REVISED ANSI/AWS A 5.5-1996 SPECIFICATION FOR LOW-ALLOY STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING - A REVIEW

by
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INTRODUCTION

Among all the electrodes available for shielded metal arc welding process, Low-Alloy steel electrodes are most important since these electrodes are used for fabrication and maintenance of a wide range of industrial applications including refineries, petrochemical plants, fertilizer plants, power plants, process plants, chemical plants, off-shore and on-shore oil processing plants, cross-country pipe lines, sub-sea pipe lines for transporting petroleum products, transport industry, earth-moving equipment etc.

Weight watchers link the reduction of weight to a life-style which ensures the durability of a person's life. Weight watching in welding leads to the reduction of the total weight of a construction, resulting in lower costs and increasing competitiveness. Therefore, design engineers and chemical engineers are switching over to low-alloy high strength steels for many applications reducing substantially overall weight of the fabricated items.

Every business has become competitive and therefore, a consumer expects better quality for the same amount he uses to pay for the product. In the industrial scenario, design engineers are busy in devising ways and means of Increasing productivity and bringing down unit cost of product so that such manufacturers can continue to have an edge over others. For all such developments, new metallurgical alloys are getting developed which have higher strength and can operate at higher temperatures and pressures. Similarly, for cryogenic applications, better high purity clean alloys have been developed which have made the life of maintenance engineers easy since break-downs are rare and reliability factor has increased considerably.

AWS/SFA 5.5 Specification for low-alloy steel electrodes was previously revised in the year 1981 and after 15 years now in the year 1996 the specification has been revised with quite a few additions of electrodes, few deletions of electrodes, and in seven cases of electrodes, classification numbers have been changed to new classification numbers. When we go through the new ANSI/AWS 5.5 specification, we are convinced that the revised new specification has removed anomalies which were existing in earlier specification and has added all required classifications.

CLASSIFICATION OF AWS A 5.5 SPECIFICATION

Scope

Under the scope of ANSI/AWS A 5.5 '96 specification, first time it is mentioned that these low-alloy steel electrodes include steel alloys in which no single alloying element exceeds 10.5 percent. Such limit of single alloying element was not mentioned in the earlier specification.

Classification System

Mandatory classification designators

The system for mandatory classification follows the standard pattern.

Table - I
The composition designator suffix letters identifying (allowing elements) composition of the weld metal

COMPOSITION - MAIN ALLOYING ELEMENTS					
Designator suffix letter of the Classification	**C**	**Cr**	**Mo**	**Ni**	
- Al	—	—	0.40 - 0.65	—	—
- Bl	—	0.40 - 0.65	0.40 - 0.65	—	—
- B2	—	1.0 - 1.50	0.40 - 0.65	—	—
- B2 L	0.05 Max	"	"	—	—
- B3	—	2.0 - 2.50	0.90 - 1.20	—	—
- B3L	0.05 Max	"	"	—	—
- B4L	"	1.75 - 2.25	0.40 - 0.65	—	—
- B5	"	0.40 - 0.60	1.0 - 1.25	—	V = 0.005
- B6	"	4.0 - 0.65	0.45 - 0.65	—	—
- B6L	0.05 Max	"	"	—	—
- B7		6.0 - 8.0	"	—	—
- B7L	0.05 Max	"	"	—	—
- B8	—	8.0 - 10.5	0.85 - 1.20	—	—
- B8L	0.05 Max	"	"	—	—
- B9	—	"	"	—	V = 0.15-0.30 N
	—	—	—	—	b = 0.02-0.10
	—	—	—	—	N = 0.02-0.07
- Cl	—	—	—	2.0 - 2.75	—
- CIL	0.05 Max	—	—	"	—
- C2	—	—	—	3.0 - 3.75	—
- C2L	0.05 Max	—	—	"	—
- C3	—	—	—	0.80 - 1.10	—
- C3L	0.05 Max	—	—	"	—
- C4	—	—	—	1.10 - 2.0	—
- C5L	0.05 Max	—	—	6.0 - 7.25	—
- NMl	—	—	.0.40 - 0.65	0.80 - 1.10	—
- Dl	—	—	0.25 - 0.45		Mn:1.0-1.75
- D2	—	—	"		Mn:1.65-2.0
- D3	—	—	0.40-0.65		Mn:1.0-1.80
- G	—	0.30 Min	0.20 Min	0.50 Min	—
- M	—	Military	See individual	—	—
	—	Spec.	Spec.	—	—
- Pl	—	0.30 MAX	0.50 MAX	1.0 MAX	V-0.10 MAX
- W[1]	—	0.15 - 0.30	—	0.20 - 0.40	Cu-0.30-6.60
- W2	—	0.40 - 0.80	—	0.40 - 0.80	Cu-0.30-0.75

The letter "E" at the beginning of each classification designation stands for electrode.

The first two (or three) digits designate tensile strength of the weld metal. The third (or fourth) digit designates the welding position in which electrodes are usable and the kind of current for which the electrodes are suitable.

With the exception of similar military electrodes. [e.g. E (X) XX 18 M (I)] the classification includes a suffix designator, separated by a hyphen from the tensile strength and usability designators. The composition designator identifies the chemical composition of the weld metal as specified in Table - I.

Optional supplemental designators

Optional supplemental designators are used in order to identify electrode classifications that have met certain supplemental requirements as agreed to between the supplier and the purchaser.

An optional supplemental designator "HZ" following the mandatory classification system indicated an average diffusible hydrogen content of not more than "Z" ml/100g of deposited metal when tested in accordance with ANSI/AWS A 4.3 specification (where "Z" is 4, 8 or 16).

Another optional designator "R" designates the electrode met the requirements of the absorbed moisture test. It identifies classification that has been exposed to a humid environment for a given length of time and tested for low moisture absorption, in addition to the standard moisture test required for classification of low hydrogen electrodes.

The complete classification system of the low-alloy steel electrode, consisting of mandatory designators is explained in the Table - II.

Examples :

E (X) XXYY - X	E 8018 - B2
E (X) XXYY M	E 10018 M
E (X) XXYY MI	E 12018 MI
E (X) XXYY M-HZ	E 9018 M-H4
E (X) XXYY MI-HZ	E 12018 MI-H4
E (X) XXYY-X-HZR	E 9018-B3-H4R

New additions in the revised AWS/5.5 - 96 specification

In the revised specification there are 85 types of low-alloy steel electrodes whereas in the earlier published specification of the year 1981, there are 54 types of electrodes. In other words, in the revised specification 31 nos. of new low-alloy steel electrodes have been added.

The list of these new additional electrodes is given in the Table - III.

It is interesting and informative to see what are these 31 types of new low-alloy electrodes.

New additions in cellulosic types of electrodes.

In all, 6 new types of cellulosic electrodes have been added in the latest specification.

These new types are as under :

1) E 7010 - PI
2) E 8010 - PI
3) E 11010 - G
4) E 11011 - G
5) E 12010 - G
6) E 12011 - G

E 7010 - PI & E 8010 - PI Electrodes :

Out of above 6 types of cellulosic electrodes, the first two electrodes viz. E 7010 - PI and E 8010 - PI have appropriate suffix PI designator which clearly indicates that these two electrodes are designed primarily for welding typical high strength pipe butt joints with vertical welding position with downward or upward progression. Both the types produce deep penetrating spray type arcs and thin, easily removable slag. The suppliers of these two types of electrodes provide sufficient alloying elements in the weld metal so that weld metal could meet the increased mechanical properties requirements. Typical applications are welding of API grade pipe 5L - X52 for E 7010 - PI and API grade pipe 5L - X65 for E 8010 - PI electrodes.

Mechanical properties of the weld metal deposited using E 7010 - PI and E 8010 - PI electrodes.

E - 7010 - PI and E 8010 - PI electrodes need to meet following

requirements in the as-welded condition.

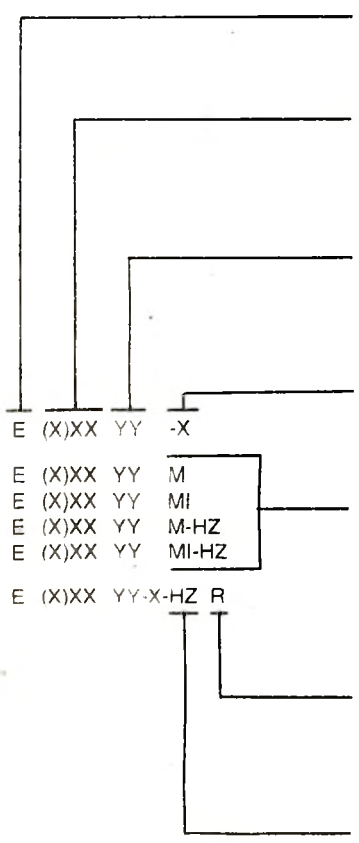
Types of Cellulosic electrodes	UTS MPa Min	Yield strength MPa, min	Elongation (%) E 4 d min	Heat treatment
E 7010 - PI	480	415	22	NIL
E 7010 - AI	480	390	22	AW or PWHT
E 7010 - G	480	390	22	AW or PWHT
E 8010 - PI	550	460	19	NIL
E 8010 - G	550	460	19	AW or PWHT

CHARPY V-NOTCH REQUIREMENTS

	Average min	Single value min
E 7010-PI	27J at-29°C	20J at-29°C
E 8010-PI	27J at-29°C	20J at-29°C

Table - II
Order of Electrode Mandatory and Optional Supplemental Designators

Mandatory Classification Designators *



Designates an electrode. This designator may be deleted from the actual product imprint required for the identification of the electrode.

Designates the tensile strength (minimum), in ksi, of the weld metal when produced in accordance with the test assembly preparation section of this specification. See Table 3.

Designates the welding position in which electrodes are usable, the type of covering and the kind of current for which the electrodes are suitable. See Table 1.

Designates the chemical composition of the undiluted weld metal produced by the electrode using shielded metal arc welding. See Table 2.

Designates an electrode intended to meet most military requirements (greater toughness and elongation). See Tables 3 and 4.

Optional Supplemental Designators

Designates that the electrode met the requirements of the absorbed moisture test (an optional supplemental test for all low hydrogen electrodes). See Table 11.

Designates that the electrode met the requirements of the diffusible hydrogen test (an optional supplemental test of the weld metal from low hydrogen electrodes, as-received or conditioned - with an average value not exceeding "Z" ml of H_2 per 100g of deposited metal, where "Z" is 4, 8 or 16). See Table 12.

* The combination of these designators constitutes the electrode classification.

[For all Figures & Tables refer Revised text : ANSI / AWS 5.5 1996 SPEC. Ed.]

Previous specification has not specified any impact equirements for popular types such as E 7010 G, E 7010 - Al or E 8010 G types of electrodes. By specifying E 7010 - Pl and E 8010 - Pl electrodes for welding high strength pipe lines, fabricators can always ensure highest quality of the weld joint.

E 11010G, E11011G, E12010G & E12011G

Even though these new four cellulosic types of low-alloy steel electrodes have been added in the new specification, user industries will take quite some time to get convinced about their suitability, especially depositing tough and crack-free weld metal. However, with new challenges being accepted by the developing engineers, we should see availability of such electrodes having ductile and tough weld metal meeting code requirements.

New Chrome-moly low-alloy steel electrodes

New additions in EXXYY - B2L group of electrodes.

Under the group EXXYY-B2L, three new types of electrodes have been added. These electrodes are :

1) E 7015 - B2L
2) E 7016 - B2L
3) E 7018 - B2L

While regular Cr-Mo electrodes produce weld metal with about 0.08% carbon, the 'L - Grades' are limited to a maximum of 0.05% carbon. While the lower percent carbon in the weld metal will improve ductility and lower hardness, it will also reduce the high-temperature strength and creep resistance of the weld metal.

In previous revisions of ANSI/ AWS A 5.5, electrodes classified in this standard as E 7015 - B2L and E 7018 - B2L were classified as E 8015 B2L and E 8018 B2L. The strength designations and room temperature strength requirements after PWHT have been reduced to reflect the fact that commercial products have been producing marginal tensile strength results in classification tests over many years. The base metals with which these classifications are generally used have lower strength requirements than were reflected by the former electrode classifications. Therefore, unless the higher strength indicated by the former classifications of these electrodes is specifically necessary for a particular welding procedure, the E 7015-B2L and E 7018-B2L classifications of the latest standard should be considered as identical to the corresponding E 8015-B2L and E 8018-B2L respectively.

In the revised specification, E 7016-B2L classification has been added newly with a lower silicon limit of 0.60% maximum in the weld metal. Such electrode is considered to be ideal for inplant pipe line welding.

Table - III
New Types added in AWS A 5.5/96 Specification

1.	E 7015 - B2L
2.	* E 7016 - B2L
3.	* E 7018 - B2L
4.	* E 8015 - B3L
5.	* E 8018 - B3L
6.	E 8015 - B6
7.	E 8016 - B6
8.	E 8018 - B6
9.	E 8015 - B6L
10.	E 8016 - B6L
11.	E 8018 - B67
12.	E 8015 - B7
13.	E 8016 - B7
14.	E 8018 - B7
15.	E 8015 - B7L
16.	E 8016 - B7L
17.	E 8018 - B7L
18.	E 8015 - B8
19.	E 8016 - B8
20.	E 8018 - B8
21.	E 8015 - B8L
22.	E 8016 - B8L
23.	E 8018 - B8L
24.	E 9015 - B9
25.	E 9016 - B9
26.	E 9018 - B9
27.	E 7018 - C3L
28.	E 8016 - C4
29.	E 8018 - C4
30.	E 9015 - C5L
31.	* E 8018 - NMI
32.	E 8018 - DI
33.	E 9018 - D3
34.	E 7027 - G
35.	E 7010 - PI
36.	E 8010 - PI
37.	* E 7018 - WI
38.	* E 8018 - W2
39.	E 11010 - G
40.	E 11011 - G
41.	E 12010 - G
42.	E 12011 - G

* Classification of these electrodes has been revised compared to earlier classification numbers.

E 8015 - B3L & E 8018 - B3L

In previous revision of ANSI/AWS A 5.5 specification electrodes classified as E 9015 B3L and E 9018 B3L have been reclassified in the latest revision as E 8015 B3L and E 8018 B3L. The base metals with which these classifications are generally used have lower tensile strength of about 550 MPa.

5 Cr - 1/2 Mo Low-Alloy steel electrodes in the new ANSI/ AWS A 5.5 specification

Following six 5 Cr 1/2 Mo low-alloy steel electrodes have been added.

1) E 8015 - B6
2) E 8016 - B6
3) E 8018 - B6
4) E 8015 - B6L
5) E 8016 - B6L
6) E 8018 - B6L

5 Cr 1/2 Mo electrodes were formerly classified as E 502 - 15 and E 502 - 16 in AWS A 5.4 - 92 specification for Stainless Steel electrodes for shielded metal arc welding. Many users of the specification AWS A 5.4 still continue to use E 502 - 15 and E 502 - 16 classification and these classifications will continue to be used till AWS committee revise AWS A 5.4 specification and delete or drop Cr-Mo electrodes having chromium content not more than 10.5 percent. Following table compares classification of 5 Cr 1/2 Mo electrodes based on AWS A 5.5-96 and AWS A 5.4-92 specification.

7 Cr - 1/2 Mo low-alloy steel electrodes in the revised specification.

Following six 7 Cr - 1/2 Mo low-alloy steel electrodes have been added.

i) E 8015 - B7
ii) E 8015 - B7L
iii) E 8016 - B7
iv) E 8016 - B7L
v) E 8018 - B7
vi) E 8018 - B7L

AWS A 5.4 - 92 Specification classified 7Cr - 1/2 Mo electrodes as E7 Cr-16. As mentioned earlier, this classification based on AWS A5.4 Specification will continue to be in use till next revision of AWS A5.4 Specification.

Therefore, for welding base metal grade A 213 - T 7 or A 335 - P7 pipe, E 8018 - B7 electrodes are matching and would produce desired results.

Electrodes for welding 9Cr - IMo material type A123-T9 or A335-P9 pipe

The revised specification A 5.5 has included following six electrodes for welding A 123 - T9 or A 335 - P9 pipes.

i) E 8015 - B8
ii) E 8015 - B8L
iii) E 8016 - B8
iv) E 8016 - B8L
v) E 8018 - B8
vi) E 8018 - B8L

AWS A 5.4-92 specification covers 9 Cr-I Mo electrodes under classifications E 505 - 15 or E 505-16.These classifications will be used by some users till AWS A 5.4 gets revised and in the revised version 9 Cr - I Mo classifications are dropped or deleted. In the revised version extra-low carbon grade has found the place since such electrodes are required for welding corresponding base metal having low carbon content.

Modified 9 Cr - I Mo electrodes for welding A 231 - T91 tubes, A 335-P91 pipe and A 387 Gr.T 91 plate

E 9015 - B9, E 9016 - B9 & E 9018 - B9 are altogether new

Classification of 5 Cr 1/2 Mo Electrodes

Classification based on AWS A 5.5-96 Specification	Equivalent Classification based on AWS A 5.4-92 Specification
E 8015 - B6	E 502 - 15
E 8015 - B6L	Not classified
E 8016 - B6	E 502 - 16
E 8016 - B6L	Not classified
E 8018 - B6	Not classified
E 8018 - B6L	Not classified

electrodes and have been developed in the last few years. These are low hydrogen electrodes modified with niobium vanadium and nitrogen designed to provide creep strength, toughness, fatigue life and oxidation and corrosion resistance at elevated temperatures. These electrodes are expected to find more and more uses especially in power plants.

Nickel Steel electrodes

"L" grade 1% Ni steel electrode type E 7018 C3L.

In the revised specification "L" grade 1% Ni steel electrode has been classified as E 7018 C3L. It is well-known that with lower levels of carbon, low temperature toughness improves to match the base metal properties of nickel steels. The min charpy v-notch impact requirement for E 7018 C3L electrode is 27 J at - 51°C whereas for E 8018 C3 electrode impact requirement is 27 J at –40°C.

Two new 1.5% Ni steel electrodes

First time in this specification, following two new 1.5% Ni steel electrodes have been added having suffix designator as "C4".

i) E 8016 - C4
ii) E 8018 - C4

The minimum charpy v-notch impact requirement for both the types is 27 J at –51°C.

6.5% Ni steel electrode - E 9015 -C5L

"L" grade 6.5% Ni steel electrode having classification E 9015 C5L has been introduced in this specification. The nickel content in the weld metal is in the range 6.0 - 7.25% and impact requirement is 27 J at - 115°C (-175°F). Recommended post weld heat treatment temperature is 579±14% since higher PWHT can lead to embrittlement problem.

Revision in Nickel-moly steel electrode E 8018 - NMI

Previously classified E 8018 NM electrode has been reclassified as E 8018 NMI in the revised specification. This electrode is recommended for applications without PWHT. Some typical applications are the welding of high-strength, low-alloy of micro-alloyed structural steels.

Manganese - Moly Electrodes

In the category of Mn-Mo electrodes following two new types have been added.

i) E 8018 - DI
ii) E 9018 - D3

In the new specification, depending on the strength of base metal, Mn-Mo electrodes can be selected for use. In the previous specification the electrode which was classified as E 9018 - DI has been classified as E 9018 DI or E 8018 - DI depending upon mechanical properties of the weld-metal. Similarly E 8018-D3 classification of previous specification has been classified as E 8018-D3 and E 9018-D3.

New classification under Suffix Designator "G"

In this specification High-iron oxide, iron powder type electrode has been classified as E 7027-G. However, E 7027 - G electrode has limited applications in the industries. The advantage of the electrode is, it can be welded with relatively high current range and is best suited for long fillet welds in structural applications.

Weathering Steel Electrodes

In the revised specification, weathering steel electrodes have been redesigned as E7018 - WI and E 8018 - W2 compared to previous specification's E 7018 W and E 8018 W respectively. Both the electrodes produce weld metal that matches the corrosion resistance and the colouring of the ASTM weathering type structural steels such as ASTM A 242 and A 588.

SULPHUR CONTENT IN THE WELD METAL OF ELECTRODES

In the revised specification sulphur limit in the weld metal has been brought down to 0.03% from 0.04%. Lower level of sulphur in the weld metal reduces hot cracking of the weld metal and improves toughness properties especially at sub-zero temperature.

For critical applications like welding of P-91 and T-91 material, the sulphur and phosphorous in the weld metal of electrodes, types E 9018 B9, should be extremely low. Both the elements individually do not exceed 0.01% and hence improve toughness of the weld metal.

PREPARATION OF GROOVE WELD TEST ASSEMBLIES

In the new specification, groove test assemblies are prepared depending upon the types of electrodes. For E XXX18 M (I) electrode, dimensions of the test assemblies and procedure of welding for groove are different compared to other E (X) XXXX-X low-alloy steel electrodes. Details of the groove weld test are given under para 8.4 of ANSI/AWS A 5.5-96 specification. Changes in the groove test as compared to previous specification are as under.

AA) Type of base metal to be used for weld test assemblies :

Details are given under Table VI of the latest AWS A 5.5 specification. For example, as per revised specification, A 285 grade C or A 283 grade D plates cannot be used for groove test of E (X) XXXX-M (I) electrodes whereas ASTM A 36 or A 131 grade 'B' or equivalent base plates can be used for groove test assemblies of all types of low-alloy steel electrodes.

BB) The test assemblies for groove weld test have to be prepared as specified in figure 2 or 4 of the revised specification.

Details of figure 2 are applicable for all low-alloy electrodes except those classified as E (X) XXX-M (I) types of electrodes. Details of figure 4 are applicable for E(X)XXX-M(I) types of electrodes.

CC) In the earlier specification, bevel angle of the plate for groove test assemblies was 22 1/2^0 whereas in the revised specification bevel angle is 10^0 for all electrodes except classified as E (X) XXXX-M (I). The bevel angle for the test plate is 30^0 for electrodes classified as E (X) XXXX-M (I).

DD) Sizes of electrodes 2.4, 3.2 and 5.6 have been included in the revised specification.

EE) In the revised specification for E (X) XXXX-M (I) type electrodes, there is no provision for surfacing edges of the grooves and the contacting face of the backing plate with the electrode being tested before welding the joint.

All necessary details of preparation of test assemblies are specified in figure 2 and figure 4 of the revised specification. By revising the procedure for E (X) XXXX-M (I) electrodes for preparation of groove weld assemblies, it is expected to minimise variations observed for same size and type of electrodes from one laboratory to another laboratory.

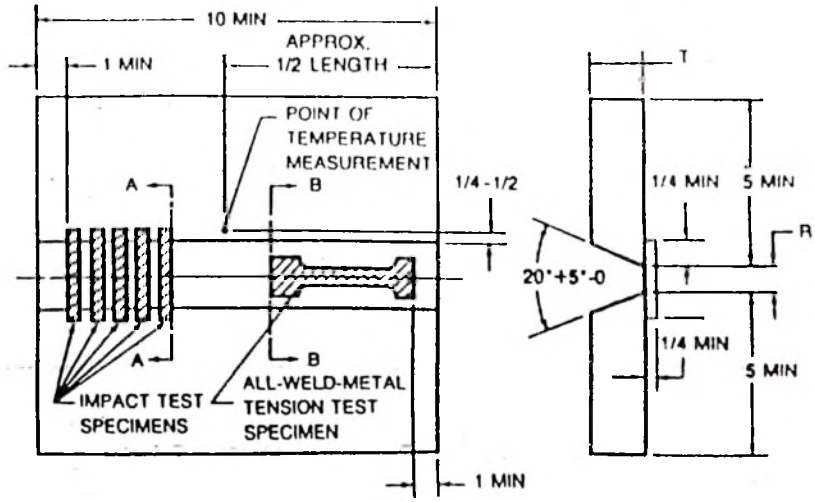
LOW-MOISTURE-ABSORBING LOW-HYDROGEN ELECTRODES

First time in this specification, a provision for identifying low-moisture-absorbing-low-hydrogen electrodes has been made by having optional "R" suffix designator. The test is carried out by exposing sufficient number of electrodes (as received or conditioned) at a temperature of 80^{0}F (26.7^{0}C) and 80% RH for a period of not less than 9 hours by a suitable method. Details of absorbed moisture test are given in para 15 of the specification.

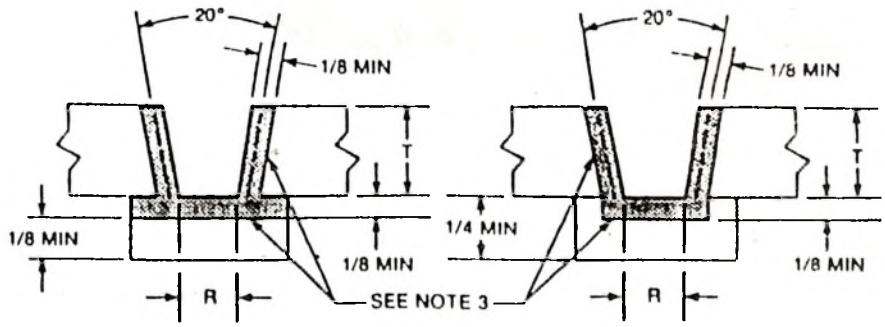
DIFFUSIBLE HYDROGEN TEST

Under para 16.0 of revised specification, details of diffusible hydrogen tests are mentioned. The test is to be carried out according to one of the methods given in ANSI/AWS A 4.3 specification, "Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic and Ferritic weld metal produced by arc welding".

The diffusible hydrogen test for low-hydrogen electrodes is optional. Diffusible hydrogen content in the weld metal of low-hydrogen electrodes of low-alloy steel can be represented by

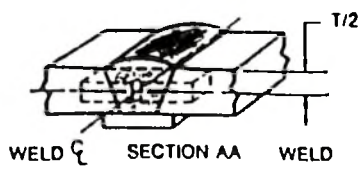


(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS

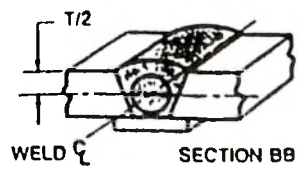


(B) GROOVE PREPARATION OF TEST PLATE

SI EQUIVALENTS	
in.	mm
1/8	3.2
1/4	6.4
1/2	13
1	25
5	125
10	250

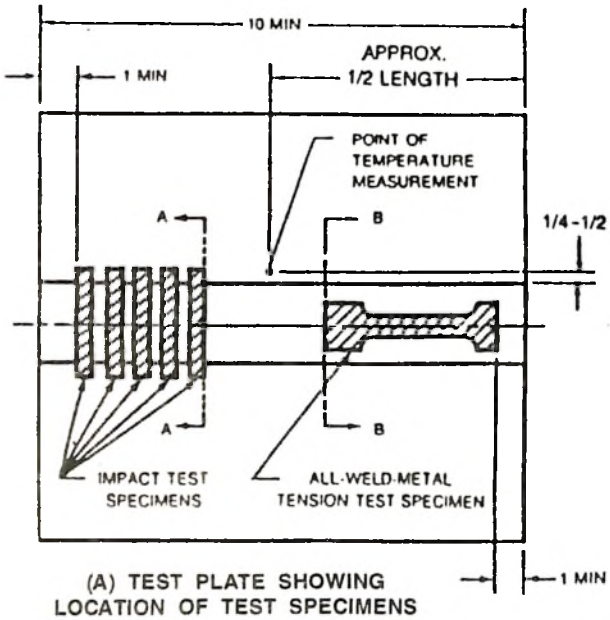


(C) ORIENTATION AND LOCATION OF IMPACT TEST SPECIMEN

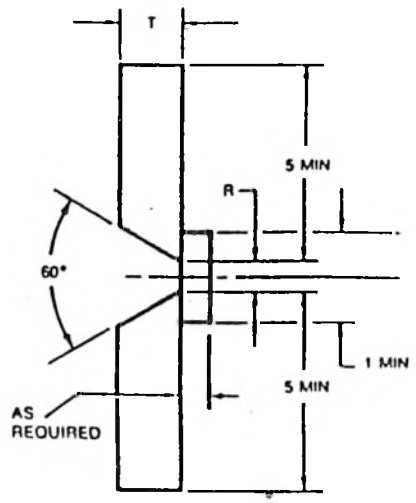


(D) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN

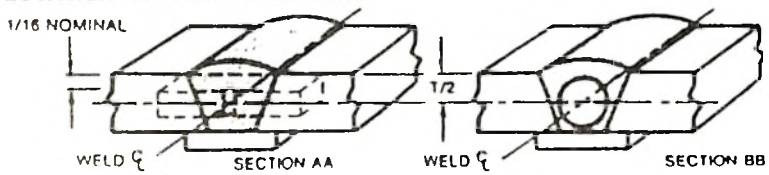
Fig. 2 : Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using All Electrode Classifications Except EXX18M(1)



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) JOINT PREPARATION



(C) ORIENTATION OF IMPACT SPECIMEN

(D) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN

SI EQUIVALENTS	
in.	mm
1/8	3.2
1/4	6.4
1/2	13
1	25
5	125
10	250

Electrode Size		(T) Min. Plate Thickness		(R) Max. Root Opening		Number of Layers	
in.	mm	in.	mm	in.	mm	Minimum	Maximum
3/32	2.4	1/2	13	1/4	6.4	See Note 2	
1/8	3.2	1/2	13	1/4	6.4	See Note 2	
5/32	4.0	3/4	19	1/2	13	7	9
3/16	4.8	3/4	19	1/2	13	7	9
7/32	5.6	3/4	19	1/2	13	7	8
1/4	6.4	1	25	1/2	13	9	11

Notes :

1. All dimensions except angles are in inches.
2. Pass and layer sequence shall be reported.
3. Base metal shall be as specified in Table 6
4. The surface to be welded shall be clean.
5. Prior to welding, the assembly may be preset to yield a welded joint sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5 degrees of plane. A welded test assembly that is more than 5 degrees out of plane shall be discarded. Straightening of the test assemby is prohibited.
6. Welding shall be performed in the flat position, using the type of current specified in Table 5 for the classification.
7. The preheat and interpass temperature shall be as specified in Table 7 for the classification being tested.
8. Layers should be approximately 1/8 in. thick with each layer being started at the finishing end of the preceding layer.
9. The weld shall be made with stringer beads or with maximum weave no wider than 2-1/2 times the diameter of the core wire.
10. The completed weld shall have a reinforcement of standard proportions, 1/32 in. minimum; 1/8 in. maximum. For electrodes larger than 1/8 in. (3.2 mm), the root beads may be made with 3/32 or 1/8 in. (2.4 or 3.2mm) electrodes.

Fig. 4 : Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by using EXX18M(1)

adding appropriate designator such as H16, HB or H4.

By adding appropriate designators as an optional to mandatory classification for low-alloy steel electrode for diffusible hydrogen content of the electrode, users could always select best electrodes for critical applications, especially for welding high-tensile steels of various grades and could almost eliminate risk of hydrogen induced cracking.

POST-WELD HEAT-TREATMENT FOR LOW-ALLOY NICKEL STEEL ELECTRODES

In the revised specification, post-weld heat treatment temperatures for low-alloy Nickel steel electrodes have been lower because higher PWHT temperature can lead to embrittlement problem.

Post weld heat treatment temperatures for low-alloy Nickel steel electrodes are as under :

	Earlier PWHT Temperatures	PWHT Temperatures as per revised specification
E 8016-C1 E 8018-C1 E 7015-C1L E 7016-C1L E 7018-C1L	620±14°C	605±14°C
E 8016-C2 E 8018-C2 E 7015-C2L E 7016-C2L E 7018-C2L		
E 9015-C5L		579±14°C

CONCLUSION

1) After 15 years ANSI/AWS A 5.5 specification has been revised.

2) In the new specification 31 new types of electrodes have been included and in 7 types classification code numbers have been revised.

3) The revised classification system for low-alloy steel electrodes is consisting of mandatory classification designators and optional supplemental designators.

4) For the first time separate designator to the classification system has been provided for cellulose electrodes for pipe line welding, for example E 7010 - P1 and E 8010 P1.

5) Procedure for groove weld test has been revised. Bevel angle of the test plate for groove weld has been changed to 10° for all low-alloy electrodes except type E (X) XXXX-M (1). Bevel angle of the plate for groove test for E (X) XXXX-M (1) electrode is now 30°.

6) Electrodes types 5 Cr - 1/2 Mo, 7 Cr - ½Mo, 9 Cr - 1 Mo, which are covered by ANSI/AWS A 5.4 specification are now covered under revised ANSI/AWS A 5.5-96 specification.

7) Separate optional designator for classification system has been provided for Low-Moisture-absorbing low-hydrogen basic coated electrodes.

8) Similarly separate optional designator for classification system has been provided for representing Diffusible hydrogen content in the weld metal of Low-hydrogen electrodes.

9) Revised specification has provided important information for various low-alloy steel electrodes and users find the specification quite useful and informative.