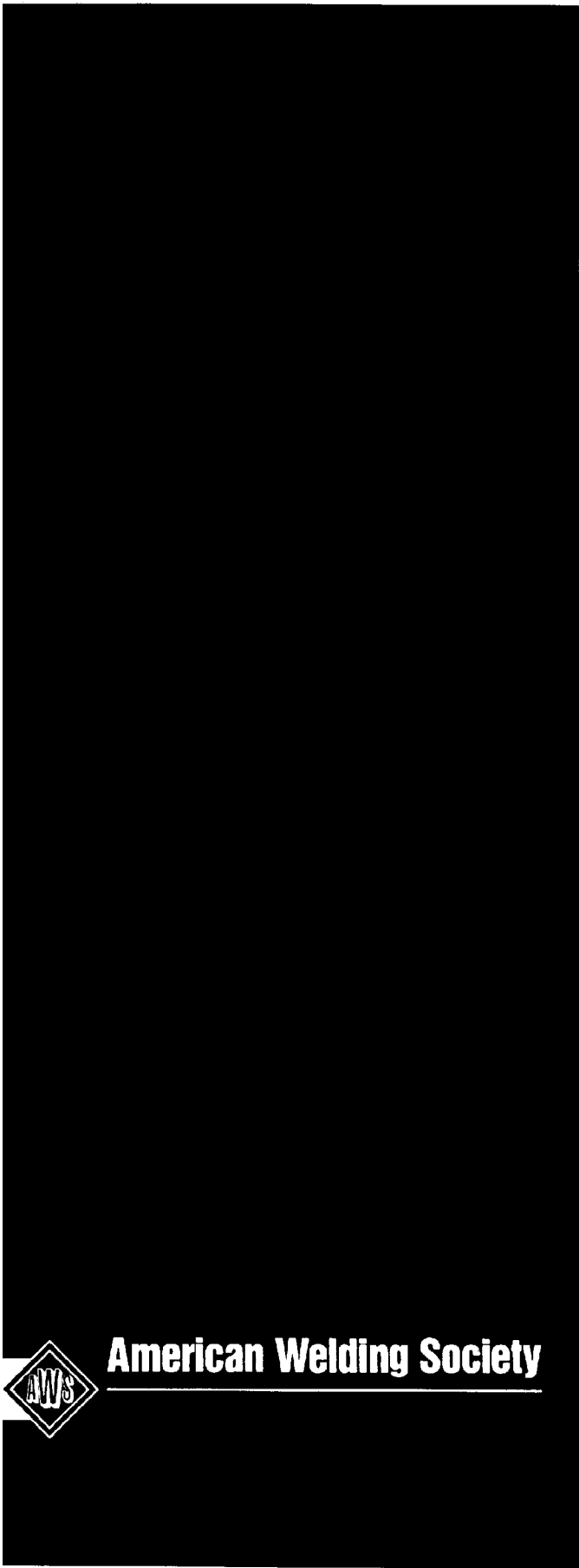


ANSI/AWS A5.32/A5.32M-97
An American National Standard



Specification for Welding Shielding Gases



American Welding Society

Key Words— Argon, carbon dioxide, helium,
hydrogen, nitrogen, oxygen,
shielding gases, welding gases

ANSI/AWS A5.32/A5.32M-97
An American National Standard

Approved by
American National Standards Institute
December 8, 1997

Specification for Welding Shielding Gases

Prepared by
AWS Committee on Filler Metals

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This specification for welding shielding gases specifies minimum requirements for the composition and purity of the most popular single-component shielding gases. Classification designators for both single and multicomponent gases are introduced. Other topics include testing procedures, package marking, and general application guidelines.

This specification makes use of both U.S. Customary Units and the International System of Units (SI). Since these are not equivalent, each system must be used independently of the other.



American Welding Society

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Foreword

(This Foreword is not a part of ANSI/AWS A5.32/A5.32M-97, *Specification for Welding Shielding Gases*, but is included for information purposes only.)

This is a new issue of a specification that has been discussed and drafted many times over the last ten years. Thanks to the persevering efforts of Chair Nils Larson and the rest of the Subcommittee on Shielding Gases, the new ANSI/AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*, is now a reality. The simplicity of its classification system is readily apparent. The requirements are clear and concise and reflect the safest and most economical product for the application.

This document 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 values in any way. In selecting rational metric units, ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry*, is used where suitable. Tables and figures make use of both U.S. Customary and SI units, which with the application of the specified tolerances provide for interchangeability of products in both the U.S. Customary and SI Units.

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society. A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

This is the first publication of this document.

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Specification for Welding Shielding Gases

1. Scope

This specification prescribes requirements for the classification of shielding gases. Gases may be supplied in either gaseous or liquid form, but when used in welding, the shielding is always in the gaseous form. Gas shielded arc welding processes include, but are not limited to: manual, semiautomatic, mechanized, and automatic gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), electrogas welding (EGW), and plasma arc welding (PAW).

Part A *General Requirements*

2. Normative References

2.1 ASTM Standards¹

E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

E260, *Standard Practice for Packed Column Gas Chromatography*

2.2 CGA Publications²

G-4.3, *Commodity Specification for Oxygen*

G-5.3, *Commodity Specification for Hydrogen*

G-6.2, *Commodity Specification for Carbon Dioxide*

G-9.1, *Commodity Specification for Helium*

G-10.1, *Commodity Specification for Nitrogen*

G-11.1, *Commodity Specification for Argon*

P-15, *Filling of Industrial and Medical Nonflammable Compressed Gas Cylinders*

3. Classification

3.1 The shielding gases covered by the A5.32/A5.32M specification are classified using a system that is independent of U.S. Customary Units and the International System of Units (SI). Classification is according to chemical composition of the shielding gas as specified in 13.1.

3.2 Gases classified under one classification shall not be classified under any other classification in this specification. Individual gases shall meet or exceed the requirements of Table 1.

3.3 The gases classified under this specification are intended for use with the gas shielded arc welding processes listed in the Scope. This does not prohibit their use with any other process for which they are found suitable.

4. Acceptance

Acceptance³ of the gases by the user shall be in accordance with the tests and requirements of Parts B and C of this specification.

3. See Section A3 (in the Annex) for more information.

1. ASTM standards can be obtained from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

2. CGA publications can be obtained from Compressed Gas Association, Inc., 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202-4102.

Table 1
Gas Type, Purity, and Dew Point Requirements for Shielding Gas Components

Gas	AWS Classification	Product State	Minimum Purity (%)	Maximum Moisture ^a (ppm)	Dew Point Maximum Moisture at 1 Atmosphere		CGA Class
					°F	°C	
Argon	SG-A	Gas	99.997	10.5	-76	-60	Type I G-11.1 Grade C
		Liquid	99.997	10.5	-76	-60	Type II G-11.1 Grade C
Carbon Dioxide	SG-C	Gas	99.8	32	-60	-51	G-6.2 Grade H
		Liquid	99.8	32	-60	-51	G-6.2 Grade H
Helium	SG-He	Gas	99.995	15	-71	-57	Type I G-9.1 Grade L
		Liquid	99.995 ^b	15	-71	-57	Type II G-9.1 Grade L
Hydrogen	SG-H	Gas	99.95	32	-60	-51	Type I G-5.3 Grade B
		Liquid	99.995 ^c	32	-60	-51	Type II G-5.3 Grade A
Nitrogen	SG-N	Gas	99.9	32	-60	-51	Type I G-10.1 Grade F
		Liquid	99.998	4	-90	-68	Type II G-10.1 Grade L
Oxygen	SG-O	Gas	99.5	Not Applicable	-54	-48	Type I G-4.3 Grade B
		Liquid	99.5	Not Applicable	-82	-63	Type II G-4.3 Grade B

Notes:

a. Moisture specifications are guaranteed at full cylinder pressure, at which the cylinder is analyzed.

b. Including neon.

c. Including helium.

5. Certification

By affixing the AWS specification and classification designations on the packaging enclosing the product, the supplier (manufacturer) certifies that the product meets all of the requirements of the specification.⁴

6. Units of Measure and Rounding-Off Procedure

6.1 This specification uses U.S. Customary Units and the SI Units. The measurements are not exact equivalents; therefore each system must be used independently of the other without combining values in any way. The specification with the designation of A5.32 uses the U.S. Customary Units. The specification with the designation of A5.32M uses SI Units. The latter are shown in appropriate columns in tables and in figures, and within brackets [] when used in the text.

⁴ See Section A4 (in the Annex) for further information concerning certification and the testing called for to meet this requirement.

6.2 For the purpose of determining conformance with this specification, values shall be rounded to the nearest unit in accordance with the rounding-off method given in ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

Part B **Tests, Procedures, and Requirements**

7. Summary of Tests

Compositional analysis of the shielding gas is the only test required for classification of a product under this specification. Tests required for each single gas are specified in Table 2. The purpose of these tests is to determine the purity and dew point of the shielding gas.

8. Retest

If any gas fails to meet its requirements, that test shall be repeated twice. The results of both retests shall meet the requirement of this specification.

Table 2
Tests Required for Classification

	Gas Purity	Dew Point	Mixture Composition
Single gas	Req.	Req.	Not Applicable
Multicomponent gas	Req. ^a	Req. ^b	Req. ^c
Special gas mixture ^d	Req.	Req.	Not Required

Notes:

- Each gas of a multicomponent mixture shall be tested for and meet the purity requirements of that specific gas (see Section 9 and Table 1).
- The multicomponent gas mixture shall meet the dew point requirement not greater than the highest dewpoint of the individual gases in the mixture (see Section 10 and Table 1).
- Individually filled cylinders or one cylinder from each filling manifold group, shall be tested for and meet the requirements of Part B, Tests, Procedures, and Requirements for the mixture composition.
- These gases are classified as SG-B-G.

If the results of one or both retests fail to meet the requirement, the gas being tested shall be considered as not meeting the requirements of this specification for that classification.

In the event that appropriate procedures were not followed in preparing the test sample(s) or in conducting the tests, the test shall be considered invalid, without regard to whether the test was actually completed, or whether test results met or failed to meet the requirement. In this case, the requirement for two retests of the gas sample does not apply.

9. Chemical Analysis

Samples of gas(es) for chemical analysis shall be drawn from an individual cylinder, vessel or from the gas outlet source. The sample shall be analyzed by acceptable methods. Results of chemical analysis of a specific gas(es) shall comply with the requirements of Table 1 for the gas being analyzed. The referee method for chemical analysis of gases shall be ASTM E 260, *Standard Practice for Packed Column Gas Chromatography*. When mixed gases are being analyzed, the volumetric percentage of minor components shall be within ± 10 percent relative to the nominal percentage of the minor component of the classification. See 13.1 and 13.3 for examples.

10. Dew Point Determination

Sample gases for dew point analysis shall be drawn from the individual cylinder, vessel, or gas outlet source. Any standard dew point measurement method may be used. Dew point may be expressed in °F at one atmo-

sphere pressure (14.7 psia), [°C at 760 mm of mercury], or in ppm. The Dew Point Conversion Chart, see Table 3, may be used to convert dew point measurements to or from °F, °C, or ppm. Results of the dew point test shall meet, or exceed, the requirements of Table 1 for the gases being analyzed.

Part C

Manufacture, Packaging, and Identification

11. Method of Manufacture

Shielding gases classified according to this specification may be manufactured by any method that will produce gas or gas mixtures that meet the requirements of this specification.

11.1 Cylinder Residual Gases. All gas containers shall either be evacuated or, if not evacuated, residual gases shall be analyzed for composition and purity prior to filling.⁵

12. Packaging

Gases and gas mixtures shall be packaged in accordance with Department of Transportation (DOT) regulations for protection during shipment and normal storage conditions.⁶ Cylinder sizes shall be as agreed upon between purchaser and supplier. Cylinders shall be labeled in accordance with Sections 13 and 14.

13. Identification

13.1 Individual gas components are identified by the following codes:

- A — Argon
- C — Carbon Dioxide
- He — Helium
- H — Hydrogen
- N — Nitrogen
- O — Oxygen

5. CGA P-15, *Filling of Industrial and Medical Nonflammable Compressed Gas Cylinders*, can be obtained from the Compressed Gas Association, Inc., 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202-4102.

6. DOT regulations can be obtained from the Department of Transportation, NASSIF Building, 400 7th Street S.W., Washington, DC 20590.

Table 3
Dew Point Conversion Chart
 (1 Atmosphere) (70°F @ 14.7 psia/21°C @ 760 mm [Hg])

Dew Point			Dew Point			Dew Point		
°F	°C	ppm	°F	°C	ppm	°F	°C	ppm
-130	-90.0	0.1	-73	-58.3	13.3	-38	-38.9	144
-120	-84.4	0.25	-72	-57.8	14.3	-37	-38.3	153
-110	-78.9	0.63	-71	-57.2	15.4	-36	-37.8	164
-105	-76.1	1.00	-70	-56.7	16.6	-35	-37.2	174
-104	-75.6	1.08	-69	-56.1	17.9	-34	-36.7	185
-103	-75.0	1.18	-68	-55.6	19.2	-33	-36.1	196
-102	-74.4	1.29	-67	-55.0	20.6	-32	-35.6	210
-101	-73.9	1.40	-66	-54.4	22.1	-31	-35.0	222
-100	-73.3	1.53	-65	-53.9	23.6	-30	-34.4	235
-99	-72.8	1.66	-64	-53.3	25.6	-29	-33.9	250
-98	-72.2	1.81	-63	-52.8	27.5	-28	-33.3	265
-97	-71.7	1.96	-62	-52.2	29.4	-27	-32.8	283
-96	-71.1	2.15	-61	-51.7	31.7	-26	-32.2	300
-95	-70.6	2.35	-60	-51.1	34.0	-25	-31.7	317
-94	-70.0	2.54	-59	-50.6	36.5	-24	-31.1	338
-93	-69.4	2.76	-58	-50.0	39.0	-23	-30.6	358
-92	-68.9	3.00	-57	-49.4	41.8	-22	-30.0	378
-91	-68.3	32.8	-56	-48.9	44.6	-21	-24.4	400
-90	-67.8	3.53	-55	-48.3	48.0	-20	-28.9	422
-89	-67.2	3.84	-54	-47.8	51	-19	-28.3	448
-88	-66.7	4.15	-53	-47.2	55	-18	-27.8	475
-87	-66.1	4.50	-52	-46.7	59	-17	-27.2	500
-86	-65.6	4.78	-51	-46.1	62	-16	-26.7	530
-85	-65.0	5.3	-50	-45.6	67	-15	-26.1	560
-84	-64.4	5.7	-49	-45.0	72	-14	-25.6	590
-83	-63.9	6.2	-48	-44.4	76	-13	-25.0	630
-82	-63.3	6.6	-47	-43.9	82	-12	-24.4	660
-81	-62.8	7.2	-46	-43.3	87	-11	-23.9	700
-80	-62.2	7.8	-45	-42.8	92	-10	-23.3	740
-79	-61.7	8.4	-44	-42.2	98	-9	-22.8	780
-78	-61.1	9.1	-43	-41.7	105	-8	-22.2	820
-77	-60.6	9.8	-42	-41.1	113	-7	-21.7	870
-76	-60.0	10.5	-41	-40.6	119	-6	-21.1	920
-75	-59.4	11.4	-40	-40.0	128	-5	-20.6	970
-74	-58.9	12.3	-39	-39.4	136	-4	-20.0	1020

The classification system is based on volumetric percentages. The classification designators remain the same for both U.S. Customary Units and the SI units. The shielding gas classification system is composed of the following designator and number arrangement:

(1) **SG—Shielding Gas Designator.** The letters SG at the beginning of each classification designation identifies the product as a shielding gas. These letters are followed by a hyphen.

(2) **SG-B—Base Gas Designator.** Shielding gases are classified according to chemical composition. The letter immediately to the right of SG- indicates the singular or major gas in the shielding gas or mixture (see Figure 1).

(3) **SG-B XYZ—Minor Gas Component Designators.** The letter(s) immediately following the base gas indicates the minor individual gas indicators in decreasing order of percent. These letters are followed by a hyphen.

(4) **SG-B XYZ- %/ %/ %—Percentage Designators.** A slash shall be used to separate the individual minor components' percentages for two or more component mixtures. See Figure 2 and Table 4. The percentage designator shown need not be present on the container's label.

(5) **S-B-G—Special Gas Mixture.** Shielding gases may be classified as special and carry the 'G' designation. The base gas must be identified. Minor gases need not be identified but must be covered in 13.1 or represented by the "X" designation. The percentage of each component shall be as agreed upon between the purchaser and supplier. See Figure 3. The "X" designation shall be used when a gas mixture component is not covered by the six base gases specified. The gas represented by the "X" must appear in parentheses after the "G". See Figure 4.

AWS classifications for typical gas mixtures are shown in Table 4.

Table 4
AWS Classifications for
Typical Gas Mixtures

AWS Classification	Typical Gas Mixtures (%)	Gas
SG-AC-25	75/25	Argon + Carbon Dioxide
SG-AO-2	98/2	Argon + Oxygen
SG-AHe-10	90/10	Argon + Helium
SG-AH-5	95/5	Argon + Hydrogen
SG-HeA-25	75/25	Helium + Argon
SG-HeAC-7.5/2.5	90/7.5/2.5	Helium + Argon + Carbon Dioxide
SG-ACO-8/2	90/8/2	Argon + Carbon Dioxide + Oxygen
SG-A-G	Special	Argon + Mixture

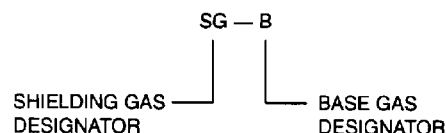


Figure 1—Classification System for a Single Gas

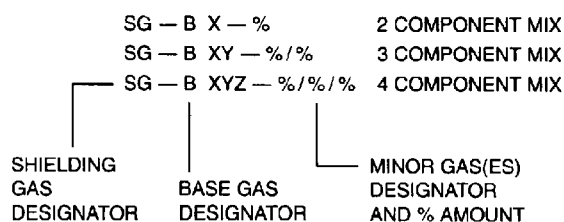


Figure 2—Classification System for Multicomponent Shielding Gases

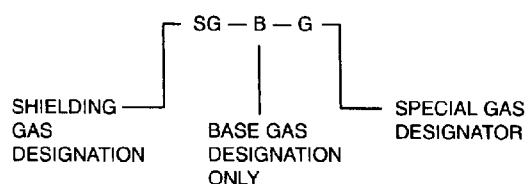
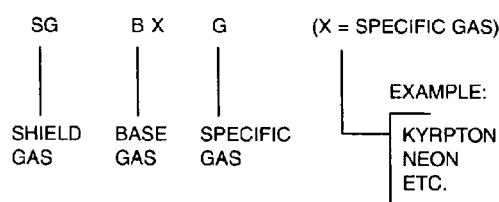


Figure 3—Classification System for Special Multicomponent Shielding Gases



Note: When "X" is used in the classification, the designator gas represented by "X" **must** be disclosed within parentheses after the letter "G".

Figure 4—Classification System for "X" Designator Shielding Gases

13.2 As stated in Section 9 of this specification, when mixed gases are classified in accordance with this specification, the percentage of the minor component(s) shall have a tolerance of $\pm 10\%$ relative to the minor percentage component. To compute the minor component range, multiply the minor component percentage by 0.10 to get the $\pm$ tolerance figure.

Example:

Ar – 25% CO₂ SG-AC-25

$$25 \times 0.1 = 2.5$$

$$25 - 2.5 = 22.5$$

$$25 + 2.5 = 27.5$$

Ar with 22.5 to 27.5% CO₂

Ar – 2% O₂ SG-AO-2

$$2 \times 0.1 = 0.2$$

$$2 - 0.2 = 1.8$$

$$2 + 0.2 = 2.2$$

Ar with 1.8 to 2.2% O₂

14. Marking of High-Pressure Cylinders, Liquid Containers, and Bulk Vessels

14.1 All cylinders and containers shall be marked in accordance with DOT regulations plus the following information, legibly marked on, or attached to, each cylinder:

- AWS specification and classification designation (year of issue may be excluded).
- Supplier's name and product trade designation (name of gas)
- Approved DOT warning label

14.2 The following example designates the minimum labeling requirement to comply with this specification.

This product conforms to AWS A5.32, classified as SG-AC-25

Annex

Guide to AWS Specification for Welding Shielding Gases

(This Annex is not a part of ANSI/AWS A5.32/A5.32M-97, *Specification for Welding Shielding Gases*, but is included for information purposes only.)

A1. Introduction

The purpose of this guide is to correlate the shielding gas classifications with their intended use so the specification can be used effectively. Appropriate welding processes are referred to whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the welding processes for which each shielding gas is suitable.

A2. Classification System

A2.1 The system for identifying the shielding gas classifications in this specification follows the standard pattern used in AWS filler metal specifications. The letter SG at the beginning of each classification designation stands for shielding gas. The letter immediately to the right of SG- indicates the singular or base gas in the shielding gas mixture.

For shielding gas mixtures, the letter designators immediately following the base gas designator indicate minor individual gas components in decreasing order of percent. These letters are followed by a hyphen and nominal whole numeric value of each minor gas volumetric percentage. If there are more than one minor gas component, each numeric value in decreasing order is separated by a virgule (/).

A2.2 "G" Classification

A2.2.1 This specification includes shielding gases classified as SG-B-G. The last "G" indicates that the shielding gas is of a "General" classification. It is "General" because not all of the particular requirements specified for each of the other classifications are met. The

intent in establishing this classification is to provide a means by which shielding gases that differ, for example, chemical composition, from other classifications and do not meet the composition specified for any of the classifications in this document can still be classified. This is to allow a useful shielding gas—one that otherwise would have to await a revision of the specification—to be classified immediately under the existing document. This means that two shielding gases—each bearing the same "G" classification—may be quite different in some respect, for example, chemical composition.

A2.2.2 The point of difference (although not necessarily the amount of that difference) between shielding gas of a "G" classification and shielding gas of a similar classification without the "G" (or even with it, for that matter) will be readily apparent from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

Not Specified is used in those areas of the specification that refer to the results of some particular test. It indicates that the requirements for that test are not specified for that particular classification.

Not Required is used in those areas of the specification that refer to the tests that must be conducted in order to classify a shielding gas. It indicates that that test is not required because the requirements (results) for the test have not been specified for that particular classification.

Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify a shielding gas to that classification. When a purchaser wants the information provided by that test, in order to consider a particular product of that classification for a certain application, the purchaser will have to arrange for that information with the supplier of

the product. The purchaser will have to establish with that supplier just what the testing procedures and the acceptance requirements are to be for that test. The purchaser should specify that information in the purchase order.

A2.2.3 Request for Shielding Gas Classification

A2.2.3.1 When a shielding gas cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that shielding gas. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals recommends that the manufacturer still request that a classification be established for that shielding gas, as long as the shielding gas is of commercial significance.

A2.2.3.2 A request to establish a new shielding gas classification shall be a written request, and it needs to provide sufficient detail to permit the Committee on Filler Metals or the Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. The request needs to state the variables and their limits, for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed.

A2.2.3.3 The request should be sent to the Secretary of the Committee on Filler Metals at AWS Headquarters. Upon receipt of the request, the Secretary will do the following:

- (1) Assign an identifying number to the request. This number shall include the date the request was received.
- (2) Confirm receipt of the request and give the identification number to the person who made the request.
- (3) Send a copy of the request to the Chair of the Committee on Filler Metals and the Chair of the particular Subcommittee involved.
- (4) File the original request.
- (5) Add the request to the log of outstanding requests.

A2.2.3.4 All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairpersons of the Committee and Subcommittee. Any request outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report it to the Chair of the Committee on Filler Metals for action.

A2.2.3.5 The Secretary shall include a copy of the log of all requests pending and those completed during

the preceding year with the agenda for each Committee on Filler Metals meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

A3. Acceptance

Acceptance of all shielding gases classified under this specification is in accordance with the tests and requirements of Part B and C of this specification. Any testing a purchaser requires of the supplier, for gases shipped in accordance with this specification, shall be clearly stated in the purchase order. In the absence of any such statement in the purchase order, the supplier may ship the gases with whatever testing the supplier normally conducts on gases of that classification. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this "certification" is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped, and that that material met the requirements of the specification. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the "certification" required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance Program" in ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.⁷

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding. They are the following:

- (1) Dimensions of the space in which the welding is done (with special regard to the height of the ceiling).

7. AWS standards can be obtained from AWS at 550 N.W. LeJeune Rd., Miami, FL 33126.

(2) Number of welders and welding operators working in that space.

(3) Rate of evolution of fumes, gases, or dust, according to the materials and processes used.

(4) The proximity of the welders or welding operators to the fumes, as these fumes issue from the welding zone, and to the gases and dusts in the space in which they are working.

(5) The ventilation provided to the space in which the welding is done.

A5.2 American National Standard ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the sections on "Health Protection and Ventilation."

A6. Welding Considerations

The properties of gases affect the performance of all arc welding processes. The ionization potential of the shielding gas influences the ease of arc initiation and stability. Thermal conductivity of a gas determines the voltage and energy constant of the arc. Gases such as carbon dioxide can have higher heat conductivity than helium at arc temperatures because of the effects of disassociation and recombination.

Reactive and oxidizing gases such as carbon dioxide (CO₂) and oxygen (O₂) can have detrimental effects on base metals such as aluminum, nickel, titanium, zirconium, and tungsten. For this reason, carbon dioxide or oxygen cannot be used as the shielding gas for gas tungsten arc welding.

Proper gas selection is crucial to efficient welding in the most cost-effective manner. Many factors must be considered. These are not limited to the following:

- (1) Type and thickness of base metal being welded
- (2) Arc characteristics
- (3) Metal transfer
- (4) Travel speed
- (5) Depth and width of fusion
- (6) Cost of welding
- (7) Mechanical properties
- (8) Root opening
- (9) Cleanliness of the base material
- (10) Spatter
- (11) Arc cleaning action
- (12) Gas purity
- (13) Joint configuration
- (14) Welding position
- (15) Fume generation

A7. Description and Intended Use of the Shielding Gases

A7.1 Single Gases. All single gases described in this specification may be purchased either as a liquid or as a gas. If liquid, the material must be gasified prior to being supplied to the welding area.

A7.1.1 SG-A (Argon). Argon is a chemically inert gas which is used both singularly and in combination with other gases to achieve desired arc characteristics for the welding of both ferrous and nonferrous metals. Almost all arc welding processes can use argon or mixtures containing argon to achieve good weldability, mechanical properties, arc characteristics and productivity. Argon is used for welding of nonferrous materials such as aluminum, nickel, copper, magnesium alloys, and reactive metals, which include zirconium and titanium. The low-ionization potential of argon creates an excellent current path and superior arc stability. In the GMAW process, argon produces a constricted arc column at a high current density which causes the arc energy to be concentrated in a small central area of the weld pool. The result is a depth of fusion profile which may have a distinct finger-like shape. Argon is also used for single-side melt-through welding with or without consumable inserts.

A7.1.2 SG-C (Carbon Dioxide). Carbon dioxide is an active gas used primarily for GMAW and FCAW. The heat of the arc dissociates the carbon dioxide into carbon monoxide and free oxygen. This oxygen will combine with elements transferring across the arc to form oxides which are released from the weld pool in the form of slag and scale. Although carbon dioxide is an active gas and produces an oxidizing effect, sound welds and acceptable mechanical properties can be achieved in many, but not all, metals and alloys. An electrode having higher amounts of deoxidizing elements is sometimes needed to compensate for the reactive nature of the gas. Carbon dioxide can be used for solid electrode GMAW with short circuiting and globular transfer and FCAW of carbon and stainless steel. Carbon dioxide cannot be used for spray transfer with GMAW.

The popularity of carbon dioxide is due to common availability as well as its lower cost per unit volume. The lower cost per unit of gas does not automatically translate to lowest cost per foot of deposited weld and is greatly dependent on the welding application. The final weld cost with carbon dioxide shielding gas is influenced by bead contour, electrode spatter, and spatter removal. The lower deposition efficiency for carbon dioxide caused by fume and spatter loss will influence the final weld cost.

Argon is often mixed with carbon dioxide to improve the operating characteristics. If mechanical properties are

to be maximized, a carbon dioxide and argon mixture is often recommended.

A7.1.3 SG-N (Nitrogen). Shielding gases containing nitrogen are not recommended for welding carbon steel. Nitrogen will combine with other elements at high temperatures which is why it is not recommended as a primary gas, but is used in combination with other gases for selected applications. Nitrogen is often used as a gas to protect the weld root from atmospheric contamination. Nitrogen root shielding of stainless steel welds may cause problems in those applications where control of the ferrite content is critical. Increased nitrogen content of the weld may reduce the ferrite level. Small additions ($\leq 3\%$) of nitrogen have been combined with argon for GMA and GTA welding of duplex stainless steel.

A7.1.4 SG-He (Helium). Helium, a chemically inert gas, is used for weld applications requiring higher heat inputs. Helium may improve wetting action, depth of fusion, and travel speeds. It does not produce the stable arc provided by argon. Helium has higher thermal conductivity and a wider arc column than argon. The higher voltage gradient increases heat input compared with argon, promoting increased weld pool fluidity and better wetting action. This is an advantage when welding aluminum-based, magnesium-based, and copper-based alloys. Using GMAW, 100-percent helium will only produce globular transfer. The argon percentage must be at least 20 percent when mixed with helium to produce and maintain a stable spray transfer.

A7.1.5 SG-O (Oxygen). Oxygen is never used as a base component of a shielding gas. It can be used as a minor component.

A7.1.6 SG-H (Hydrogen). Hydrogen (H_2) is chemically active and most commonly used at low percentages (1 to 35%) as the minor component in a gas mixture (see Section A8, General Safety Considerations).

A7.2 Binary Shielding Gas Mixtures

A7.2.1 SG-AO (Argon + Oxygen Mixtures). The addition of oxygen to argon with the GMAW process improves the arc characteristics and increases weld pool fluidity by reducing the surface tension of the weld metal. Oxygen is an active gas which intensifies the arc plasma, increasing heat input, travel speed, depth of fusion, and wetting. In GMAW, the addition of small amounts (1 to 8%) of oxygen to argon stabilizes the welding arc, increases the filler metal droplet rate, lowers the spray arc transition current, and influences bead shape. The weld pool is more fluid allowing improved weld bead wetting. Oxygen is not used with GTAW because of its detrimental effect on the tungsten electrode.

A7.2.1.1 SG-AO-1 (Ar + 1% O_2). This mixture is primarily used for spray transfer on stainless steels. One-percent oxygen is usually sufficient to stabilize the arc, increase the droplet rate and provide good fluidity of the weld pool.

A7.2.1.2 SG-AO-2 (Ar + 2% O_2). This mixture is used for spray arc welding on carbon steels, low-alloy steels and stainless steels. It provides additional wetting action over SG-AO-1. Weld mechanical properties and corrosion resistance (stainless steels) of welds made using the SG-AO-2 and SG-AO-1 shielding gases are comparable.

A7.2.1.3 SG-AO-5 (Ar + 5% O_2). This mixture provides a more fluid but controllable weld pool. It is the most commonly used argon plus oxygen mixture for general carbon steel welding. The additional oxygen permits higher travel speeds on some weld applications.

A7.2.1.4 SG-AO-8 (Ar + 8% O_2). This mixture provides additional depth of fusion over SG-AO-5. Slightly lower arc voltage or increased wire feed speed should be used. The higher weld pool fluidity and lower spray transition current of this mixture are advantageous on some applications. This mixture can be used in the short circuiting and spray modes of transfer. Greater oxidation of the weld metal, with increased loss of manganese and silicon, should be expected.

A7.2.2 SG-AC (Argon + Carbon Dioxide Mixtures). The additions of carbon dioxide to argon can produce a wide range of welding characteristics from high-current spray transfer to low-current short circuiting transfer.

The dissociation of carbon dioxide in the arc provides oxygen for improved wetting and arc stabilization. The high thermal conductivity of carbon dioxide tends to increase the width of fusion as compared to SG-AO mixtures.

When using GMAW with solid carbon steel wires, SG-AC mixtures containing more than 20 percent carbon dioxide will not support spray transfer.

A7.2.2.1 SG-AC-1 through 10 (Ar + 1 to 10% CO_2). Mixtures in this range may produce all modes of metal transfer useful on a variety of steel thicknesses. Depth of fusion is improved and porosity may be reduced when using SG-AC compared to SG-AO.

In the 5 to 10 percent carbon dioxide range the arc column becomes more defined. These mixtures are effective on material with mill scale. SG-AC-5 is commonly used with GMAW for heavy-section low-alloy steel welding.

A7.2.2.2 SG-AC-11 through 20 (Ar + 11 to 20% CO_2). This mixture range has been used with various

GMAW and FCAW applications. Most applications are on carbon and low-alloy steels. By mixing argon and carbon dioxide within this range, maximum productivity on thin-gauge materials can be achieved. The lower carbon dioxide percentages increase deposition efficiency by lowering spatter loss.

A7.2.2.3 SG-AC-21 through 49 (Ar + 21 to 49% CO₂). Mixtures in this range are used in the short circuiting GMAW mode and all positions of flux cored arc welding.

SG-AC-25 is widely used to replace pure carbon dioxide. These mixes operate well on light-gauge material at low currents, and at high currents on heavy materials producing good arc stability, weld pool control, bead appearance, and high productivity.

A7.2.2.4 SG-AC-50 (Ar + 50% CO₂). This mixture (not supplied at full cylinder pressure because the CO₂ would liquefy a full pressure) is used where increased heat input and depth of fusion are needed. Recommended material thickness is 1/8 in. [3 mm] minimum for the globular mode of metal transfer. This mixture is satisfactory for pipe welding using the short circuiting transfer mode. Good wetting and bead shape without excessive weld pool fluidity are the main advantages for the pipe welding application. When welding at high current levels, the metal transfer is more like welding in pure carbon dioxide than other previously described argon mixtures, but some reduction in spatter loss can be realized due to the argon addition.

A7.2.3 SG-AHe Gases (Argon + Helium Mixtures). These mixtures are often recommended for GMA and GTA welding of aluminum where an increased width of fusion is required and bead appearance is of primary importance. Generally, the heavier the material the higher the percentage of helium. Small percentages of helium, as low as 10%, will affect the arc. In GMAW, as the helium percentage is increased, the arc voltage and depth of fusion will increase while minimizing porosity.

A7.2.3.1 SG-AHe-10 through 50 (Ar + 10 to 50% He). These mixtures are used for welding nonferrous base metals. Mixtures in this range provide an increase in heat input and travel speed, with improved bead appearance.

A7.2.4 SG-HeA (Helium + Argon Mixtures). Helium and argon mixtures are used primarily for GMA and GTA welding of nonferrous base metals, such as reactive metals, aluminum, copper, nickel, magnesium, and their alloys. They are also used for welding some carbon steels. These mixtures are used on thicker base metals. Argon addition to a helium base gas will decrease the heat input and improve arc starting characteristics. As argon percentages increase, the arc voltage, spatter, and weld

depth-to-width ratio will decrease. In GMAW, the argon content must be at least 20 percent to produce and maintain a stable spray transfer.

A7.2.4.1 SG-HeA-10 through 25 (He + 10 to 25% Ar). These mixtures are used for welding copper over 1/2 in. [13 mm] thick and aluminum over 3 in. [75 mm] thick. Their high heat input improves weld fusion. They may be used for short circuiting transfer with nickel filler metals.

A7.2.4.2 SG-HeA-25 through 50 (He + 25 to 50% Ar). These mixtures increase heat input and reduce porosity of welds in copper, aluminum, and magnesium. They are used for welding aluminum and magnesium greater than 1/2 in. [13 mm] thick in the flat position.

A7.2.5 SG-AH (Argon + Hydrogen Mixtures) (see Section A8, Safety Considerations). Commercial argon-hydrogen gas mixtures produce reducing atmospheres. SG-AH-1, SG-AH-2, or SG-AH-5 are used for GTAW, GMAW, and PAW on a variety of base metals including the following:

- (1) nickel and nickel alloys
- (2) austenitic chromium-nickel stainless steels
- (3) low-alloy steels (PAW only)

Mixtures containing up to 15 percent hydrogen (SG-AH-15) are used for GTAW of chrome-nickel stainless steels. Its high heat conductivity makes these mixtures useful in selected GTAW applications. Additions of hydrogen increase weld heat input permitting faster travel speeds, increased depth of fusion, improved bead wetting, and broader weld bead profile. Hydrogen additions to argon provide a reducing atmosphere which removes oxygen and oxides from the weld area.

A7.2.6 SG-NH (Nitrogen + Hydrogen Mixtures). This root shielding gas may be used in the fabrication of chrome-nickel stainless steels. The ferrite precaution outlined in A7.1.3 applies also to applications using SG-NH-5, or higher, as a root shielding medium.

A7.3 Ternary Shielding Gas Mixtures

A7.3.1 SG-ACO (Argon + Carbon Dioxide + Oxygen Mixtures). Mixtures containing these three components are versatile due to their ability to operate using short circuiting, globular, spray, and high-current-density spray transfer. Several ternary compositions are available, and their application will depend on the desired metal transfer.

A7.3.1.1 SG-ACO-5 through 10/1 through 6 (Ar + 5 to 10% CO₂ + 1 to 6% O₂). The advantage of these mixtures is their ability to shield carbon steel and low-alloy steel of all thicknesses using any mode of metal transfer. These mixtures produce good welding characteristics and mechanical properties on carbon and low-

alloy steels. On thin-gauge base metals, the oxygen constituent improves arc stability at low current levels (30 to 60 A) permitting the arc to be kept short and controllable. This helps minimize excessive melt-through and distortion by lowering the total heat input into the weld zone.

A7.3.2 SG-AHeC and SG-HeAC (Argon + Helium + Carbon Dioxide Mixtures). Helium and carbon dioxide additions to argon increase the heat input to the weld, increasing bead wetting and fluidity. The weld bead profile becomes flatter and wider.

A7.3.2.1 SG-AHeC-10 through 40/1 through 15 (Ar + 10 to 40% He + 1 to 15% CO₂). Mixtures in this range have been developed for pulsed spray welding of carbon, low-alloy, and stainless steels. These mixtures are most often used on heavy sections, in positions other than flat. Good mechanical properties and weld pool control are characteristic of these mixtures.

A7.3.2.2 SG-HeAC-25 through 35/1 through 5 (He + 25 to 35% Ar + 1 to 5% CO₂). These mixtures are used for short circuit GMAW of high-strength steels and stainless steels, especially for welding positions other than flat. The carbon dioxide content is kept low to insure good weld metal toughness. The helium provides the heat necessary for good weld pool fluidity.

A7.3.2.3 SG-HeAC-7.5/2.5 (90% He + 7.5% Ar + 2.5% CO₂). This mixture is widely used for short circuit GMAW of stainless steel in all positions. The carbon dioxide content is kept low to minimize carbon pickup and assure good corrosion resistance, especially in multipass welds. The carbon dioxide plus argon addition provides good arc stability and depth of fusion. The high helium content provides higher heat input to overcome the high-viscosity nature of the stainless steel weld pool. Applications include welding carbon steel, stainless and alloy steels.

A7.3.3 SG-AHeO (Argon + Helium + Oxygen). Helium additions to argon plus oxygen mixtures increase arc energy with the GMAW process on ferrous base metals. Argon/helium/oxygen mixtures have been used for spray arc welding and surfacing low-alloy and stainless steels to improve the fluidity of the weld pool and the resultant bead shape as well as reduce porosity.

A7.4 Quaternary Shielding Gas Mixtures

SG-AHeCO (Argon + Helium + CO₂ + O₂ Mixtures). This combination may be used for high-deposition GMAW using the high-current-density transfer mode. These mixtures produce weld metal with good mechanical properties, and can be used throughout a wide range of deposition rates. Their major application is

welding low-alloy, high-strength steel base metals, and they have been used on carbon steel for high-productivity welding.

ARGON, CARBON DIOXIDE, HELIUM, AND NITROGEN HAZARD:

- Argon, carbon dioxide, helium, and nitrogen can displace oxygen in a worker's breathing zone which can result in asphyxiation, and possibly death, when released in poorly vented, confined work areas. Argon and carbon dioxide cause a special concern since they are heavier than air and may concentrate in low areas such as in the bottom of pressure vessels, tanks, pits, and ships.
 - Unless adequate ventilation and breathing air are supplied, care must be taken with any of these gases when they are released in enclosed areas or confined spaces. A safety watch should be provided and in attendance anytime a worker is using any of these gases in a vessel.
 - Additional information can be found in ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, CGA publications, and from suppliers of the aforementioned gases.
-

HYDROGEN WARNING:

- Hydrogen is a highly flammable gas. A mixture of hydrogen with oxygen or air in a confined area will explode when brought in contact with a flame or other source of ignition. Concentrations of hydrogen between 4 and 75 percent by volume in air are relatively easy to ignite by a low-energy spark and may cause an explosion. Smoking, open flames, unapproved electrical equipment, and other ignition sources must not be permitted in hydrogen areas. Store containers outdoors or in other well-ventilated areas.
 - Before making any installation, become thoroughly familiar with NFPA (National Fire Protection Association) Standards No. 50-A, *Standard for Gaseous Hydrogen Systems at Consumer Sites*; and 50-B, *Standard for Liquefied Hydrogen Systems at Consumer Sites*; and with all local safety codes. For further safety information, refer to supplier MSDS sheets on hydrogen safety.
 - Take every precaution against hydrogen leaks. Escaping hydrogen cannot be detected by sight, smell, or taste.
-

A8. General Safety Considerations

A8.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn in combination with goggles or equivalent to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flame. Aprons, cape-sleeves, leggings, and shoulder covers with hibs designed for welding service should be used. Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph.

Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load. Disconnection under load produces arcing of the contacts and may cause burns or shock, or both. (*Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.*)

The following sources are for more detailed information on personal protection:

(1) ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(2) *Code of Federal Regulations*, Title 29 Labor, Chapter XVII, Part 1910, OSHA General Industry Standards available from the U.S. Government Printing Office, Washington, DC 20402.

(3) ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, American National Standards Institute, 11 West 42 Street, New York, NY 10036.

(4) ANSI/ASC Z41.1, *Safety-Toe Footwear*, American National Standards Institute, 11 West 42 Street, New York, NY 10036.

A8.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity.

To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open-circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open-circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

Recognized safety standards should be followed, such as ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*; *National Electrical Code*; and *NFPA No. 70*, available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

A8.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management personnel and welders alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the filler metal, shielding gas, base metal, welding process, current level, arc length, and other factors.

The possible effects of overexposure range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever. The possibility of more serious health effects exists when especially toxic materials are involved. In confined spaces, the shielding gases and fumes might displace breathing air to cause asphyxiation.

Various gases are generated during welding. Some are a product of the decomposition of fluxes and electrode coatings. Others are formed by the action of arc heat or ultraviolet radiation emitted by the arc on atmospheric constituents and contaminants. Potentially hazardous gases include carbon monoxide, oxides of nitrogen, ozone, and decomposition products of chlorinated hydrocarbons, such as phosgene.

One's head should always be kept out of the fumes. Sufficient ventilation, exhaust at the arc, or both, should be used to keep fumes and gases from one's breathing zone and the general area.

In some cases, natural air movement will provide enough ventilation. Where ventilation may be questionable, air sampling should be used to determine if corrective measures should be applied.

More detailed information on fumes and gases produced by the various welding processes may be found in the following:

(1) The permissible exposure limits required by OSHA can be found in CFR Title 29, Chapter XVII, Part 1910. The OSHA, *General Industry Standards*, is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

(2) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Suite 600, Cincinnati, OH 45240-1634.

(3) The results of an AWS-funded study, *Fumes and Gases in the Welding Environment*, is available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

A8.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

Radiant energy may be ionizing (such as x-rays), or nonionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, depending on the radiant energy's wavelength and intensity, if excessive exposure occurs.

A8.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptable limits by use of suitable shielding enclosing the welding area.

A8.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base-metal composition, fluxes, and any coating or plating on the base metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser beam welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by nonionizing radiant energy from welding include the following measures:

(1) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute, 11 West 42 Street, New York, NY 10036. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect passersby from incidental exposure.

(2) Exposed skin should be protected with adequate gloves and clothing, as specified in ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society.

(3) Reflections from welding arcs should be avoided, and all personnel should be protected from intense reflections. (Note: Paints using pigments of substantially zinc oxide or titanium dioxide have a lower reflectance for ultraviolet radiation.)

(4) Screens, curtains, or adequate distance from aisles, walkways, etc., should be used to avoid exposing passersby to welding operations.

(5) Safety glasses with UV-protective side shields have been shown to provide some protection from ultraviolet radiation produced by welding arcs.

A8.4.3 Ionizing radiation information sources include:

(1) AWS F2.1, *Recommended Safe Practices for Electron Beam Welding and Cutting*, available from the American Welding Society.

(2) Manufacturer's product information literature.

A8.4.4 Nonionizing radiation information sources include:

(1) Hinrichs, J. F. "Project committee on radiation-summary report." *Welding Journal*, January 1978.

(2) National Technical Information Service. Nonionizing radiation protection, Special Study No. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*. Springfield, VA 22161: National Technical Information Service, ADA-033768.

(3) ——. Nonionizing radiation protection, Special Study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs*. Springfield, VA 22161: National Technical Information Service, ADA-043023.

(4) Moss, C. E., and Murray, W. E. "Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting." *Welding Journal*, September 1979.

(5) Marshall, W. J., Sliney, D. H., *et al.* "Optical radiation levels produced by air-carbon arc cutting processes." *Welding Journal*, March 1980.

(6) American National Standards Institute, ANSI/ASC Z136.1, *Safe Use of Lasers*, published by American National Standards Institute, 11 West 42 Street, New York, NY 10036.

(7) ——. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(8) ——. ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute, 11 West 42 Street, New York, NY 10036.

(9) Moss, C. E. "Optical radiation transmission levels through transparent welding curtains." *Welding Journal*, March 1979.

A9. Safety References

Material Safety Data Sheets (MSDS) are available from the supplier of the shielding gas. Additional safety references are shown in Table A1.

Table A1
Additional Information

Code	Title
From Compressed Gas Association (CGA)^a	
CGA-G4	Oxygen
CGA-G5	Hydrogen
CGA-G6	Carbon Dioxide
CGA-G6.3	Carbon Dioxide Cylinder Filling and Handling Procedures
CGA-P-9	The Inert Gases Argon, Nitrogen, and Helium
P-1	Safety Handling of Compressed Gases in Containers
P-12	Safety Handling of Cryogenic Liquids
P-14	Accident Prevention in Oxygen-Rich and Oxygen-Deficient Atmospheres
SB-2	Oxygen-Deficient Atmospheres
C5.10-94 ^b	Recommended Practices for Shielding Gases for Welding and Plasma Arc Cutting
From American Welding Society (AWS)^b	
AWS	Arc Welding Safely
AWS-AWN	Arc Welding and Cutting Noise
AWS-CAWF	Characterization of Arc Welding Fumes
AWS-EWH-1	Health I, Effects of Welding on
AWS-EWH-2	Health II, Effects of Welding on
AWS-EWH-3	Health III, Effects of Welding on
AWS-EWH-4	Health IV, Effects of Welding on
AWS-EWH-5	Health V, Effects of Welding on
AWS-EWH-6	Health VI, Effects of Welding on
AWS-EWH-7	Health VII, Effects of Welding on
AWS-FGW	Fumes and Gases in the Welding Environment
AWS-LVOS	Ozone Sampling with Spill Proof Impingers, Lab Validation of
AWS-SHP	Welding Safety and Health Information Packet
AWS-TWFR	Toxicity of Welding Fumes in Rats
AWS-WFC	Welding Fume Control with Mechanical Ventilation
AWS-WFDP	Welding Fume Control, A Demonstration Project
AWS-F1.1	Sampling Airborne Particulates Generated by Welding and Allied Processes, Methods for
AWS-F1.2	Measuring Fume Generation Rates and Total Fume Emission for Welding and Allied Processes, Laboratory Method for
AWS-F1.3	Evaluating Contaminants in the Welding Environment: A Sampling Strategy Guide
AWS-F.2	Lens Shade Selector
AWS-F6.1	Sound Level Measurement of Manual Arc Welding and Cutting Processes, Method for
ANSI/ASC-Z49.1	Safety in Welding, Cutting, and Allied Processes

Notes:

a. Compressed Gas Association, 1235 Jefferson Davis Drive Highway, Arlington, VA 22202.

b. American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

AWS Filler Metal Specifications by Material and Welding Process

	OFW	SMAW	GTAW GMAW PAW	FCAW	SAW	ESW	EGW	Brazing
Carbon Steel	A5.2	A5.1	A5.18	A5.20	A5.17	A5.25	A5.26	A5.8, A5.31
Low-Alloy Steel	A5.2	A5.5	A5.28	A5.29	A5.23	A5.25	A5.26	A5.8, A5.31
Stainless Steel		A5.4	A5.9, A5.22	A5.22	A5.9	A5.9	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11	A5.14		A5.14			A5.8, A5.31
Aluminum Alloys		A5.3	A5.10					A5.8, A5.31
Copper Alloys		A5.6	A5.7					A5.8, A5.31
Titanium Alloys			A5.16					A5.8, A5.31
Zirconium Alloys			A5.24					A5.8, A5.31
Magnesium Alloys			A5.19					A5.8, A5.31
Tungsten Electrodes			A5.12					
Brazing Alloys and Fluxes								A5.8, A5.31
Surfacing Alloys	A5.13, A5.21	A5.13, A5.21	A5.13, A5.21					
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	

AWS Filler Metal Specifications and Related Documents

AWS Designation	Title
FMC	Filler Metal Comparison Charts
UGFM	Users Guide for Filler Metals
A4.2	Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal
A4.3	Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding
A5.01	Filler Metal Procurement Guidelines
A5.1	Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
A5.2	Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding
A5.3	Specification for Aluminum and Aluminum Alloy Electrodes for Shielded Metal Arc Welding
A5.4	Specification for Stainless Steel Welding Electrodes for Shielded Metal Arc Welding
A5.5	Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
A5.6	Specification for Covered Copper and Copper Alloy Arc Welding Electrodes
A5.7	Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes
A5.8	Specification for Filler Metals for Brazing and Braze Welding
A5.9	Specification for Bare Stainless Steel Welding Electrodes and Rods
A5.10	Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods
A5.11	Specification for Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc Welding
A5.12	Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding and Cutting
A5.13	Specification for Solid Surfacing Welding Rods and Electrodes
A5.14	Specification for Nickel and Nickel Alloy Bare Welding Electrodes and Rods
A5.15	Specification for Welding Electrodes and Rods for Cast Iron
A5.16	Specification for Titanium and Titanium Alloy Welding Electrodes and Rods
A5.17	Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
A5.18	Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding
A5.19	Specification for Magnesium Alloy Welding Electrodes and Rods
A5.20	Specification for Carbon Steel Electrodes for Flux Cored Arc Welding
A5.21	Specification for Composite Surfacing Welding Rods and Electrodes
A5.22	Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding
A5.23	Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
A5.24	Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods
A5.25	Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag
A5.26	Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding
A5.28	Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding
A5.29	Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding
A5.30	Specification for Consumable Inserts
A5.31	Specification for Fluxes for Brazing and Braze Welding
A5.32	Specification for Welding Shielding Gases

For ordering information, contact the Order Department, American Welding Society, 550 N.W. LeJeune Road Miami, FL 33126. Phone: 1-800-334-9353.