


AWS C2.16/C2.16M:2002
An American National Standard



Guide for Thermal-Spray Operator Qualification



American Welding Society



Key Words—Thermal-spray operator qualification, knowledge test, skill test, flame spraying, spray and fusing, arc spraying, plasma spraying, HVOF spraying

AWS C2.16/C2.16M:2002
An American National Standard

Approved by
American National Standards Institute
July 23, 2002

Guide for Thermal-Spray Operator Qualification

Supersedes ANSI/AWS C2.16-92

Prepared by
AWS C2 Committee on Thermal Spraying

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This guide contains recommendations for thermal-spray operator qualification based on knowledge and skill testing. Twelve individual thermal-spray operator qualification tests (TSOQT) are included for engineering and corrosion control applications: one each for job knowledge, high velocity oxygen fuel (HVOF) spraying and flame spray-fusing, two for arc spraying, and three each for flame spraying and air-plasma spraying.



American Welding Society

550 N.W. LeJeune Road, Miami, Florida 33126

Table of Contents

	Page No.
<i>Personnel</i>	iii
<i>Foreword</i>	v
<i>List of Tables</i>	ix
<i>List of Figures</i>	ix
<i>List of TSOQT Tables</i>	ix
<i>List of TSOQT Figures</i>	ix
1. Scope	1
1.1 Exclusion	1
1.2 Safety Considerations	1
1.3 Units of Measure and Rounding-Off Procedures	1
1.4 Referenced Documents	1
2. Abbreviations and Definitions	2
3. Provision of Testing	3
3.1 Thermal-Spray Operator Qualification Test (TSOQT)	3
3.2 Thermal-Spray Employer Test Shop or Facility	3
3.3 Test Supervisor	3
4. Qualification Requirements	3
4.1 Qualification Test	3
4.2 Test Supervisor	3
4.3 Test Shop or Facility	4
5. Classification Categories and Application Method	4
6. Essential Factors for Qualification Testing	4
6.1 Thermal-Spray Equipment Operation	5
6.2 Masking Procedure	5
6.3 Surface Preparation	5
6.4 Application Hardware	5
7. Range of Qualification	5
7.1 General	5
7.2 Application Method	5
7.3 Feedstock Composition Types	5
7.4 Qualification Scope	5
7.5 Supervision	5
7.6 Shapes and Dimensions of Test Pieces and Specimens	5
7.7 Test Methods and Sample Testing	5
7.8 Acceptance Requirements for Test Pieces	5
8. Examination and Testing	7
8.1 Job Knowledge Test	7
8.2 Skill (Practical Ability) Test	7
8.3 Retests	7

	Page No.
9. Documentation of Thermal-Spray Operator Performance Qualification	7
9.1 Period of Validity for Qualification	7
9.2 Prolongation	8
9.3 Scheduling	8
9.4 Thermal-Spray Operators with Expired or Canceled Qualification Status.....	8
9.5 Requalification	8
9.6 Interruption Periods in Thermal-Spray Work	8
10. Identification/Qualification Documents	8
11. Maintenance of Qualification.....	8
12. Renewal of Qualification.....	8
13. Revocation.....	8
14. Reinstatement.....	8
TSOQT No. JK-1 Job Knowledge for the Thermal-Spray Operator Qualification Tests	9
TSOQT No. APS-1 Air Plasma Spraying Metals and Alloy Powders for Engineering Purposes.....	13
TSOQT No. APS 2 Air Plasma Spraying Ceramics for Engineering Purposes	17
TSOQT No. APS-3 Air Plasma Spraying Metal Based Carbides for Engineering Purposes.....	21
TSOQT No. AS-1 Arc Spraying Zinc, Aluminum, and Their Alloys and Composites for Corrosion Protection of Steel	25
TSOQT No. AS-2 Arc Spraying Metal Alloys for Engineering Purposes	31
TSOQT No. FS-1 Flame Spraying Zinc, Aluminum, and their Alloys and Composites for Corrosion Protection of Steel	35
TSOQT No. FS-2 Flame Spraying Metal and Alloy Wires and Ceramic Rods for Engineering Purposes.....	41
TSOQT No. FS-3 Flame Spraying Metal and Alloy Powders for Engineering Purposes	45
TSOQT No. FS-4 Flame Spraying Self-Fluxing Alloys for Engineering Purposes	49
TSOQT No. A&FS-1 Arc and Flame Spraying Zinc Anodes on Reinforced Concrete	53
TSOQT No. HVOF-1 High Velocity Oxygen Fuel (HVOF) for Engineering Purposes: Metals and Alloys.....	59
<i>Nonmandatory Annexes</i>	<i>63</i>
<i>Annex A—Safety Information for Thermal Spraying.....</i>	<i>63</i>
<i>Annex B—Proposed Procedure for Calibration of Portable Test Instruments to the ASTM C 633 Test Method.....</i>	<i>71</i>
<i>Annex C—Guidelines for Preparation of Technical Inquiries for AWS Technical Committees</i>	<i>73</i>
<i>List of AWS Documents on Thermal Spraying.....</i>	<i>75</i>

List of Tables

Table		Page No.
1	Thermal-Spray Qualification Process Classifications	4
2	Thermal-Spray Application Classification by Gun Movement and Workpiece Control	4
3	Feedstock Class for TSOQT	6
A1	Graphic Symbols	64
A2	Noise Levels Produced by Spray Guns	68
A3	Recommended Shade Numbers for Helmets and Goggles	68

List of Figures

Figure		Page No.
B1	Calibration Fixture	71

List of TSOQT Tables

TSOQT No.	Table	Page No.
APS-1	1 Thermal Spray Process and Spray Parameters for Air Plasma Spraying Metals and Alloys for Engineering Purposes	16
APS-2	1 Thermal Spray Process and Spray Parameters for Air Plasma Spraying Ceramics for Engineering Purposes	20
APS-3	1 Thermal Spray Process and Spray Parameters for Air Plasma Spraying Metal Based Carbides for Engineering Purposes	24
AS-1	1 Thermal Spray Process and Spray Parameters for Arc Wire Spraying for Corrosion Protection	28
	2 Tensile-Bond Qualification Requirements for Thermal-Spray Operators	29
AS-2	1 Thermal Spray Process and Spray Parameters for Arc Spraying Metal Alloys for Engineering Purposes	34
FS-1	1 Thermal Spray Process and Spray Parameters for Flame Wire Spraying Zinc, Aluminum, and Their Alloys and Composites for Corrosion Protection of Steel	38
	2 Tensile-Bond Qualification Requirements for Thermal-Spray Operators	39
FS-2	1 Thermal Spray Process and Spray Parameters for Flame Wire Spraying Metal and Alloy Wires and Ceramic Rods for Engineering Purposes	44
FS-3	1 Thermal Spray Process and Spray Parameters for Air Plasma Spraying Metals and Alloys for Engineering Purposes	48
FS-4	1 Thermal Spray Process and Spray Parameters for Flame Spraying Self-Fluxing Alloys	52
A&FS-1	1 Thermal Spray Process and Spray Parameters for Arc Spraying Zinc Anodes on Concrete	57
	2 Thermal Spray Process and Spray Parameters for Flame Wire Spraying Zinc Anodes on Concrete	58
HVOF-1	1 Thermal Spray Process and Spray Parameters for HVOF Spraying Powders for Engineering Purposes	62

List of TSOQT Figures

TSOQT No.	Figure	Page No.
APS-1	1 Test Piece for Air Plasma Spraying Metal and Alloys	15
APS-2	1 Test Piece for Air Plasma Spraying Ceramics	19
APS-3	1 Test Piece for Air Plasma Spraying Metal Based Carbides	23
AS-1	1 Test Piece for Arc-Sprayed Aluminum and Zinc Coatings	27
	2 Thermal-Spray Coating Bend Test: Pass/Fail Example	27
AS-2	1 Test Piece for Flame- and Arc-Sprayed Metal Alloy Coatings	33
FS-1	1 Test Piece for Flame- and Arc-Sprayed Aluminum and Zinc Coatings	37
	2 Thermal-Spray Coating Bend Test: Pass/Fail Example	27
FS-2	1 Test Piece for Flame- and Arc-Sprayed Metal Alloy Coatings	43
FS-3	1 Test Piece for Flame- and Arc-Sprayed Metal Alloy Coatings	47
FS-4	1 Test Piece for Flame-Sprayed Self-Fluxing Alloy Coating	51
A&FS-1	1 Thermal-Spray Coating Bend Test: Pass/Fail Examples	55
	2 Thermal-Spray Operator Certificate for AWS A&FS-1:Manual	56
HVOF-1	1 Test Piece for HVOF- and Arc-Sprayed Metal Alloy Coatings	61

Guide for Thermal-Spray Operator Qualification

1. Scope

This guide recommends the knowledge and skill requirements for thermal-spray operator qualification.

These recommendations include:

- (1) Rules for thermal-spray operator knowledge
- (2) Performance qualifications
- (3) Specific Thermal-Spray Operator Qualification Tests (TSOQT) for flame, arc, plasma, and high velocity oxygen fuel (HVOF) spray methods.

The term qualified thermal-spray operator is used synonymously with thermal-spray technician.

1.1 Exclusion. AWS C2.16/C2.16M does not supersede an employer or contractor from continuing to qualify thermal-spray operators in accordance with the following AWS and other standards and references such as:

- (1) MIL-STD-1687, *Thermal Spray Processes for Naval Ship Machinery Applications*.
- (2) MIL-STD-2138, *Metal Sprayed Coatings for Corrosion Protection Aboard Naval Ships* (Metric).
- (3) Various original equipment manufacturer's (OEM) or after-market repair, thermal-spray process, and spray parameter specifications.
- (4) Material Safety Data Sheets (MSDSs) for abrasive blasting and thermal-spray feedstock materials.
- (5) ISO 14917, *Thermal Spraying—Terminology, Classification*.
- (6) ISO 14918, *Thermal Spraying—Approval Testing of Thermal Sprayers*.

Employers of thermal-spray operators may impose supplementary requirements to this guide.

1.2 Safety Considerations. Thermal-spray operators must have the basic knowledge and skills to include: safe assembly, setting up, operating, and closing down procedures of equipment; personal protection; fire hazards; dust explosions; electrical hazard; flash backs; leak detection; ultraviolet radiation; and noise. Annex A summarizes safety information for thermal spraying.

1.3 Units of Measure and Rounding-Off Procedures.

This specification makes use of both U.S. Customary Units and the International System of Units [SI]. The measurements are not exact equivalents; therefore each system must be used independently of the other without combining in any way. The specification with the designation C2.16 uses U.S. Customary Units. The specification C2.16M uses SI Units. The latter are shown in appropriate columns in tables or within brackets [] when used in the text.

For the purposes of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting values in accordance with the rounding-off method given in ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

1.4 Referenced Documents

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard referred to applies.

- (1) Thermal Spraying, Chapter 28, *AWS Welding Handbook*, Vol. 2, 1991.¹
- (2) *AWS Thermal Spraying, Practice, Theory, and Applications*, 1985.
- (3) AWS C2.18, *Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and Their Alloys and Composites*.
- (4) AWS C2.20-0X, *Specification for Zinc Thermal-Spray Coatings for Reinforced Concrete*, in preparation.

1. Available from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5776.