

Recommended Practices for Surfacing and Reconditioning of Industrial Mill Rolls



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Key Words—Surfacing, hardfacing, mill rolls,
reconditioning

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An American National Standard

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Recommended Practices for Surfacing and Reconditioning of Industrial Mill Rolls

1st Edition

Prepared by the
American Welding Society (AWS) D14 Committee on Machinery and Equipment

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This standard provides guidance, based upon experience, for preparing, building up and overlaying by welding, postweld heat treating, finish machining, inspecting, and record-keeping of new and reconditioned industrial mill rolls.



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Foreword

This foreword is not a part of AWS D14.7/D14.7M:2005, *Recommended Practices for Surfacing and Reconditioning of Industrial Mill Rolls*, but is included for informational purposes only.

With the increasing use of welding to repair and build up industrial rolls, the AWS D14 Committee on Machinery and Equipment saw a need to provide guidance in this application of welding so that standard procedures and recommendations could be established. With the critical applications in which these rolls are often used, it is important to have guidelines for properly repairing or reconditioning them.

While welding (mainly submerged arc welding) has been used for repairs and recondition of industrial mill rolls for a number of years prior to the issuance of this standard, it was felt that an industry standard should be developed to provide guidance in the proper application of this process. Work on this first edition began in the mid-1990s and has culminated in the publication of this standard in 2005.

Your comments for improving the *Recommended Practices for Surfacing and Reconditioning of Industrial Mill Rolls* are welcome. Submit comments to the Managing Director, Technical Services Division, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; telephone (305) 443-9353; fax (305) 443-5951; e-mail info@aws.org; or via the AWS web site <<http://www.aws.org>>.

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Recommended Practices for Surfacing and Reconditioning of Industrial Mill Rolls

1. Scope

An industrial mill roll can be defined as any roll or cylindrical body that transports, processes, guides or performs a function in creating a product in the heavy metals, paper, plastic, or lumber industries. These rolls can come in many shapes and sizes (as shown in Figure 1), and include, but are not limited to, table rolls, guide rolls, caster rolls, pinch rolls, leveler rolls, straightener rolls, bridle rolls, and blocker rolls.

This standard provides guidance, based upon experience, for preparing, building up and overlaying by welding, postweld heat treating (PWHT), finish machining, inspecting, and record-keeping of new and reconditioned industrial mill rolls. While mainly used in the primary metal-working industry, industrial mill rolls are also used in other applications. Because common practice predominately employs submerged arc welding (SAW), this document emphasizes SAW. However many of the principles are applicable, with suitable modifications, to gas metal arc welding (GMAW), flux cored arc welding (FCAW), and electroslag cladding.

This standard makes use of both U.S. Customary Units and the International System of Units (SI). The measurements may not be exact equivalents; therefore each system should be used independently of the other without combining in any way. The designation D14.7 uses U.S. Customary Units. The designation D14.7M uses SI Units. The latter are shown in appropriate columns in tables and figures or within brackets []. Detailed dimensions on figures are in inches. A separate tabular form that relates the U.S. Customary Units with SI Units may be used in tables and figures.

Safety and health issues and concerns are beyond the scope of this standard, and therefore are not fully addressed herein. 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.

Welding symbols shown on drawings should be compatible with those shown in AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. Special conditions or deviations should be fully explained by added notes, details, or definitions.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

2.1 AWS References¹

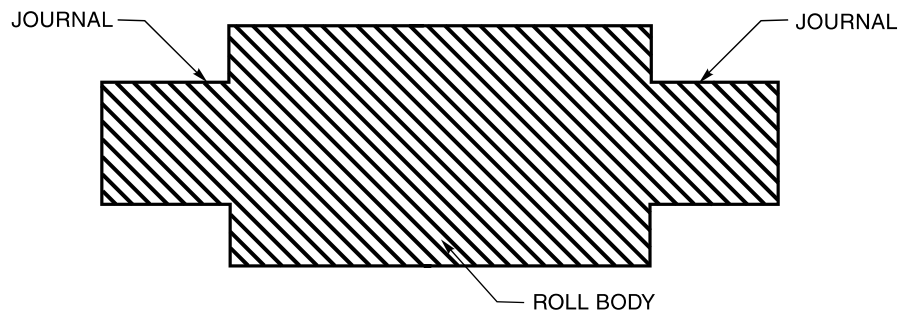
1. AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*
2. AWS A3.0, *Standard Welding Terms and Definitions*
3. AWS A5.17, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*
4. AWS A5.23, *Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
5. AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

2.2 ASTM References²

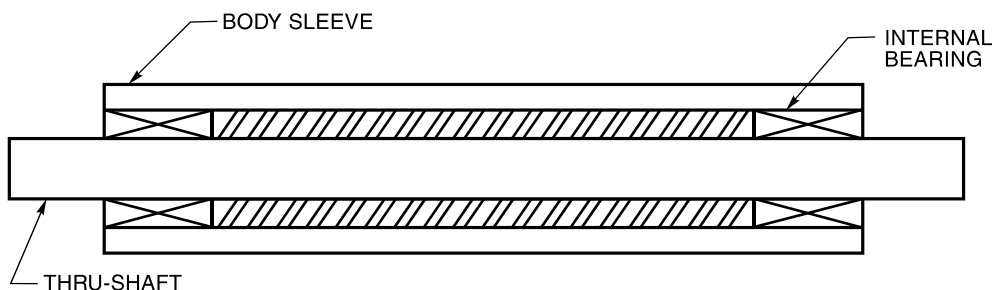
1. ASTM A 388, *Standard Practice for Ultrasonic Examination of Heavy Steel Forgings*

¹ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

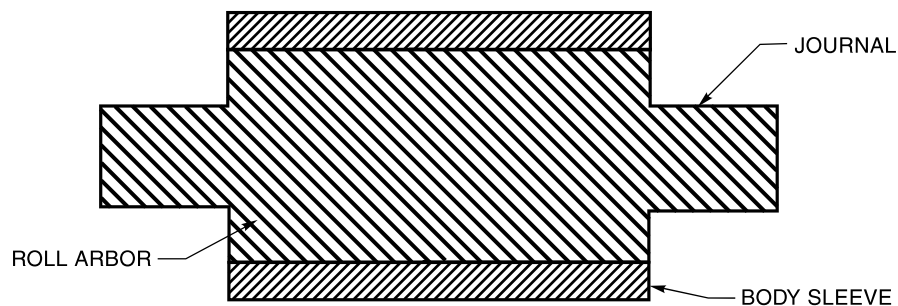
² ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.



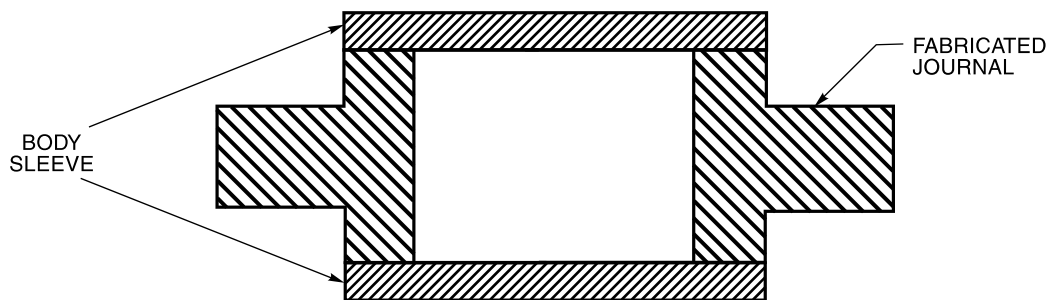
(A) SOLID ROLL WITH INTEGRAL JOURNALS



(B) CYLINDER ROLL WITH INTERNAL BEARING AND THRU-SHAFT



(C) SOLID ROLL WITH SLEEVED BODY AND INTEGRAL JOURNALS



(D) CYLINDER ROLL WITH FABRICATED JOURNALS

Figure 1—Typical Roll Types and Nomenclature

2. ASTM E 165, *Standard Test Method for Liquid Penetrant Examination*

3. ASTM E 709, *Practice for Magnetic Particle Examination*

4. ASTM G 48, *Standard Test Methods for Pitting and Crevice Corrosion Control Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*

3. Definitions

Welding terms used in this standard are in accordance with AWS A3.0, *Standard Welding Terms and Definitions*, which should be referred to for a complete list of terms used in welding. The terms that follow are defined specifically for the purpose of this recommended practice and may be a variation of the term as defined in AWS A3.0.

buildup, industrial rolls. A process of either filling in a void or enlarging an undersized component roll. This process can be performed on a roll body or journal. The weld buildup used in this process typically matches or exceeds the mechanical properties of the base metal.

buttering. The process of creating an intermediate weld layer that allows an overlay or buildup material to be used without creating a crack sensitive alloy. A butter layer provides good weldability between a base metal and an overlay. The butter layer(s) used in this process typically dilutes and mixes with the base material to create a weldable alloy.

dilution. The change in chemical composition of the weld metal caused by the admixture of the base metal or previous weld metal in the weld bead. It is

expressed as the percentage of base metal or previous weld metal in the weld bead.

journal. The part of the roll which provides support for the roll and can contain components like bearings, seals, and chocks (see Figure 1).

overlay, industrial rolls. The process of creating the final composition and mechanical properties of the surface of the roll. The welding overlay is intended to enhance or restore the service performance of the roll (see Figure 2).

roll body. The part of the roll area which is in contact with the product being supported, transported, or shaped (see Figure 1).

spalling. The breaking of weld metal particles away from the base metal or previous hardfacing layers.

4. Base Materials for Rolls, Arbors, Sleeves, and Fabricated Journals

4.1 Overview. The selection of materials for rolls is generally based on the conditions the roll will see in service and whether the roll is to be reconditioned or overlaid at some point in its life. The material procurement specification for a new roll should include material grade, method of manufacture (casting, forging, rolling, etc.), heat treatment and hardness. For a reconditioned roll, efforts should be made to establish the composition and hardness for both the base metal and the surfaces to be reconditioned. Mechanical properties, thermal processing, and weldability of the material are important considerations generally incorporated into the specification for the roll.

4.2 Chemical Composition. Different base materials require different welding techniques and precautions to prevent cracking. Requirements for preheat, postweld

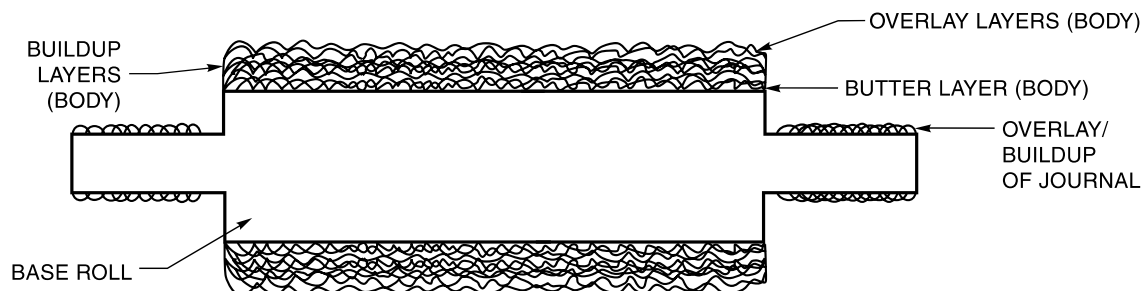


Figure 2—View of Typical Roll Cross Section

heat treatment, and interpass temperature all vary with carbon equivalent (CE_{IIW}). Therefore, it is essential that the compositions of base materials be known before welding. Chemical analysis is recommended to provide information regarding the general weldability of the base metal, the presence of elements detrimental to welding (i.e., high P, high S, or high V), and the sensitivity to stress relief cracking. Table 1 shows the chemical composition of commonly used forged roll materials.

4.3 Weldability. AWS A3.0 defines weldability as “the capacity of the material to be welded under the imposed fabrication conditions into a specific, suitably designed structure and to perform satisfactorily in the intended service.” Weldability is also the ability to weld a material without introducing any cracks or other defects and to achieve the desired properties for the intended application. Over the years, attempts have been made to provide single numbers to characterize the weldability of steels to cover heat-affected zone (HAZ) hardenability and HAZ hydrogen cracking tendency. The most useful formula for hardenability was simplified by a subcommittee of the International Institute of Welding (IIW) into the following “carbon equivalent” formula (Equation 1):

Equation 1:

$$CE_{IIW} = \%C + \%Mn/6 + \% (Cr + Mo + V)/5 + \% (Ni + Cu)/15$$

Note: Generally, steels with CE_{IIW} values above 0.5 are more difficult to weld.

Table 2 shows the CE_{IIW} of commonly used forged roll materials and the suggested minimum preheat temperatures. Generally, the higher the carbon equivalent, the higher the required preheat temperature.

4.4 Mechanical Properties. The two most important mechanical properties for the roll prior to overlaying are yield strength and toughness. The yield strength, at room temperature or at the elevated temperatures the roll might see in service, should be high enough to support the load and resist permanent bending. The toughness of the roll, as measured by the Charpy V-notch impact test, is an indication of the resistance to catastrophic failure from small defects or surface cracks that might initiate and propagate during service. The tests used to measure these properties are generally performed in accordance with appropriate ASTM standard procedures.

Occasionally rolls are procured to hardness requirements only. The approximate yield strength and tensile strength properties of the roll can be estimated from the Brinell hardness, using the following general rules of thumb:

1. Tensile Strength (ksi) is approximately (Brinell Hardness–10)/2

2. Yield Strength (ksi) of a quenched and tempered low alloy steel roll is typically 75% to 80% of the tensile strength.

Table 1 shows the mechanical properties of commonly used forged roll materials. Other materials not listed in the table may be used. Technical information for these materials can usually be obtained from the roll supplier.

Table 1
Typical Chemical Composition and Mechanical Properties of Typical Forged Roll Materials^a

Grade	C	Mn	Si	Ni	Cr	Mo	V	Yield Strength		CVN Notch Toughness ^b	
								ksi	MPa	ft-lb	J
4130	0.30	0.50	0.22	0.20	0.90	0.20	0.05	75	515	60	81
4140	0.40	0.85	0.22	0.20	0.90	0.20	0.05	90	620	65	88
4340	0.40	0.80	0.30	1.80	0.80	0.25	0.05	130	895	20	27
8620	0.20	0.80	0.22	0.50	0.50	0.17	—	45	310	90	136
SCM822M	0.23	0.80	0.24	0.65	1.10	0.40	0.07	83	570	160	217
13CrMo44	0.13	0.55	0.22	—	0.95	0.55	—	50	345	50	68
16CrMo44	0.17	0.65	0.22	0.20	1.00	0.42	0.05	70	485	200	271
FXLC130	0.19	1.00	0.30	1.30	1.15	0.39	—	115	795	20	27
Astralloy V	0.23	0.90	0.30	3.50	1.40	0.30	—	150	1035	20	27
21CrMoV511	0.22	0.40	0.35	0.40	1.30	1.03	0.28	100	690	100	136

^a Select data extracted from: Handerhan, K., The Importance of Fracture Mechanics in the Design of Forged Continuous Caster Rolls, Table IV, *Proceedings from the 1989 Mechanical Working and Steel Processing Conference*.

^b Test Temperature: 70°F [21°C]

Source: Data provided courtesy of the Elwood City Forge Company.

Table 2
Carbon Equivalent and Associated Preheat
Temperatures of Typical Forged Materials

Grade	CE _{IW}	Minimum Preheat Temperature, °F [°C]
4130	0.63	350 [180]
4140	0.79	450 [230]
4340	0.87	500 [260]
8620	0.50	300 [150]
SCM822M	0.72	400 [205]
13CrMo44	0.52	250 [120]
16CrMo44	0.59	325 [165]
FXLC130	0.75	425 [220]
Astralloy	0.95	550 [290]
21CrMoV511	0.83	425 [220]

Source: Data provided courtesy of The Stoodly Company and derived from the graphs in Figure 3.

4.5 Thermal Processing. The heat treatment given a roll is important in that it not only establishes the required mechanical properties, but also, to some extent, controls the performance of the roll during service. Ideally, the selection of the base material and its thermal processing should be such that the roll is resistant to degradation of its mechanical properties during operation at elevated temperatures.

5. Surface Preparation

5.1 General

5.1.1 Proper preparation of the surface of a roll for weld overlay is critical to the success of the welding of new rolls and reconditioning of used rolls. The roll should be cleaned, inspected, and cleared of all linear indications (cracks) and other defects that could cause potential failures. A qualified inspector (qualified to SNT TC-1A, QC1, or other equivalent programs) should conduct the inspection of the prepared surface. The surfaces of the roll should be premachined to provide allowance for the specified deposit thickness and proper welding techniques. Many cleaning processes can expose employees and the environment to potentially harmful fumes and particulates. Surface preparation practices should be reviewed for compliance to applicable safety and environmental regulatory standards, and material safety data sheets (MSDSs) should be consulted.

5.1.2 To determine the areas of the roll that require welding, the existing condition of the roll should be compared to the drawing/specifications as agreed upon by the

end user and Manufacturer. Consideration should be given to areas adjacent to the weld, since the welding and heating operations may alter these surfaces to an out-of-tolerance condition. Similarly, other areas of the roll, such as long, small diameter journals, may distort during welding which should be considered when developing a scope of the work.

5.2 Stress Relieving Prior to Processing

5.2.1 Overview. It is common practice in many shops to perform a stress relief heat treatment on used rolls before beginning the repair process. The stress relief treatment should be conducted at a temperature that does not alter the mechanical properties of the roll's base material. This thermal treatment serves to reduce stresses from both processing and service conditions. It can also reduce the hardness of the roll surface to facilitate easier machining and undercutting for repair.

5.2.2 Parameters. The stress relief temperature is based upon the chemical composition of the base material but is typically between 900°F [480°C] and 1150°F [620°C]. Heating and cooling rates are a function of the mass, configuration, and composition of the roll's base material. These can range from a slow rate of 15°F [8°C] per hour to a fast rate of 200°F [110°C] per hour. There is significant risk that heating too quickly or causing temperature nonuniformity can cause the roll's base material to catastrophically fail. The soak time at maximum temperature is usually based on 0.5 hour per inch [25 mm] of roll material thickness. These types of treatments are usually performed in a furnace that has temperature uniformity within a range of 50°F [30°C] during the heating, soak and cooling steps of the treatment. The capability of the furnace should be known before processing rolls.

5.2.3 Precautions. It might be necessary to protect areas of the roll such as journals, keyways, etc., from scaling during thermal treatment. A suitable high-temperature protective coating may be used to protect areas not intended for subsequent repair.

5.3 Surface Condition. The roll should be free of grease, oil, paint, scale, rust and other contaminants prior to inspection and welding. The condition of the roll surface should be compatible with the inspection method used.

5.4 Methods of Cleaning

5.4.1 Degreasing. The surface of the roll may be cleaned of grease and other hydrocarbon products by using a suitable degreasing solvent. Additional cleaning as required should be performed to provide a clean surface.

5.4.2 Baking. The roll can be cleaned in a furnace by heating to a temperature sufficient to burn off greases and paints. Temperatures during cleaning should remain below the typical base metal tempering range or the properties of the roll could be altered.

5.4.3 Machining. Machining is an efficient method of removing rust, scale, and dirt from the roll surface in preparation for inspection and welding. Additional degreasing and cleaning may be necessary to remove oil or coolant residue from the surface and to clean the areas of the roll which were not premachined.

5.4.4 Grinding, Blasting, or Brushing. Hand grinding, sand blasting or wire brushing can be used to remove burnt or loose residue from the roll surface. When wire brushing, an appropriate type of wire brush suitable with the roll material should be used. Hand grinding can be beneficial for localized cleaning.

5.5 Inspection after Cleaning. Inspection of the roll is recommended after cleaning to develop a scope of the work for repairs and to ensure that the roll is properly prepared for welding. Inspections should be performed and documented as called for by quality requirements, internal or external. A qualified inspector (qualified to SNT TC-1A, QC1, or other equivalent programs) should conduct the inspection of the prepared surface. A typical form for recording incoming inspection results is shown in Figure C.1 of Annex C.

5.5.1 Visual Inspection. The roll should be inspected for its general condition and obvious damage such as open cracks, spalls, and gouges. The heat identification number, which can be used to track the data on roll life and repair history of the roll, should be recorded. The identification numbers should be permanent markings and should be enhanced, if necessary.

5.5.2 Dimensional Inspection. The roll should be identified and inspected to determine out-of-tolerance conditions which would affect the performance of the roll in service. Dimensional inspection should include the body, bearing journals, seal journals, and drive journals. Indicated runout of journals should be measured and the results considered when establishing the Scope of Work.

5.5.3 Nondestructive Examination. 100% nondestructive examination of all roll surfaces is recommended. The roll should be inspected by one or more of the following nondestructive examination methods:

1. Liquid penetrant testing (PT) (see ASTM E 165),
2. Magnetic particle testing (MT) (see ASTM E 709),
3. Ultrasonic examination (UT) (see ASTM A 388),

4. Hardness testing (may be conducted to verify the nature of the surface prior to overlaying).

The acceptance criteria for the tests should be established between the end user and the Manufacturer.

5.6 Premachining for Welding

5.6.1 General. All of the areas for welding should be machined undersize to allow for the specified weld deposit thickness. Additional metal removal may be required if buttered and/or buildup layers are needed between the base metal and final weld deposit. When premachining the body of the rolls, the deposit thickness per pass should be considered so that final machining occurs within the last overlay layer and not the interface between two layers. Generally, areas requiring welding should be undercut by machining to a minimum of 0.040 in. [1 mm] per side.

5.6.2 Radius and Transition Areas. To prevent stress risers and slag inclusions, welding in sharp corners and square shoulders should be avoided. When premachining, transitions between different diameters should be sloped at a 15° angle or greater and the corner radius should be at least 1/4 in. [6 mm] or greater.

5.6.3 Defect Removal

5.6.3.1 Hand Grinding. Short, shallow defects that are small in number can be removed by hand grinding.

5.6.3.2 Machining. To remove numerous or deep discontinuities, the area should be machined using a circumferential method by plunge or side cutting as necessary with a lathe tool. After the discontinuity is removed, the sides of the groove should be beveled and the root should be radiused to permit complete fusion during the welding operation.

5.7 Inspection after Machining. Nondestructive examination should be performed using one or more of the methods listed in 5.5.3 to insure the complete removal of all unacceptable indications.

5.8 Documentation and Reporting. The documentation and reporting of all inspections should be completed as called for by quality requirements, internal and external. Refer to Figure C.1, Annex C for typical inspection documentation.

6. Welding Consumables

6.1 Overview. The vast majority of surfacing and reconditioning of industrial mill rolls is done by the submerged arc welding (SAW) process. SAW with strip electrodes is also used. A limited amount of work is done by flux cored arc welding (FCAW) and very minor

amounts are done by shielded metal arc (SMAW), gas tungsten arc (GTAW), or gas metal arc welding (GMAW). Limited thermal spray has also been applied.

This section briefly describes SAW consumables. Consumables for SAW include both flux and filler metal. (Additional details are found in Annex A.)

6.2 Flux Types. Fluxes may be produced by:

1. Melting the various oxides and fluorides together, then crushing to size (fused fluxes);
2. Mixing powdered oxides, fluorides, and possibly metallic ingredients with a water glass binder, pelletizing, and drying the particles that result (bonded fluxes);
3. Mechanically mixing the ingredients without a bonding agent.

From the point of view of metallurgical reactions during welding, a given flux may be described as acid, basic, or neutral depending on the various oxides and fluorides present in the flux (see A4 for details). Finally, a given flux may contain alloying elements to be added to the weld metal, or it may be unalloyed. Each flux characteristic has an influence on the welding results with a given welding electrode. Since the SAW fluxes commonly used for industrial mill rolls are not classified, it is usually beneficial to establish a relationship with the flux supplier to understand the flux characteristics and to obtain recommendations for flux storage and handling.

6.3 Wire Electrodes. Except for a few mild steel electrodes classified according to AWS A5.17, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*, wire electrodes for industrial mill rolls are generally not classified by AWS. Solid mild steel electrodes are used for buttered layers and some buildup (often in the journal area of a roll). But most buildup and overlaying are done with tubular wire electrodes.

These tubular electrodes may be designed to deposit low-alloy steel (usually for buildup), tool steel (usually for cladding work rolls, guide rolls, and the like where corrosion resistance is not an issue), or stainless steel (where corrosion resistance is important, such as continuous caster rolls which operate in an environment including spray water as well as mold compounds). A given wire is generally designed for use with a particular flux to obtain optimum deposit composition and properties. Therefore, it is important to follow the wire manufacturer's recommendations for flux selection.

Wire electrodes for industrial mill roll welding are often supplied in drums containing as much as 750 lbs [340 kg] or more. The wire in the drums is laid loosely around a center, not tightly wound as might be on a reel or coil. The wire loops can shift if the drum is tilted or

rolled, which can result in tangling when the wire is subsequently fed out of the drum into the welding station. Drums should be maintained vertical at all times, to avoid tangling of the wire.

7. Properties of Weld Deposits

7.1 General. The choice of filler metals for journal repair, weld buildup, and overlay is primarily dictated by the composition of the roll material and the roll operating conditions. For rolling applications that are conducted at room or ambient temperature, the hardness and the compressive strength of the overlay may be the only consideration. For hot rolling applications, the elevated temperature hardness and strength as well as the ductility are important considerations. This situation could further be complicated if corrosive conditions accompany the rolling operation. Typically, buildup and overlay welding materials fall into the following four categories for industrial roll welding:

1. Mild steel for journal repair and roll body buttering,
2. Low alloy steel for journal repair and roll body buildup,
3. Stainless steel (12% Cr) overlay, and
4. Tool steel overlay.

As noted above, the mild steel deposition is typically aimed to produce an undiluted low-carbon deposit of no more than 1.6% Mn and 0.8% Si. However, dilution from the roll body material will generally produce a somewhat higher carbon low-alloy steel deposit. Such deposits are often adequate for journals. The other three general alloy categories are aimed at roll body performance and requirements based on the in-service conditions of the roll. The optimum deposit composition and heat treatment will change from application to application.

7.2 Properties and Composition of Buildup Materials

7.2.1 Properties. Except for chemical composition, all properties of buildup materials should be tested in the heat treated condition. The heat treatment of the test pad prepared for such tests should correspond to the heat treatment the roll will experience during surfacing and reconditioning.

7.2.2 Composition. Buildup materials are used to bring the journal and roll dimensions up to where sufficient overlay material can be deposited so that the machined surface of the overlay is at the required chemical composition and therefore has the required properties for the application. The composition of the buildup

alloys can range from very basic carbon steel to complex low-alloy steel and have been described in the earlier section. Some of the typical compositions used for industrial mill rolls are shown in Table 3. Generally, the simple carbon steels are used to build up dimensions on rolls, which do not require high compressive strengths in their applications.

Another situation where these low carbon steel compositions might be used is where the roll base material is of a high-carbon, high-hardenability material. The deposition of a low-carbon steel will minimize formation of brittle zones in the first layer of the butter material and therefore reduce the risk of cracking. Low-alloy steel deposits serve to provide high compressive strength and a tough matrix, which slows crack propagation.

For solid (hard) wire filler metals, composition usually refers to that of the solid (hard) wire itself as specified by AWS. With tubular wire, the composition refers to that of the weld deposit. The composition should be determined from a pad that is deposited using the welding parameters and flux and wire combination that represent the actual welding condition. Typically, four or more layers of weld metal are deposited to make the pad. The chemical analysis is conducted on the last layer. A typical method can be found in AWS A5.23, *Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*, for preparing a weld pad for chemical analysis.

7.2.3 Hardness. The hardness of the weld deposit reflects its tensile strength. It is primarily governed by the carbon content, although the manganese, silicon, and alloy (e.g., Cr, Mo) levels can also influence it. A rela-

tively hard weld deposit may not be desirable because it could be more prone to cracking. The hardness of the buildup materials will change as a function of the service temperature of the rolls. A room temperature hardness range may be included in the purchasing specification for the buildup materials. A method of deposition (number of layers and welding parameters) as well as the acceptance/rejection range should be agreed upon between the Purchaser and the Manufacturer.

7.2.4 Tensile Properties. The buildup materials are generally chosen so that their tensile strength matches the tensile properties of the base material. The tensile properties are typically evaluated with the weld metal in the heat-treated condition. Tensile properties can be requested as a part of the specification. The details of testing should be worked out between the Purchaser and the Manufacturer. The methods of weld deposition and testing are well covered by AWS filler metal specifications AWS A5.17, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*, AWS A5.23, *Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*, and test specification AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. Typical tensile properties of the low-alloy buildup overlays listed in Table 3 are shown in Table 4.

7.2.5 Impact Toughness. The impact toughness of the buildup material has a significant effect on the ability of a crack that has developed in the overlay material to propagate into the roll. The impact toughness is governed by several factors:

1. Composition of the weld deposit,
2. Preheat and interpass temperature,

Table 3
Typical All-Weld-Metal Compositions Used for Industrial Mill Rolls

	Low Alloy Build-Up			12% Cr Stainless Steel Overlay				Tool Steel Overlay	
	BU1	BU2	BU3	SS1	SS2	SS3	SS4	TS1	TS2
C	0.15	0.15	0.05	0.16	0.04	0.15	0.12	0.28	0.16
Mn	0.9	0.8	0.6	1.2	1.0	1.2	1.1	1.5	1.2
Si	0.5	0.4	0.4	0.5	0.6	0.5	0.4	0.4	0.6
Cr	1.7	0.5	1.4	12.0	13.0	12.0	13.0	6.5	6.0
Ni	—	0.5	2.4	—	4.5	2.0	2.5	—	—
Mo	0.6	0.2	0.4	—	1.0	1.0	1.0	1.0	1.4
V	—	—	—	—	—	0.15	0.18	0.15	—
W	—	—	—	—	—	—	—	1.0	1.1
Nb	—	—	—	—	—	—	0.18	—	—
As-Welded Hardness (HRC)	30	23	25	46	36	44	47	52	45

Source: Data provided courtesy of The Stoodly Company.