PART

2

Rules for Welding and Fabrication

APPENDIX 2 Requirements for the Approval of Filler Metals

CONTENTS

PART

2

APPENDIX 2 Requirements for the Approval of Filler Metals

SECTION 1 General

1 Scope

1.1 Condition of Approval

The scope and conditions of classification contained in Part 1, Chapter 1 of the ABS *Rules for Building and Classing Steel Vessels* are applicable to the approval of welding filler metals, insofar as they are appropriate. Approval will be for each plant of each manufacturer carrying out its own quality control inspection and certification.

1.3 Approval Procedure *(1 October 1993)*

Welding filler metals intended for hull construction will be approved by ABS, subject to compliance with the requirements and test schedules as outlined herein. The requirements are based on the following:

1.3.1

Guarantee by the manufacturer of the minimum properties

1.3.2

Inspection of the manufacturing facility by an ABS Surveyor

1.3.3

Testing of selected samples

The test assemblies are to be prepared and tested in the presence of an ABS Surveyor. The Surveyor is to be satisfied that the manufacturer's plant and method of filler metal production are capable of ensuring reasonable uniformity in production. The Bureau is to be notified of any alterations proposed to be made in the production of filler metals.

1.5 Aluminum Filler Metals

Approval of aluminum filler metals is covered in Appendix 2-5-A2 of the ABS *Rules for Materials and Welding – Aluminum and Fiber Reinforced Plastics (FRP)*.

3 Grading

3.1 ABS Grades *(1997)*

Filler metals are divided into three groups based on the steel for which they are intended.

Ordinary-Strength Steel (2-1-2/Table 1 through 2-1-2/Table 4)	No suffix.
Higher-Strength Steel (2-1-3/Table 1 through 2-1-3/Table 4)	Suffix Y and Y400
Quenched and Tempered Steel (*MODU Rules* 3-1-A3/Tables 1 and 2)	Suffix YQ420 through YQ690

Each group is further divided into multiple levels based on the strength and/or toughness, the latter being represented by the toughness digit 1 through 5. Exact combination of digit/suffix and corresponding tensile and impact requirements are indicated in 2-A2-1/Table 1 and 2-A2-1/Table 2.

3.3 Other Standards

At the option of the manufacturer, filler metals may be approved to a recognized standard. The required tests and procedures for such approval are to be in accordance with the specified standard. In addition, annual inspection and testing are to be carried out for continued approval.

3.5 Special Properties

Welding filler metals may be approved to the manufacturer's guaranteed minimum properties over and above or in addition to the requirements for the applicable standard. Notations indicating guaranteed minimum properties will be added, as appropriate, upon verification by test.

5 Manufacturer's Guarantee *(1 Oct. 1994)*

Each plant of the manufacturer is to file an application for each filler metal indicating the following:

- Specification and Grade/Classification
- Electrode (wire) size and welding position
- Flux or shielding gas
- Current/Polarity
- Recommended volts and amperage
- Guaranteed all-weld-metal chemical and mechanical properties
- Guaranteed hydrogen content (for H15, H10, H5, Y or Y400 designation)

7 Plant Inspection

7.1 Initial Inspection

Before marketing the product, each plant manufacturing welding filler metals submitted for ABS approval is to be inspected by an ABS Surveyor to satisfy himself that the facilities, production method, quality assurance procedures, etc., in that plant are adequate to maintain uniform and acceptable quality in production.

The Surveyor is also to satisfy himself that the testing machines are maintained in an accurate condition and that a record of periodical calibration is maintained up to date.

Where a plant approved by ABS intends to commence production of a new product, plant inspection may be required for the facilities, production methods, and quality control procedures for the new product.

7.3 Annual Inspection *(1 October 1993)*

Each plant manufacturing ABS-approved welding filler metals is to be inspected by an ABS Surveyor at an interval of approximately 12 months. The extent of the inspection is as indicated in 2-A2-1/7.1.

9 Test Requirements

9.1 General

When the plant inspection required in 2-A2-1/7 is completed, representative filler metal samples will be selected by the Surveyor for welding and testing in his presence. The preparation of the test assemblies and test specimens are to be in accordance with the following:

9.3 Test Plate Material

9.3.1 Deposited Metal Test and Diffusible Hydrogen Test *(1997)*

Except as indicated below, any grade of ordinary-strength or higher-strength hull structural steel may be used for the preparation of all test assemblies.

For the deposited metal test assemblies of YQ Grades, fine grain structural steel compatible with the properties of the weld metal is to be used. Alternatively, other steel may be used, provided the groove is buttered with the filler metal.

9.3.2 Butt Weld Test and Fillet Weld Test *(2006)*

For butt weld test assembly and fillet weld test assembly, as applicable, one of the grades of steel, or equivalent, as listed below for the individual grade of filler metals is to be used:

Grade 1	A
Grade 2	A, B, D
Grade 3	A, B, D, E
Grade 1 Y	AH32, AH36
Grade 2 Y	AH32, AH36, DH32, DH36
Grade 3 Y	AH32, AH36, DH32, DH36, EH32, EH36
Grade 4 Y	AH32, AH36, DH32, DH36, EH32, EH36, FH32, FH36
Grade 2 Y 400	AH40, DH40
Grade 3 Y 400	AH40, DH40, EH40
Grade 4 Y 400	AH40, DH40, EH40, FH40
Grade 3 YQXXX :	AQZZ, DQZZ
Grade 4 YQXXX	AQZZ, DQZZ, EQZZ
Grade 5 YQXXX	AQZZ, DQZZ, EQZZ, FQZZ

(XXX/ZZ = 420/43, 460/47, 500/51, 550/56, 620/63 and 690/70)

For Y grade filler metals, the tensile strength of the base metal is to be at least 490 N/mm^2 (50 kgf/mm^2, 71 ksi).

9.3.3 Ordinary and Higher-strength Filler Metals (Dual Approvals) *(1 Oct. 1994)*

The required deposit metal test assemblies may be made using either ordinary or H32/36 higher-strength hull structural steel. The required butt weld test assemblies are to be made using steel with a tension strength of 490 N/mm^2 (50 Kgf/mm^2, 71 ksi) or greater. The test results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade.

Dual approval of Y400 grade filler metals will be specially considered.

9.3.4 Electroslag or Electrogas Welding for Higher-Strength Steel *(2005)*

For unrestricted approval, the test plate should contain niobium close to its maximum allowable limit of 0.05%. Where such a plate is not used, the filler metal approval may be restricted to plates other than niobium treated.

11 Welding Conditions

The welding conditions used, such as amperage, voltage, travel speed, etc., are to be held within the range recommended by the manufacturer for normal good welding practice. Where a filler metal is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the welding of the test assemblies, unless specified otherwise by the applicable standard of 2-A2-1/3.3.

13 Chemical Analysis

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer.

15 Deposited Metal Tension Test

15.1 Specimen Type and Preparation

The deposited metal tension test specimens are to be machined to the dimensions indicated in 2-A2-1/Figure 1, care being taken that the longitudinal axis coincides with the center of the weld and the mid-thickness of the plate.

15.3 Hydrogen Removal

The tension test specimen may be subjected to a temperature not exceeding 250°C (482°F) for a period not exceeding 16 hours for hydrogen removal, prior to testing.

15.5 Test Requirements *(1 Oct. 1994)*

The values of tensile strength, yield stress and elongation are to be recorded. The results are to conform to the requirements of 2-A2-1/Table 1.

17 Butt Weld Tension Test

17.1 Specimen Type and Preparation

The butt weld tension test specimens are to be machined to the dimensions indicated in 2-A2-1/Figure 2. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

17.3 Test Requirements *(1 Oct. 1994)*

The results are to conform to the tensile strength requirement of 2-A2-1/Table 1. The position of the fracture is to be reported.

19 Impact Test

19.1 Specimen Type and Preparation *(1996)*

The impact test specimens are to be of the Charpy V-notch type and machined to dimensions indicated in 2-A2-1/Figure 3. The test specimens are to be cut with their longitudinal axis perpendicular to the weld and are to be taken from the middle of the plate thickness for multi-pass welds, from the middle of the second (2^{nd}) run for two-run technique welds and from 2 mm ($^5/_{64}$ in.) maximum below one surface for electroslag or electrogas welds. The notch is to be positioned in the center of the weld, unless specified otherwise in 2-A2-3/17 and 2-A2-4/17. The notch is to be cut perpendicular to the surface of the plate. The test temperature of the test pieces is to be controlled to within 1°C (2°F) of the required temperature.

19.3 Test Requirements *(1 Oct. 1994)*

The average value of three specimens is to conform to the required average in 2-A2-1/Table 1, according to the applicable grade and welding technique. Only one value may be below the required average and it is to be not less than 70% of the required average.

19.5 Retest

When the results fail to meet the above requirements but conditions (2-A2-1/19.5.2) and (2-A2-1/19.5.3) below are complied with, three additional specimens may be taken from the same assembly and the results added to those previously obtained to form a new average. The retest is acceptable, if for the six specimens, all of the following conditions are met.

19.5.1

The new average is not less than the required average.

19.5.2

No more than two individual values are below the required average.

19.5.3

No more than one individual value is below 70% of the required average.

If the test is unsatisfactory, further tests may be made, at the discretion of the Surveyor, on a new assembly. In such cases, all required tests, including those previously found satisfactory, are to be carried out.

21 Butt Weld Bend Test

21.1 Specimen Type and Preparation

The butt weld face and root bend test specimens are to be 30 mm (1.2 in.) in width. The upper and lower surfaces of the weld are to be filed, ground, or machined flush with the surface of the plate. The corners of the specimens may be rounded to a radius not exceeding 2 mm ($^5/_{64}$ in.).

21.3 Test Requirements *(1997)*

The test specimens are to be bent through an angle of 120 degrees around a pin or mandrel having the following diameter:

Ordinary Strength	Three times the thickness of the specimen
Y and Y400	Three times the thickness of the specimen
YQ420, YQ460 & YQ500	Four times the thickness of the specimen
YQ550, YQ620 & YQ690	Five times the thickness of the specimen.

For a face bend, the face of the weld is to be in tension during testing and for a root bend, the root of the weld is to be in tension during testing. The specimens are to withstand bending without developing any crack or discontinuity greater than 3.2 mm ($^1/_8$ in.) in length on the tension surface of the specimen. For electroslag or electrogas welded test assemblies, side bend tests are to be used in lieu of root and face bend tests.

21.5 Alternative Test for YQ-Grades *(1997)*

For YQ-Grade, a bending elongation test in accordance with 2-A2-1/Figure 4 may be accepted. For this alternative, the bending elongation on gauge length $Lo = Ls + t$ (Ls = width of weld, t = specimen thickness) is to meet the minimum elongation requirements in 2-A2-1/Table 1.

23 Diffusible Hydrogen Test *(1997)*

23.1 Optional or Required Test *(2005)*

Ordinary-strength, shielded metal arc welding electrodes and flux-cored wire may be submitted at the option of the manufacturer to a hydrogen test. When found satisfactory, an appropriate suffix will be added to the grade.

Higher-strength, shielded metal arc welding electrodes and flux cored wires, and YQ grade shielded metal arc welding electrodes, submerged arc welding wire-flux combinations, and flux-cored wires are to be submitted to a hydrogen test. Test results are to meet the requirements for the following notations, except that Y-grade electrodes with a diffusible hydrogen content greater than H10 and Y-grade flux-cored wires with a diffusible hydrogen content greater than H15 will be specially identified, as indicated in 2-A2-1/23.7, 2-A2-2/11.3, and 2-A2-4/13.1.3.

Y-Grade shielded metal arc electrodes	H10
Y-Grade flux-cored wires	H15
YQ420/460/500 Grades	H10
YQ550/620/690 Grades	H5

23.3 Test Methods *(2005)*

The diffusible hydrogen content of the weld metal is to be determined in accordance with the test methods prescribed in ISO 3690 or AWS A4.3, or any other method such as the gas chromatographic method that correlates with ISO 3690 with respect to cooling rate and delay times during preparation of the weld samples and hydrogen volume determinations.

The thermal conductivity deduction (TCD) method, such as that described in BS-6693 Appendix C, is also acceptable provided the equipment is calibrated against another standard such as AWS A4.3 or ISO 3690.

23.5 Alternative Test Method

In lieu of the test methods indicated in 2-A2-1/23.3, a recognized alternate procedure may be considered for Grades other than YQ. The following glycerine method will be acceptable.

Four test specimens are to be prepared measuring approximately 12 × 25mm ($^1/_2$ × 1 in.) in cross section by 125 mm (5 in.) in length. The test specimens may be any grade of hull structural steel and are to be weighed to the nearest 0.1 gm before welding. On the wider surface of each test specimen, a single bead of welding is to be deposited about 100 mm (4 in.) in length with a 4 mm ($^5/_{32}$ in.) electrode, using about 150 mm (6 in.) of the electrode. The welding is to be carried out with as short an arc as possible and with a current of approximately 150 amperes.

The electrodes, prior to welding, can be subjected to the normal drying process recommended by the manufacturer. Within thirty seconds of the completion of the welding of each specimen, the slag is to be removed and the specimen quenched in water having a temperature of approximately 20°C (68°F). After an additional 30 seconds the specimens are to be cleaned and placed in an apparatus suitable for the collection of hydrogen by displacement of glycerin. The glycerin is to be kept at a temperature of 45°C (113°F) during the test. All four test specimens are to be welded and placed in the hydrogen collecting apparatus within 30 minutes.

The specimens are to be kept immersed in the glycerin for a period of 48 hours and after removal are to be cleaned in water or suitable solvent, dried, and weighed to the nearest 0.1 gram to determine the amount of weld deposited. The amount of gas evolved is to be measured to the nearest 0.01 ml and corrected for temperature and pressure to 0°C (32°F) and 760 mm (30 in.) Hg.

23.7 Test Requirements *(2005)*

The individual and average diffusible hydrogen content of the four specimens is to be reported and the average value in milliliters (ml) per 100 grams is not to exceed the following:

Suffix	*AWS A4.3 or ISO 3690*	*Glycerin Method*
H15	15	10
H10	10	5
H5	5	-

All higher-tensile strength steel grade shielded metal arc electrodes with an average value above the H10 requirement and flux cored wires with an average value above the H15 requirement are to be identified with “non-low hydrogen electrode, requires special approval for use with higher-strength steel”.

25 Special Tests

25.1 Nondestructive Testing

The welded assemblies may be subjected to radiographic or ultrasonic examination to ascertain any discontinuities in the weld prior to testing.

25.3 Additional Tests

This Bureau may specify any additional tests as may be necessary.

27 Licensee Approvals *(2007)*

When a filler metal is manufactured in more than one plant of the same company or by a licensee company, a complete set of approval tests is to be carried out on the samples selected from products of the main plant. In the other plants, a reduced test program equivalent to annual check tests plus diffusible hydrogen test may be permitted, if the main plant and licensee can certify that the materials used, the fabrication process and final products by the licensee are identical to those in the main plant. Affidavits from both the main plant and licensee are to be submitted attesting to this fact. However, should there be any doubt, a complete test series may be required.

Note: Wire-flux combinations for submerged arc welding. If a unique flux is combined with different wires coming from several factories belonging to the same firm, it is acceptable, after initial approval, to perform only one test series if the various wires conform to the same technical specification.

29 Annual Check Tests *(1996)*

The facilities and associated quality control systems, where approved filler metals are manufactured, are subject to an annual inspection in accordance with 2-A2-1/7.3. Annual check tests are to be conducted in accordance with 2-A2-2/13; 2-A2-3/15 and 2-A2-3/19.3; 2-A2-4/15; or 2-A2-4/17.3, whichever is applicable for the welding process. Test data are to conform to the applicable requirements.

29.1 Upgrading and Uprating *(1 October 1993)*

Upgrading and uprating of welding filler metals will be considered at the manufacturer's request. Generally, tests from butt weld assemblies and, where applicable, a diffusible hydrogen test will be required in addition to the normal annual check tests. The data is to conform to the applicable requirements. See also 2-A2-2/13.3, 2-A2-3/15.3, 2-A2-3/19.5, 2-A2-4/15.3 and 2-A2-4/17.5.

29.1.1 Upgrading

Upgrading refers to notch toughness and, consequently, Charpy V-notch impact tests are required from butt weld and deposited metal test assemblies. The impact tests are to be conducted at the upgraded temperature.

29.1.2 Uprating

Uprating refers to the extension of approval to also cover the welding of higher-strength steels (dual approvals). For this purpose, butt-weld tests are to be carried out as required in 2-A2-1/9.3.3.

31 Quality Assurance Program *(1 October 1993)*

Where an ABS-approved Quality Assurance Program is maintained and a periodical audit is carried out satisfactorily, the attendance of the Surveyor at the annual check test may be waived, provided the results of the annual check test are examined by the Surveyor and found in accordance with the applicable requirements.

33 Retests *(2006)*

Where the result of a tension or bend test does not comply with the requirements, two test specimens of the same type are to be prepared and tested from the original test assembly, if possible. A new assembly may be prepared using welding consumables from the same batch. The new assembly is to be made with the same procedure (particularly number of runs) as the original assembly. Testing of the new assembly is to include CVN testing. See 2-A2-1/19.5 for impact retests.

FIGURE 1
Deposited Metal Tension Test Specimen *(2005)*

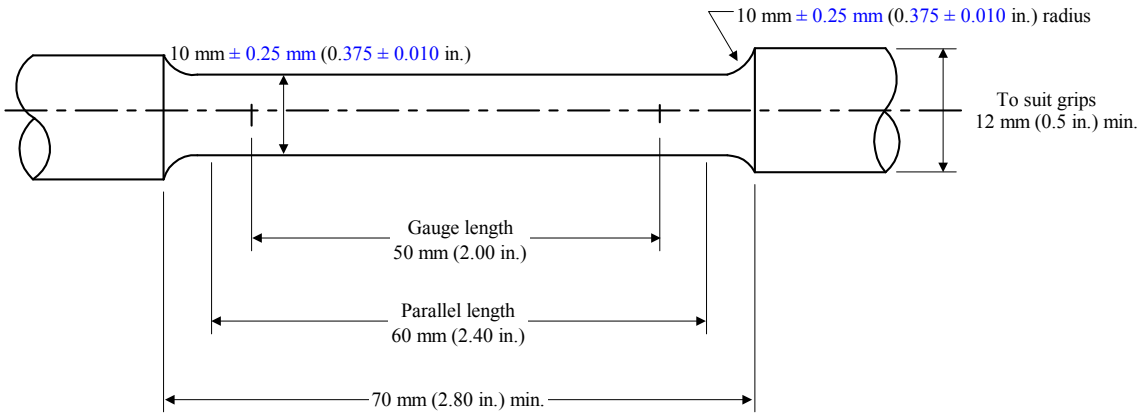
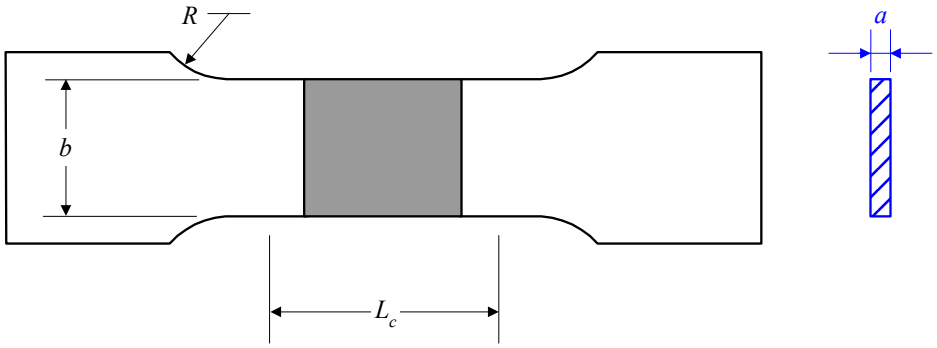


FIGURE 2
Butt Weld Tension Test Specimen *(2005)*



Flat specimen, the weld to be machined (or ground) flush with the surface of the plate, with the following dimensions is to be used:

a = t

b = 12 for $t \leq 2$

b = 25 for $t > 2$

L_c = width of weld + 60 mm

R > 25 mm

FIGURE 3
Charpy V-Notch Impact Test Specimen

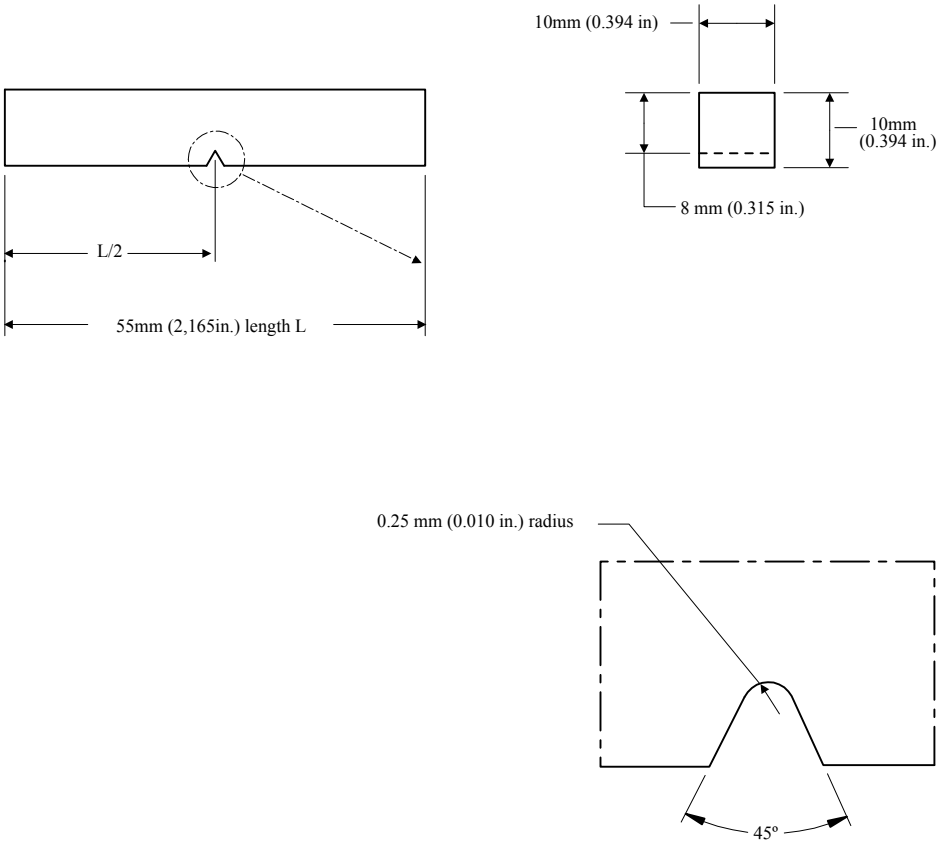


FIGURE 4
Bending Elongation Test *(1997)*

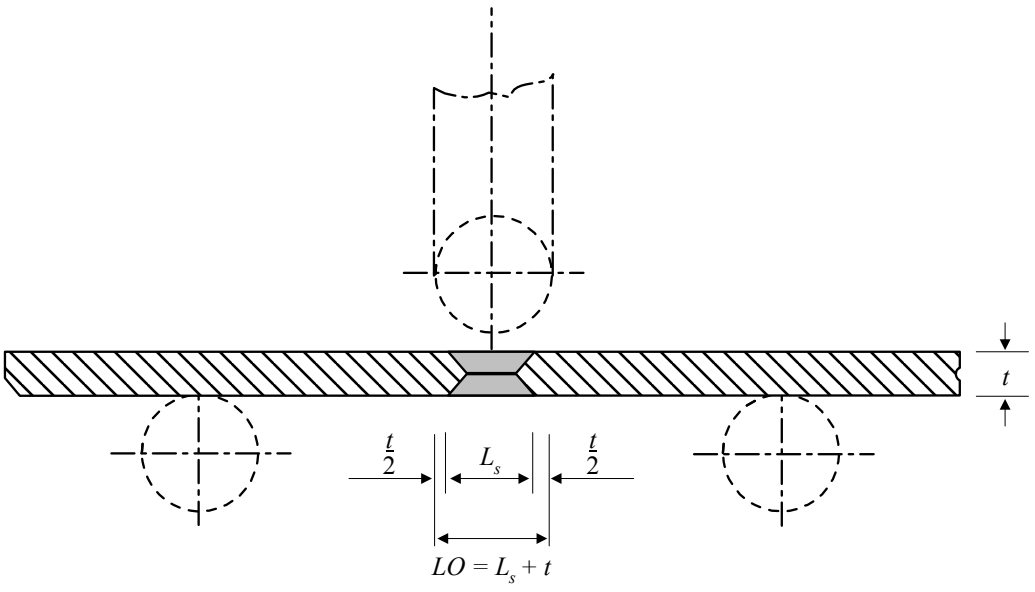


TABLE 1
Tension Test Requirements *(2006)*

The tensile requirements are based on the type of test specimen (longitudinal or transverse) specified elsewhere in these Requirements for the particular combination of weld process and the type of required test.

To find the required tension test properties, first locate in the "process" column the welding process for which the filler metal is intended (e.g., wire-flux). Then locate in that line under "applicable test" column the test in question (e.g., DM/M). The required properties are found below the box in which the particular test is located (longitudinal specimen for the example chosen).

Process	*Applicable Tests*	
MW	DM	BW
WF	DM/M, DM/TM, BW/T, BW/TM	BW/M, BW/T, BW/TM
WG/SA	DM	BW
WG/A	DM/M, DM/TM, BW/T, BW/TM	BW/M, BW/T, BW/TM
ESEG	BW	BW

Required Properties				
Grade [3]	*Longitudinal Specimen*			*Transv. Specimen (1999)*
	Tensile Strength N/mm^2 (kgf/mm^2, ksi)	*Yield Point, min. N/mm^2 (kgf/mm^2, ksi)*	*Elongation min. %*	*Tensile Strength, min. N/mm^2 (kgf/mm^2, ksi)*
1, 2 & 3 *(2006)*	400/560 (41/57, 58/82)	305 (31, 44)	22	400 (41, 58)
1Y [1], 2Y, 3Y & 4Y	490/660 (50/67, 71/95)	375 (38, 54)	22	490 (50, 71)
2Y400, 3Y400 & 4Y400	510/690 (52/70, 74/100)	400 (41, 58)	22	510 (52, 74)
XYQ420 [4]	530/680 54/69, 77/98)	420 (43,61)	20	530 (54, 77)
XYQ460 [4]	570/720 (58/73, 83/104)	460 (47, 67)	20	570 (58, 83)
XYQ500 [4]	610/770 (62/78, 88/112)	500 (51, 73)	18	610 (62, 88)
XYQ550 [4]	670/830 (68/85, 97/120)	550 (56, 80)	18	670 (68, 97)
XYQ620 [4]	720/890 (73/91, 104/129)	620 (63, 90)	18	720 (73, 104)
XYQ690 [4]	770/940 (78/96, 112/136)	690 (70, 100)	17	770 (78, 112)

Abbreviations:

MW:	Covered Electrode for Manual Welding	A:	Automatic
WF:	Wire-flux Combination	M:	Multi-run
WG:	Wire-gas Combination	T:	Two run*[2]
ESEG:	Electroslag or Electrogas	TM:	Two run & Multi-run*[2]
SA:	Semi-automatic	DM:	Deposited Metal Test
		BW:	Butt Weld Test

Notes:

1 Grade 1Y not applicable to MW and WG/SA.

2 Two run not applicable to YQ Grades.

3 X = 3, 4 or 5. See 2-A2-1/Table 2. (1999)

4 *(2006)* Specifications for high strength quenched and tempered steels, for which these XYQ grades of welding consumables are intended, may be found in Appendix 3-1-A3, "Guide for Material Selection for ABS Grades of High Strength Quenched and Tempered Steel" of the ABS *Rules for Building and Classing Mobile Offshore Drilling Units*.

TABLE 2
Impact Test Requirements *(2006)*

There are two levels of energy requirements depending upon the particular combination of weld process, types of required test and, where applicable, welding position.

To find the required energy, first locate under "process" column the welding process for which the filler metal is intended (e.g., wire-gas, semi automatic). Then locate in that line under "applicable test" column the test/position in question (e.g., BW/F). The required energy is found in the box under the particular test/position combination for respective grade (47J for the example chosen if it is Grade 2Y or 3Y).

Process		*Applicable Tests*	
MW		DM, BW/F/H/OH	BW/V
WF		—	DM, BW
WG/SA		DM, BW/F/H/OH	BW/V
WG/A		—	DM, BW
ESEG		—	BW/V
Required Temperature/Energy			
Grade	*Temp °C (°F)*	*Av. Absorbed Energy J (kgf-m, ft-lbf)*	*Av. Absorbed Energy J (kgf-m, ft-lbf)*
1	20 (68)	47 (4.8, 35)	34 (3.5, 25)
2	0 (32)	47 (4.8, 35)	34 (3.5, 25)
3	-20 (-4)	47 (4.8, 35)	34 (3.5, 25)
1Y [1]	20 (68)	See Note 1	34 (3.5, 25)
2Y	0 (32)	47 (4.8, 35)	34 (3.5, 25)
3Y	-20 (-4)	47 (4.8, 35)	34 (3.5, 25)
4Y	-40 (-40)	47 (4.8, 35)	34 (3.5, 25)
2Y400	0 (32)	47 (4.8, 35)	41 (4.2, 30)
3Y400	-20 (-4)	47 (4.8, 35)	41 (4.2, 30)
4Y400	-40 (-40)	47 (4.8, 35)	41 (4.2, 30)
XYQ420 [2]	-20 (-4) X=3 -40 (-40) X=4 -60 (-76) X=5	47 (4.8, 35)	47 (4.8, 35)
XYQ460 [2]		47 (4.8, 35)	47 4.8, 35)
XYQ500 [2]		50 (5.1, 37)	50 (5.1, 37)
XYQ550 [2]		55 (5.6, 41)	55 (5.6, 41)
XYQ620 [2]		62 (6.3, 46)	62 (6.3, 46)
XYQ690 [2]		69 (7.0, 51)	69 (7.0, 51)
Alternate Temperature and Energy			
3	-10 (14)	61 (6.2, 45)	44 (4.5, 33)
1Y	10 (50)	—	40 (4.1, 30)
1Y	0 (32)	27 (2.8, 20)	—
2Y	-10 (14)	—	27 (2.8, 20)
2Y	-20 (-4)	27 (2.8, 20)	—
3Y	-10 (14)	68 (6.9, 50)	52 (5.3, 38)
3Y	-30 (-22)	—	27 (2.8, 20)
3Y	-40 (-40)	27 (2.8, 20)	—

Notes:

1 Grade 1Y not applicable to MW and WG/SA.

2 *(2006)* Specifications for high strength quenched and tempered steels, for which these XYQ grades of welding consumables are intended, may be found in Appendix 3-1-A3, "Guide for Material Selection for ABS Grades of High Strength Quenched and Tempered Steel" of the ABS *Rules for Building and Classing Mobile Offshore Drilling Units*.

Abbreviations:-

F: Flat

V: Vertical

(See also 2-A2-1/Table 1.)

PART

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APPENDIX 2 Requirements for the Approval of Filler Metals

SECTION 2 Electrodes for Shielded Metal Arc Welding

1 General

The annual check test shall consist of two deposited metal test assemblies welded and tested in accordance with 2-A2-2/5.

3 Chemical Analysis

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer.

5 Deposited Metal Test Assemblies

5.1 Test Assembly *(2005)*

Two deposited metal test assemblies, as indicated in 2-A2-2/Figure 1, are to be welded in the flat position, one using 4 mm ($^5/_{32}$ in.) electrodes or the smallest size manufactured, whichever is greater, and the other using the largest size manufactured. If an electrode is produced in one size only or if the largest size produced is 4 mm ($^5/_{32}$ in.) or less, one test assembly is sufficient. The weld metal is to be deposited in single or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm ($^5/_{64}$ in.) and not more than 4 mm ($^5/_{32}$ in.) thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3.

5.3 Test Specimens *(1 Oct. 1994)*

One tension and one set of three impact specimens are to be prepared from each deposited metal test assembly, as indicated in 2-A2-2/Figure 1, and the results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade and welding technique.

7 Butt Weld Test Assemblies

7.1 Test Assemblies

One butt weld test assembly, as indicated in 2-A2-2/Figure 2, is to be welded in each position (flat, vertical-up, vertical-down, overhead and horizontal) for which the electrode is recommended by the manufacturer, except that those electrodes meeting the requirements for flat and vertical positions will be considered as also complying with the requirements for the horizontal position. Where the electrode is only to be approved in the flat position, one additional test assembly is to be welded in that position.

7.3 Welding Procedure *(1996)*

In general, the following welding procedure is to be adopted in making the test assemblies:

Flat. First run using 4 mm ($^5/_{32}$ in.) electrodes; remaining runs except last two layers with 5 mm ($^3/_{16}$ in.) or above according to the normal welding practice with the electrodes; the runs of the last two layers with the largest size electrodes manufactured. When a second flat assembly is required, the runs of the last three layers are to be welded with the largest size electrode manufactured.

Horizontal. First pass with 4 mm ($^5/_{32}$ in.) or 5 mm ($^3/_{16}$ in.) diameter electrode. Subsequent passes with 5 mm ($^3/_{16}$ in.) diameter electrode.

Vertical-up and Overhead. The first run with 3.25 mm ($^1/_8$ in.) electrodes; remaining runs with the largest diameter recommended by the manufacturer for the position concerned.

Vertical down. The electrode diameter used is to be as recommended by the manufacturer.

For all assemblies, the back weld is to be made with 4 mm ($^5/_{32}$ in.) electrodes in the welding position appropriate to each test sample, after removing the root run to clean metal. For electrodes suitable only for flat position welding, the test assemblies may be turned over to carry out the back weld.

Normal welding practice is to be used, and between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F) but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After welding, the test assemblies are not to be subjected to any heat treatment.

7.5 Test Specimens *(2008)*

One tension, one face bend, one root bend are to be prepared from each butt weld test assembly together with one set of three impact specimens from the flat and vertical test assemblies, as indicated in 2-A2-2/Figure 2. The results of tension and impact tests are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade, position and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

9 Fillet Weld Test Assemblies

9.1 General *(2005)*

For gravity fillet welding electrodes (including combination gravity/manual electrodes), fillet weld testing is required in addition to deposited metal testing. Butt weld testing is not required. For gravity welding electrodes (including combination gravity/manual electrodes) intended for both fillet and butt welding, fillet weld testing is required in addition to deposited metal and butt weld testing. Gravity welding equipment is to be used in welding fillet weld test assemblies. Such fillet weld tests are to be carried out and tested in accordance with 2-A2-2/9.3 through 2-A2-2/9.7 using gravity welding equipment and the longest size electrode manufactured.

The following applies to SMAW electrodes other than gravity electrodes: An electrode other than YQ Grades is considered approved for fillet welding in position for which the butt weld test of 2-A2-2/7 was satisfactory. Electrodes meeting the flat butt weld requirements will be considered as complying with the requirements for horizontal fillet (HF) welds. Where an electrode is submitted for approval for fillet welds only, the butt weld tests indicated in 2-A2-2/7 may be omitted and fillet weld tests are to be carried out and tested in accordance with 2-A2-2/9.3 through 2-A2-2/9.7.

9.3 Test Assemblies

One fillet weld test assembly, as indicated in 2-A2-2/Figure 3, is to be welded in each position for which the electrode is recommended by the manufacturer.

9.5 Welding Procedure

The length *L* of the fillet test assemblies is to be sufficient to allow for the tests required in 2-A2-2/9.7 and is to provide for at least the deposition of the entire length of the electrode being tested. One side is to be welded using the maximum size electrode manufactured and the second side using the minimum size of electrode manufactured that is recommended for fillet welds. The fillet size will, in general, be determined by the electrode size and the welding current employed during testing. The fillet weld is to be carried out with the longest size electrode using the welding equipment and technique recommended by the manufacturer. The current used while conducting the test, and the manufacturer's recommended current range are to be reported for each electrode size and welding position.

9.7 Test Specimens

9.7.1 Macrographs and Hardness Tests *(1 Oct. 1994)*

Each fillet weld test assembly is to be sectioned, as indicated in 2-A2-2/Figure 3, to form three macro-sections. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity, undercut and slag inclusions. Hardness readings are to be made on each section. The number and location of hardness readings are to approximate those indicated in 2-A2-2/Figure 4. The hardness of the weld is to be determined and is to meet the following listed equivalent values.

Load	*Grade 1, 2, 3*	*Grades Y, Y400 and YQ*
Diamond Pyramid (Vickers) Hardness-10 kg (98 N)	To be reported for information	150 min.
Rockwell B-100 kg (980 N)		80 min.

The hardness of the heat affected zone (HAZ) and base metal are also to be determined and reported for information only.

9.7.2 Breaking Test

One of the remaining sections of the fillet weld is to have the weld, on the side welded first, gouged or machined to facilitate breaking the fillet weld on the other side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the side welded second is to be gouged or machined and the section fractured using the above procedure. The fractured surfaces are to be examined and there is to be no evidence of incomplete penetration or internal cracking and they are to be reasonably free from porosity.

11 Low Hydrogen Approval *(1997)*

11.1 Ordinary-Strength Filler Metals *(1997)*

Electrodes which have satisfied the requirements of Grades 2 and 3 may, at the option of the manufacturer, be subjected to a hydrogen test, as specified in 2-A2-1/23.3. A suffix indicating the hydrogen amount will be added to the grade number of those electrodes to indicate compliance with the hydrogen test requirements specified in 2-A2-1/23.7.

11.3 Higher-Strength Filler Metals *(1997)*

Electrodes which are submitted for approval according to Grades 2Y, 3Y, 4Y, 2Y400, 3Y400 or 4Y400 are to be subjected to a hydrogen test and are to meet the requirement specified in 2-A2-1/23.7 for the H10 suffix. Such suffix, however, will not be added to the grade. Electrodes meeting H5 requirements will be so identified. Electrodes meeting the higher-strength requirements, except for hydrogen test, will require special approval for use on higher strength steel for each user and will be so identified in the list of approved electrodes.

11.5 YQ Grade Filler Metals *(2005)*

Electrodes which are submitted for approval according to YQ Grades are to be subjected to a hydrogen test, as specified in 2-A2-1/23.1. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix will not be added to the grade.

13 Annual Check Tests

13.1 General *(1 October 1993)*

The annual check test shall consist of two deposited metal test assemblies welded and tested in accordance with 2-A2-2/5.

13.3 Upgrading and Uprating *(2008)*

Upgrading of electrodes will be considered at the manufacturer's request. In addition to the two deposited metal tests indicated in 2-A2-2/13.1, a butt weld test assembly is to be welded as indicated in 2-A2-2/7 for each position initially tested, and sets of three impact specimens from each test assembly are to be tested at the upgraded temperature.

Uprating refers to the extension of approval to also cover the welding of higher-strength steels (dual approvals). For this purpose, butt weld tests are to be carried out, as required in 2-A2-1/9.3.3 and 2-A2-2/7. In addition, the diffusible hydrogen test required by the grade or suffix referred to in 2-A2-2/11.1 and 2-A2-2/11.3 is to be conducted.

FIGURE 1
Deposited-Metal Test Assembly for Manual and Gas-Metal Arc Welding

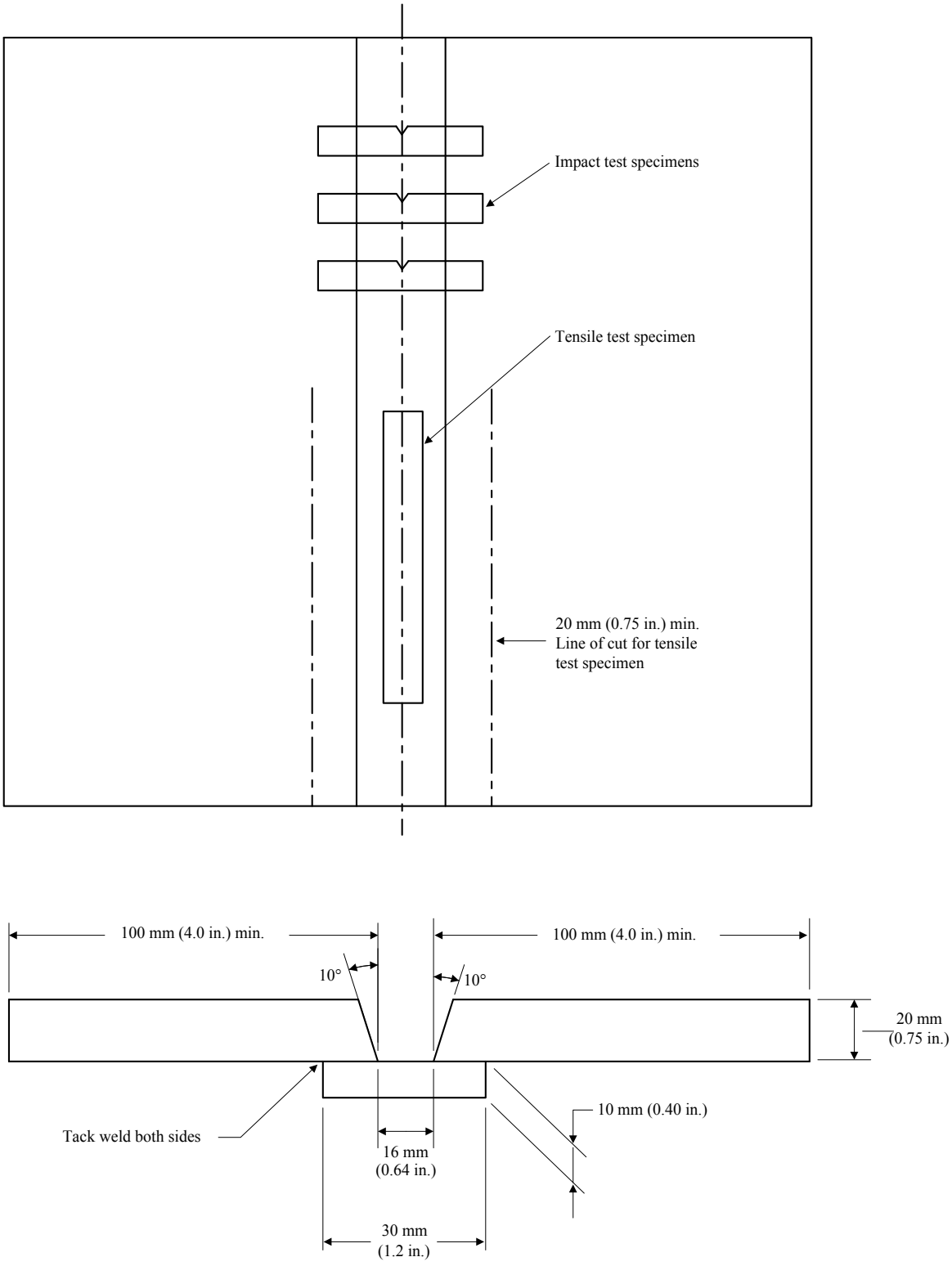


FIGURE 2
Butt-Weld Test Assembly for Manual and Gas-Metal Arc Welding

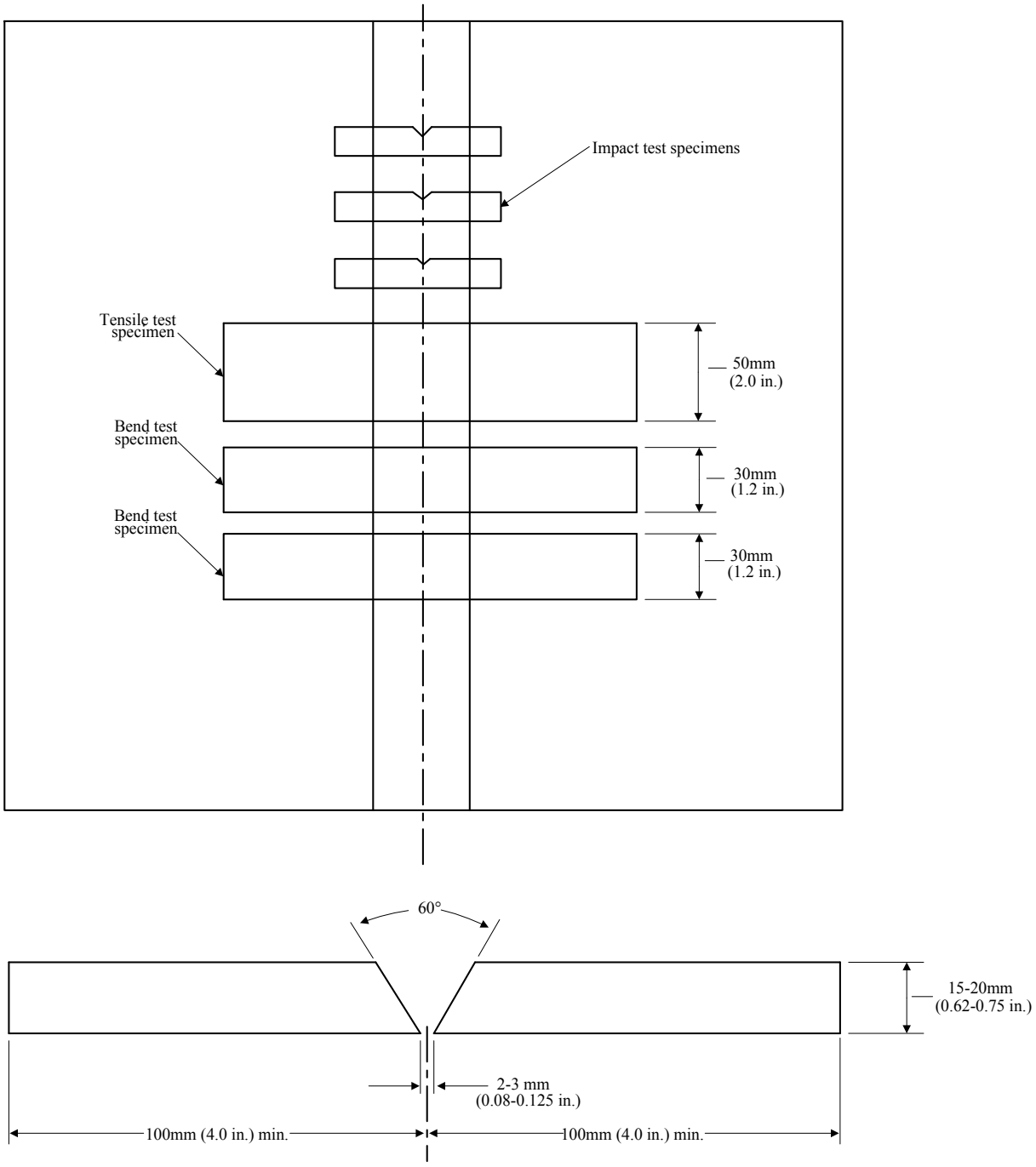


FIGURE 3
Fillet-Weld Test Assembly

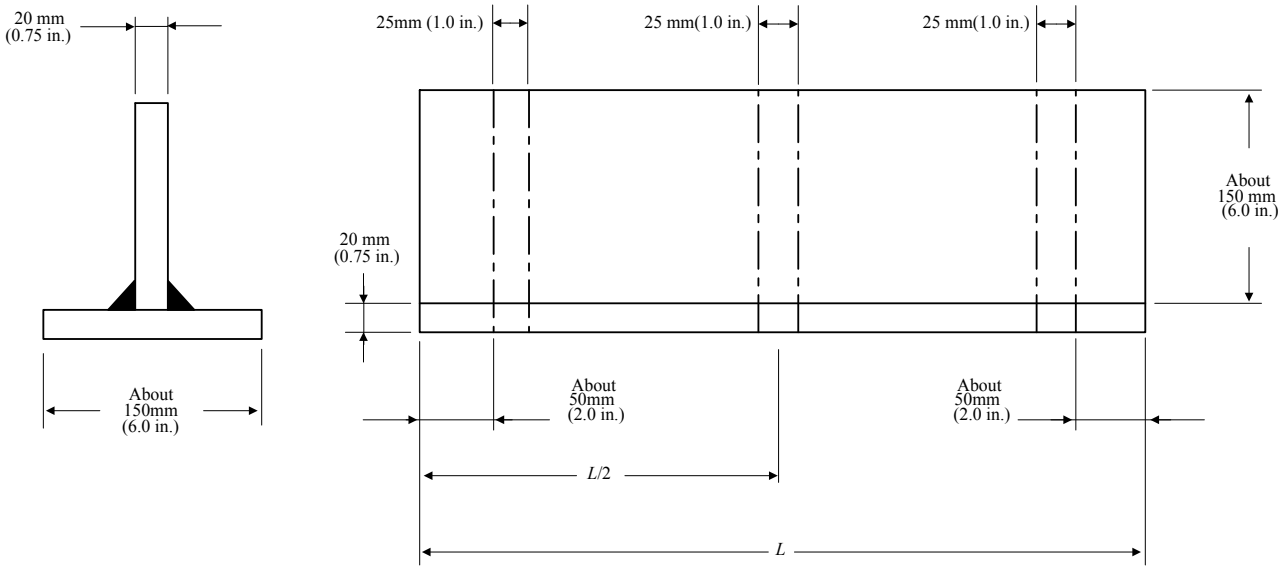
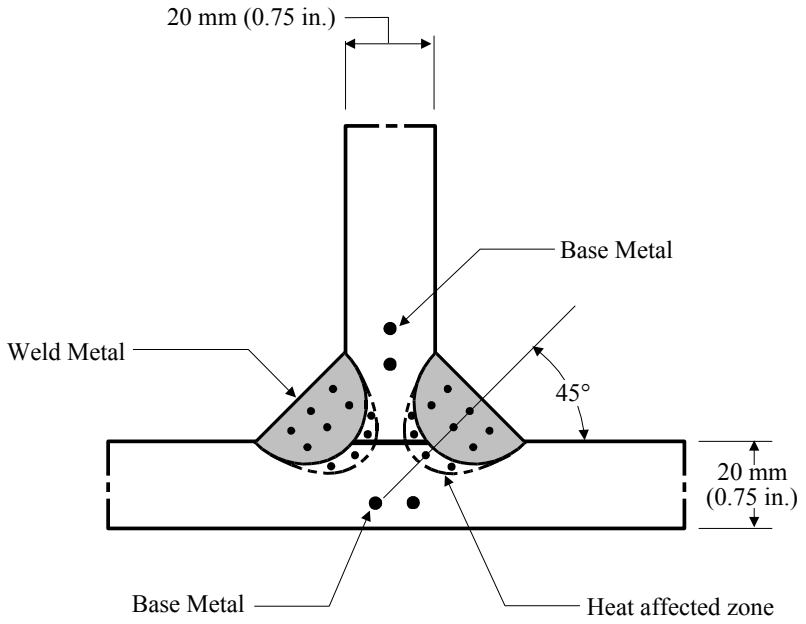


FIGURE 4
Fillet Weld Hardness Test Locations



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PART

2

APPENDIX 2 Requirements for the Approval of Filler Metals

SECTION 3 Wire-Flux Combinations for Submerged Arc Welding

1 General *(1997)*

This test program is intended for the approval of automatic or semi-automatic, single-electrode submerged arc welding. Provisions are made for the testing of weld metal deposited by multi-run and two-run (one pass each side) techniques. For YQ Grades automatic welding, a multi-run technique is contemplated. Application for high heat input process, such as automatic welding two-run technique, may be considered under 2-A2-1/3.5 and approval by a technical office. Where a manufacturer states that a particular wire-flux combination is suitable for welding with both techniques, both series of tests are to be carried out. The suffix **T**, **M**, or **TM** will be added to the grade to indicate two-run technique, multi-run technique, or both techniques, respectively.

3 Chemical Analysis

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer.

5 Deposited Metal Test Assemblies for Multi-run Technique

5.1 Test Assembly *(2005)*

One deposited metal test assembly, as indicated in 2-A2-3/Figure 1, is to be welded in the flat position using the wire size recommended by the manufacturer. The direction of deposition of each run is to alternate from each end of the plate and after completion of each run, the flux and welding slag are to be removed. The thickness of each layer is not to be less than the size of the wire, or 4 mm ($^5/_{32}$ in.), whichever is the greater. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. The welding conditions (amperage, voltage, and travel speed) are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding. The welded test assembly is not to be subjected to heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3.

5.3 Test Specimens *(1 Oct. 1994)*

Two tension and one set of three impact specimens are to be prepared from the deposited metal test assembly, as indicated in 2-A2-3/Figure 1, and the results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade and welding technique.

7 Butt Weld Test Assemblies for Multi-run Technique

7.1 Test Assembly

One butt weld test assembly, as indicated in 2-A2-3/Figure 2, is to be welded in the flat position using the wire size recommended by the manufacturer. The welding conditions are to be essentially the same as those indicated in 2-A2-3/5.1 for deposited metal test assembly. The back weld is to be applied in the flat position after removing the root run to clean metal. After being welded, the test assembly is not to be subjected to any heat treatment.

7.3 Test Specimens

Two tension, two face bend and two root bend together with one set of three impact specimens are to be prepared from the butt weld test assembly, as indicated in 2-A2-3/Figure 2, and the results of tension and impact tests are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

9 Butt Weld Assemblies for Two-run Technique

9.1 Test Assemblies *(2005)*

Two butt weld test assemblies, as indicated in 2-A2-3/Figure 3, are to be welded in the flat position. The maximum size of wire, grades of steel plate, and the edge preparation to be used are also to be in accordance with 2-A2-3/Figure 3. At the request of the manufacturer, small deviations in the edge preparation may be allowed. The root gap is not to exceed 1.0 mm (0.04 in.). Each test assembly is to be welded in two runs, one from each side, using welding conditions (amperage, voltage, and travel speed) which are in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to 100°C (212°F) or less, the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any treatment.

9.3 Test Specimens *(1 Oct. 1994)*

Two tension, one face bend, one root bend, and one set of three impact specimens are to be prepared from each butt weld assembly, as indicated in 2-A2-3/Figure 3 and 2-A2-3/Figure 4, and the results of tension and impact tests are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3. The edges of all test specimens and also the discards are to be examined to ensure complete fusion and interpenetration of the welds.

9.5 Longitudinal All-Weld-Metal Tension Test *(1 Oct. 1994)*

Where the combination is to be approved for two-run technique only, one longitudinal all-weld-metal tension specimen is to be cut from the thicker butt weld test assembly, as indicated in 2-A2-3/Figure 3, and machined to the dimensions indicated in 2-A2-1/Figure 1, care being taken that the longitudinal axis coincides with the center of the weld and is approximately 7 mm (0.28 in.) below the plate surface on the side from which the second run is made. The test specimen may be subjected to a temperature not exceeding 250°C (482°F) for up to 16 hours for hydrogen removal, prior to testing. The results of the tests are to conform to the requirements of 2-A2-1/Table 1.

11 Fillet Weld Tests

Where a wire-flux combination is submitted for approval for fillet welds only, then the butt weld tests may be omitted, and fillet weld tests are to be carried out and tested in accordance with the applicable parts of 2-A2-4/11.3 to 2-A2-4/11.7.

13 Low Hydrogen Approval *(1997)*

13.1 YQ Grade Wires – Flux Combination *(2005)*

All wire-flux combination of this grade are to be submitted to the diffusible hydrogen test, as required by 2-A2-1/23.1. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix will not be added to the grade.

15 Annual Check Tests

15.1 General *(1996)*

The annual check tests for each approved technique shall consist of the following.

Multi-run Technique. One deposited metal test assembly is to be welded in accordance with 2-A2-3/5.1. One tension and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-3/5.3.

Two-run Technique. One butt weld test assembly of 20 mm (0.75 in.) thickness is to be welded in accordance with 2-A2-3/9.1. One transverse tension, one face bend, one root bend, and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-3/9.3 and 2-A2-3/9.5. One longitudinal tension test specimen is also to be prepared where wire-flux combination is approved solely for the two-run technique.

15.3 Upgrading and Uprating *(2008)*

Upgrading of wire-flux combinations will be considered at the manufacturer's request. For multi-run technique, in addition to the deposited metal test indicated in 2-A2-3/15.1, one butt weld test assembly is to be welded, as indicated in 2-A2-3/7, and one set of three impact specimens is to be tested at the upgraded temperature. For the two-run technique, butt weld testing is to be carried out as indicated in 2-A2-3/15.1, except the test assembly is to be fabricated using the maximum thickness approved.

Uprating refers to the extension of approval to also cover welding of higher-strength steels (dual approvals). For this purpose butt weld tests are to be carried out as required in 2-A2-3/7 and 2-A2-3/9, and 2-A2-1/9.3.3, as applicable.

17 Multiple Electrodes

Wire-flux combinations for multiple electrode submerged arc welding will be subject to separate approval tests. They are to be carried out generally in accordance with the requirements of this section.

19 Electroslag Welding *(1996)*

19.1 General *(1997)*

Where approval is requested for wire-flux combinations other than YQ Grades, (with or without consumable nozzles) for use in electroslag welding, two test assemblies of 20–25 mm (0.75–1.0 in.) and 35–40 mm (1.38–1.58 in.) or more in thickness are to be prepared with a minimum root opening of 16 mm (0.63 in.), or with another joint design sufficient to allow the selection of the following test specimens. The chemical composition of the plates including the content of grain refining elements is to be reported.

- 2 longitudinal tension specimens from the axis to the weld,
- 2 transverse tension specimens,
- 2 side bend specimens,
- 3 Charpy-V specimens notched at the center of the weld,
- 3 Charpy-V specimens with their notches in the weld metal at 2 mm ($^5/_{64}$ in.) from the fusion line,
- 2 macro-sections.

The results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2, according to the applicable grade and welding technique.

19.3 Annual Tests *(1996)*

One butt test assembly of 20–25 mm (0.75–1.0 in.) or more in thickness is to be prepared. One longitudinal tension, one transverse tension, two side bend and two sets of three Charpy V-notch specimens are to be prepared and tested. The notch of the impact specimens is to be located at the center of the weld and 2 mm (0.08 in.) from the fusion line in the weld. One macro-section is also to be examined.

The test results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2, according to the applicable grade and welding technique.

19.5 Upgrading and Uprating *(1996)*

Upgrading and uprating will be considered at the manufacturer's request. Full tests as indicated in 2-A2-3/19.1 will be required.

The test results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2, according to the applicable grade and welding technique.

FIGURE 1
Deposited-Metal Test Assembly for Submerged Arc Welding – Multi-run Technique and Automatic Gas-Metal Arc Welding

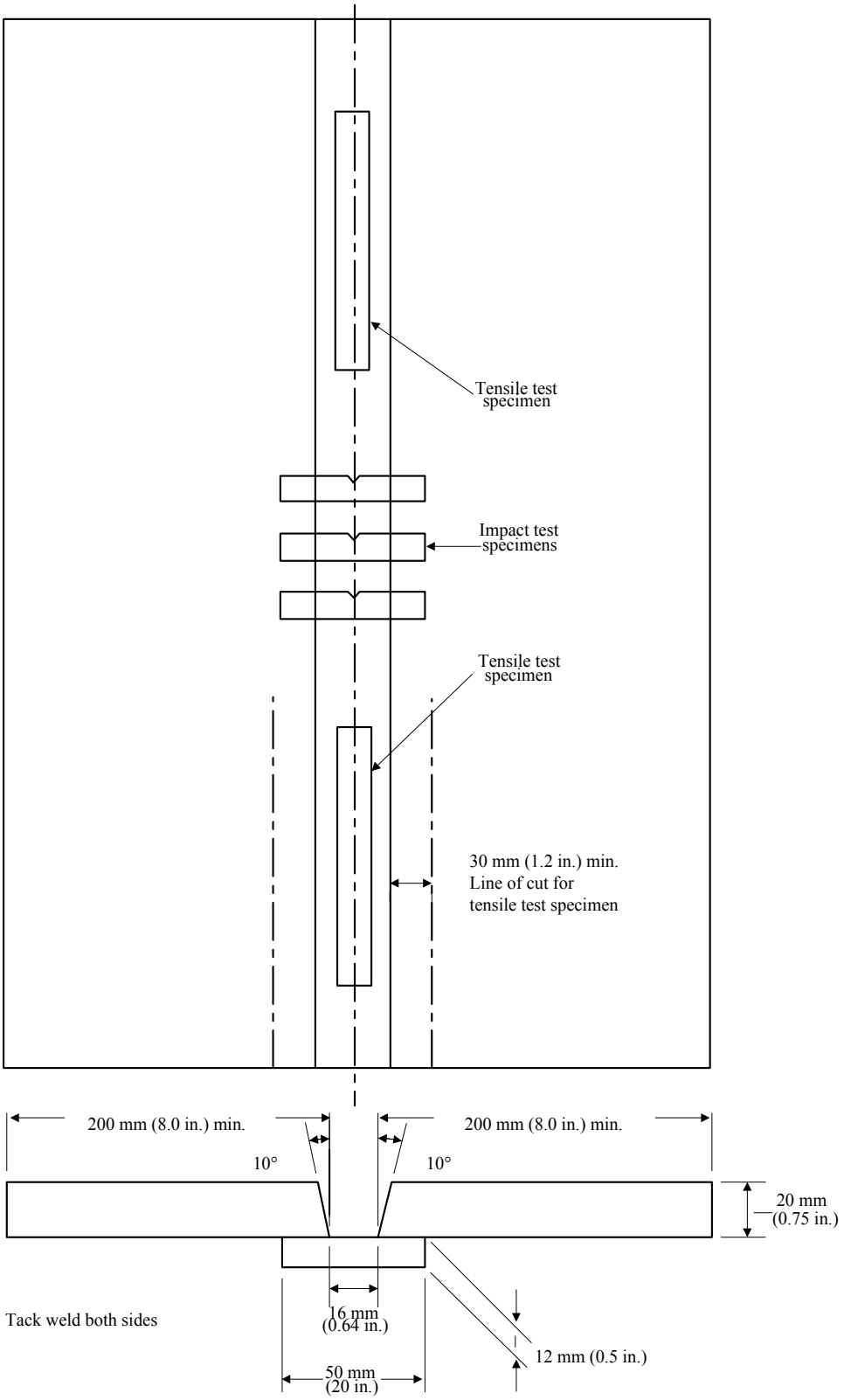


FIGURE 2
Butt-Weld Test Assembly for Submerged Arc Welding – Multi-run Technique *(2008)*

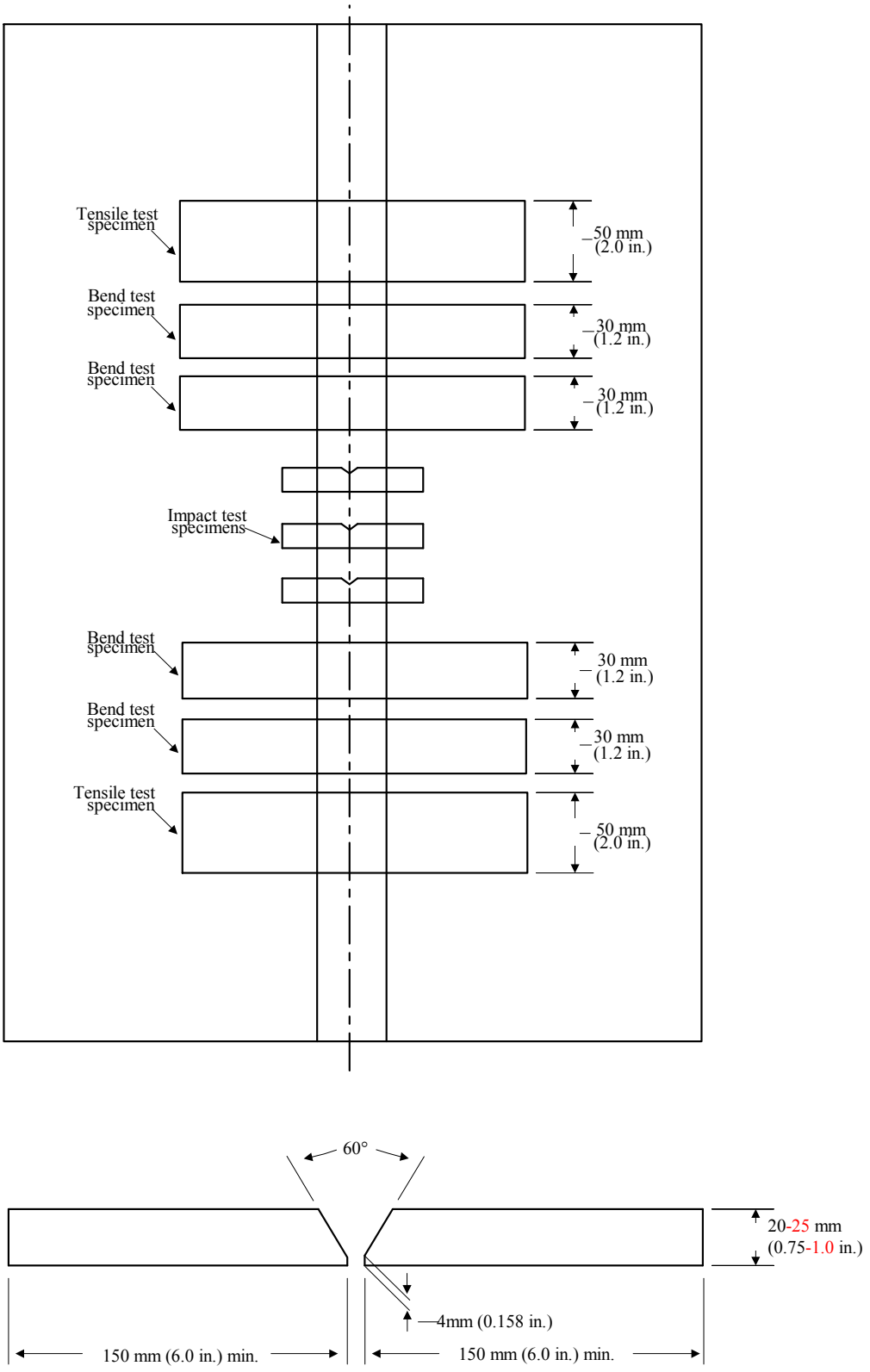


FIGURE 3
Butt-Weld Test Assembly for Submerged Arc Welding – Two-run Technique *(1997)*

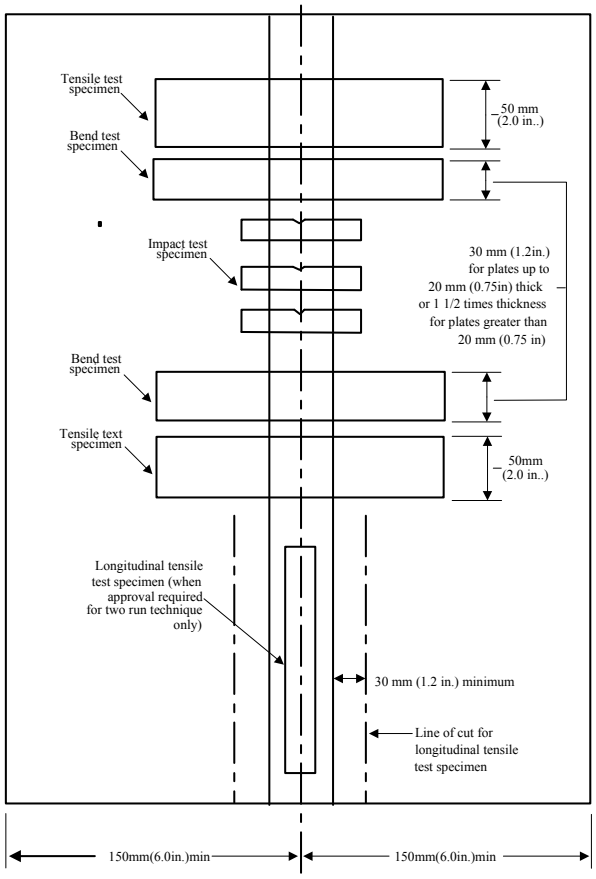
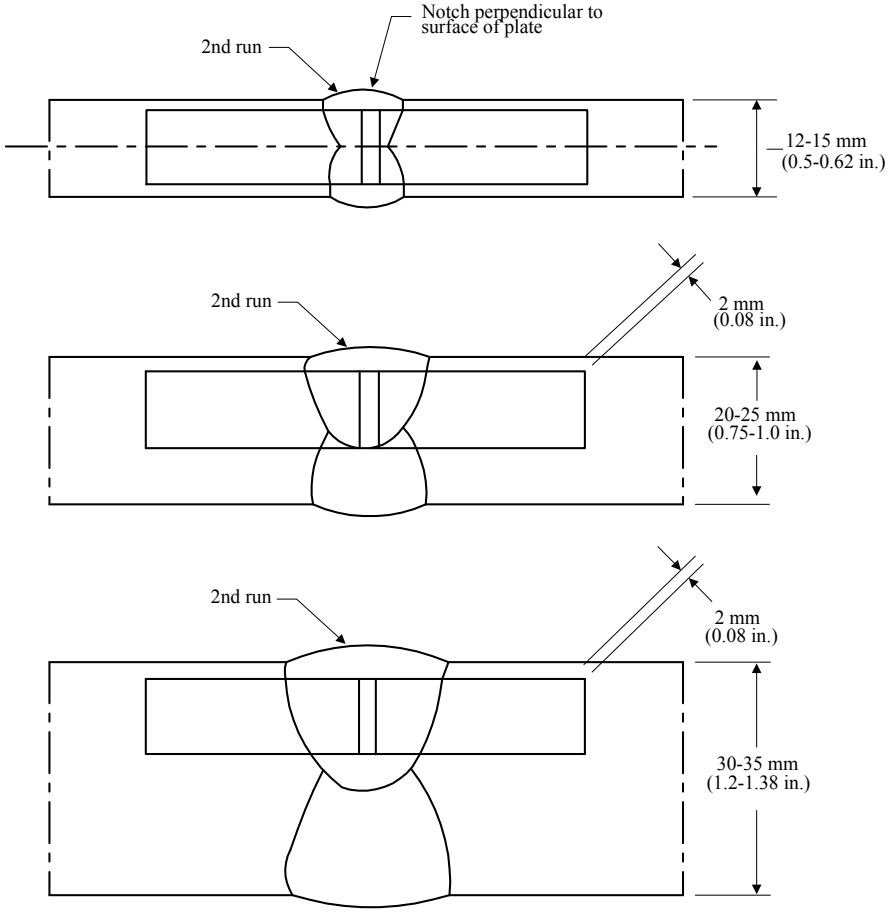


Plate Thickness	*Preparation*	*Maximum sizes of Wire*	*Grades of Steel*		
			Wire Flux Grade	*Ordinary Strength*	*Higher Strength*
12-15 mm (0.5-0.62 in.)		5 mm (0.20 in.)	1, 1Y	A	AH32/36
20-25mm (0.75-1.0 in.)	60° 8-12mm (0.32-0.50in.)	6 mm (0.25 in.)	1, 1Y	A	AH332/36
			2, 2Y	A/B/D	AH/DH32/36
			2Y400	-	AH/DH40
			3, 3Y	A/B/D/E	AH/DH/EH32/36
			3Y400	-	AH/DH/EH40
			4Y	-	AH/DH/EH/FH32/36
			4Y400	-	AH/DH/EH/FH40
30-35 mm (1.2-1.38 in.)	70° 6-14mm (0.24-0.55in.)	7 mm (0.28 in.)	2, 2Y	A/B/D	AH/DH32/36
			2Y400	-	AH/DH40
			3, 3Y	A/B/D/E	AH/DH/EH32/36
			3Y400	-	AH/EH/EH40
			4Y	-	AH/DH/EH/FH32/36
			4Y400	-	AH/DH/EH/FH40

FIGURE 4
Butt-Weld Impact Specimen Location for Submerged and Gas-Metal Arc Welding – Two-run Technique



PART

2

APPENDIX 2 **Requirements for the Approval of Filler Metals**

SECTION 4 **Wire and Wire Gas Combinations for Gas Metal Arc Welding and Flux Cored Wires for Flux Cored Arc Welding**

1 General *(1997)*

This test program is intended for the approval of wire-gas combinations and flux cored wires with or without shielding gas intended for semi-automatic or automatic arc welding techniques. For both techniques, the welding gun provides continuous wire feed; for semi-automatic welding, the welding gun is held manually, and for automatic welding, the welding gun is machine held with various degrees of controlled motion provided by the machine. The impact requirements for the semi-automatic welding technique and those for the automatic welding technique are indicated separately in 2-A2-1/Table 1 and 2-A2-1/Table 2, according to the applicable grade. The suffix **SA** will be added to the grade to indicate approval for manual semi-automatic or machine-automatic gas-metal arc welding. The suffix **A** will be added to the Grade to indicate approval for machine automatic welding only. An additional suffix **T** will be added to the grade to indicate approval for two-run (one pass each side) technique for machine automatic welding. Wire-gas combinations and flux cored wires approved for semi-automatic welding may be used for automatic welding under the procedure recommended by the manufacturer, except that for the two-run automatic technique, testing in accordance with 2-A2-4/9 is required. For YQ Grades semi-automatic or automatic welding, a multi run technique is contemplated. Application for high heat input process, such as semi-automatic or automatic welding two-run technique, may be considered under 2-A2-1/3.5 and approval by the technical office.

3 Chemical Analysis and Shielding Gas Compositions *(2008)*

The chemical analysis of the deposited weld metal is to be supplied by the manufacturer. The trade name of the shielding gas, when used, as well as its composition, is to be reported. The approval of a wire in combination with any particular gas can be applied or transferred to any combination of the same wire and any gas in the same numbered group as defined in 2-A2-4/Table 1.

TABLE 1
Compositional Limits of Designated Groups of Gas Types and Mixtures *(2008)*

Group		*Gas composition (Vol. %)*			
		CO_2	O_2	H_2	*Ar*
M1	1	>0 to 5	--	>0 to 5	Rest (1, 2)
	2	>0 to 5	--	--	Rest (1, 2)
	3	--	>0 to 3	--	Rest (1, 2)
	4	>0 to 5	>0 to 3	--	Rest (1, 2)
M2	1	>5 to 25	--	--	Rest (1, 2)
	2	--	>3 to 10	--	Rest (1, 2)
	3	>5 to 25	>0 to 8	--	Rest (1, 2)
M3	1	>25 to 50	--	--	Rest (1, 2)
	2	--	>10 to 15	--	Rest (1, 2)
	3	>5 to 50	>8 to 15	--	Rest (1, 2)
C	1	100	--	--	--
	2	Rest	>0 to 30	--	--

Notes:

1 Argon may be substituted by Helium up to 95% of the Argon content.

2 Approval covers gas mixtures with equal or higher Helium contents only.

5 Deposited Metal Test Assemblies for Semi-automatic and Automatic Testing

5.1 Semi-automatic Test Assemblies *(2005)*

Two deposited metal test assemblies, as indicated in 2-A2-2/Figure 1, are to be welded in the flat position, one using 1.2 mm (0.045 in.) wire or the smallest size manufactured, whichever is greater, and the other using 2.4 mm ($^3/_{32}$ in.) wire or the largest size manufactured. If a wire is produced in one size only or if the largest size produced is 1.2 mm (0.045 in.) or less, one test assembly is sufficient. The weld metal is to be deposited in single or multi-run layers according to recommended practice and the thickness of each layer of weld metal is to be between 2 mm ($^5/_{64}$ in.) and 6 mm ($^{15}/_{64}$ in.). Between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3.

5.3 Test Specimens for Semi-automatic

One tension and one set of three impact specimens are to be prepared from each deposited metal test assembly, as indicated in 2-A2-2/Figure 1, and the results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade.

5.5 Automatic Test Assembly *(2008)*

For automatic welding one test assembly, as indicated in 2-A2-3/Figure 1, is to be welded in the flat position using 2.4 mm ($^3/_{32}$ in.) wire or the largest size manufactured. The thickness of each layer is not to be less than 3 mm ($^1/_8$ in.). Between each run, the assembly is to be left in still air until it has cooled to 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assembly is not to be subjected to any heat treatment, except hydrogen removal, as permitted in 2-A2-1/15.3

5.7 Test Specimens for Automatic

Two tension and one set of three impact specimens are to be prepared from the test assembly, as indicated in 2-A2-3/Figure 1, and the results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade.

7 Butt Weld Test Assemblies for Semi-automatic and Automatic Techniques

7.1 Test Assemblies

One butt weld test assembly, as indicated in 2-A2-2/Figure 2, is to be welded in each position (flat, vertical-up, vertical-down, overhead, and horizontal) for which the wire is recommended by the manufacturer, except that wires meeting the requirements for flat and vertical positions will be considered as also complying with the requirements for horizontal position. Where the wire is only to be approved in the flat position, one additional test assembly is to be welded in that position.

7.3 Welding Procedure *(2005)*

In general, the following welding procedure is to be adopted in making the test assemblies:

Flat. First run using 1.2 mm (0.045 in.) wire or the smallest size manufactured, whichever is greater; remaining runs with 2.4 mm ($^3/_{32}$ in.) wire or the largest size manufactured. Where a second flat assembly is required, it is to be prepared using wires of different sizes.

Vertical-up, Vertical-down, Overhead and Horizontal. First run with 1.2 mm (0.045 in.) wire or the smallest size manufactured, whichever is greater; remaining runs using the largest size wire recommended by the manufacturer for the position involved.

In all cases, the back weld is to be made with 1.2 mm (0.045 in.) wire or the smallest size manufactured, whichever is greater, after removing the root run to clean metal. Normal welding practice is to be used and between each run, the assembly is to be left in still air until it has cooled to less than 250°C (482°F), but not below 100°C (212°F), the temperature being taken in the center of the weld on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment.

7.5 Test Specimens *(2005)*

One tension, one face bend, one root bend, and one set of three impact specimens are to be prepared from each butt-weld test assembly, as indicated in 2-A2-2/Figure 2. The results of tension and impact tests are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade, position and welding technique. The results of bend tests are to meet the requirements of 2-A2-1/21.3.

9 Butt Weld Test Assemblies for Two-run Technique

9.1 Test Assemblies

Two butt weld test assemblies, as indicated in 2-A2-4/Figure 1, are to be welded in the flat position. One test assembly is to be welded using 1.2 mm (0.045 in.) wire or the smallest size manufactured, whichever is greater and one test assembly using 2.4 mm ($^3/_{32}$ in.) wire or the largest size wire recommended by the manufacturer for two-run technique. Each test assembly is to be welded in two runs, one from each side. Between each run, the assembly is to be left in still air until it has cooled to 100°C (212°F), the temperature being taken in the center of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment.

9.3 Test Specimens *(1996)*

Two tension, one face bend, one root bend and one set of three impact specimens are to be prepared from each butt weld test assembly, as indicated in 2-A2-4/Figure 1 and 2-A2-3/Figure 4. If approval is requested for welding plate thicker than 25 mm (1.0 in.), one assembly is to be prepared using plates approximately 20 mm (0.75 in.) in thickness and the other using plates of the maximum thickness for which approval is requested. For assemblies using plates over 25 mm (1.0 in.) in thickness, the edge preparation is to be reported for information. The results of tension and impact tests are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade. The results of bend tests are to meet the requirements of 2-A2-1/21.3. The edges of all test specimens and also the discards are to be examined to ensure complete fusion and interpenetration of the welds.

9.5 Longitudinal All-Weld-Metal Tension Test

Where the wire is to be approved for two-run technique only, one longitudinal all-weld-metal tension specimen is to be cut from the thicker butt weld test assembly, as indicated in 2-A2-4/Figure 1, and machined to the dimensions indicated in 2-A2-1/Figure 1, care being taken that the longitudinal axis coincides with the center of the weld and is about 7 mm (0.28 in.) below the plate surface on the side from which the second run is made. The test specimen may be subjected to a temperature not exceeding 250°C (482°F) for a period not exceeding 16 hours for hydrogen removal, prior to testing. The results of the test are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2 for the applicable grade.

11 Fillet Weld Tests

11.1 General

A wire-gas combination or flux cored wire is considered approved for fillet welding in the welding position for which the butt weld test of 2-A2-4/7 was satisfactory. A wire-gas combination or flux cored wire meeting the flat butt weld requirements will be considered as complying with the requirements for horizontal fillet (HF) welds. Where a wire-gas combination or a flux cored wire is submitted for approval for fillet welding only, the butt weld tests indicated in 2-A2-4/7 and 2-A2-4/9 may be omitted, and fillet weld tests are to be carried out and tested in accordance with 2-A2-4/11.3 and 2-A2-4/11.5.

11.3 Test Assemblies

One fillet weld test assembly, as indicated in 2-A2-2/Figure 3, is to be welded in each welding position for which the wire is recommended by the manufacturer.

11.5 Welding Procedure

The length L of the fillet weld test assemblies is to be sufficient to allow for the tests prescribed in 2-A2-2/9.5. One side is to be welded using the maximum size wire manufactured and the second side is to be welded using the minimum size wire manufactured and recommended for fillet welding. The fillet size will in general be determined by the wire size and the welding current employed during testing. The fillet welding is to be carried out with the welding equipment and technique recommended by the manufacturer. The manufacturer's recommended current range is to be reported for each wire size and welding position.

11.7 Test Requirements

The results of hardness and breaking tests are to meet the requirements of 2-A2-2/9.7.

13 Low Hydrogen Approval

13.1 Flux Cored Wire

13.1.1 Welding Conditions for Test Assemblies *(2005)*

When flux cored wires undergo diffusible hydrogen testing as indicated in 2-A2-4/13.1.2, 2-A2-4/13.1.3 and 2-A2-4/13.1.4 below, the following apply unless otherwise specified by the diffusible hydrogen test standard. Welding of diffusible hydrogen test assemblies is to be carried out using the same welding conditions (including contact tip to work distance) that were used in welding the deposited metal test assembly. The travel speed may be adjusted to give a weight of weld deposit per sample similar to manual electrodes.

13.1.2 Ordinary Strength Wires *(2005)*

A flux-cored wire which has satisfied the requirements of grade 2 or 3 may, at the manufacturer's option, be submitted to the diffusible hydrogen test, as detailed in 2-A2-1/23.3 or 2-A2-1/23.5. A suffix indicating the hydrogen amount will be added to the grade number to indicate compliance with the hydrogen test requirements specified in 2-A2-1/23.7.

13.1.3 YQ-Grade Wires *(2005)*

All flux-cored wires of this grade are to be submitted to the diffusible hydrogen test, as required by 2-A2-1/23.1. The YQ420/460/500 grades meeting the H5 requirements will be so identified. Otherwise, the H-suffix will not be added to the grade.

13.1.4 Higher Strength Wires *(2005)*

Flux-cored wires submitted for approval according to Grades 2Y, 3Y, 4Y, 2Y400, 3Y400 or 4Y400 are to be subjected to a hydrogen test, as detailed in 2-A2-1/23.3 or 2-A2-1/23.5. Diffusible hydrogen test results are to meet the requirement specified in 2-A2-1/23.7 for the H15 suffix. Such suffix, however, will not be added to the grade. Flux cored wires meeting H5 or H10 requirements will be so identified. Electrodes meeting the higher-strength requirements, except for the hydrogen test, will require special approval for use on higher strength steel for each user and will be so identified in the list of approved consumables.

15 Annual Check Tests

15.1 General *(1 October 1993)*

The annual check tests for each approved technique shall consist of the following:

Semi-automatic and Automatic. One deposited metal test assembly is to be welded using 2.4 mm ($^3/_{32}$ in.) wire or the largest size manufactured in accordance with 2-A2-4/5.1 or 2-A2-4/5.5 as applicable. One tension and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-4/5.3 or 2-A2-4/5.7, as applicable.

Two-run Automatic Technique. One butt weld test assembly of 20 mm (0.75 in.) thickness is to be welded using 2.4 mm ($^3/_{32}$ in.) or the largest size manufactured in accordance with 2-A2-4/9.1. One longitudinal tension, one face bend, one root bend and one set of three impact specimens are to be prepared and tested in accordance with 2-A2-4/9.3 and 2-A2-4/9.5. A longitudinal tension test will not be required for wires also approved for multi-run technique.

15.3 Upgrading and Uprating *(2008)*

Upgrading of wire-gas combinations and flux cored wires will be considered at the manufacturer's request. For semi-automatic and automatic welding, in addition to the deposited metal test indicated in 2-A2-4/15.1, a butt weld test assembly is to be welded as indicated in 2-A2-4/7 for each position initially tested, and sets of three impact specimens from each test assembly are to be tested at the upgraded temperature.

Uprating refers to the extension of approval to also cover welding of higher-strength steels (dual approvals). For this purpose butt weld tests are to be carried out as required in 2-A2-4/7 or 2-A2-4/9, and 2-A2-1/9.3.3, as applicable. In addition, the diffusible hydrogen test required by the grade or suffix referred to 2-A2-4/13.1.2 and 2-A2-4/13.1.4 is to be conducted.

17 Electrogas Welding *(1996)*

17.1 General *(1997)*

Where approval is requested for wire-gas combinations other than YQ Grades, (with or without consumable nozzles or self-shielding gas) for use in electrogas welding, two test assemblies of 20-25 mm (0.75-1.0 in.) and 35-40 mm (1.38-1.58 in.) or more in thickness are to be prepared with a minimum root opening of 16 mm (0.63 in.), or with another joint design sufficient to allow the selection of the following test specimens. The chemical composition of the plates including the content of grain refining elements is to be reported.

- 2 longitudinal tension specimens from the axis to the weld.
- 2 transverse tension specimens,
- 2 side bend specimens,
- 3 Charpy-V specimens notched at the center of the weld,
- 3 Charpy-V specimens with their notches in the weld metal at 2 mm ($^5/_{64}$ in.) from the fusion line,
- 2 macro-sections.

The results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2, according to the applicable grade and welding technique.

17.3 Annual Tests *(1996)*

One butt test assembly of 20–25 mm (0.75–1.0 in.) or more in thickness is to be prepared. One longitudinal tension, one transverse tension, two side bend and two sets of three Charpy V-notch specimens are to be prepared and tested. The notch of the impact specimens is to be located at the center of the weld and 2 mm (0.08 in.) from the fusion line in the weld. One macro-section is also to be examined.

The test results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2, according to the applicable grade and welding technique.

17.5 Upgrading and Uprating *(1996)*

Upgrading and uprating will be considered at the manufacturer's request. Full tests as indicated in 2-A2-4/17.1 will be required.

The test results are to conform to the requirements of 2-A2-1/Table 1 and 2-A2-1/Table 2, according to the applicable grade and welding technique.

FIGURE 1
Butt-Weld Test Assembly for Gas-Metal Arc Welding – Two-run Technique

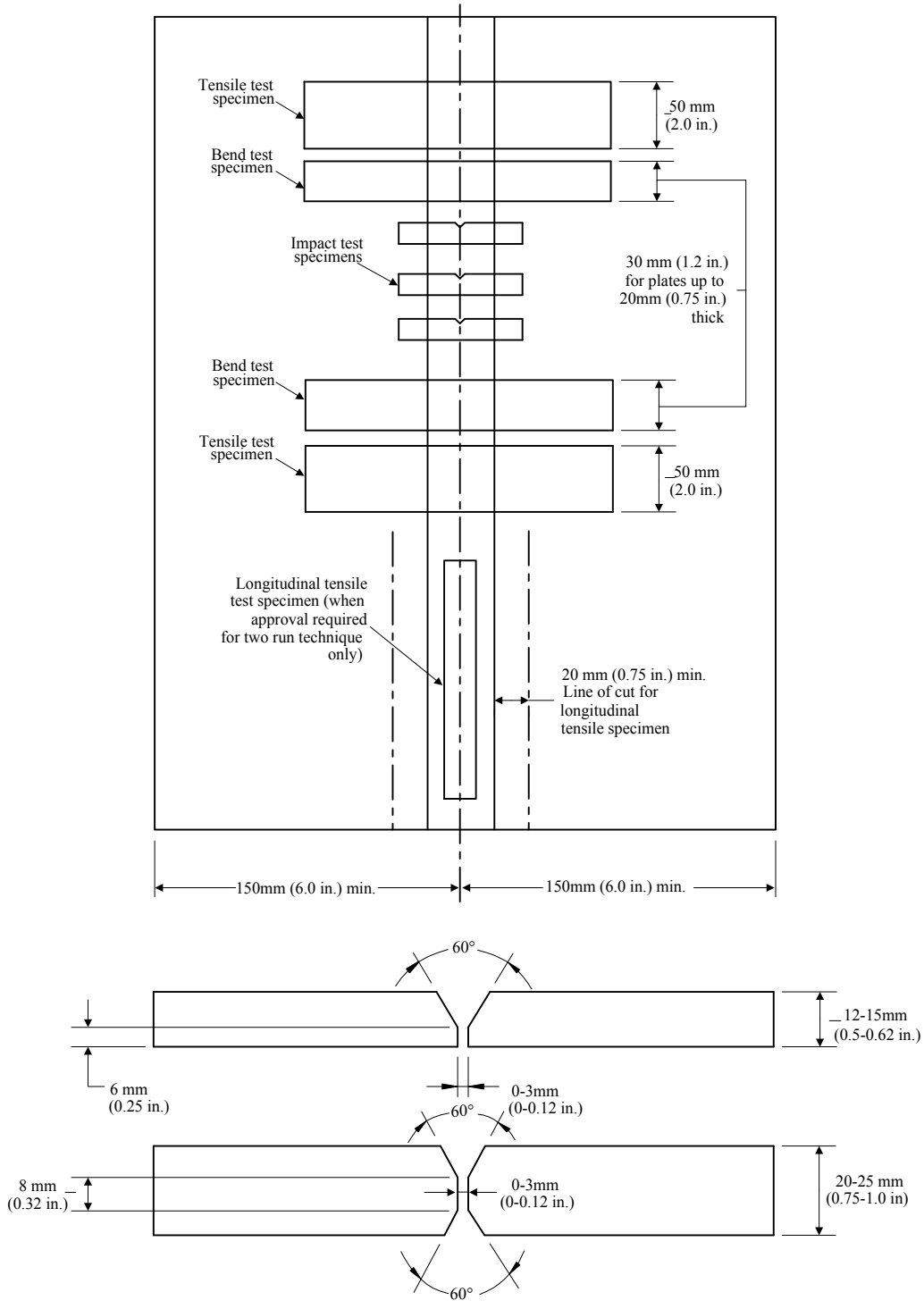
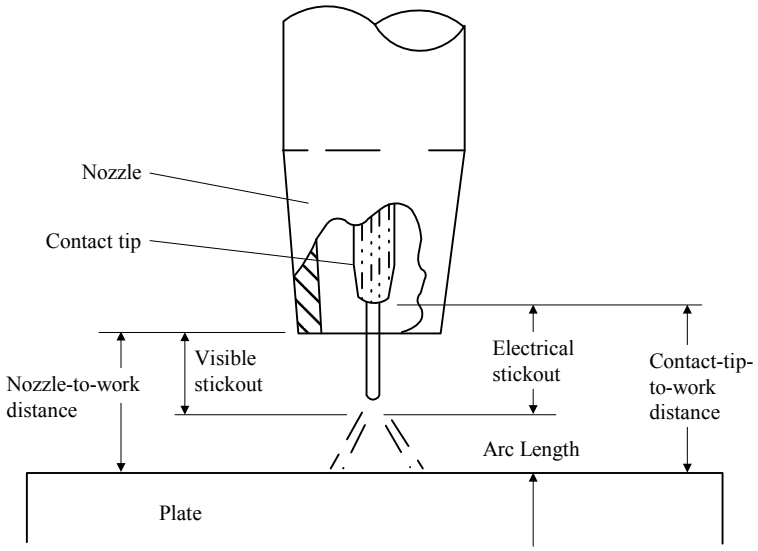


FIGURE 2
Contact Tip to Work Distance *(2005)*



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PART

2

Rules for Welding and Fabrication

APPENDIX 3 Application of Filler Metals to ABS Steels *(1997)*

A chart indicating acceptable ABS filler metal grades for welding various ABS grades of hull steel is given below.

ABS Hull Structural Steel	*Acceptable ABS Filler Metal Grade*
Ordinary Strength	
A to 12.5 mm (1/2 in.) inclusive	1, 2, 3, 1Y**, 2Y, 3Y, 4Y
A over 12.5 mm (1/2 in.), B, D	2, 3, 2Y, 3Y, 4Y
E	3, 3Y, 4Y
*Higher Strength	
AH 32/36 to 12.5 mm (1/2 in.) inclusive	1Y, ** 2Y, 2Y400, 3Y, 3Y400, 4Y, 4Y400
AH 32/36 over 12.5 mm (1/2 in.), DH32/36	2Y, 2Y400, 3Y, 3Y400, 4Y, 4Y400
EH32/36	3Y, 3Y400, 4Y, 4Y400
FH32/36	4Y, 4Y400
AH40, DH40	2Y400, 3Y400, 4Y400
EH40	3Y400, 4Y400
FH40	4Y400
*High Strength Quenched and Tempered *(1997)*	
XQ43	ZYQ420, ZYQ460, ZYQ500
XQ47	ZYQ460, ZYQ500
XQ51	ZYQ500, ZYQ550
XQ56	ZYQ550, ZYQ620
XQ63	ZYQ620, ZYQ690
XQ70	ZYQ690

Note:

For X = A or D, Z = 3, 4 and 5
For X = E, Z = 4 and 5
For X = F, Z = 5

The tensile strength range of ABS ordinary strength hull structural steel is 400-520 N/mm^2, (41-53 kgf/mm^2, 58-75 ksi). The tensile strength range for ABS H32/H36 higher strength hull structural steel is 440-620 N/mm^2 (45-63 kgf/mm^2, 64-90 ksi). For ABS H40 higher strength hull structural steel, the tensile strength range is 510-650 N/mm^2 (52-66 kgf/mm^2, 74-94 ksi). The ABS filler metal grades for welding ordinary and higher strength hull structural steels are assigned according to Charpy V-notch impact requirements, aimed at providing comparable levels of notch toughness of the various grades of steel. Because of inherent differences in the quality of machine

automatic versus manual and manual semi-automatic produced welds, the impact strength requirements for both ordinary and higher strength filler metal grades are divided into two levels according to whether the process used is automatic or manual. The specific value requirements may be found in 2-A2-1/Table 2.

* *(2008)* Non-low hydrogen type electrode and wire approvals for welding higher strength steels (denoted by * in the list) are subject to satisfactory procedure tests at the user's plant. Use of non-low hydrogen electrodes and wires on higher strength steels is limited to steels with carbon equivalent of 0.41% or less (see 2-1-3/7.1). Furthermore, these procedure tests should include fabrication of a double fillet weld assembly(ies) representative of material(s) and thickness(es) to be used in production. Weld on the first side is to be allowed to cool to ambient temperature before the second side weld is made. Three macrosections (a section from the center, and a section at one inch from each end), taken 72 hours (minimum) after welding are to be free of weld and heat affected zone cracks when etched and examined at 10X magnification.

** Grade 1Y not applicable to manual welding electrodes and semi-automatic wire-gas combinations.

PART

2

Rules for Testing and Certification of Materials

APPENDIX 4 Procedure for the Approval of Manufacturers of Rolled Hull Structural Steel *(2003)*

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PART

2

APPENDIX 4 **Procedure for the Approval of Rolled Hull Structural Steel Manufacturer** *(2003)*

1 Scope

In accordance with 2-1-1/1.2, this Appendix provides specific requirements for the approval of manufacturers of rolled hull structural steel.

The manufacturer approval procedure is intended to verify the manufacturer's capability of furnishing satisfactory products in a consistent manner under effective process and production controls in operation including programmed rolling.

3 Approval Application

3.1 Documents to be Submitted

3.1.1 Initial Approval

The manufacturer is to submit to the Bureau request of approval together with proposed approval test program (see 2-A4/5.1) and general information relative to:

3.1.1(a) Name and address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products for shipbuilding and for other applications, as deemed useful.

3.1.1(b) Organization and quality

- Organizational chart
- Staff employed
- Organization of the quality control department and its staff employed
- Qualification of the personnel involved in activities related to the quality of the products
- Certification of compliance of the quality system with IS0 9001 or 9002, if any.
- Approval certificates already granted by other Classification Societies, if any.

3.1.1(c) Manufacturing facilities

- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of finished products
- Equipment for systematic control during fabrication

3.1.1(d) Details of inspections and quality control facilities

- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- Equipment for non destructive examinations
- List of quality control procedures

3.1.1(e) Type of products (plates, sections, coils), grades of steel, range of thickness and target material properties as follows:

- Range of chemical composition and aim analyses, including grain refining, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and supply condition, the different ranges are to be specified, as appropriate
- Target maximum carbon equivalent according to IIW formula
- Target maximum P_{cm} content for higher strength grades with low carbon content $C < 0.13\%$
- Production statistics of the chemical composition and mechanical properties (ReH, Rm, A% and KV). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

3.1.1(f) Steelmaking

- Steel making process and capacity of furnace/s or converter/s
- Raw material used
- Deoxidation and alloying practice
- Desulphurisation and vacuum degassing installations, if any
- Casting methods: ingot or continuous casting. in the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided, as appropriate.
- Ingot or slab size and weight
- Ingot or slab treatment: scarfing and discarding procedures

3.1.1(g) Reheating and rolling

- Type of furnace and treatment parameters
- Rolling: reduction ratio of slab/bloom/billet to finished product thickness, rolling and finishing temperatures
- Descaling treatment during rolling
- Capacity of the rolling stands

3.1.1(h) Heat treatment

- Type of furnaces, heat treatment parameters and their relevant records
- Accuracy and calibration of temperature control devices

3.1.1(i) Programmed rolling. For products delivered in the controlled rolling (CR) or thermo-mechanical rolling (TM) condition, the following additional information on the programmed rolling schedules is to be given:

- Description of the rolling process
- Normalizing temperature, re-crystallization temperature and Ar3 temperature and the methods used to determine them
- Control standards for typical rolling parameters used for the different thickness and grades of steel (temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- Calibration of the control equipment

3.1.1(j) Recommendations for working and welding, in particular, for products delivered in the CR or TM condition

- Cold and hot working recommendations, if needed, in addition to the normal practice used in the shipyards and workshops
- Minimum and maximum heat input, if different from the ones usually used in the shipyards and workshops (15 – 50 kJ/cm)

3.1.1(k) Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by the Bureau is to be included.

3.1.1(l) For the approval of the semi-finished products such as slabs, blooms and billets, the above information in 2-A4/3.1.1(a) through 2-A4/3.1.1(f) is to be given.

3.1.2 Changes to the Approval Conditions

Where any one or more of the following cases 2-A4/3.1.2(a) through 2-A4/3.1.2(e) are applicable, the manufacturer is to submit to the Bureau the documents required in 2-A4/3.1.1 together with the request of changing the approval conditions,

3.1.2(a) Change of the manufacturing process (steel making, casting, rolling and heat treatment)

3.1.2(b) Change of the maximum thickness (dimension)

3.1.2(c) Change of the chemical composition, added element, etc.

3.1.2(d) Subcontracting the rolling, heat treatment, etc.

3.1.2(e) Use of the slabs, blooms and billets manufactured by other companies which are not approved.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted, except the approval test program (see 2-A4/5.1).

5 Approval Tests

5.1 Extent of the Approval Tests

The extent of the test program is specified in 2-A4/5.11 and 2-A4/5.13. The test program may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular, a reduction of the indicated number of casts, steel plate thicknesses and grades to be tested or complete omission of the approval tests may be considered, taking into account:

i) Approval already granted by other Classification Societies and documentation of approval tests performed

ii) Grades of steel to be approved and availability of long term historical statistic results of chemical and mechanical properties

iii) Approval for any grade of steel also covers approval for any lower grade in the same strength level, provided that the target analyses, method of manufacture and condition of supply are similar.

iv) For higher tensile steels, approval of one strength level covers the approval of the strength level immediately below, provided the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same.

v) Change of the approval conditions

vi) Approval of the semi-finished products such as slabs, blooms and billets.

On the other hand, an increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

5.3 Approval Test Program

Where the number of tests differs from those shown in 2-A4/5.11 and 2-A4/5.13, the program is to be confirmed by the Bureau before the commencement of the tests.

5.5 Approval Survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant. An inspection by the Surveyor of the plant in operation will be required.

If the testing facilities are not available at the works, the tests are to be carried out at recognized laboratories.

5.7 Selection of the Test Product

For each grade of steel and for each manufacturing process (e.g., steel making, casting, rolling and condition of supply), one test product with the maximum thickness (dimension) to be approved is, in general, to be selected for each kind of product.

In addition, for initial approval, the Bureau will require selection of one test product of average thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified C_{eq} or P_{cm} values and grain refining micro-alloying additions.

5.9 Position of the Test Samples

The test samples are to be taken, unless otherwise agreed, from the product (plate, flat, section, bar) corresponding to the top of the ingot, or, in the case of continuous casting, a random sample.