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BRITISH STANDARD : AEROSPACE SERIES**METHODS FOR**

MEASURING COATING THICKNESS BY NON-DESTRUCTIVE TESTING

CONTENTS

	Page
Foreword	1
METHODS	
1. Scope	2
2. Terms and definitions	2
3. Classification of coatings and substrates	2
4. Underlying principles and applications of methods of measurement	2
5. General limitations	3
6. Safety precautions	4
7. Approvals	4
8. Testing procedures	4
9. Calibration standards	5
APPENDIX	
A. Applicable methods of non-destructive testing	8

FOREWORD

This British Standard, prepared under the authority of the Aerospace Industry Standards Committee, is one of a series for the non-destructive testing of aerospace materials, components and structures. Other standards in this series cover radiographic, magnetic particle, etch and penetrant inspection methods.

For the purposes of this standard, combinations of coating and substrate are classified in association with the available methods of measuring coating thickness, and the basic principles of the methods of measurement by means of non-destructive testing techniques are described together with the procedures for their application. The standard is not intended to be used as a level of acceptance or rejection as both of these aspects should be covered in an appropriate application standard or be agreed between the interested parties.

It is emphasized that non-destructive testing

methods, being complementary to one another, should always be considered in relationship to testing as a whole. When non-destructive testing methods or techniques are specified for measuring coating thickness, the most suitable method and amount of inspection compatible with the ultimate application for the product should be employed. Bearing in mind that the characteristics of individual types of equipment can vary, it is also essential for the operator to be fully conversant with the equipment used.

This standard makes reference to the following:

- BS 204. Glossary of terms used in telecommunication (including radio) and electronics.
- BS 205. Glossary of terms used in electrical engineering.
- BS 3683. Glossary of terms used in non-destructive testing.
- BS 4758. Electroplated coatings of nickel for engineering purposes.

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METHODS

1. SCOPE

1.1 This British Standard is concerned with methods for the measurement by non-destructive means of the thickness of single coatings, such as paint or plating on metallic substrates, and applies both to the inspection of components during their manufacturing stages and also when subsequently in service.

1.2 While one of the methods described can be applied to the estimation of the thickness of anodic coatings on aluminium alloys, the general measurement of the depth of conversion coatings, of corrosion, of case hardening and of decarburization is not considered.

1.3 The standard does not specify checks on the physical condition of the coatings, e.g., on their surface texture, continuity or adhesion, and it should be borne in mind that variation in these factors may affect the accuracy of thickness measurement.

2. TERMS AND DEFINITIONS

2.1 For the purposes of this British Standard, the terms and definitions given in BS 3683 apply. Attention is also drawn to BS 204 and BS 205.

2.2 Unless otherwise stated, the terms 'conducting' and 'magnetic' refer specifically to electrically conducting and magnetic electrically conducting properties of materials respectively.

2.3 In addition, 'by agreement' means that specific agreement has been reached between the purchaser and the supplier, and any inspecting authority concerned.

3. CLASSIFICATION OF COATINGS AND SUBSTRATES

3.1 The applicability of the available methods of measurement by means of non-destructive testing depends on the particular combination of coating and substrate under consideration. These combinations, together with examples given in parentheses, include the following:

(1) Non-conducting coatings on non-magnetic conducting substrates. (Paint or plastics on aluminium alloys.)

(2) Non-conducting coatings on magnetic substrates. (Paint or plastics on steel.)

(3) Non-magnetic conducting coatings on non-magnetic conducting substrates. (Chromium on brass.)

(4) Non-magnetic coatings on non-conducting substrates. (Chromium on plastics.)

(5) Non-magnetic conducting coatings on magnetic substrates. (Chromium on steel.)

(6) Magnetic coatings on non-magnetic conducting substrates. (Nickel on stainless steel or brass.)

(7) Magnetic coatings on magnetic substrates. (Nickel on steel.)

(8) Magnetic coatings on non-conducting substrates. (Nickel on plastics.)

3.2 Attention is drawn to Appendix A in which a convenient means of identifying the methods which can be applied to any particular coating-substrate combination has been tabulated. Although a number of methods are listed for each general coating-substrate combination, it should not be inferred that each method will necessarily be suitable for every material combination eligible for inclusion in that particular coating-substrate group.

4. UNDERLYING PRINCIPLES AND APPLICATIONS OF METHODS OF MEASUREMENT

4.1 Eddy current method

4.1.1 The factors which govern the effective reactance and resistance of the test coil in eddy current inspection include:

(1) the size and shape of the test coil,

(2) the size and shape of the workpiece,

(3) the frequency of the alternating current in the test coil,

(4) the electrical conductivity, magnetic permeability and homogeneity of the workpiece,

(5) temperature,

(6) the coupling or separation between the coil and the surface of the workpiece.

4.1.2 If the influence of the other factors remains sensibly constant, the last mentioned effect can be used to measure the thickness of non-conducting coatings on non-magnetic or magnetic substrates. If the thicknesses and relative electrical conductivities of the coating and substrate are suitable the method may also be applied to the measurement of non-magnetic conducting coatings on a non-magnetic conducting base.

4.2 Magnetic attraction method

4.2.1 In the magnetic attraction method, one pole of a permanent magnet is placed in contact with non-magnetic coatings on magnetic substrates. The normally applied force required to pull off the magnet becomes a measure of the coating thickness.

4.2.2 Its applications include the measurement of paint and plating on steel and also, of thin magnetic coatings on a non-metallic backing.

4.3 Magnetic reluctance method

4.3.1 By the magnetic reluctance method, a non-magnetic coating on a magnetic substrate becomes a gap in a magnetic circuit and its thickness is estimated in terms of the reluctance which it thus introduces. The magnetic circuit may be achieved by either a permanent magnet or an electro-magnet.

4.3.2 In one variant, the flux associated with a permanent magnet passes partly through the workpiece by way of the coating and partly through an auxiliary flux path shunting the workpiece. The latter includes a simple form of fluxmeter which gives readings which may be related to the varying reluctance of coatings of different thicknesses, including the measurement of thin magnetic coatings on non-magnetic materials.

4.4 Radiation back scatter method

4.4.1 In applying the radiation back scatter method, radiation (beta-particles, x-rays, bremsstrahlung, etc.) from a suitable source is directed at the coating under test. The indications of a suitably disposed radiation detector become a measure of the back scatter either arising from the coating or arising from the substrate and attenuated by the coating and, hence, of its thickness.

4.4.2 The principle may be used to measure the thickness of coatings on substrates when the thicknesses of both fall between certain limits and when there is a suitable difference between the atomic numbers of the materials concerned.

4.5 Thermo-electric method

4.5.1 In one application of the thermo-electric method, a metallic probe maintained at a controlled, above ambient temperature is placed in contact with the coating to be measured. The resulting rise in temperature at the junction between the coating and the substrate depends on the thickness of the coating and is sensed in terms of the electrical potential established between the dissimilar metals, i.e. Seebeck effect.

4.5.2 This method has found particular application in the measurement of magnetic coatings on a magnetic substrate.

5. GENERAL LIMITATIONS

5.1 Characteristics of methods

5.1.1 Non-destructive methods of coating thickness measurement are applicable only to materials which possess the particular property or properties on which such methods are based. Furthermore, if both the coating and the substrate exhibit these properties, they must of necessity do so to a consistently different degree.

5.1.2 For example, the eddy current method is effective only when there is sufficient difference in conductivity between the coating and substrate, and the magnetic attraction and reluctance methods only when there is sufficient difference in magnetic properties between the coating and substrate.

5.2 Variations in the properties underlying the test

5.2.1 It should not be assumed that nominally similar coatings and substrates have identical properties. Electrolytically applied coatings, for

instance, may vary in density, homogeneity and metallurgical condition according to the method of production. Similarly, the properties of substrates depend on composition and heat treatment. For this reason, calibration standards are necessary, see 9.

5.2.2 Some specimens may exhibit sufficient anisotropy to affect the readings given by equipment which makes simultaneous contact at two positions. In this event, it may be advisable to standardize the direction of the probe or to take several readings with the probe straddling the test area in various directions and to average the indications.

5.3 Thickness of coatings and substrates

5.3.1 There are usually limitations connected with measuring the thickness of coatings and substrates, for example, the tendency for the uncertainty of measurement at the lower end of equipment scales to be approximately constant and to be a high percentage of the actual thickness to be estimated.

5.3.2 The discrimination obtainable in most instances also decreases if the thickness of the coatings and substrates are respectively greater or less than certain limiting values. As an example, the beta ray back scatter method requires that the thickness of the coating should be less than the saturation value for the coating material and the thickness of the substrate should be greater than the saturation value for the substrate material.

5.3.3 When such effects are due to the substrate, it may be possible to improve the accuracy of determination without re-calibration by temporarily building up the thickness with similar material placed in contact with the uncoated side.

5.3.4 In some cases, the thickness of the substrate may be unimportant as in the measurement of a nickel coating on a non-magnetic substrate.

5.4 Geometrical effects

5.4.1 In addition to the possibility of the coating thickness itself being non-uniform, all the methods under consideration tend to have limitations related to geometrical variations in the component under test. Edge effects, proximity to drilled holes, and changes of contour or section can influence the accuracy of measurement obtained by all methods unless calibration specimens representative of the test conditions are used.

5.4.2 Variations in the surface condition of the workpiece can also reduce the accuracy of measurement. Precautions should be taken to repeat readings at nearby positions and to ensure that calibration specimens have a surface texture similar to the component under test.

5.4.3 Surface curvature affects measurement of coating thickness particularly when the sensing device has been designed and calibrated for use