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An American National Standard

Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing



American Welding Society

Key Words — austenitic pipe, chromium-nickel pipe, gas metal arc welding, gas tungsten arc welding, recommended practice, stainless steel pipe, shielded metal arc welding

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Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing

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Abstract

This document presents a detailed discussion of the metallurgical characteristics and weldability of many grades of austenitic stainless steel used in piping and tubing. The delta ferrite content as expressed by ferrite number (FN) is explained, and its importance in minimizing hot cracking is discussed.

A number of Figures and Tables illustrate recommended joint designs and procedures. Appendix A presents information on the welding of high-carbon stainless steel cast pipe fittings.

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Foreword

(This Foreword is not a part of D10.4-86, *Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing* but is included for information purposes only.)

These recommended practices are intended to provide information which may be used to avoid, or at least minimize, difficulties in welding austenitic stainless steel piping and tubing. The term *pipe* used in the text also includes *tube*. Cast chromium-nickel stainless steel pipe with carbon content above 0.20 percent requires practices different from the austenitic stainless steels, therefore they are covered in the Appendix.

The first document on this subject was approved by the AWS Board of Directors in August 1955 under the title, *The Welding of Austenitic Chromium-Nickel Steel Piping and Tubing, A Committee Report* and published as AWS D10.4-55T. This version was revised in 1966.

In 1979, a major updating of the document was completed and published as AWS D10.4-79, *Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing*. This version presented a detailed discussion of the role of delta ferrite in austenitic chromium-nickel steel welds.

The present document further expands and refines this information and, in addition, contains an Appendix which gives recommendations for welding high-carbon stainless steel castings.

Comments or inquiries pertaining to these recommended practices are welcome. They should be addressed to: Secretary, AWS Committee on Piping and Tubing, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135.

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Recommended Practices for Welding Austenitic Chromium-Nickel Stainless Steel Piping and Tubing

Introduction

The ideal piping system would be a single piece of pipe, so formed, shaped, sized, and directed as to contain or convey the fluid required by the process in which it is involved. For most systems this cannot be. Changes in size, shape, direction, and operating conditions usually preclude such a fabrication. Joints become necessary. Piping systems usually must be made of many different components, and the joints that connect them must be as strong and serviceable as the components themselves. Therefore, engineers and mechanics should try to apply those joining methods which most nearly meet the conditions of one-piece fabrication and also allow for necessary assembly, erection, maintenance, and operation.

Most of the austenitic stainless steels are readily weldable when the proper procedures and techniques are followed. They can be joined by most of the fusion welding processes, and good pipe welders can adapt very quickly from carbon steel or low alloy steel to stainless steel. Orbiting pipe welding machines are also very adaptable to these materials.

The instructions in these recommended practices can be put to use by any competent pipe welder in any good shop or field site. Reasonable care is required, as in any pipe welding operation; however, careful adherence to the procedure requirements will usually produce excellent welds in stainless steel piping and tubing.

1. Material Compositions and Specifications

1.1 Compositions. Chemical composition ranges and type numbers for those stainless steels generally available in wrought piping and tubing are listed in Table 1. These are American Iron and Steel Institute (AISI) Standard Compositions. Chemical composition ranges and designations for five stainless steels generally available as cast pipe are shown in Table 2. These are included because cast valves and fittings are considered part of a piping system.

The weldability of castings may be somewhat less than that of a wrought stainless steel of the same type. This is because fully austenitic castings have much larger grains than similar wrought material. Consequently, there is less grain boundary area along which to disperse the impurities. As a result, there may be a tendency toward hot cracking when welding some castings. However, proper control of the composition of the casting, to obtain four to ten percent delta ferrite, can prevent hot cracking.

1.2 Specifications. Typical American Society for Testing and Materials (ASTM) specifications covering piping and tubing in both cast and wrought form (seamless or welded) are listed in Table 3. ASTM employs the AISI type numbers for designating the austenitic types. However, the ASTM chemical composition requirements differ slightly from the AISI requirements and will vary slightly in different ASTM specifications. The composition ranges specified for cast tubular products are identical with those of the American Castings Institute (ACI). Specifications for covered welding electrodes and welding rods and electrodes are provided in Tables 4 and 5.

2. Base Metals

2.1 Primary Types (304, 305, 309, and 310). These materials have many applications and are widely used for their corrosion and oxidation resistance, high-temperature strength, and low-temperature properties. However, there are a number of welding-related characteristics that may affect all of these, as noted below.

Types 304 and 305 may become sensitized by welding, depending on their carbon content and the manner in which they are welded, and as a result may require solution annealing to restore immunity to intergranular

Table 1
Types of Chromium-Nickel Stainless Steel Available in Piping and Tubing

	Chemical Composition Limit, Percent[a]							
Type	C	Mn	Si	Cr	Ni[b]	P	S	Other Elements
304	0.08	2.00	1.00	18.0–20.0	8.0–10.5	0.045	0.03	—
304H	0.04–0.10	2.00	1.00	18.0–20.0	8.0–10.5	0.045	0.03	—
304L	0.03	2.00	1.00	18.0–20.0	8.0–12.0	0.045	0.03	—
304LN	0.03	2.00	1.00	18.0–20.0	8.0–10.5	0.045	0.03	0.10–0.15 N
304N	0.08	2.00	1.00	18.0–20.0	8.0–10.5	0.045	0.03	0.10–0.16 N
305	0.12	2.00	1.00	17.0–19.0	10.5–13.0	0.045	0.03	—
308	0.08	2.00	1.00	19.0–21.0	10.0–12.0	0.045	0.03	—
309	0.20	2.00	1.00	22.0–24.0	12.0–15.0	0.045	0.03	—
309S	0.08	2.00	1.00	22.0–24.0	12.0–15.0	0.045	0.03	—
310	0.15	2.00	1.50	24.0–26.0	19.0–22.0	0.045	0.03	—
310S	0.08	2.00	1.50	24.0–26.0	19.0–22.0	0.045	0.03	—
316	0.08	2.00	1.00	16.0–18.0	10.0–14.0	0.045	0.03	2.0–3.0 Mo
316H	0.04–0.10	2.00	1.00	16.0–18.0	10.0–14.0	0.045	0.03	2.0–3.0 Mo
316L	0.03	2.00	1.00	16.0–18.0	10.0–14.0	0.045	0.03	2.0–3.0 Mo
316LN	0.03	2.00	1.00	16.0–18.0	10.0–14.0	0.045	0.03	2.0–3.0 Mo 0.10–0.3 N
316N	0.08	2.00	1.00	16.0–18.0	10.0–14.0	0.045	0.03	2.0–3.0 Mo 0.10–0.16 N
317	0.08	2.00	1.00	18.0–20.0	11.0–15.0	0.045	0.03	3.0–4.0 Mo
317L	0.03	2.00	1.00	18.0–20.0	11.0–15.0	0.045	0.03	3.0–4.0 Mo
321	0.08	2.00	1.00	17.0–19.0	9.0–12.0	0.045	0.03	5 × % C min. Ti
321H	0.04–0.10	2.00	1.00	17.0–19.0	9.0–12.0	0.045	0.03	5 × % C min. Ti
347	0.08	2.00	1.00	17.0–19.0	9.0–13.0	0.045	0.03	10 × % C min. Cb + Ta[c]
347H	0.04–0.10	2.00	1.00	17.0–19.0	9.0–13.0	0.045	0.03	10 × % C min. Cb + Ta
348	0.08	2.00	1.00	17.0–19.0	9.0–13.0	0.045	0.03	10 × % C min. Cb + Ta[c] 0.2 Cu
348H	0.04–0.10	2.00	1.00	17.0–19.0	9.0–13.0	0.045	0.03	10 × % C min. Cb + Ta[c] 0.2 Cu

a. Single values are maximums.
b. For some tubemaking processes, the nickel content of certain austenitic types must be slightly higher than shown.
c. Ta is optional.

Table 2
Types of Chromium-Nickel Stainless Steel Castings

ASTM[b] Designation	Nominal Composition	Chemical Composition, Percent[a]							
		C	Mn	P	S	Si	Cr	Ni	Other Elements
CF3	19–9	0.03	1.50	0.04	0.04	2.00	17.0–21.0	8.0–12.0	—
CF8	19–9	0.08	1.50	0.04	0.04	2.00	18.0–21.0	8.0–11.0	—
CF8M	19–10 Mo	0.08	1.50	0.04	0.04	2.00	18.0–21.0	9.0–12.0	2.0–3.0 Mo
CF3M	19–10 Mo	0.03	1.50	0.04	0.04	1.50	17.0–21.0	9.0–13.0	2.0–3.0 Mo
CH8	25–12	0.08	1.50	0.040	0.040	1.50	22.0–26.0	12.0–15.0	—
CPK20	25–20	0.20	1.50	0.040	0.040	1.00	23.0–27.0	19.0–22.0	—
CH20	25–12	0.20	1.50	0.040	0.040	2.00	22.0–26.0	12.0–15.0	—

Note: Chromium-nickel stainless steel castings with carbon content above 0.20% are covered in the Appendix of this report.

a. Single values are maximums.
b. American Society for Testing and Materials.

Table 3
ASTM Specifications Applicable to Austenitic Stainless Steel Piping and Tubing Components

Specification Designation	Product
A213	Seamless ferritic and austenitic alloy steel boiler, superheater, and heat-exchanger tubes
A249	Welded austenitic steel boiler, superheater, heat-exchanger, and condenser tubes
A269	Seamless and welded austenitic stainless steel tubing for general service
A270	Seamless and welded austenitic stainless steel sanitary tubing
A271	Seamless austenitic chromium-nickel steel still tubes for refinery service
A312	Seamless and welded austenitic stainless steel pipe
A351	Austenitic steel castings for valves, flanges, fittings, and other pressure-containing parts
A358	Electric fusion welded austenitic chromium-nickel alloy steel pipe for high-temperature service
A376	Seamless austenitic steel pipe for high temperature central-station service
A403	Wrought pipe fittings
A409	Welded large outside diameter light-wall austenitic chromium-nickel alloy steel pipe for corrosive or high-temperature service
A430	Austenitic steel forged and bored pipe for high-temperature service
A451	Centrifugal cast austenitic steel pipe for high-temperature service
A452	Centrifugal cast austenitic cold wrought stainless steel pipe for high-temperature service
A688	Welded tubes

attack when exposed to certain corrosive environments. (See 9.2 for a detailed discussion of this form of corrosive attack.) However, these steels often are used in the as-welded condition when it is known that the service condition does not produce intergranular attack.

The likelihood of corrosive attack on material sensitized by welding is not so great for the higher chromium grades such as Types 309 and 310. However, these types cannot be considered totally immune to intergranular attack when they are in a sensitized condition.

2.2 Chromium-Nickel-Molybdenum Types (316 and 317). The addition of molybdenum to the chromium-nickel alloys does not alter their welding characteristics in any significant way. However, the welds themselves may display slightly greater susceptibility to intergranular corrosion in sensitized heat-affected zones than Type 304 in nitric acid service. Molybdenum reduces the resistance of stainless steel to corrosion by nitric acid.

2.3 Stabilized Types (321 and 347). Titanium, columbium and tantalum are carbide stabilizing elements. During the steel making process, they combine with carbon before chromium does. Thus, in subsequent welding, the formation of chromium carbides is minimized. When chromium carbide forms, the adjacent metal is depleted of chromium, thus reducing the materials corrosion resistance.

However, during welding, a very narrow zone immediately adjacent to the fusion line, in the heat-affected zone (HAZ) of the weld, is heated to a temperature high enough to dissolve almost all of the titanium, columbium and tantalum carbides. If the welded joint is subsequently heated to a temperature in the vicinity of 1200°F (650°C) chromium carbides will precipitate at the grain boundaries. Thus, the conditions are set up for what is known as "knife line attack" in a corrosive environment.

Knife line attack can be prevented by reheating the welded joint to a temperature in the vicinity of 1600°F (870°C). At this temperature, titanium, columbium, and tantalum carbides precipitate in preference to chromium carbides since their solubility temperature is lower than that of chromium carbide. This is called a "stabilizing heat-treatment" since it does not impair the corrosion resistance of the steel.

Type 321 is stabilized with titanium, while Type 347 is stabilized with columbium and tantalum. Type 321 displays a greater susceptibility to knife line attack than Type 347 because of the lowered solution temperature of titanium carbide compared with columbium and tantalum carbide.

2.4 Low Carbon Types (304L, 309S, 310S, and 316L). These types are low carbon modifications of the corresponding or primary grades. In Types 304L and 316L, an extra low carbon content (0.030 percent maximum) minimizes the precipitation of chromium carbide both during welding and any sensitizing postweld heat treatment. This in turn preserves the corrosion resistance of the weldment. Similarly, Types 309S and 310S with 0.08 percent maximum carbon, reduces the likelihood of corrosion in comparison with their higher carbon counterparts.

Table 4
Electrodes and Welding Rods used in Welding Specific Cast and Wrought Austenitic Stainless Steels

Type of Stainless Steel		Composition	Covered Electrodes, Specification AWS A5.4,	Bare Welding Rods or Electrodes, Specification AWS A5.9,
Wrought	Cast[a]	Nominal	Shielded Metal Arc Welding	Gas Tungsten Arc, Gas Metal Arc, and Submerged Arc Welding
304	CF-8	18-8	—	—
304H	—	18-8	E308	ER308
305	—	20-10	—	—
304L	CF-3	18-8LC	E308L E347	ER308L ER347
309	CH20	25-12	E309	ER309
309S	CH8	25-12LC	E309 E309Cb	ER309
310	CPK-20	25-20	E310	ER310
310S	—	25-20LC	E310 E310Cb	ER310
316	CF-8M	18-12Mo	E316[b]	ER316[b]
316H	CF-12M	18-12Mo	E16-8-2 E316[b]	ER16-8-2 ER316[b]
316L	CF-3M	18-12MoLC	E316L[b] E318[b]	ER316L
317	—	19-14Mo	E317	ER316
317L	—	19-14MoLC	E317L	ER317L
321	—	18-10Ti	E347[c]	ER321
321H	—	18-10Ti	—	ER347
347	—	18-10Cb	—	—
347H	—	18-10Cb	—	—
348	—	18-10Cb	E347	ER348
348H	—	18-10Cb	—	—
—	CF-8C	18-10Cb	—	—

a. Castings higher in carbon but otherwise of generally corresponding compositions are available in the heat-resisting grades. These castings carry the "H" designation (HF, HH, and HK, for instance). Electrodes best suited for welding these high carbon versions are the standard electrodes recommended for the corresponding but lower carbon corrosion-resistant castings shown above (see Appendix).
b. Joints containing 316, 316L, 317, and 318 weld metal may occasionally display poor corrosion resistance in the "as-welded" condition, particularly where hot oxidizing acids are involved. Corrosion resistance of the weldment, for all grades of Cr-Ni-Mo base metal may be restored by rapid cooling from 1950-2050° F (1065-1120° C).
c. Type 321 covered electrodes are not manufactured because titanium is not readily transferred across an electric arc.

2.5 "H" Types (304H, 316H, 321H, 347H, and 348H). Carbon contributes to the high-temperature strength of austenitic stainless steel. This precludes the application of austenitic Cr-Ni steel having an extra low carbon content in high-temperature service where strength is an important consideration. Five steels are identified with the "H" suffix for use at high temperature. In these steels, the carbon content must be held within a specified range (i.e., 0.04-0.10 percent), rather than being held at or below a maximum carbon level.

2.6 Stainless Steel for Nuclear Service (Types 348 and 348H). For nuclear applications, where pipe may become radioactive, the long-term serviceability of the steel can be improved by limiting its tantalum content. Type 348 and 348H steels have properties similar to Types 347 and 347H, respectively, except that they contain no more than 0.10 percent tantalum. For this same purpose, limitations may also be placed on the cobalt content.

In most nuclear applications, the most common types of stainless steels have been 304, 304L, 316, and 316L.

Table 5*
Chemical Composition Requirements for Weld Metal from Corrosion-Resisting Steel Covered Welding Electrodes[a, b]

AWS Classification[c]	C[d]	Cr	Ni	Mo	Cb plus Ta	Mn	Si	P	S	N	Cu
E307	0.04–0.14	18.0–21.5	9.0–10.7	0.5–1.5	—	3.3–4.75	0.90	0.04	0.03	—	0.75
E308	0.08	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E308H	0.04–0.08	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E308L	0.04	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E308Mo	0.08	18.0–21.0	9.0–12.0	2.0–3.0	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E308MoL	0.04	18.0–21.0	9.0–12.0	2.0–3.0	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E309	0.15	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E309L	0.04	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E309Cb	0.12	22.0–25.0	12.0–14.0	0.75	0.70–1.00	0.5–2.5	0.90	0.04	0.03	—	0.75
E309Mo	0.12	22.0–25.0	12.0–14.0	2.0–3.0	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E310	0.08–0.20	25.0–28.0	20.0–22.5	0.75	—	1.0–2.5	0.75	0.03	0.03	—	0.75
E310H	0.35–0.45	25.0–28.0	20.0–22.5	0.75	—	1.0–2.5	0.75	0.03	0.03	—	0.75
E310Cb	0.12	25.0–28.0	20.0–22.0	0.75	0.70–1.00	1.0–2.5	0.75	0.03	0.03	—	0.75
E310Mo	0.12	25.0–28.0	20.0–22.0	2.0–3.0	—	1.0–2.5	0.75	0.03	0.03	—	0.75
E312	0.15	28.0–32.0	8.0–10.5	0.75	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E316	0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E316H	0.04–0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E316L	0.04	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E317	0.08	18.0–21.0	12.0–14.0	3.0–4.0	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E317L	0.04	18.0–21.0	12.0–14.0	3.0–4.0	—	0.5–2.5	0.90	0.04	0.03	—	0.75
E318	0.08	17.0–20.0	11.0–14.0	2.0–2.5	6 × C min to 1.00 max	0.5–2.5	0.90	0.04	0.03	—	0.75
E320	0.07	19.0–21.0	32.0–36.0	2.0–3.0	8 × C min to 1.00 max	0.5–2.5	0.60	0.04	0.03	—	3.0–4.0
E320LR	0.035	19.0–21.0	32.0–36.0	2.0–3.0	8 × C min to 0.40 max	1.50–2.50	0.30	0.020	0.015	—	3.0–4.0
E330	0.18–0.25	14.0–17.0	33.0–37.0	0.75	—	1.0–2.5	0.90	0.04	0.03	—	0.75
E330H	0.35–0.45	14.0–17.0	33.0–37.0	0.75	—	1.0–2.5	0.90	0.04	0.03	—	0.75
E347	0.08	18.0–21.0	9.0–11.0	0.75	8 × C min to 1.00 max	0.5–2.5	0.90	0.04	0.03	—	0.75
E349[e,f]	0.13	18.0–21.0	8.0–10.0	0.35–0.65	0.75–1.2	0.5–2.5	0.90	0.04	0.03	—	0.75
E16-8-2	0.10	14.5–16.5	7.5–9.5	1.0–2.0	—	0.5–2.5	0.60	0.03	0.03	—	0.75

*Note: See Table 1, AWS A5.4-81.

a. Analysis shall be made for the elements which for specific values are shown in the table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements, except iron, is not present in excess of 0.50 percent.

b. Single values shown are maximum percentages except where otherwise specified.

c. Suffix -15 electrodes are classified with direct current, electrode positive. Suffix -16 electrodes are classified with alternating current and direct current, electrode positive. Electrodes up to and including 5/32 in. (4.0 mm) in size are usable in all positions. Electrodes 3/16 in. (4.8 mm) and larger are usable only in the flat groove and fillet position and horizontal fillet position.

d. Carbon shall be reported to the nearest 0.01 percent except for the classification E320LR for which carbon shall be reported to the nearest 0.005 percent.

e. Titanium shall be 0.15 percent max.

f. Tungsten shall be from 1.25 to 1.75 percent.

However, problems resulting from the use of these types in certain systems of boiling water reactors have resulted in the development of special nuclear grades. These provide an additional margin of resistance to intergranular stress corrosion cracking in the BWR environment. Other specialized techniques have been developed to minimize this cracking problem with conventional materials.

2.7 High Carbon Cast Types (HF, HH, HK, HE, HT, HI, HU, and HN). In many applications requiring resistance to oxidation, cast Cr-Ni austenitic heat-resisting steels are used. These castings are modifications of the wrought types. The first five listed are basically the Types 304, 309, 310, 312, and 330 with carbon content increased up to about 0.75 percent. The three other types involve higher carbon content and some changes in the chromium, or nickel, or chromium-nickel composition. These cast alloys are designed for higher temperature service then the primary types.

The welding of high carbon (over 0.20 percent) stainless steel castings requires special high carbon electrodes to match the high-temperature strength and creep prop-

erties. In addition, special welding techniques and procedures are required for these materials to compensate for the low elongation and the aging characteristics associated with these alloys.

Weldability differs greatly between high carbon austenitic stainless steel and both wrought and lower carbon components. Weld techniques, filler metal selection, and special treatments for a particular high carbon stainless steel, HK-40, are given in Appendix A.

2.8 Low Carbon Cast Types (CF3, CF8, CF8C, CF8M, CF3M, CH8, CPK20, and CH20). Table 2 lists the most widely used types of chromium-nickel stainless steel castings with carbon contents under 0.20 percent. These castings, although their compositions are not identical, may be welded in the same way as their wrought equivalents as listed below:

Cast alloy	Wrought equivalent
CF3	304L
CF8	304
CF8M	316
CF3M	316L
CH8	309S
CPK-20	310
CF8C	347
CH20	309

3. Filler Metal

3.1 Selection of Filler Metal. Filler metals that yield weld metal of the same general composition as the base metals are available. However, the selection of a suitable filler metal to join a particular type of base metal is not always accomplished by matching the type numbers or even actual chemical compositions. The performance of present-day welding electrodes and rods has been improved through modifications in composition to control weld structure, which in turn determines the properties of the weld metal. In some instances, new designations are applied to the filler metals because of extensive modifications in composition. The types of austenitic stainless steel used in piping and the filler metals commonly used for joining them are shown in Table 4.

3.2 Welding Electrodes. Chemical composition requirements of weld metal from welding electrodes and rods are given in Tables 5 and 6 and the latest editions of AWS publications; A5.4, *Specification for Covered Corrosion-Resisting Chromium-Nickel Steel Welding Electrodes* and A5.9, *Specification for Corrosion-Resisting Chromium-Nickel Steel Bare and Composite Metal Cored and Stranded Welding Electrodes and Welding Rods*.

3.2.1 Covered Electrodes. There are two kinds of coverings commonly used on stainless steel electrodes, "lime" and "titania." The lime covering is designated by the suffix -15 and the titania by -16. The -15 is for use with direct current, electrode positive, and the -16 for use with alternating current or direct current, electrode positive. Some -16 coverings operate satisfactorily with direct current, electrode negative and may be used in special cases where shallower penetration is desired.

The -16 electrode has a less penetrating arc and produces flatter, smoother welds in the horizontal and flat positions, with easier slag removal than the -15 . The original -16 types were distinctly inferior to the -15 types when welding in positions other than flat (out-of-position welding); thus, the -15 type was preferred for this work. Improvement in out-of-position welding characteristics of the -16 types has caused increased use of this type in areas where the -15 type was traditionally used. Where maximum assurance of highest metallurgical quality weld metal is required, the -15 type may still be preferred.

Both types of coverings are hygroscopic, and excessive moisture absorption may cause welding problems such as porosity, flaking and flaring of the covering, and erratic arc action.

For electrodes in opened containers, the humidity, length of time of exposure, types of service, and weld metal quality required are factors which will determine the need for redrying before use. It is preferable to avoid the need for redrying by keeping the electrodes warm and dry at all times. When redrying is necessary, the electrode manufacturer's recommendation should be followed. In general, unless the manufacturer advises to the contrary, long times above 650°F (343°C) temperatures are to be avoided, as the covering may be damaged.

3.2.2 Bare Filler Metal. Since these materials do not have coverings, their storage and care present no problem with respect to moisture absorption. However, storage areas should be dry and clean to avoid contamination from dirt, oils, and other lubricants and extraneous chemicals, such as sulfur bearing materials.

These materials are supplied in straight lengths, in coils with or without support, and on spools.

AWS specification A5.9 has specific requirements for identification of bare filler metal. Cut lengths present an identification problem after they have been removed from the container. However, adhesive tags on one or both ends or identification marking are effective identification methods.

AWS specification A5.30, *Specification for Consumable Inserts*, has specific requirements for identification of consumable inserts. See 7.2 and 7.3 for details of their use.