AWS Adds Two-Run Option for Flux-Electrode Classification

Important revisions to AWS filler metal specification A5.23 are explained in detail

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The submerged arc welding process has been used for many years by manufacturers seeking to improve quality, increase productivity, reduce costs, and enhance welder comfort. This automated arc welding process utilizes continuous solid or cored (composite) electrodes with a granular welding flux. The flux's main function is to shield the molten weld pool from the atmosphere. The flux is deposited along the weld joint ahead of the welding arc(s). The high current-carrying capacity of the electrodes and the ability to utilize welding procedures employing multiple electrodes make the submerged arc process a good choice for downhill welding applications requiring deep penetration, high deposition rates, fast travel speed, or some combination thereof.

The A5.17 and A5.23 Specifications

The American Welding Society classifies carbon and low-alloy submerged arc electrodes and fluxes with two specifications. These are AWS A5.17/A5.17M, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding,* and AWS A5.23/A5.23M, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding.* These specifications make use of both U.S. Customary Units and the International System of Units [SI]. Solid electrodes under both specifications are classified based upon their chemical compositions. Tubular (composite) electrodes are classified based upon the weld deposit composition developed with the electrode and a particular flux. Fluxes are not classified independently but are classified with an electrode of a specific classification based upon the mechanical properties of the weld metal deposited in a 1 in [25 mm] thick groove joint with the flux-electrode combination. The test groove joint typically requires 12 to 15 weld passes to complete. The A5.23/A5.23M low-alloy specification also has specific requirements for weld deposit composition. The A5.17/A5.17M carbon steel specification does not.

Fig. 1 — Cross section of multiple pass flux-electrode classification weld.

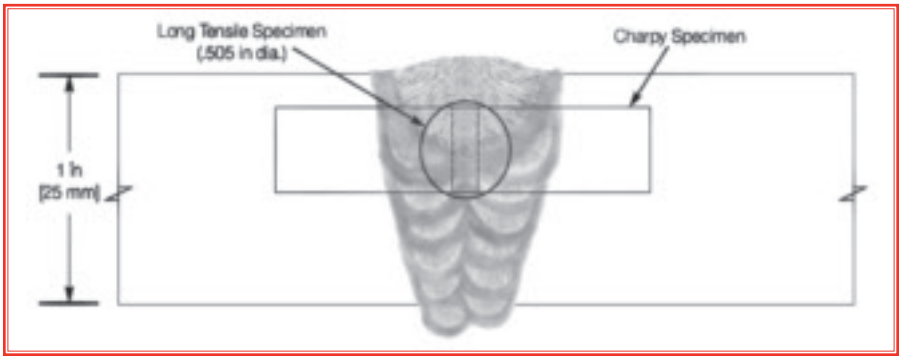

Fig. 2 — Charpy and tensile specimen locations for multiple pass classification test.

Revisions to A5.23/A5.23M Specification

The 2007 editions of both the AWS A5.17/A5.17M carbon steel and AWS A5.23/A5.23M low-alloy steel submerged arc specifications have been published this year. The A5.17/A5.17M-97 (R2007) edition is simply a reaffirmation of the

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ANSI/AWS A5.17/A5.17M-97 specification issued in 1997. No technical changes were made to that specification. However, major changes have been incorporated into the A5.23/A5.23M:2007 low-alloy specification. The most noteworthy of these changes is the addition of a two-run classification system. The AWS A5B Subcommittee on Carbon and Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding has added a two-run classification option in recognition of the fact that mechanical properties obtained on a two-run and other limited-pass welds with a given flux-electrode combination can be significantly different than the mechanical properties obtained on multiple pass welds using the same flux-electrode combination.

Two-Run and Multiple Pass Welds

The differences in the mechanical properties obtained on multiple pass welds from those developed on two-run and other limited pass welds can be attributed in great part to their respective microstructures. In multiple pass welding, the reheating of each weld pass by the subsequent weld pass has the effect of refining the grain structure of that pass. As a result, the completed multiple pass weld consists of a network of fine grain regions that serve to enhance the Charpy V-notch properties of the weld — Figs. 1, 2. The use of higher-basicity fluxes can further improve the V-notch properties of multiple pass welds by reducing the grain boundary oxygen (oxide) inclusion levels. Also, any adverse effect from admixture with the base plate is minimized due to the low dilution factor.

On two-run (limited-pass) welds, the grain refinement mechanism described above for multiple pass welds is minimal. The second pass of a two-run weld consists entirely of as-deposited microstructure that is not conducive typically to developing good weld metal V-notch properties — Fig. 3. In addition, the base plate dilution factor of limited pass welds can exceed 50%. As a result, the mechanical properties obtained with any flux-electrode combination on a limited pass weld can be expected to vary with the base plate composition. The approaches taken to develop good Charpy V-notch properties on limited-pass welds are of necessity different than those used for multiple pass welds. These include, for example, the design of special fluxes that promote finer grain weld structures and the use of electrodes alloyed with molybdenum, titanium, and/or boron to promote a fine acicular ferrite structure and to retard the growth of grain boundary ferrite.

Limitation of Existing Classification

The existing multiple pass flux-electrode classification provides users a reasonable basis for identifying candidate flux-electrode combinations to meet their multiple pass application requirements. However, for limited pass applications such as the fabrication of structural steel shapes, pipe for oil and gas transmission, and wind towers the usefulness of multiple pass flux-electrode classifications for identifying candidate flux-electrode combinations that meet their application requirements is questionable. It is for this reason that a two-run flux-electrode classification option has been added to the AWS A5.23/A5.23M specification. The low-alloy A5.23/A5.23M specification was selected as the residence document for the two-run classification because (1) low-alloy electrodes classified under this specification are commonly used to develop good mechanical properties on limited pass welds, and (2) the strength level requirements in this document are higher than those found in the A5.17/A5.17M carbon steel specification and better meet the requirements of commercial practice.

The two-run weld test assembly is a nominal 1/2 in [12 mm] thick butt joint weld which is welded with one pass on each side. The base plate material and welding conditions are defined in the specification. Full-size Charpy V-notch impact specimens and a 0.250 in diameter longitudinal tensile test specimen are machined from the completed weldment and tested to determine conformance to mechanical property requirements — Fig. 4. The two-run flux-electrode classification has no weld metal composition requirement.

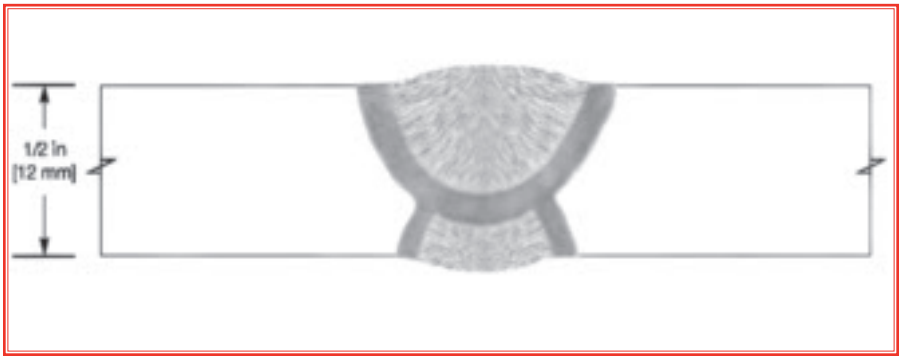

Fig. 3 — Cross section of two-run flux-electrode classification weld.

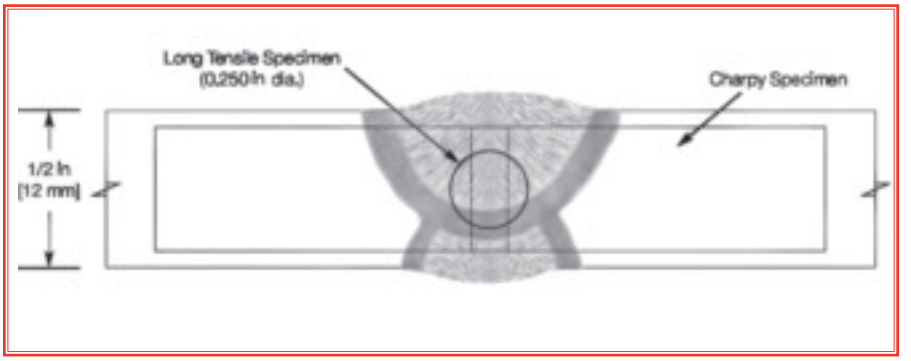

Fig. 4 — Charpy and tensile specimen location for two-run classification test.

The Classification System Outlined

The classification system is outlined as follows.

FXTXXG – EXX – HX, where,

- The letter **F** indicates a submerged arc welding flux.
- The letters **XT** indicate the minimum tensile strength on a two-run classification.
- The **X** in the fourth position indicates the condition of heat treatment, if any.
- The **X** in the fifth position indicates Charpy V-notch properties.
- The **G**, when present, indicates that the test joint was not constructed from one of the steels prescribed in the specification but from another steel as agreed to between purchaser and supplier.
- The **EXX** indicates the classification of electrode used in producing the weld.
- The **HX** is an optional, supplemental hydrogen designator. This designator is optional and does not constitute part of the flux-electrode classification.

Two examples of flux-electrode two-run classifications are given below. The examples shown are in U.S. Customary Units.

Example 1. **F7TA4-EM12K** is a complete designation for a flux-electrode two-run classification. It refers to a flux that, when used with an EM12K electrode to weld the base plate prescribed in accordance with the two-run welding conditions called for in the AWS A5.23/A5.23M:2007 specification, will produce weld metal in the as-welded condition having a minimum tensile strength of 70,000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at –40°F.

Example 2. **F8TA2G-EA1** is a complete designation for a flux-electrode two-run classification. It refers to a flux that, when used with an EA1 electrode to weld the test plate in accordance with the two-run welding conditions called for in the AWS A5.23/A5.23M:2007 specification, will produce weld metal in the as-welded condition having a minimum tensile strength of 80,000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at –20°F. The **G** in the classification indicates that the base steel used is not one of the test steels prescribed in the specification but is some other steel (such as an API 5LX70 pipe steel) as agreed between purchaser and supplier.

Additional Changes to A5.23

In addition to the two-run classification, higher classification strength levels have been added to the AWS A5.23/A5.23M:2007 revision to reflect the use of higher-strength steels in practice today. Changes were also made to composition requirements for EB9 electrodes and B9 weld deposits, as well as changes to the diameter tolerance for composite electrodes. This revision includes new classifications EA1TiB and EA2TiB, that are titanium-boron-containing electrodes useful in developing improved Charpy V-notch impact properties on single-pass welds.◆