristic	Requirement	Test Method	Frequency
Density	±4%	Appendix D	Once per batch for each shipment
Gel time	±20% for gel time ≤20 s ±15% for gel time >20 s	Appendix E	Once per batch for each shipment
Particle size analysis	<32 µm sieve±15% <150 µm sieve±5%	Appendix F, or ASTM D 1921 Method B using sieves specified in Appendix F.	Once per batch for each shipment
Volatile content	0.50% max. (absolute value)	Appendix G	Once per batch for each shipment
DSC Analysis	Glass transition temperature (T_{gi}) ±4°C Heat of reaction (ΔH) ±15% Peak exothermic temperature (T_p) ±3°C Final glass transition temperature (T_{gf}) ±3°C	Appendix H	Once per batch for each shipment
Foaming Cross-sectional	Rating ≤3	Appendix I	Once per batch for each shipment
Foaming Interfacial	Rating ≤3	Appendix I	Once per batch for each shipment
Impact resistance	≤550µm = 1.5 J >550µm = 3 J There shall be no holiday.	ASTM G 14	Once per batch for each shipment
Flexibility	Min. of 3.75°/pipe diameter for ≤600 µm coating thickness. No cracking. For greater coating thicknesses, testing to be by agreement between the purchaser and supplier	Appendix L	Once per batch for each shipment
Resistance to hot water	Adhesion rating ≤ 2 after 24 h	Appendix K	Once per batch for each shipment
Resistance to cathodic disbondment	65 ±3°C; 24 h test ≤6 mm average radial disbondment.	AS 4352	Once per batch for each shipment

TABLE B3
FBE COATING PERFORMANCE

Characteristic	Requirement	Test Method	Frequency
Adhesion	Rating ≤ 2	Appendix J	One pipe in every 50 pipe coated
DSC Analysis	$\Delta T_g \leq 4^\circ\text{C} \geq 95\%$	Appendix H	Twice per shift
Foaming Cross-sectional	Rating ≤ 3	Appendix I	Once in every day of production
Foaming Interfacial	Rating ≤ 3	Appendix I	Once in every day of production
A1 Interface contamination	Rating $\leq 25\%$ of area	Appendix S	Once in every day of production. For information only
Determination of surface dust	Rating ≤ 5	AS 3894.6	Twice in every day of production
Impact resistance	$\leq 550 \mu\text{m} = 1.5 \text{ J}$ $> 550 \mu\text{m} = 3 \text{ J}$ There shall be no holiday.	ASTM G 14	One pipe in every 100 pipe coated
Flexibility	Min. of 3.75° /pipe diameter for $\leq 600 \mu\text{m}$ coating thickness. No cracking. For greater coating thicknesses, testing to be by agreement between the purchaser and supplier	Appendix L	Once in every day of production
Resistance to hot water	Adhesion rating ≤ 2 after 24 h	Appendix K	Once in every day of production
Resistance to cathodic disbondment	$65 \pm 3^\circ\text{C}$; 24 h test $\leq 6 \text{ mm}$ average radial disbondment.	AS 4352	Once in every day of production
	$22.5 \pm 2.5^\circ\text{C}$; 28 day test $\leq 7 \text{ mm}$ average radial disbondment, no blistering	AS 4352	Annual qualification test on production applied powder
A1 Holiday testing	<p>Mill testing shall be in accordance with AS 3894.1 using a detector with constant DC voltage output.</p> <p>All subsequent testing (including field testing) shall be in accordance with AS 3894.1 using a detector with constant DC voltage output, but with the voltage set 65% of the specified values in AS 3894.1.</p> <p>For all testing, the detector output voltage shall be set at the calculated value as measured using a certified calibrated voltmeter appropriate to the detector being used. The voltage shall be set daily at the commencement of each shift and measured at the end of each shift. It shall not vary by more than 2% over the shift.</p> <p>Rolling spring electrodes shall not be used for any testing.</p>	AS 3894.1	Every pipe

TABLE B4
FIELD-APPLIED COATING

Characteristic	Requirement	Test Method	Frequency
Adhesion	Rating ≤ 2	Appendix J	One joint in every 50 joints coated
MEK Rub	No coating residue to be removed	Visual inspection	One joint in every 50 joints coated
DSC Analysis	$\Delta T_g \leq 4^\circ\text{C} \geq 95\%$	Appendix H	By agreement between purchaser and supplier
Foaming Cross-sectional	Rating ≤ 3	Appendix I	Once in every day of production
Uniformity of heating	Max. variation $\pm 12^\circ\text{C}$	Appendix M	Tested at each start up and any change in weather conditions
Heat decay period	Application time \leq heat decay period	Appendix N	Tested at each start up and any change in weather conditions
Holiday testing	In accordance with AS 3894.1. Rolling spring electrodes shall not be used. NOTE: If coating material has been subjected to moisture absorption, subsequent test voltage for field testing may be carried out at 80% of the specified value	AS 3894.1	Every joint

TABLE B5
LIQUID-APPLIED EPOXY REPAIR COATING TESTS

Characteristic	Requirement	Test Method	Frequency
Adhesion	Rating ≤ 2	Appendix J	At any change in material or application method
Resistance to hot water	Adhesion rating ≤ 2 after 24 h	Appendix K	At any change in material or application method
Resistance to cathodic disbondment	65 \pm 3°C; 24 h test ≤ 6 mm average radial disbondment.	AS 4352	At any change in material or application method
	22.5 \pm 2.5°C; 28 day test ≤ 7 mm average radial disbondment, no blistering	AS 4352	At any change in material or application method
Holiday testing	In accordance with AS 3894.1. Rolling spring electrodes shall not be used. Care shall be taken to ensure that parent coating material is not subjected to a voltage exceeding the requirements of AS 3894.1. NOTE: If coating material has been subjected to moisture absorption, subsequent test voltage for field testing may be carried out at 80% of the specified value.	AS 3894.1	Every repair

APPENDIX C
CHEMICAL PRETREATMENT
(Informative)

C1 GENERAL

Chemical pretreatment of the pipe surface after blast cleaning and before powder application may be performed, but is not essential to meet the performance requirements of this Standard.

Phosphate pretreatment provides an extra degree of certainty that the substrate is chemically clean and readily wetted by the molten powder.

Chromate pretreatment also provides an inorganic 'conversion coating', which improves the corrosion resistance, cathodic disbonding resistance and adhesion performance under hot, wet conditions. It also increases the application temperature range, which can be used to achieve the full interfacial properties mentioned above.

C2 CHROMATE PRETREATMENT

The chromate pretreatment solution should be of the dried-in-place, non-rinse type and should deposit an adherent, thin layer of mixed silicates, chromates and oxides. Conventional chromate pretreatment solutions intended for aluminium and zinc are not suitable. The supplier's recommendations for solution strength, application temperature, contact time and drying conditions should be followed.

C3 PHOSPHATE PRETREATMENT

Phosphate pre-treatment should be used to clean steel surfaces where chloride concentrations are greater than the specified tolerance given in Clause 3.1.1(l).

Proprietary iron phosphating solutions specifically designed for mitigating chloride contamination on FBE coated pipe, should be used. The supplier's recommendations for solution strength, application temperature and contact time should be followed. Excess chemical should be removed by thorough water washing.

C4 WATER QUALITY

A1 | Any water used in the pretreatment process should be demineralized with a maximum conductivity of 10 $\mu\text{S}/\text{cm}$.

APPENDIX D
DENSITY OF POWDER
(Normative)

D1 SCOPE

This Appendix sets out the method for establishing the density of FBE powder for pipe coating application.

D2 PRINCIPLE

Using a pyknometer and a solvent of known density, the mass of a representative small fixed volume of the powder is determined and the density calculated.

D3 APPARATUS AND REAGENT

The following apparatus and reagent are required:

- (a) 100 mL pyknometer.
- (b) Suitable analytical balance with readings in tenths of a gram.
- (c) Thermometer, graduated in degrees Celsius.
- (d) Glass stirring rod.
- (e) Solvent (high flash aliphatic naphtha, e.g. Shell X2) of density known to 1%.

D4 CONDITIONS

The following conditions shall apply:

- (a) The pyknometer shall be the same temperature as the material being tested.
- (b) All materials shall be weighed at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ unless otherwise specified.

D5 PROCEDURE

The procedure shall be as follows for aerated materials:

- (a) Place pyknometer and lid on balance and tare.
- (a) Fill pyknometer with material being tested to approximately 50 g.
- (b) Weigh the pyknometer and contents to the nearest tenth of a gram using an analytical balance.
- (c) Add solvent until pyknometer is approximately four-fifths filled.
- (d) Mix contents thoroughly with a small glass stirring rod.
- (e) Rinse rod using solvent into pyknometer.
- (f) Cover pyknometer and allow to stand for 5 min (this permits mixture to defoam and powder to settle).
- (g) Fill pyknometer with solvent.

- (h) Place lid on pyknometer and press down until fully seated, during which operation the surplus solvent will exude from the hole located in the lid. Remove excess material, which has been emitted through the hole, with a cloth wiper. (It is a necessary part of the procedure that only solvent flows through the hole to ensure that the pyknometer is completely filled when the cover is firmly seated.)
- (i) Weigh the pyknometer and contents to the nearest tenth of a gram using an analytical balance.

D6 CALCULATION

The calculation of the density (D) is as follows:

$$D = m_p / (V - m_s / \kappa)$$

where

- D = density, in grams per millilitre
 m_p = mass of powder, in grams
 V = volume of pyknometer, in millilitres
 m_s = mass of solvent, in grams
 κ = density of the solvent, in grams per millilitre

D7 REPORT

The calculated density of the powder shall be reported to two decimal places.

APPENDIX E
GEL TIME OF POWDER

(Normative)

E1 SCOPE

This Appendix sets out the method for the laboratory determination of the gel time of FBE powder for pipe coating application.

E2 APPARATUS

The following apparatus is required:

- (a) Hotplate with temperature control to $\pm 2^{\circ}\text{C}$.
- (b) Surface thermometer with an accuracy of 1°C .
- (c) Doctor blade with a 500 μm gap.
- (d) Stopwatch.
- (e) Short length of 0.8 mm diameter (approximate) wire.

E3 PROCEDURE

The procedure shall be as follows:

- (a) Set the hotplate to 200°C or as per manufacturer's specification, and allow the temperature to stabilize.
- (b) Place approximately 0.5 g to 1 g of powder on the hotplate, and immediately draw a film of powder across the surface using the doctor blade. The area of the film shall be approximately 3 cm^2 to 5 cm^2 .
- (c) Start the stopwatch immediately after the powder in the test area melts on the hotplate.
- (d) Push one end of the wire across the hotplate and about 10 mm from the edge of the film. The probing end of the wire shall be maintained clean. Repeat this action until the film no longer flows back into the path of the wire and the coating tears as the wire is pushed through. Stop the stopwatch. The elapsed time is the gel time.

The test shall be carried out 3 times.

E4 REPORT

The gel time shall be reported as the arithmetic average of the three results.

APPENDIX F PARTICLE SIZE ANALYSIS OF POWDER

(Normative)

F1 SCOPE

This Appendix sets out a method for determining the particle size of FBE powder coatings for pipe coating application. Alternative systems may be used, as agreed by the purchaser.

F2 APPARATUS

The following apparatus is required:

- (a) Vacuum sieve unit (e.g. Alpine model 200 LS).
- (b) Balance, reading to 0.01 g.
- (c) Two 200 mm diameter sieves with 32 μm and 150 μm sieve cloths respectively (brass or stainless steel).

F3 PROCEDURE

The procedure shall be as follows:

- (a) Weigh empty (clean and dry) the appropriate sieve (see Table 2) to 0.01 g (m_1).
- (b) Weigh between 10 g and 20 g of powder sample on top of the sieve (m_2).
- (c) Move sieve with powder to vacuum sieve unit (air jet sieve).
- (d) Place cover on sieve and secure sieve.
- (e) Start the vacuum sieve unit and keep it operating for 3 min, for air jet to sieve only, maintain vacuum in excess of 250 mm of water.
- (f) Move sieve to balance.
- (g) Weigh sieve with remains of powder to 0.01 g (m_3).

F4 CALCULATION

The percentage of powder passing through each sieve is calculated as follows:

$$p = (m_2 - m_3) \times 100 / (m_2 - m_1)$$

where

- p = percentage of powder passing a given sieve
- m_2 = initial mass of sieve and powder
- m_3 = final mass of sieve and residual
- m_1 = mass of sieve

F5 REPORT

The percentage of powder passing through each sieve shall be reported as a whole percent.

APPENDIX G
VOLATILE CONTENT OF POWDER
(Normative)

G1 SCOPE

This Appendix sets out the method for determining the total volatile content at $105 \pm 5^\circ\text{C}$ of FBE powder for pipe coating application, which can normally be interpreted as moisture content.

G2 APPARATUS

The following apparatus is required:

- (a) Analytical balance to weigh to an accuracy of 0.1 mg.
- (b) Aluminium pans.
- (c) Oven controlled at $105 \pm 5^\circ\text{C}$.
- (d) Desiccator with activated silica gel.

G3 PROCEDURE

The procedure shall be as follows:

- (a) Dry the pan to constant mass.
- (b) Weigh the aluminium pan and record the mass (m_1).
- (c) Add approximately 1.5 g powder to the pan and record the mass accurately (m_2).
- (d) Place the pan plus sample in the oven at $105 \pm 5^\circ\text{C}$.
- (e) Remove the pan after 2 h and place in a desiccator to cool for 5 min.
- (f) Weigh the dried sample and pan immediately after removal from the desiccator (m_3).
- (g) Repeat the test.

G4 CALCULATION

The volatile content for each test is calculated as follows:

$$\text{Volatile content (\%)} = (m_2 - m_3) \times 100 / (m_2 - m_1)$$

G5 ASSESSMENT

The average of the two results shall be quoted. If the results differ by more than 10% the procedure in Paragraph G3 shall be repeated and the results re-calculated. The volatile content shall then be the average of the four tests.

G6 REPORT

The average percent volatile content shall be reported to an accuracy of 2 significant figures.

APPENDIX H
DSC ANALYSIS
(Normative)

H1 SCOPE

This Appendix describes a method, using differential scanning calorimetry (DSC), for the analysis of FBE powder coatings.

H2 APPLICATION

The procedures in this Appendix are used for measurement of the following:

- (a) For a powder —
 - (i) glass transition temperatures (T_{g1}) (initial) and (T_{gf}) (final);
 - (ii) heat of reaction (ΔH) (i.e. the heat evolved during the cure process); and
 - (iii) peak exotherm temperature (T_p).
- (b) For a coating chip —
 - (i) glass transition temperatures (T_{g1}) and (T_{g2});
 $\Delta T_g = T_{g2} - T_{g1}$ is a measure of the degree of undercure of coating.
 - (ii) percentage cure (calculated from the residual heat of reaction (ΔH_r)).

H3 DEFINITIONS

For the purpose of this Appendix the definitions below apply.

H3.1 Differential scanning calorimetry (DSC)

A thermal analysis technique that measures the difference between the heat flow rate to a sample and to an inert reference, whilst both are subjected to a controlled temperature program. Changes in specific heat of the sample and exothermic or endothermic processes are measured as a function of temperature (or time).

H3.2 Glass transition temperature (T_g)

The temperature (or temperature range) at which the FBE powder or coating undergoes a sudden change in physical properties. An increase in specific heat occurs at T_g and this is evident as a shift in the DSC trace. T_g is defined as the onset of the baseline shift and is the temperature at the intersection of the extrapolated baseline and the tangent to the curve at the point of inflection (where the slope of the curve is maximal). The construction is shown in Figure H1.

H3.3 Heat of reaction (ΔH)

The heat produced as the FBE powder is cured. If the coating is not completely cured, a small amount of residual heat of reaction will be evolved on reheating, and can be measured by DSC. The exothermic peak area (see Figure H1) is bounded by the peak curve and a straight line drawn from the point of onset of cure (x) to the tangent to the curve at the completion of the peak (y).

H3.4 Peak exotherm temperature (T_p)

The temperature at which the curve displacement from the interpolated baseline is a maximum (see Figure H1).

H3.5 Percentage cure

The fraction of the total available reaction achieved during the application of the coating. It is determined via the residual heat of reaction (ΔH_r) and the maximum available heat of reaction (ΔH) using the following equation:

$$\% \text{ cure} = 100(\Delta H - \Delta H_r)/\Delta H$$

H4 PRINCIPLE

A sample and an inert reference are heated at a constant temperature scan rate in a DSC instrument.

A scan is made from ambient to a temperature slightly beyond the completion of the reaction exotherm. This records thermal changes in the sample over the temperature range and allows T_g , T_p and ΔH to be determined.

The sample is then cooled rapidly to ambient temperature and a further scan is made to determine T_g of the fully cured material.

The ΔH value is calculated from the area under the exothermic peak. The area can be measured by electronic integration, planimeter or a cut and weigh method. This area is converted to an energy term (expressed in joules per gram) according to the scaling on the thermal power and time base axes.

The form of the calculation of ΔH is as follows:

$$\Delta H = E.A.t_c S/m$$

where

- E = instrument calibration constant
- A = the peak area, in square centimetres
- t_c = the time to traverse 1 cm, in seconds
- S = the power axis sensitivity, in milliwatts per centimetre
- m = the mass of the sample, in milligrams

NOTE: 1 watt = 1 joule/second and 1 calorie = 4.184 J.

For a coating chip, the residual ΔH value is measured in the same way and is used to calculate the percentage cure.

It is essential that samples are pretreated before measurement to remove moisture and provide a consistent thermal history. With coating chip samples, absorption of moisture can result in erroneously high ΔT_g values.

H5 APPARATUS

The following apparatus is required:

- (a) DSC instrument with sufficient calorimetric sensitivity to resolve the relevant thermal transitions.
- (b) Aluminium sample pans and lids, as provided by the instrument manufacturer.
- (c) Appropriate accessories to the DSC instrument to produce fast cooling from the maximum temperature used to ambient temperature.
- (d) Analytical balance able to weigh to 0.1 mg.
- (e) A crimping tool to crimp the aluminium lid in place on the sample pan.
- (f) Dry nitrogen supply and connections to enable the measurements to be carried out under a flowing nitrogen atmosphere.

H6 CALIBRATION

The thermal power axis and the temperature axis of the DSC instrument shall be calibrated. It is necessary for the temperature calibration to be carried out at the same temperature scan rate to be used in subsequent testing (20°C/min).

Prior to calibration, the baseline of the instrument, produced when empty pans are placed in both sample and reference positions, shall be adjusted to be sensibly straight and horizontal over the range 30°C to 280°C, when scanned at 20°C/min and with the same thermal sensitivity setting to be used in the testing.

H7 SAMPLE HANDLING

H7.1 FBE powder

Representative samples of powder are taken and placed in airtight containers. The temperature of the sample shall be maintained below 25°C prior to testing.

H7.2 Applied coating

Applied coating is removed from the substrate using a chisel or similar instrument. Care shall be taken to remove samples of full coating thickness.

If there is to be any delay in DSC testing, the coating sample shall be placed in an airtight vial or small glass bottle, together with some grains of activated silica gel.

H7.3 Sample identification

The following information (as appropriate) shall be recorded for each sample:

- (a) Date of sampling.
- (b) Pipe number or weld number.
- (c) Orientation of sample on pipe (clock position).
- (d) Powder batch number.

H8 DSC TEST PROCEDURE

H8.1 Conditions

The instrument setting will vary according to design details. However, the following conditions shall be observed:

- (a) A temperature scan rate (scan speed) of 20°C/min.
- (b) If ΔH is to be measured, the instrument shall be run in a time base mode while the exothermic peak is plotted.
- (c) A flowing nitrogen atmosphere.

H8.2 FBE powder (see Figure H1)

H8.2.1 Sample preparation

10 mg to 15 mg of the powder shall be weighed to the nearest 0.1 mg into the sample pan and the lid shall be crimped in place. Four breather holes shall be pierced in the lid to prevent sample pressurization.

H8.2.2 Sample preconditioning

The sample shall be heated in the instrument from ambient to 75°C at 20°C/min and rapidly cooled back to ambient. This preconditioning achieves a standard physical state of the sample prior to measurement. The preconditioning trace shall be recorded.

H8.2.3 Measurement scans

The measurement scans shall be as follows:

Scan	Initial temp (°C)	Scan temperature rate (°C/min)	Final temp. (°C)	Cool
Scan 1	30	20	280	Fast cool
Scan 2	50	20	130	

NOTE: The initial temperature for Scan 1 may be chosen to be lower if it allows better resolution of T_{gi} .

The final temperature for Scan 1 may be chosen, with experience of a particular grade of FBE, to be just above the completion of the cure exotherm peak.

T_{gi} , T_p and ΔH are determined from Scan 1.

T_{gr} is determined from Scan 2.

H8.3 Coating chip (see Figure H2)

H8.3.1 Sample preparation

The sample of coating chip shall be cut into a finely divided form so that each piece is representative of the total cross-section and has a mass of less than 2 mg. Between 10 mg and 15 mg of the finely divided sample shall be weighed into a sample pan to the nearest 0.1 mg. A lid shall be crimped in place and four breather holes shall be pierced in the lid to allow moisture removal on preconditioning.

H8.3.2 Sample preconditioning

The sample shall be heated in the instrument from ambient to 115°C at 80°C/min, held at this temperature for 5 min and rapidly cooled to ambient. The run shall be recorded to show evidence of preconditioning. The purpose of preconditioning is to achieve a standard physical state for the sample and to remove moisture prior to the measurement scans. The time/temperature cycle is chosen to provide reasonable drying action with only slight cure advancement of undercured samples.

H8.3.3 Measurement scans

The measurement scans shall be as follows:

Scan	Initial temp (°C)	Scan temperature rate (°C/min)	Final temp (°C)	Cooling
Scan 1	50	20	260	Fast cool
Scan 2	50	20	260	

T_{g1} is determined from Scan 1.

T_{g2} is determined from Scan 2.

$\Delta T_g = T_{g2} - T_{g1}$ is calculated and quoted to the nearest 0.5°C.

ΔH_r is measured from Scan 1 if any residual exotherm is evident.

A comparison of Scan 1 and Scan 2 in the region above T_g allows any small residual exotherm to be detected. If Scan 2 shows any curvature above T_g , ΔH_r shall be measured as—

$$\Delta H_r = \Delta H (\text{Scan 1}) - \Delta H (\text{Scan 2})$$

where

ΔH (Scan 1) and ΔH (Scan 2) are calculated from apparent peak areas in Scans 1 and 2.

% Cure is calculated from—

$$\% \text{ Cure} = 100 (\Delta H - \Delta H_i) / \Delta H$$

where ΔH is the heat of reaction for the original powder used for the coating.

NOTE: An undercured coating should show both a positive ΔT_g value and some evidence of residual exotherm. A significant value of ΔT_g , with no residual exotherm usually indicates that the moisture content of the sample was high and it was incompletely dried by the preconditioning cycle. If this behaviour is observed, complete drying in a vacuum desiccator (48 h and finely divided sample is recommended) will give a truer ΔT_g figure, which is indicative of the state of cure. After vacuum drying a pretreatment to 115°C is still required, but no hold time is used.

H9 REPORT

The following shall be reported:

- T_g , ΔT_g and T_p temperature values, reported to the nearest 0.5°C.
 - ΔH values, reported in joules per gram, to the nearest 1 J/g.
 - Percentage cure, to the nearest percentage unit.
 - If no residual exotherm is evident, it is reported as 'no residual exotherm'.
- The original graphical DSC scans shall be filed and be available for inspection as required.

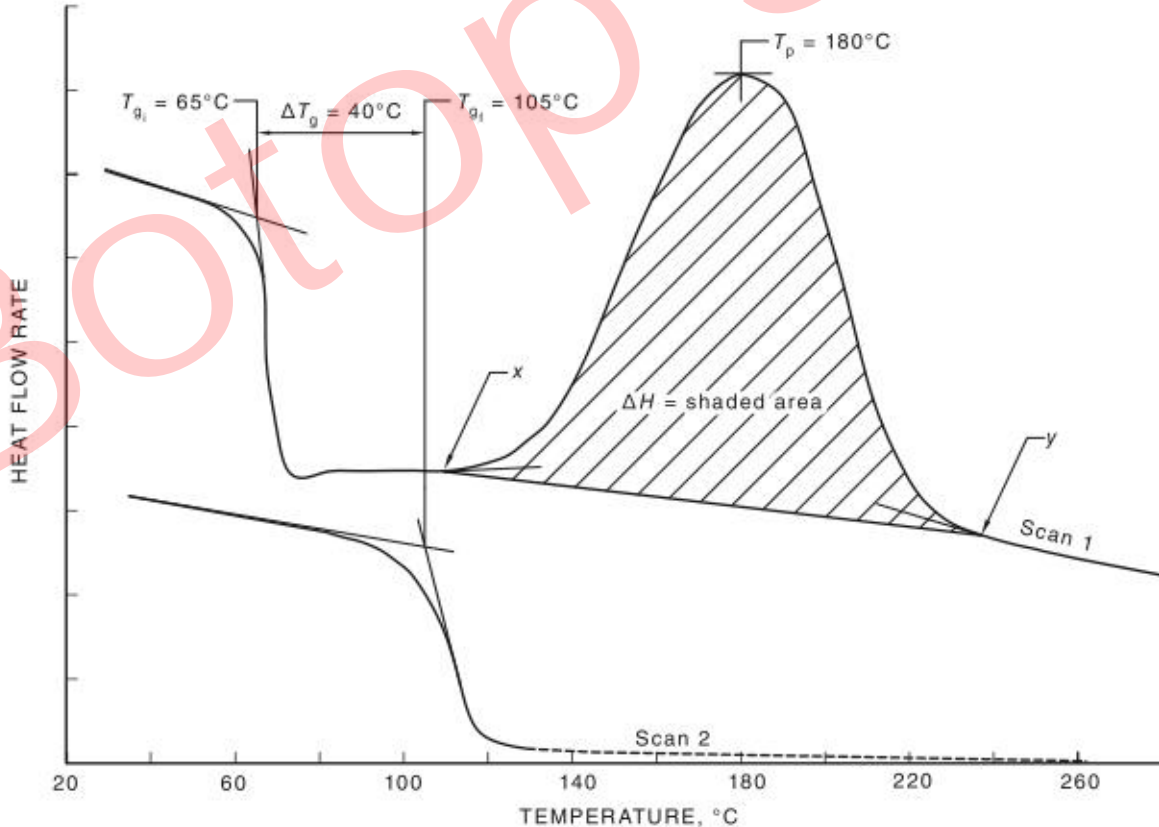


FIGURE H1 DSC TRACES OF A FBE POWDER SAMPLE

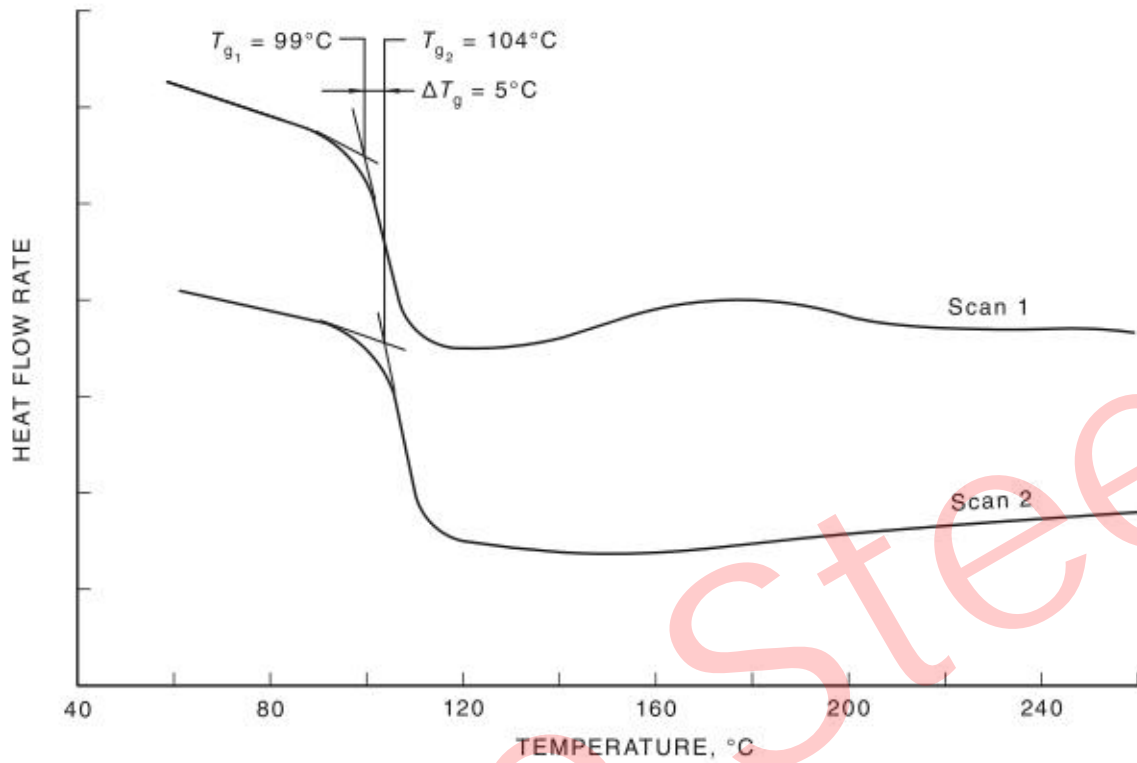


FIGURE H2 DSC TRACE OF A PARTIALLY CURED FBE COATING

APPENDIX I

FOAMING

(Normative)

11 SCOPE

This Appendix sets out the method for identifying the amount of foaming through the cross-section and on the interface of FBE powder coating.

12 APPARATUS

The following apparatus is required:

- (a) Microscope.
- (b) Tweezers.
- (c) Four-point bend device.
- (d) Freezer.
- (e) Sample panel 200 mm × 25 mm × wall thickness.

13 PROCEDURE

The procedure shall be as follows:

- (a) Take the FBE-coated sample panel and place in the freezer for 1 h.
- (b) Remove the frozen sample from the freezer, and place it in the four-point bend device. Commence bending before the sample has a chance to defrost.
- (c) Where the sample has cracked, use the tweezers to remove a representative chip.
- (d) Using a reasonable light source examine the cross-section of the coating chip at 30 × magnification.
- (e) Once recorded place the coating chip under the microscope so that the interface is showing.
- (f) Determine the foaming according to the pictorial scale shown in Figures 1 to 5 (see Note).

NOTE: Figures show substrate at lower edge of photograph.

14 REPORT

The following shall be reported:

- (a) Sample identification number and date of testing.
- (b) The cross-sectional foaming rating.
- (c) The interfacial foaming rating.



FIGURE 11 CROSS-SECTIONAL FOAMING RATING 1



FIGURE 12 CROSS-SECTIONAL FOAMING RATING 2

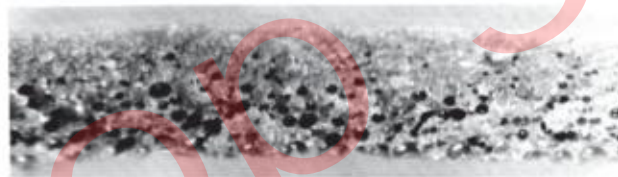


FIGURE 13 CROSS-SECTIONAL FOAMING RATING 3



FIGURE 14 CROSS-SECTIONAL FOAMING RATING 4



FIGURE 15 CROSS-SECTIONAL FOAMING RATING 5

APPENDIX J
ADHESION OF COATINGS TO STEEL
(Normative)

J1 SCOPE

This Appendix sets out the method for evaluating the adhesion of FBE coating to steel, by comparison of a forcibly disbonded area of coating with descriptive standards.

J2 APPARATUS

The following apparatus is required:

- (a) Strong pointed knife.
- (b) Safety glasses.
- (c) Set of descriptive standards.

J3 PROCEDURE

The procedure shall be as follows:

- (a) Inscribe a V-cut with two 20 mm lines intersecting at approximately 5 mm from their ends at 30° to 45°.
- (b) Insert the blade of the knife at the point of the V-cut, 45° to the surface. Then with an upward flicking action attempt to dislodge the coating within the V. If little or no coating is removed, repeat this action within the 'V' at least 4 times to confirm the integrity of the coating.
- (c) Examine the appearance of the disbonded surface and compare with the following descriptive rating set out in Table J1.

TABLE J1
DESCRIPTIVE COATING RATING

Rating	Description
1	Coating is not removed cleanly at any point in the V-cut. The entire profile contains some adherent coating
2	Coating is removed in small chips with some difficulty. Substantial coating remains adherent to the surface profile
3	Coating is removed in chips, which are slightly larger in area to the knife-point inserted under the coating. Some of the coating remains adherent to the surface of the steel within the V-cut
4	Coating is removed with no chipping of the coating, and with minimal resistance
5	No coating remains adherent to the steel within the V-cut

NOTE: This descriptive standard has been developed as a progressive scale, and should be interpreted as such. Adhesion rating '1' implies the best and '5' implies the worst

J4 REPORT

The test results shall be reported as equivalent in appearance to a numbered descriptive standard, as described.

APPENDIX K
RESISTANCE OF COATING TO IMMERSION IN HOT WATER
(Normative)

K1 SCOPE

This Appendix sets out the method for evaluating the adhesion of FBE coating to steel after immersion in hot water.

K2 APPARATUS

The following apparatus is required:

- (a) Thermostatically controlled water bath.
- (b) Strong pointed knife.

K3 TEST SPECIMENS

Test specimens shall be either—

- (a) coupons at least 75 mm × 75 mm; or
- (b) test panels made in accordance with either Appendix Q.

K4 PROCEDURE

The procedure shall be as follows:

- (a) Fill the water bath with tap water, and set to a temperature of $98 \pm 2^\circ\text{C}$.
- (b) Place two separate test specimens in the water and leave fully immersed for the required duration of test.
- (c) Remove the specimens and allow to cool in air for 1 h, or until the sample reaches ambient temperature.
- (d) Test the specimens for adhesion in accordance with the procedure described in Appendix L.

K5 REPORT

The test results shall be reported as equivalent in appearance to the numbered descriptive standard (Appendix J) for each sample.

A1 |

APPENDIX L
FLEXIBILITY
(Normative)

L1 SCOPE

This Appendix sets out the method for assuring that FBE coating has bending flexibility.

L2 APPARATUS

The following apparatus is required:

- (a) Hydraulic press.
- (b) Bending mandrels of a fixed radius.
- (c) Freezer.
- (d) Micrometer.
- (e) Vernier calliper.
- (f) Coating thickness gauge.

L3 TEST SPECIMENS

Test panels shall be 25 mm × 200 mm × 10 mm thick. Coupons shall be approximately 25 mm × 200 mm × pipe wall thickness, with the 200 mm dimension parallel to the axis of the pipe.

L4 PROCEDURE

The procedure shall be as follows:

- (a) Measure total cross-sectional thickness of each test specimen at its centre. This thickness includes coating, pipe wall thickness and pipe curvature to an accuracy of 0.1 mm.
- (b) Measure coating thickness at centre of test specimen.
- (c) Ensure the test specimen has smooth rounded edges exposing the substrate. Place the test specimen in the freezer, cool below 0°C and hold for at least 1 h.
- (d) Calculate the radius corresponding to $\beta = 3.75^\circ/\text{pipe diameter}$.
- (e) If the calculated radius of the mandrel is not available, use a smaller mandrel, which results in a more severe bend. Use the following equation to calculate the angle of deflection resulting:

$$\beta = (360/\pi) \times C / (2R + C)$$

where

β = angle of deflection, in degrees per pipe diameter length

C = sample thickness, in millimetres (see Figure L1)

R = Radius of mandrel used, in millimetres

- (f) Bend the specimen over the mandrel when surface frost turns to water. Each bend shall be completed in 10 s to 30 s.

- (g) Visually inspect the specimen for cracking and disbonding.

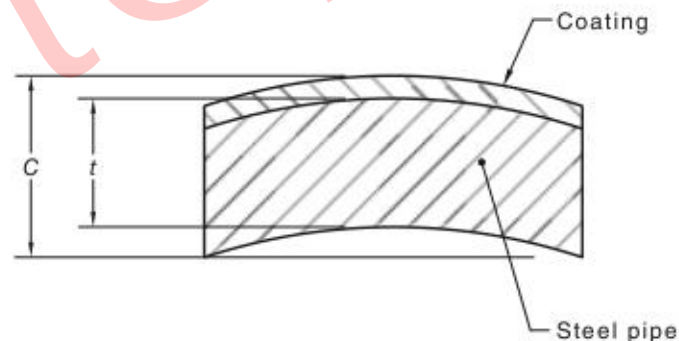
L5 REPORT

The following shall be reported:

- (a) Angle of deflection.
 (b) Cracks and disbonding, if any.

NOTES ON TEST

- 1 The requirement of 3.75° /pipe diameter length is based on common pipe field bending requirements, which allow 1.5° /pipe diameter length for pipe diameters above 273 mm (note that for sizes below 373 mm, bending of 5° /pipe diameter length is allowed). 1.5° /pipe diameter length is a nominal value and actual localized strains will be higher. The requirement of 3.75° /pipe diameter length takes account of this so that the likelihood of failure in the field is remote.
- 2 The flexibility of FBE coating is dependent on temperature and coating thickness. The requirement for flexibility in this test may need to be raised if coated pipe is required to be bent at low temperatures, with thick coating, or at large bend angles. Similarly, if pipe is not to be bent to the extremes of the pipeline codes and a different balance of properties is required, FBE of lesser flexibility may be used.
- 3 It should be recognized that different environmental or service conditions on the coating will necessitate quality assurance requirements that reflect the difference in performance required from the coating. While this Standard endeavours to indicate the variation of required quality with service temperature, it may be necessary for the purchaser to recognize the limitations, if service or environmental conditions are unusually severe or extreme.



LEGEND:
 t = pipe wall thickness
 C = overall thickness

A1 | FIGURE L1 CROSS-SECTION OF PIPE SAMPLE USED IN FLEXIBILITY TEST

APPENDIX M
UNIFORMITY OF HEATING
(Normative)

M1 SCOPE

This Appendix sets out the method for field determination of circumferential temperatures on uncoated girth weld joints of pipes.

M2 APPARATUS

The following apparatus is required:

- (a) Temperature-indicating crayons.
- (b) Production induction heating coil.

M3 PROCEDURE

The procedure shall be as follows:

- (a) Mark the joint at four equally spaced locations around its circumference with three temperature-indicating crayons for the following temperatures:
 - (i) The required application temperature.
 - (ii) 7°C above the required application temperature.
 - (iii) 7°C below the required application temperature.
- (b) Heat the joint to the required application temperature as indicated by the temperature indicator at the top of the pipe.
- (c) Remove the production induction heating coil.
- (d) Observe all temperature-indicating marks to ensure that—
 - (i) all indicating marks from crayons 7°C below the required application temperature have indicated a change;
 - (ii) all indicating marks at the required application temperature have indicated a change; and
 - (iii) all indicating marks 7°C above the required application temperature have not indicated a change.
- (e) If the conditions of Step (d) above are not satisfied, cool the joint, adjust the production induction heating coil, and repeat the test.

M4 REPORT

The following shall be reported:

- (a) The crayon temperature rating.
- (b) Indication of required change at all locations.
- (c) Adjustments made to the induction heating coil.

APPENDIX N
HEAT DECAY PERIOD

(Normative)

N1 SCOPE

This Appendix sets out the method for field determination of the time taken for uncoated steel at the girth weld joint of a pipe to cool from maximum preheat temperature to the minimum application temperature recommendation of the FBE powder manufacturer.

N2 APPARATUS

The following apparatus is required:

- (a) Temperature-indicating crayons.
- (b) Stopwatch.

N3 PROCEDURE

The procedure shall be as follows:

- (a) Mark the joint with temperature-indicating crayon for the maximum temperature.
- (b) Heat the joint until the crayon colour change occurs and start the stopwatch.
- (c) Remove the heat source.
- (d) Frequently mark with the minimum indicator crayon until it no longer changes colour and then stop the watch.
- (e) Record the elapsed time.

N4 REPORT

The elapsed time recorded in Step N3(e) above shall be reported.

APPENDIX O
WATER ABSORPTION OF COATING TEST
(Informative)

O1 SCOPE

This appendix sets out a method for measuring the water absorption by a free film of coating, immersed at 98°C in water.

O2 APPARATUS AND MATERIALS

The following apparatus and materials are required:

- (a) Application equipment (spray or fluidized bed).
- (b) Glass or PTFE substrate.
- (c) Thermostatically controlled water bath (to $\pm 2^{\circ}\text{C}$).
- (d) Oven, with temperature control to $\pm 5^{\circ}\text{C}$.
- (e) Balance, accurate to ± 1 mg.

O3 PROCEDURE

The procedure shall be as follows:

- (a) Produce a fully cured film of coating on a glass or PTFE substrate. The film should be 4 ± 0.5 mm thick, and weigh 500 mg to 1000 mg.
- (b) Dry the film at 105°C to constant mass.
- (c) Weigh the film (m_1).
- (d) Immerse the film in a water bath set at $98 \pm 2^{\circ}\text{C}$, for 24 h.
- (e) Remove the film from the water bath and wipe off surface water.
- (f) Weigh the film (m_2).

O4 CALCULATION

The percentage water absorption (A) is calculated as follows:

$$V = (m_2 - m_1) \times 100 / m_1$$

O5 REPORT

The percentage water absorption (A) to the nearest 0.1% shall be reported.

APPENDIX P
THERMAL STABILITY OF COATING TEST
(Informative)

P1 SCOPE

This Appendix sets out a method for evaluating the thermal stability of coating/steel substrate systems under cycling conditions of—

- (a) dry heat;
- (b) immersion in hot water.

P2 APPARATUS

The following apparatus is required:

- (a) Coated FBE panels, the preparation and application complying with the procedure in Appendix Q.
- (b) Oven, temperature control to $\pm 5^{\circ}\text{C}$.
- (c) Thermostatically controlled water bath (to $\pm 1^{\circ}\text{C}$).
- (d) Apparatus and standards to test adhesion in accordance with Appendix J.
- (e) Apparatus to test impact, in accordance with ASTM G 14.

P3 PROCEDURE**P3.1 Dry heat cycling**

For service to 60°C , the test is not required.

For service 60°C to 110°C , the procedure shall be as follows:

- (a) Place two coated panels in the oven at 100°C for 72 h.
- (b) Remove and leave at ambient temperature for 24 h.
- (c) Repeat Steps (a) and (b) four times, with the heat cycle reduced to 24 h.
- (d) Evaluate coating adhesion and impact resistance according to Appendix J and ASTM G 14, respectively.

P3.2 Immersion in hot water**P3.2.1 Service to 60°C**

The procedure shall be as follows:

- (a) Place two coated panels in the oven at 60°C for 72 h.
- (b) Remove and place in the water bath at 60°C for 24 h.
- (c) Remove and place in the oven at 60°C for 24 h.
- (d) Repeat Steps (a) and (b) four times.
- (e) Evaluate coating adhesion and impact resistance according to Appendix J and ASTM G 14, respectively.

P3.2.2 *Service to 110°C*

The procedure shall be as follows:

- (a) Place two coated panels in the oven at 110°C for 72 h.
- (b) Remove and place in the water bath at 98°C for 24 h.
- (c) Remove and place in the oven at 110°C for 24 h.
- (d) Repeat Steps (a) and (b) four times.
- (e) Evaluate coating adhesion and impact resistance according to Appendix J and ASTM G 14, respectively.

P4 REPORT

The following shall be reported:

- (a) Average adhesion rating.
- (b) Impact resistance of two tests conducted on each of the two panels.

APPENDIX Q
PREPARATION OF A TEST PANEL AND VISUAL INSPECTION

(Normative)

Q1 SCOPE

This Appendix sets out the method for application of FBE powder to coat standard steel test panels.

Q2 APPARATUS AND MATERIALS

The following apparatus and materials are required:

- (a) Steel panels, dimensions 100 × 200 × 6 mm, or 200 × 25 × 10 mm for the bend test.
- (b) Grit blasting booth and G40 steel grit (or pre-blasted panels).
- (c) Epoxy powder.
- (d) Non-contaminating heat source, with temperature control to $\pm 2^{\circ}\text{C}$.
- (e) Contact thermometer, thermocouple, or temperature-indicating crayon, accurate to $\pm 2^{\circ}\text{C}$.
- (f) Fluidized bed and clean, dry air supply; or electrostatic powder spray equipment.

Q3 PROCEDURE

The procedure shall be as follows:

- (a) Using grit blasting, clean the steel panels to at least Class 2½ finish (see AS 1627.4), with a blast profile within the range of 50 μm to 100 μm . The profile shall be measured by use of replication tapes.
- (b) Apply coatings to freshly blasted panels or store preblasted panels in a desiccated atmosphere or uncontaminated technical grade MEK (methyl ethyl ketone).
- (c) Heat the panels to a uniform temperature not greater than 255°C. The tolerance shall be $\pm 5^{\circ}\text{C}$. The heating time shall be not greater than 45 min.
- (d) Apply epoxy powder on all surfaces of the test panels at a uniform film thickness within the range of 400 μm to 500 μm .

Application shall be by means of—

- (i) fluidized bed; or
- (ii) multiple pass electrostatic powder spray.

The time to coat shall not exceed the time for the panel temperature to cool to 220°C, or as specified by the powder supplier.

- (e) Fully cure the coated panels, if necessary, by post-heating. The post-heating time shall not exceed 5 min in the oven at 255°C maximum temperature.

NOTE: Water quenching of fully cured panels is permitted.

Q4 TEST PANEL QUALITY

The coating produced shall form a homogeneous film over the entire surface of the panel, free from holidays, surface craters, lumps and pinholes.

Q5 REPORT

The following shall be reported:

- (a) Surface profile.
- (b) Application temperature.
- (c) Film thickness.
- (d) Further application and post cure conditioning.

Botop Steel

APPENDIX R PREPARATION OF TEST PANELS FOR REPAIR MATERIALS

(Normative)

R1 SCOPE

This Appendix sets out a method for surface preparation and the application of repair materials for the testing of such materials.

R2 APPARATUS AND MATERIALS

The following apparatus and materials are required:

- (a) Pipe coupons 100 mm × 100 mm × wall thickness previously coated with the FBE powder to be used or being used for coating operations.
- (b) Filing equipment as used for surface preparation of coating repairs.
- (c) Repair materials.
- (d) Mixing equipment—clean sheets of material and spatulas.

R3 PROCEDURE

The procedure shall be as follows:

- (a) Feather the edges of the parent coating and abrade, by filing a section approximately 10 mm to 20 mm wide, adjacent to the area to be repaired. Remove all contaminants from the surface, prior to application of repair materials.
- (b) Carry out mixing in accordance with the manufacturer's specifications. All pre-mixed repair material shall be used within 5 min of the commencement of mixing. Excess repair material shall be discarded after expiration of the 5 min period.
- (c) Spread the repair material evenly to a thickness between 1000 µm and 1500 µm with a clean spatula over the entire area to be repaired, together with the roughened zone of parent coating around the repair area.
- (d) Cure the repair material to a hard surface prior to handling. Tests on the repair materials may commence within 6 h if curing is accomplished at temperatures between 25°C and 30°C.

R4 TEST PANEL QUALITY

The repair material shall form a homogeneous film over the entire surface of the area to be repaired and the roughened region around it. The thickness of the repaired material shall be between 1000 µm and 1500 µm. The surface shall be free of holidays, surface craters and pinholes.

R5 REPORT

The following shall be reported:

- (a) The surface profile of the bare metal.
- (b) The repair materials used, including batch number and shelf life expiry date.
- (c) Film thickness, measured at three locations across the repair area.
- (d) Panel surface temperature immediately prior to application of repair material.

- (e) Curing temperature and time.
- (f) Name of person preparing the test panel.
Date and time of preparation of test panel.

Botop Steel

APPENDIX S
INTERFACIAL CONTAMINATION

(Normative)

S1 SCOPE

This Appendix sets out the method for identifying the amount of visible contamination on the interface of FBE powder coating.

S2 APPARATUS

The following apparatus is required:

- (a) Microscope.
- (b) Tweezers.
- (c) Four-point bend device.
- (d) Freezer.
- (e) Sample Panel 200 mm × 25 mm × wall thickness.

S3 PROCEDURE

The procedure shall be as follows:

- (a) Take the FBE coated sample panel and place in the freezer for 1 h.
- (b) Remove the frozen sample from the freezer, place the sample in the four-point bend device. Commence bending before the sample has a chance to defrost.
- (c) Where the sample has cracked use the tweezers to remove a representative chip.
- (d) Using a reasonable light source examine the interface of the coating chip at 30 × magnification.
- (e) Determine the percentage of contamination according to the pictorial scale shown in Figure S1.

S4 REPORT

The following shall be reported:

- (a) Sample identification number and date of testing.
- (b) The interfacial contamination percentage.

A1

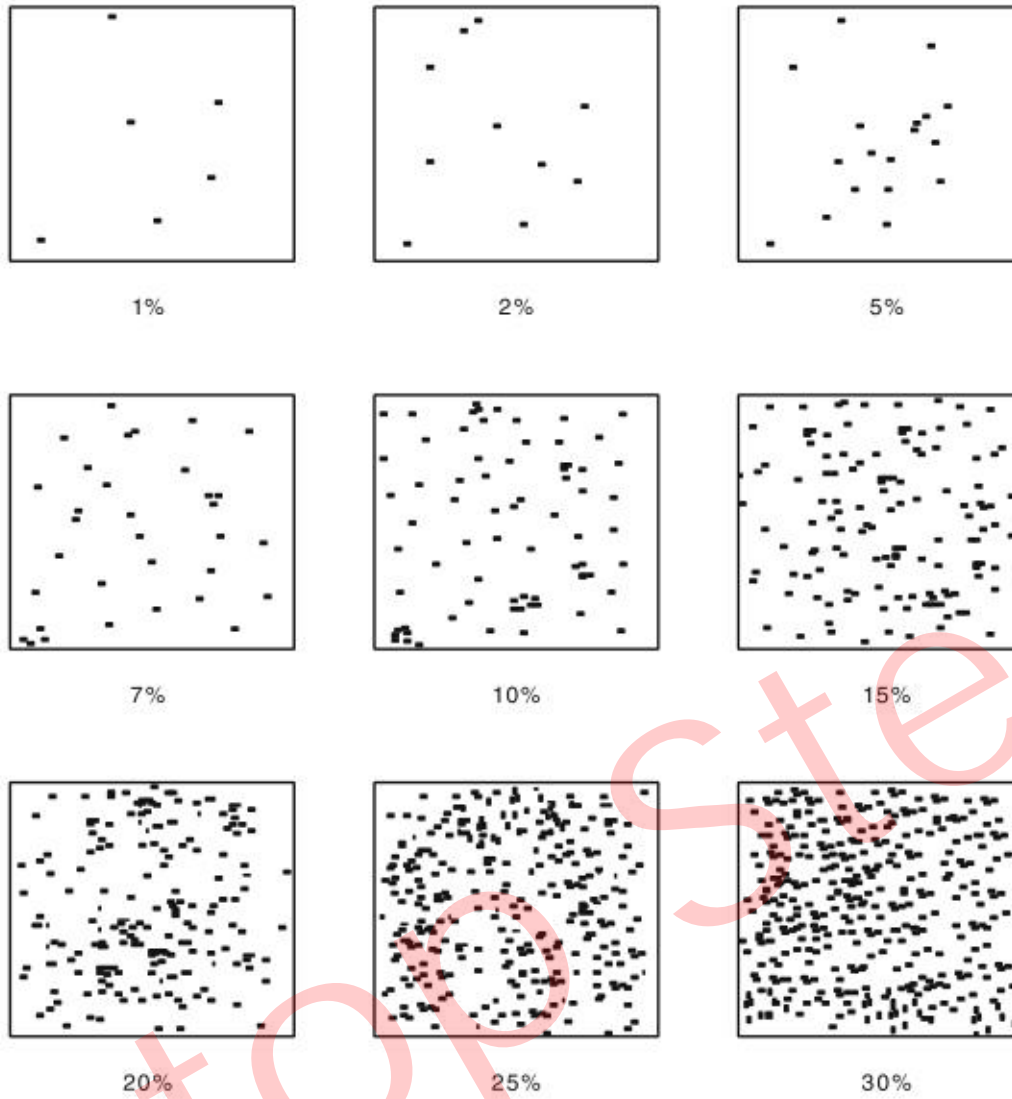


FIGURE S1 PERCENTAGE OF VISIBLE CONTAMINATION

AMENDMENT CONTROL SHEET

AS/NZS 3862:2002

Amendment No. 1 (2017)

REVISED TEXT

SUMMARY: This Amendment applies to Designation throughout, Preface, Clauses 4.1, 5.3.3 and 6.2 and Appendices B, C, K, L and S.

Published on 20 September 2017.

Botop Steel

NOTES

Botop Steel

NOTES

Botop Steel

NOTES

Botop Steel

NOTES

Botop Steel

Standards Australia

Standards Australia develops Australian Standards® and other documents of public benefit and national interest. These Standards are developed through an open process of consultation and consensus, in which all interested parties are invited to participate. Through a Memorandum of Understanding with the Commonwealth Government, Standards Australia is recognized as Australia's peak non-government national standards body. Standards Australia also supports excellence in design and innovation through the Australian Design Awards.

For further information visit www.standards.org.au

Australian Standards®

Committees of experts from industry, governments, consumers and other relevant sectors prepare Australian Standards. The requirements or recommendations contained in published Standards are a consensus of the views of representative interests and also take account of comments received from other sources. They reflect the latest scientific and industry experience. Australian Standards are kept under continuous review after publication and are updated regularly to take account of changing technology.

International Involvement

Standards Australia is responsible for ensuring the Australian viewpoint is considered in the formulation of International Standards and that the latest international experience is incorporated in national Standards. This role is vital in assisting local industry to compete in international markets. Standards Australia represents Australia at both the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

Sales and Distribution

Australian Standards®, Handbooks and other documents developed by Standards Australia are printed and distributed under licence by SAI Global Limited.

Botop Steel

For information regarding the development of Standards contact:

Standards Australia Limited
GPO Box 476
Sydney NSW 2001
Phone: 02 9237 6000
Email: mail@standards.org.au
Internet: www.standards.org.au

For information regarding the sale and distribution of Standards contact:

SAI Global Limited
Phone: 13 12 42
Email: sales@saiglobal.com



ISBN 0 7337 4089 8

<https://www.botopsteelpipe.com>

This page has been left intentionally blank.

Botop Steel