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Annex A (Informative)
Guide to AWS Specification for Surfacing Electrodes for Shielded Metal Arc Welding

This annex is not part of AWS A5.13/A5.13M:2010, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*, but is included for informational purposes only.

A1. Introduction

This guide has been prepared as an aid to prospective users of the electrodes covered by the specification in determining the classification of filler metal best suited for a particular application, with due consideration to the particular requirements for that application.

A2. Classification System

A2.1 The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter E at the beginning of each classification designation stands for electrode. The letters immediately after the E are the chemical symbols for the principal elements in the classification. Thus, CoCr is a cobalt–chromium alloy, CuAl is a copper–aluminum alloy, etc. Where more than one classification is included in a basic group, the individual classifications in the group are identified by the letters A, B, C, etc., as in ECuSn-A. Further subdivision is done by using a 1, 2, etc., after the last letter, as the 2 in ECuAl-A2. An additional letter or number has been added to some designations if the composition requirements in this specification differ somewhat from those of the earlier versions for electrodes of the same basic classification.

A2.2 From an application point of view, many classifications in this specification have a corresponding classification in AWS A5.21 *Specification for Bare Electrodes and Rods for Surfacing* (see Table A.1).

A2.3 An international system for designating welding filler metals is under development by the International Institute of Welding (IIW) for possible adoption as an ISO specification. The latest proposal for designating welding filler metals appears in AWS IFS:2002, International Index of Welding Filler Metal Classifications[9]. Table A.1 shows the proposed ISO designations applicable to filler metal classifications included in this specification.

A2.4 Request for Filler Metal Classification

(1) When a surfacing electrode or rod cannot be classified as given in this specification, the manufacturer may request that a classification be established for that welding electrode. The manufacturer may do this by following the procedure given here.

(2) A request to establish a new electrode or rod classification must be in writing, and it needs to provide sufficient detail to permit the AWS A5 Committee on Filler Metals and Allied Materials or the subcommittee to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. The request needs to state the variables and their limits, for such a classification or modification. The

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Table A.1
Comparison of Classifications

A5.13/A5.13M Classifications	A5.21 Classifications	Proposed ISO Designations[a]
EFe1	ERFe-1	EF7314
EFe2	ERFe-2	EF7418
EFe3	ERFe-3	EF7430
EFe4		EF7460
EFe5	ERFe-5	EF7413
EFe6	ERFe-6	EF7680
EFe7		EF7834
EFeMn-A		EF7909
EFeMn-B		EF7907
EFeMn-C	ERFeMn-C	EF7921
EFeMn-D		EF7932
EFeMn-E		EF7940
EFeMn-F	ERFeMn-F	EF7941
EFeMnCr	ERFeMnCr	EF7970
EFeCr-A1A	ERFeCr-A1A	EF8616
EFeCr-A2		EF8612
EFeCr-A3	ERFeCr-A3A	EF8613
EFeCr-A4	ERFeCr-A4	EF8624
EFeCr-A5	ERFeCr-A5	EF8530
EFeCr-A6		EF8621
EFeCr-A7		EF8618
EFeCr-A8		EF8629
EFeCr-E1		EF8720
EFeCr-E2		EF8812
EFeCr-E3		EF8810
EFeCr-E4		EF8724
ECoCr-A	ERCoCr-A	ECo 3006
ECoCr-B	ERCoCr-B	ECo 3012
ECoCr-C	ERCoCr-C	ECo 3113
ECoCr-E	ERCoCr-E	ECo 3021
ENiCr-C	ERNiCr-C	ENi 9946
ENiCrMo-5A	ERNiCrMo-5A	ENi 9906
ENiCrFeCo	ERNiCrFeCo	ENi 9961
ECuAl-A2	ERCuAl-A2	ECu 6180
ECuAl-B		ECu 6220
ECuAl-C	ERCuAl-C	ECu 6280
ECuAl-D	ERCuAl-D	ECu 6281
ECuAl-E	ERCuAl-E	ECu 6282
ECuSi	ERCuSi-A	ECu 6560
ECuSn-A	ERCuSn-A	ECu 5180
ECuSn-C		ECu 5210
ECuNi		ECu 7158
ECuNiAl		ECu 6328
ECuMnNiAl		ECu 6338

[a] IFS: 2002, Tables 13A and 13B

request should contain some indication of the time by which completion of the new classification or modification is needed. In particular, the request needs to include:

(a) All classification requirements as given for existing classifications, such as chemical composition ranges and usability test requirements.

(b) Any testing conditions for conducting the tests used to demonstrate that the product meets the classification requirements. (It would be sufficient, for example, to state that welding conditions are the same as for other classifications.)

(c) Information on Descriptions and intended Use, which parallels that for existing classifications, for that section of the Annex.

(d) A request for a new classification without the above information will be considered incomplete. The Secretary will return the request to the requestor for further information.

(3) The request should be sent to the Secretary of the AWS A5 Committee on Filler Metals and Allied Materials at AWS Headquarters. Upon receipt of the request, the Secretary will:

(a) Assign an identifying number to the request. This number will include the date the request was received.

(b) Confirm receipt of the request and give the identification number to the person who made the request.

(c) Send a copy of the request to the Chair of the AWS A5 Committee on Filler Metals and Allied Materials, and the Chair of the particular Subcommittee involved.

(d) File the original request.

(e) Add the request to the log of outstanding requests.

(4) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report these to the Chair of the AWS A5 Committee on Filler Metals and Allied Materials, for action.

(5) The Secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each AWS A5 Committee on Filler Metals and Allied Materials meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01M/A5.01 (ISO 14344) as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01M/A5.01 (ISO 14344). In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing he normally conducts on material of that classification, as specified in Schedule 1 or F, Table 1, of the AWS A5.01M/A5.01 (ISO 14344). Testing in accordance with any other schedule in that table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

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

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been made. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in AWS A5.01M/A5.01 (ISO 14344).

A5. Ventilation During Welding

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

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

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

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

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

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

A5.2 American National Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is particularly drawn to the section of that document on Health Protection and Ventilation. See also AWS F3.2, *Ventilation Guide for Weld Fume* for more detailed descriptions of ventilation options.

A6. Welding Considerations

A6.1 Role of Hydrogen in Surfacing. Hydrogen can be detrimental to surfacing deposits. The effect varies widely from one alloy type to another. Hydrogen can be detrimental to weld ductility and also result in hydrogen-assisted cracking in the weld metal or HAZ. In general, hydrogen's detrimental effect is the most pronounced for martensitic types, with austenitic types being the least affected. Other factors influencing hydrogen's effect include carbon and alloy contents plus in- service welding variables.

In welding there are many sources for hydrogen contamination. Coating moisture is one of the most important ones. Most electrodes are manufactured and packaged to control moisture. When received, consideration must be given to proper storage to prevent moisture pick-up. During use, improper regard to welding procedure and environmental variables can result in spalling or "hydrogen-induced" (underbead) cracking.

A6.2 Low equipment cost, great versatility, and general convenience make manual shielded metal arc welding very popular. The welding machine, which is essentially a power conversion device, is usually the main item of equipment needed. It may be a motor-generator, transformer, transformer-rectifier combination, or fuel-operated engine combined with a generator. The arc power may be either direct or alternating current. The filler metal is in the form of covered electrodes. (Bare electrode arc welding is a rarity today, though it is feasible with austenitic manganese steel electrodes.) Welding can be done in almost any location and is practicable for a variety of work, ranging from very small to quite large. For some applications, it is the only feasible method; and, for many others (especially where continuous methods do not offer significant benefits), it is the economical choice.

The operation is under the observation and control of the welder, who can easily cover irregular areas and often correct for adverse conditions. It is also helpful if the welder exercises judgment in other matters, such as holding the arc power down to minimize cracking; keeping a short arc and avoiding excessive puddling to minimize the loss of expensive alloying elements in the filler metal; minimizing dilution with base metal; and restricting hydrogen pickup. This process is used extensively for hardfacing, buttering, buildup, and cladding.

Surfacing of carbon and low-alloy steels, high-alloy steels, and many nonferrous metals may be done with the shielded metal arc process. Base metal thicknesses may range from 1/4 in [6 mm] to 18 in [450 mm]. The surfacing metals employed include low- and high-alloy steels, the stainless steels, nickel-base alloys, cobalt-base alloys, and copper-base alloys.

The welding conditions for surfacing are not fundamentally different from those used in welding a joint. The arc and weld pool are shielded by the slag or the gases, or both, produced by the electrode. The type of covering on the electrode has considerable effect on the characteristics of the weld metal. Surfacing can be done on work ranging in size from very small to quite large.

Table A.2 shows how the various shielded metal arc process variables affect the three most important surfacing characteristics: dilution, deposition rate, and deposit thickness.

The table indicates only general trends and does not cover questions of weldability or weld soundness. These factors may make it unwise to change only the indicated variable; this in turn may mean that the desired change in dilution, deposition rate, or deposit thickness may not be achieved. For example, a given welding procedure with a small electrode diameter may produce high dilution. The table indicates that a change to a large size electrode will decrease dilution. This is true, however, only if the amperage, travel speed, position, etc., also remain constant. In many cases, a larger amperage

Table A.2
Effect of Shielded Metal Arc Variables on the Three Most Important Characteristics of Surfacing

		Influence of Change on		
Variable	Change of Variable[a]	Dilution	Deposition Rate	Deposit Thickness
Polarity	AC	Intermediate	Intermediate	Intermediate
	DCEP	High	Low	Thin
	DCEN	Low	High	Thick
Amperage	High	High	High	Thick
	Low	Low	Low	Thin
Technique	Stringer	High	No effect	Thick
	Weave	Low	No effect	Thin
Bead spacing	Narrow	Low	No effect	Thick
	Wide	High	No effect	Thin
Electrode diameter	Small	High	High	Thick
	Large	Low	Low	Thin
Arc length	Long	Low	No effect	Thin
	Short	High	No effect	Thick
Travel speed	Fast	High	No effect	Thin
	Slow	Low	No effect	Thick

[a] This table assumes that only one variable at a time is changed. However, for acceptable surfacing conditions, a change in one variable may require a change in one or more other variables.

value must be used with the larger electrode size to obtain acceptable weld quality. In this case, the dilution may remain constant or even increase with the change to the larger electrode size.

The process usually achieves a deposition rate from 1–4 lb [0.5–2 kg] per hour at dilution levels from 30%–50%.

A7. Description and Intended Use of Surfacing Electrodes

A7.1 Iron-Base Electrodes

A7.1.1 EFe1 and EFe2 Electrodes

A7.1.1.1 Characteristics. Deposits made with these electrodes are a machinery grade steel suitable for application on carbon and alloy steels. With care, they can be applied crack-free. Deposits are machinable with carbide-tipped tools. Deposit hardness generally is in the range of 25–50 HRC with EFe2 electrodes providing weld metal with the higher hardness. These deposits contain sufficient alloy to attain full hardness without the need of heat treatment. Abrasion resistance is comparable to heat-treated steels of equal hardness.

A7.1.1.2 Applications. These electrodes are used to restore worn machinery parts to their original dimensions. Deposit surfaces are suitable for metal-to-metal rolling and sliding contact, such as occurs on large, low-speed gear teeth, shafts, etc. High compressive strength makes these materials suitable as a base for more abrasion-resistant materials.

A7.1.2 EFe3 Electrodes

A7.1.2.1 Characteristics. Weld metal deposited by these electrodes is an air-hardening tool steel type with high room temperature hardness (55–60 HRC). Deposits can be applied crack-free with careful procedures. The deposits cannot be machined and generally are ground when finishing is required.

A7.1.2.2 Applications. EFe3 electrodes are used to overlay surfaces and edges requiring high hardness and crack-free deposits, such as the edges of tools and dies. Deposits are compatible with many tool steels. Although generally used for metal-to-metal applications, EFe3 weld metal performs well in earth abrasion applications where high impact is encountered.

A7.1.3 EFe4 Electrodes

A7.1.3.1 Characteristics. These electrodes will have a graphitic (black) coating and are suitable for application on cast iron. Although the deposited metal is relatively brittle, crack-free deposits can be made with controlled procedures. Deposits can be machined providing they are slow cooled from an annealing temperature.

A7.1.3.2 Applications. EFe4 weld metal is used to rebuild worn cast iron machinery parts subject to metal-to-metal rolling or sliding contact. Although EFe4 weld deposits are compatible with carbon and low-alloy steel, EFe2 electrodes generally are preferred for such applications.

A7.1.4 EFe5 Electrodes

A7.1.4.1 Characteristics. EFe5 electrodes deposit a cold work type of tool steel. Hardness as-deposited should be in the range of 50–55 HRC. Weld metal deposited by EFe5 electrodes is air-hardening and machinable only after annealing.

A7.1.4.2 Applications. Typical applications include those requiring high compressive strength with moderate abrasion and metal-to-metal wear, such as machine components, shafts, and brake drums.

A7.1.5 EFe6 Electrodes

A7.1.5.1 Characteristics. Weld metal deposited by EFe6 electrodes is a high-speed tool steel with a hardness in range of 60 HRC or higher. The deposit maintains a high degree of hardness to 1100°F [600°C]. Weld metal deposited by EFe6 electrodes is air-hardening and is machinable only after annealing.

A7.1.5.2 Applications. Weld deposits may be used for metal-to-metal wear applications at temperatures up to 1100°F [600°C]. Typical applications combine high temperature service with severe abrasion and metal-to-metal wear and include shear blades, trimming dies, and punching dies.

A7.1.6 EFe7 Electrodes

A7.1.6.1 Characteristics. EFe7 series electrodes are essentially a higher carbon modification of EFe3 electrodes. Abrasion resistance of the weld deposit is improved with some sacrifice in resistance to impact. Deposits air harden, and a two-layer deposit can be expected to have a hardness of 60 HRC or higher. Stress-relief cracks (checks) typically occur through the overlay. Deposits cannot be machined.

A7.1.6.2 Applications. EFe7 electrodes are used for overlaying surfaces that require good low-stress abrasion resistance. Applications include cement chutes, fan blades, bulldozer blades, and other parts and equipment used for earthmoving or construction. Carbon and alloy steels, tool steels, and stainless steels are compatible base metals.

A7.1.7 EFeMn Series Electrodes (EFeMn-A through EFeMn-F)

A7.1.7.1 Characteristics. Deposits made with EFeMn series electrodes nominally contain 14% manganese, although they may vary from 12% to 21%. This is an amount sufficient to yield austenitic weld deposits. Austenite is a nonmagnetic, tough form of steel. To preserve the toughness, excessive heat must be avoided during welding. Stringer beads and a block sequence are recommended. The additions of other elements, such as 4% nickel, are made to give more stability to the austenite; chromium, molybdenum, and vanadium are also added singly or in combination of 0.5%–8% to increase the yield strength. Abrasion resistance is only a little better than that of low-carbon steel unless there has been sufficient impact to cause work hardening. As-deposited surfaces generally are no harder than HRC 20, but can work harden to HRC 55. Since deposits are difficult to machine, grinding is preferred for finishing.

A7.1.7.2 Applications. These electrodes are used for the rebuilding, repair, and joining of Hadfield austenitic manganese steel. Ability to absorb high impact makes such deposits ideal for the rebuilding of worn rock crushing equipment and parts subject to impact loading, such as railroad frogs.

A7.1.8 EFeMnCr Electrodes

A7.1.8.1 Characteristics. Weld metal deposited by EFeMnCr electrodes have characteristics similar to austenitic manganese deposits. The high chromium content imparts stainless steel qualities. These deposits cannot be flame cut. Although care must be taken in application to avoid heat build-up, deposits are more stable than FeMn series electrodes.

A7.1.8.2 Applications. Like EFeMn type electrodes, EFeMnCr electrodes are used for rebuilding, repair, and joining of equipment made of Hadfield austenitic manganese steel. EFeMnCr electrodes offer the added advantage of being usable for joining austenitic manganese steel both to itself and to carbon steel. EFeMnCr weld metals often are used as a base for surfacing with EFeCr types for parts subject to both wear and impact.

A7.1.9 EFeCr-A1A and EFeCr-A4 Electrodes

A7.1.9.1 Characteristics. Weld metal deposited by these electrodes will contain massive chromium carbides in an austenitic matrix providing excellent wear resistance and toughness. Surface checks are typical and give some degree of stress relief. Deposits cannot be machined and must be ground when finishing is required. To ensure the desired deposit composition, two layers are recommended. Additional layers invite spalling and must be applied with caution. Electrodes are suitable for welding on carbon, alloy, and austenitic steels as well as cast irons. The weld metal deposited by EFeCr-A1A electrodes generally provides greater resistance to impact but slightly less abrasion resistance than weld metal deposited by EFeCr-A4 electrodes.

A7.1.9.2 Applications. Deposits frequently are used to surface parts and equipment involved in sliding and crushing of rock, ore, etc., such as bucket lips and teeth, impact hammers, and conveyors. Very low coefficients of friction develop as a result of scouring by earth products.

A7.1.10 EFeCr-A2 Electrodes

A7.1.10.1 Characteristics. The weld metal deposit contains titanium carbide in an austenitic matrix. It is machinable only by grinding. Build-up should be limited to three layers to minimize relief check cracking.

A7.1.10.2 Applications. This weld metal group may be applied to both carbon steel and austenitic manganese base metal. Deposits frequently are used to hardface mining, construction, earth moving, and quarrying equipment subject to abrasion and moderate impact.

A7.1.11 EFeCr-A3 Electrodes

A7.1.11.1 Characteristics. Filler metal deposited by EFeCr-A3 electrodes is similar to a deposit made using EFeCr-A1A electrodes except, due to the lower manganese content, a martensitic matrix is present, rendering the deposit somewhat brittle. These deposits are not machinable but may be finished by grinding where necessary.

A7.1.11.2 Applications. This weld metal is a general purpose hardfacing alloy for earth abrasion applications and is suitable for low stress scratching abrasion with low impact.

A7.1.12 EFeCr-A5 Electrodes

A7.1.12.1 Characteristics. The weld deposit contains chromium carbide in an austenitic matrix. The nonmagnetic weld metal has fair machinability. Build-up should be restricted to three layers to minimize stress-relief checking.

A7.1.12.2 Applications. Surfaced components frequently are used for applications involving frictional metal-to-metal wear or earth scouring under low stress abrasion.

A7.1.13 EFeCr-A6 and EFeCr-A7 Electrodes

A7.1.13.1 Characteristics. These are a higher carbon version of EFeCr-A5 electrodes. The deposit contains hexagonal chromium carbides in an austenitic carbide matrix and has a hardness of 50–60 HRC. Deposits develop stress-relief checks. The addition of molybdenum increases wear resistance to high stress abrasion. The weld metal may be applied on carbon, alloy, or austenitic manganese steel base metal.

A7.1.13.2 Applications. Weld metal is frequently used for applications involving low stress abrasive wear combined with moderate impact.

A7.1.14 EFeCr-A8 Electrodes

A7.1.14.1 Characteristics. EFeCr-A8 is a higher chromium version of EFeCr-A3. The deposit contains hexagonal chromium carbides in an austenitic matrix and has a hardness of 50–60 HRC. The increased chromium content tends to decrease the toughness while increasing the abrasion resistance. Maximum relief checking can be expected. The weld metal may be applied to carbon, alloy, or austenitic manganese base metals.

A7.1.14.2 Applications. Weld metal is frequently used for applications involving low stress abrasion combined with minimum impact.

A7.1.15 EFeCr-EX Series Electrodes

A7.1.15.1 Characteristics. This family of electrodes deposits weld metal containing finely dispersed chromium carbides plus one or more metallic carbides (vanadium, niobium [columbium], tungsten, or titanium). The resultant deposits are not machinable, and maintain their hot hardness and abrasion resistance to 1200°F [650°C]. Deposits stress-relief check readily.

A7.1.15.2 Applications. Equipment subjected to severe high stress abrasion combined with moderate impact may be surfaced with one of the specific grades. Selection of the specific grade will be dependent on local service conditions and the specific application.

A7.2 Cobalt-Base Surfacing Electrodes

A7.2.1 ECoCr-A Electrodes

A7.2.1.1 Characteristics. Weld metal deposited by ECoCr-A electrodes is characterized by a hypoeutectic structure consisting of a network of about 13% eutectic chromium carbides distributed in a cobalt-chromium-tungsten solid solution matrix. The result is a material with a combination of overall resistance to low stress abrasive wear coupled with the necessary toughness to resist some degree of impact. Cobalt alloys also are inherently good for resisting metal-to-metal wear, particularly in high load situations that are prone to galling. The high alloy content of the matrix also affords excellent resistance to corrosion, oxidation, and elevated temperature retention of hot hardness up to a maximum of 1200°F [650°C]. These alloys are not subject to allotropic transformation and therefore do not lose their properties if the base metal subsequently is heat treated.

A7.2.1.2 Applications. The alloy is recommended for cases where wear is accompanied by elevated temperatures and where corrosion is involved, or both. Typical applications include automotive and fluid flow valves, chain saw guides, hot punches, shear blades, extruder screws, etc.

A7.2.2 ECoCr-B Electrodes

A7.2.2.1 Characteristics. Weld metal deposited by ECoCr-B electrodes is similar in composition to ECoCr-A deposits except for a slightly higher carbide content (approximately 16%). The alloy also has a slightly higher hardness coupled with better abrasive and metal-to-metal wear resistance. Impact and corrosion resistance are lowered slightly. Deposits can be machined with carbide tools.

A7.2.2.2 Applications. ECoCr-B electrodes are used interchangeably with ECoCr-A. Choice will depend on the specific application.

A7.2.3 ECoCr-C Electrodes

A7.2.3.1 Characteristics. This alloy's deposits have a higher carbide content (19%) than those made using either ECoCr-A or ECoCr-B electrodes. In fact, the composition is such that primary hypereutectic carbides are found in the microstructure. This characteristic gives the alloy higher wear resistance, accompanied by reductions in the impact and corrosion resistance. The higher hardness also means a greater tendency to stress crack during cooling. The cracking tendency may be minimized by closely monitoring preheating, interpass temperature, and postheating techniques.

While the cobalt–chromium deposits soften somewhat at elevated temperatures, they normally are considered immune to tempering.

A7.2.3.2 Applications. Weld metal deposited by ECoCr-C electrodes is used to build up mixer rotors and items that encounter severe abrasion and low impact.

A7.2.4 ECoCr-E Electrodes

A7.2.4.1 Characteristics. Welds made using ECoCr-E electrodes have very good strength and ductility at temperatures up to 1600°F [870°C]. Deposits are resistant to thermal shock, and oxidizing and reducing atmospheres. Early applications of these types of alloys were found in jet engine components such as turbine blades and vanes.

The deposit is a solid-solution-strengthened alloy with a relatively low weight-percent carbide phase in the microstructure. Hence, the alloy is very tough and will work harden. Deposits possess excellent self-mated galling resistance and also are very resistant to cavitation erosion.

A7.2.4.2 Applications. Welds made using ECoCr-E electrodes are used where resistance to thermal shock is important. Typical applications, similar to those of ECoCr-A deposits, include guide rolls, hot extrusion and forging dies, hot shear blades, tong bits, and valve trim.

A7.2.5 Typical hardness values for multilayer welds made using the cobalt-base electrodes are:

ECoCr-A	23–47 HRC
ECoCr-B	34–47 HRC
ECoCr-C	43–58 HRC
ECoCr-E	20–32 HRC

Hardness values for single layer deposits will be lower because of dilution from the base metal.

A7.3 Nickel-Base Surfacing Electrodes

A7.3.1 ENiCr-C Electrodes

A7.3.1.1 Characteristics. Undiluted weld metal of this composition exhibits a structure consisting of chromium carbides and chromium borides in a nickel-rich matrix. The nickel base and high chromium content give these deposits good heat and corrosion resistance. Care should be taken when cooling hardfacing deposits because of a tendency to stress crack. This alloy possesses excellent resistance to low stress abrasion.

A7.3.1.2 Applications. ENiCr-C weld metal flows very easily, has very high abrasion resistance, and normally takes on a high polish. Typical applications include cultivator sweeps, plow shares, extrusion screws, pump sleeves, pistons, and impellers, capstan rings, glass mold faces, centrifuge filters, sucker pump rods, etc. The deposits have high corrosion resistance and normally require grinding for finishing. Single layer deposits typically have a hardness of 35–45 HRC. Multilayer deposits typically have a hardness of 49–56 HRC.

A7.3.2 ENiCrMo-5A Electrodes

A7.3.2.1 Characteristics. Undiluted weld metal deposited by ENiCrMo-5A electrodes is a solid-solution-strengthened alloy with relatively low weight-percent carbide phase produced through secondary hardening. The resultant deposit is tough and work hardenable.

Deposits have the ability to retain hardness up to 1400 °F [760 °C]. Deposits are machinable with high-speed tool bits and have excellent resistance to high-temperature wear and impact.

A7.3.2.2 Applications. These electrodes are used to rebuild and repair hot extrusion dies, hot forging dies, sizing punches, hot shear blades, guide rolls, tong bits, blast furnace bells, etc.

A7.3.3 ENiCrFeCo Electrodes

A7.3.3.1 Characteristics. Weld metal deposited by these electrodes contain a fairly large volume fraction of hypereutectic chromium carbides distributed throughout the microstructure. The alloy offers many of the same high-performance characteristics of deposits made using ECoCr-C or ENiCr-C electrodes in terms of abrasive wear resistance. The reduced nickel or cobalt content, or both, lowers corrosion properties and galling resistance. The high volume fraction of carbides makes this alloy sensitive to cracking during cooling.

A7.3.3.2 Applications. Welds made using ENiCrFeCo electrodes are preferred where high abrasion (low impact) is a major factor. Typical applications are feed screws, slurry pumps, and mixer components.

A7.4 Copper-Base Alloy Electrodes

A7.4.1 Introduction. The copper-base alloy electrodes classified by this specification are used to deposit overlays and inlays for bearing, corrosion-resistant, or wear-resistant surfaces.

A7.4.1.1 ECuAl-A2 electrodes are used for surfacing bearing surfaces, requiring the hardness in the ranges of 130–150 HB, as well as corrosion-resistant surfaces.

A7.4.1.2 ECuAl-B and ECuAl-C electrodes are used primarily for surfacing bearing surfaces requiring hardness in the range of 140–220 HB. These alloys are not recommended for applications that require resistance to corrosion.

A7.4.1.3 ECuAl-D and ECuAl-E electrodes are used to surface bearing and wear-resistant surfaces requiring hardness in the range of 230–320 HB, such as gears, cams, sheaves, wear plates, dies, etc. These alloys are also used to surface dies that form or draw titanium, low-carbon and stainless steels. These alloys are not recommended for applications that require resistance to corrosion.

A7.4.1.4 The ECuSi electrodes are used primarily for surfacing corrosion-resistant surfaces. Copper–silicon deposits generally are not recommended for bearing service.

A7.4.1.5 Copper–tin (ECuSn-*A* and -*C*) electrodes are used primarily to surface bearing surfaces where the lower hardness of these alloys is required, for surfacing corrosion-resistant surfaces, and, occasionally, for applications requiring wear resistance.

A7.4.1.6 Copper–nickel (ECuNi) electrodes are used for rebuilding 70/30, 80/20, and 90/10% copper–nickel alloy or the clad side of copper–nickel clad steel. Preheating generally is not necessary.

A7.4.1.7 Copper-nickel-aluminum electrodes (ECuNiAl) are used to rebuild nickel-aluminum-bronze castings or wrought components. Typical applications are those requiring a high resistance to corrosion, erosion, or cavitation in salt or brackish water.

A7.4.1.8 Copper-manganese-nickel-aluminum (ECuMnNiAl) electrodes are used to rebuild or surface cast manganese-nickel-aluminum bronze castings or wrought material. Typical applications include those requiring excellent resistance to corrosion, erosion, and cavitation.

A7.4.2 Applications

A7.4.2.1 Hardness Ranges. See Table A.3 for typical hardness ranges.

A7.4.2.2 Hot Hardness. The copper-base alloy filler metals are not recommended for use at elevated temperatures. Mechanical properties, especially hardness, will tend to decrease consistently as the temperature increases above 400°F [200°C].

A7.4.2.3 Impact. In general, as the aluminum content increases, impact resistance decreases rapidly. The impact resistance of deposits made by using ECuAl-A2 electrodes will be the highest of the copper-base alloy classifications. Deposits made using ECuSi electrodes have good impact properties. Deposits made using ECuSn electrodes have low impact values.

A7.4.2.4 Oxidation Resistance. Weld metal deposited by any of the ECuAl family of electrodes forms a protective oxide coating upon exposure to the atmosphere. Oxidation resistance of the copper–silicon deposit is fair, while that of copper–tin deposits is comparable to the oxidation resistance of pure copper.

A7.4.2.5 Corrosion Resistance. Several copper base alloy filler metals are used rather extensively to surface areas subject to corrosion from reducing type acids, mild alkalies, and salt water. They should not be used in the presence of oxidizing acids, such as HNO_3, or when sulfur compounds are present. Filler metals producing deposits of higher hardness may be used to surface areas subject to corrosive action as well as erosion from liquid flow for such applications as condenser heads and turbine runners.

A7.4.2.6 Abrasion. None of the copper-base alloy deposits is recommended for use where severe abrasion is encountered in service.

Table A.3
Approximate Weld Deposit Hardness (SMAW)

	Brinell Hardness[a]	
AWS Classification	3000 kg Load	500 kg Load
ECuAl-A2	130–150	—
ECuAl-B	140–180	—
ECuAl-C	180–220	—
ECuAl-D	230–270	—
ECuAl-E	280–320	—
ECuSi	—	80–100
ECuSn-A	—	70–85
ECuSn-C	—	85–100
ECuNi	—	60–80
ECuNiAl	160–200	—
ECuMnNiAl	160–200	—

[a] As-welded condition.

A7.4.2.7 Metal-to-Metal Wear. Copper–aluminum deposits with hardnesses of 130 to approximately 320 HB are used to overlay surfaces subjected to excessive wear from metal-to-metal contact. For example, ECuAl-E electrodes are used to surface dies, and to draw and form stainless and carbon steels and aluminum.

All of the copper-base alloy filler metals classified by this specification are used to deposit overlays and inlays for bearing surfaces, with the exception of the CuSi filler metals. Silicon bronzes are considered poor bearing alloys. Copper-base alloy filler metals selected for a bearing surface should produce a deposit of 50–75 HB under that of the mating part. Equipment should be designed so that the bearing will wear in preference to the mating part.

A7.4.2.8 Mechanical Properties in Compression. Deposits of the ECuAl filler metals have high elastic limits and ultimate strengths in compression ranging between 25 000–65 000 psi [170–450 MPa] and 120 000–171 000 psi [825–1180 MPa], respectively. The elastic limit of ECuSi deposits is around 22 000 psi [150 MPa] with an ultimate strength in compression of 60 000 psi [415 MPa]. The ECuSn deposits will have an elastic limit of 11 000 psi [75 MPa] and an ultimate strength of 32 000 psi [220 MPa].

A7.4.2.9 Machinability. All of these copper-base alloy deposits are machinable.

A7.4.2.10 Heat Treatment. Ordinarily, no heat treatment is needed in surfacing with copper-base alloy filler metals.

A7.4.2.11 Welding Characteristics. To minimize dilution from the base metal when surfacing with copper-base electrodes, the first layer should be deposited using as low an amperage as practical. Excessive base metal dilution can result in reduced machinability and service performance. The manufacturer should be consulted for specific welding parameters.

A7.4.2.12 Preheat. Generally, a preheat is not necessary unless the part is exceptionally large; in this case, a 200°F [100°C] preheat may be desirable to facilitate the smooth flow of the weld metal. At no time should the preheat temperature be above 400°F [200°C] when applying the first layer. On subsequent layers, an interpass temperature of approximately 200°F–600°F [100°C–300°C] will simplify deposition of the weld metal.

A7.5 Tungsten Carbide Electrodes

A7.5.1 Characteristics. Tungsten carbide covered electrodes contain 60% by weight tungsten carbide granules. The WC1 carbide is a mixture of WC and W_2C. The WC2 carbide is macrocrystalline WC. Hardness of the matrix of the deposit can be varied from 30 HRC to 60 HRC depending on welding technique. Hardness of individual carbide particles typically is about 2400 HV20. The abrasion resistance of tungsten carbide deposits is outstanding.

A7.5.2 Applications. Tungsten carbide deposits are applied on surfaces subjected to sliding abrasion combined with limited impact. Such applications are encountered in earth drilling, digging, and farming. Specific tools that may require this type of surfacing overlay include oil drill bits and tool joints, earth handling augers, excavator teeth, farm fertilizer applicator knives, and cultivator shares.

A8. Discontinued Classifications

Some classifications have been discontinued from one revision of this specification to another. This results either from changes in commercial practice or changes in the classification system used in the specification. The classifications that have been discontinued are listed in Table A.4, along with the year in which they were last included in the specification.

A9. General Safety Considerations

A9.1 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Clause A5 and below. Safety and health information is available from other sources, including but not limited to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

A9.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and health Fact Sheets are revised and additional sheeets added periodically.

Table A.4
Discontinued Electrode and Rod Classifications[a]

AWS Classification	Last A5.13 (ASTM A 399) Publication Date	AWS Classification	Last A5.13 (ASTM A 399) Publication Date
RFeCr-A2	1956	ERCuAl-A3[c]	1980
EFeCr-A2	1956	RCuAl-C[b]	1980
ECuZn-E	1956	RCuAl-D[b]	1980
RCuAl-B	1970	RCuAl-E[b]	1980
RCuSn-E	1970	ERCuSn-A	1980
ECuSn-E	1970	RCuSn-D[b]	1980
RFe5-A	1980	RNiCr-A[b]	1980
RFe5-B	1980	RNiCr-B[b]	1980
RFeCr-A1	1980	RNiCr-C[b]	1980
RCoCr-A[b]	1980	EFe5-A	1980
RCoCr-B[b]	1980	EFe5-B	1980
RCoCr-C[b]	1980	EFe5-C	1980
RCuZn-E	1980	EFeCr-Al	1980
ERCuSi-A[c]	1980	ENiCr-A	1980
ERCuAl-A2[c]	1980	ENiCr-B	1980

[a] See A8, Discontinued Classifications (in Annex A), for information on discontinued classifications.
[b] These AWS classifications have been transferred to AWS A5.21:2001 with the revised prefix of "ER" for electrode/rod made from solid stock or prefix of "ERC" for electrode/rod made from metal or flux cored composite stock.
[c] These AWS classifications have been transferred to AWS A5.21:2001 without a change in the classification designation for solid bare electrodes and rods or with the prefix "ERC" for electrode/rod made from metal or flux cored stock.

A9.3 AWS Safety and Health Fact Sheet Index (SHF)[10]

No.	Title
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Spaces*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*
19	*Laser Welding and Cutting Safety*
20	*Thermal Spraying Safety*
21	*Resistance Spot Welding*
22	*Cadmium Exposure from Welding & Allied Processes*
23	*California Proposition 65*

[10] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Rd, Miami, FL 33126.

24 *Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25 *Metal Fume Fever*
26 *Arc Welding Distance*
27 *Thoriated Tungsten Electrodes*
28 *Oxyfuel Safety: Check Valves and Flashback Arrestors*
29 *Grounding of Portable and Vehicle Mounted Welding Generators*
30 *Cylinders: Safe Storage, Handling, and Use*
31 *Eye and Face Protection for Welding and Cutting Operations*
33 *Personal Protective Equipment (PPE) for Welding & Cutting*
34 *Coated Steels: Welding and Cutting Safety Concerns*
36 *Ventilation for Welding & Cutting*
37 *Selecting Gloves for Welding & Cutting*

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Annex B (Informative)
Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS A5.13/A5.13M:2010, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*, but is included for informational purposes only.

B1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

B2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

B2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry along with the edition of the standard that contains the provision(s) the inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

B2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

B2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation is an official interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

B4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

B5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The *AWS Board Policy Manual* requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

B6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

AWS Filler Metal Specifications by Material and Welding Process

	OFW	SMAW	GTAW GMAW PAW	FCAW	SAW	ESW	EGW	Brazing
Carbon steel	A5.2	A5.1	A5.18	A5.20	A5.17	A5.25	A5.26	A5.8, A5.31
Low-alloy steel	A5.2	A5.5	A5.28	A5.29	A5.23	A5.25	A5.26	A5.8, A5.31
Stainless steel		A5.4	A5.9, A5.22	A5.22	A5.9	A5.9	A5.9	A5.8, A5.31
Cast iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel alloys		A5.11	A5.14	A5.34	A5.14	A5.14		A5.8, A5.31
Aluminum alloys		A5.3	A5.10					A5.8, A5.31
Copper alloys		A5.6	A5.7					A5.8, A5.31
Titanium alloys			A5.16					A5.8, A5.31
Zirconium alloys			A5.24					A5.8, A5.31
Magnesium alloys			A5.19					A5.8, A5.31
Tungsten electrodes			A5.12					
Brazing alloys and fluxes								A5.8, A5.31
Surfacing alloys	A5.21	A5.13	A5.21	A5.21	A5.21			
Consumable inserts			A5.30					
Shielding gases			A5.32	A5.32			A5.32	

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AWS Filler Metal Specifications and Related Documents

Designation	Title
FMC	*Filler Metal Comparison Charts*
IFS	*International Index of Welding Filler Metal Classifications*
UGFM	*User's Guide to Filler Metals*
A4.2M (ISO 8249)	*Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*
A4.3	*Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*
A4.4M	*Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*
A5.01M/A5.01 (ISO 14344)	*Procurement guidelines for consumables – Welding and allied processes – Flux and Gas Shielded Electrical Welding Processes*
A5.02/A5.02M	*Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*
A5.1/A5.1M	*Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*
A5.2/A5.2M	*Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding*
A5.3/A5.3M	*Specification for Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*
A5.4/A5.4M	*Specification for Stainless Steel Welding Electrodes for Shielded Metal Arc Welding*
A5.5/A5.5M	*Specification for Low Alloy Steel Electrodes for Shielded Metal Arc Welding*
A5.6/A5.6M	*Specification for Covered Copper and Copper-Alloy Arc Welding Electrodes*
A5.7/A5.7M	*Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes*
A5.8/A5.8M	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M	*Specification for Bare Stainless Steel Welding Electrodes and Rods*
A5.10/A5.10M	*Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods*
A5.11/A5.11M	*Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding*
A5.12/A5.12M	*Specification for Tungsten and Tungsten-Alloy Electrodes for Arc Welding and Cutting*
A5.13/A5.13M	*Specification for Surfacing Electrodes for Shielded Metal Arc Welding*
A5.14/A5.14M	*Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*
A5.15	*Specification for Welding Electrodes and Rods for Cast Iron*
A5.16/A5.16M	*Specification for Titanium and Titanium Alloy Welding Electrodes and Rods*
A5.17/A5.17M	*Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.18/A5.18M	*Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.19	*Specification for Magnesium Alloy Welding Electrodes and Rods*
A5.20/A5.20M	*Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*
A5.21	*Specification for Bare Electrodes and Rods for Surfacing*
A5.22/A5.22M	*Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*
A5.23/A5.23M	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.24/A5.24M	*Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods*
A5.25/A5.25M	*Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*

Designation	Title
A5.26/A5.26M	*Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding*
A5.28/A5.28M	*Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.29/A5.29M	*Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*
A5.30/A5.30M	*Specification for Consumable Inserts*
A5.31	*Specification for Fluxes for Brazing and Braze Welding*
A5.32/A5.32M	*Specification for Welding Shielding Gases*
A5.34/A5.34M	*Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding*