

Chapter 10. Welding Procedure Specifications

Many factors contribute to the end result of a welding operation, whether manual shielded metal arc welding of plain carbon steel, or gas shielded arc and electron beam welding of the exotic super alloys. Because of these variations, it is always desirable and often essential that the vital elements associated with the welding of joints are described in sufficient detail to permit exact reproduction and to afford a clear understanding of the intended practices by all concerned. Generally, proposed practices have to be proved adequate by either procedure qualification tests or by sufficient prior use and service experience to guarantee dependability. The purpose of a welding procedure specification is, therefore, to define and document the details that are to be carried out in welding specific materials or parts. To fulfill this purpose efficiently, welding procedure specifications should be as concise and clear as possible, without extraneous detail.

Description and Important Details

Two quite different types of welding procedure specifications are in common use. One is a broad, general type that applies to all welding of a given kind on a specific material. The other is a narrower, more definitive type that spells out in detail the welding of a single size and type of joint in a specific material or part. Only the broader, more general type is usually required by code, classification agency, customer, building, insurance, or other regulatory agencies.

The narrower, more definitive type is most frequently used by manufacturers for their own

control of repetitive in-plant welding operations or by purchasers desiring certain specific metallurgical, chemical, or mechanical properties. However, either type may be required by a customer or agency, depending upon the nature of the welding involved and the judgment of those in charge. In addition, the two types are sometimes combined to varying degrees, with addenda sections to show the exact details for specific joints attached to the broader, more general specification.

Arrangement and details of the welding procedure specifications as written should be in accordance with the contract or purchase requirements and good industry practice. They should be sufficiently detailed to ensure welding that will satisfy the requirements of the applicable code, rules, or purchase specifications.

The following paragraphs list the details usually covered in welding procedure specifications.

Scope: The welding processes, the material, and the governing specifications should be stated and made quite clear.

Base Metals and Applicable Specifications: The base metals should be specified. This may be done either by giving the chemical composition or by referring to the applicable specifications. In addition, if the base metal requires special care before welding, this also should be indicated (i.e., normalized, annealed, quenched and tempered, solution treated, cold worked, etc.)

In some cases, these factors are very important. A welding procedure that would provide excellent results with one material might not

62 / WELDING INSPECTION

provide the same results with another, or even with the same material handled differently. Thus, the fabricator should identify material and indicate its thickness.

Welding Process: The welding process(es) that is (are) to be used should be clearly defined.

Type, Classification, Composition, and Storage of Filler Metals: Composition, identifying type, or classification designation of the filler metal should always be specified to ensure proper use. In addition, sizes of filler metal or electrodes that can be used when welding different thicknesses of material in the different positions should be designated. Filler metal marking is usually sufficient for identification. For some applications, additional details are specified. These may include manufacturer, type, heat, lot, or batch of the welding consumables.

However, marking does not always guarantee that the electrode is in satisfactory condition. Certain types of filler metals and fluxes require special conditions during storage and handling for satisfactory service. For example, low hydrogen electrodes must be conditioned at elevated temperature to reduce the moisture content. The welding procedure should state requirements such as these.

Type of Current and Current Range:

Whenever welding involves the use of electric current, the type of current should be specified. Some electrodes work better on ac, some on dc. If dc is specified, the polarity should be indicated, since most electrodes operate better on a given polarity. In addition, the current ranges for the different size electrodes for different positions and for welding various thicknesses of material should be specified.

Arc Voltage and Travel Speed: For all arc welding processes, it is common practice to list voltage ranges. Ranges for travel speed are mandatory for automatic welding processes and are desirable many times for semiautomatic processes. Also, when welding some steels where heat input is an important consideration, it becomes imperative that the permissible limits for travel speed are noted.

Joint Designs and Tolerances: Permissible joint design details should be indicated, as well as the designated sequence for welding. This

may be done by means of cross-sectional sketches showing the thickness of material and details of the joint or by referring to standard drawings or specifications. Tolerances should be indicated for all dimensions. These tolerances are important, since, for example, increasing the root face or decreasing the included angle or root opening creates a condition wherein even the most expert welder could not produce a satisfactory weld.

Joint Preparation and Cleaning of Surfaces for Welding:

The methods that may be used to prepare joints and the degree of surface cleaning required should be designated in the procedure specification. This may include oxygen cutting, air carbon arc, or plasma cutting (with or without after-cleaning). It may also involve machining or grinding followed by vapor, ultrasonic, dip, or lint-free cloth cleaning with any of a variety of special cleaners. (Methods and practices should conform to the application requirement.) Finally, the methods or practices specified for the production work should be used when qualifying the welding procedure. This includes the use of weld spatter-resisting compounds on the surfaces.

Tack Welding: Whenever the tack welding practices can affect the end results, details concerning just what is to be done in connection with tack welds should be included in the welding procedure specification. In many cases, methods and practices associated with tack welding prior to finish welding are vital.

Joint Welding Details: All details that influence weld quality, in terms of the specification requirements, should be clearly outlined. This usually includes the sizes of electrodes for the different portions of the joints and the different positions, the arrangement of weld passes for filling the joints, pass width or electrode weave limitations, current ranges, and whatever other details are important. These details help determine the soundness of welds and influence the properties of finished joints.

Positions of Welding: A procedure specification should always designate the positions in which the welding is to be (or may be) done. In addition, the manner in which the welding is to be done *in each position* should be designated (i.e., electrode or torch size permissible,

current or gas flow range, number, thickness, and arrangement of weld passes, etc.).

Preheat and Interpass Temperatures:

Whenever preheat or interpass temperatures are significant factors in the production of sound joints, or influence the properties of weld joints, the temperature limits should be specified. With heat-treated alloy steels, neither the preheat nor interpass temperature should exceed the final tempering temperature used to heat treat the base metal. In many cases, the preheat and interpass temperatures must be *kept within a well defined specified range* to avoid degradation of the base metal heat-affected zone.

Preheat and interpass temperatures are generally determined by touching the workpiece close to the weld joint with indicating crayon or pill materials. These melt at a specified temperature or indicate the temperature by the color of the mark. Contact pyrometers and temperature-indicating paints are also used.

When these materials are used on austenitic stainless steels, nickel alloys, and some other materials, care should be taken to ensure that these materials do not contain elements that are injurious (such as sulfur, zinc, lead, mercury, and chlorine).

Peening: Indiscriminate use of peening should not be tolerated; however, it is sometimes used to avoid cracking or to correct distortion of the weld or base metals. If peening is to be used, the details of its application and tooling should be covered in the approved procedure specifications.

Heat Input: Heat input during welding is usually of great importance (for example, when welding heat-treated steels and alloys). Whenever heat input can influence final weld results, it should be prescribed with the details for control outlined in the procedure specification.

Root Preparation Prior to Welding from Second Side: When joints are to be welded from both sides, the methods that are to be used (or may be used) to prepare the second side should be delineated in the procedure specification. This may include chipping, grinding, air carbon arc or oxyfuel gouging, or whatever is needed to prepare the root. Frequently, this preparation is of primary importance in producing weld joints free from cracks and other unsound conditions.

Removal of Weld Sections for Repair:

When a weld is not completely satisfactory the first time it is made, local sections or the complete weld may have to be removed for repair. The methods to be used for removing welds or sections of weld for such repair should be designated in the welding procedure specification. Quite often, the removal methods are the same as those for preparation of the second side of joints for welding. In these cases, the two may be covered together in the welding procedure specification.

Repair Welding: Details of repair welding methods and procedures should be delineated in the welding procedure specification.

Inspection: Type and extent of inspection each weld joint is to receive should be defined in the welding procedure specification. Such inspection may include radiography, magnetic particle, ultrasonic, liquid penetrant, or other more specialized examinations of joints. It may, perhaps, include only visual observation, but whatever the nondestructive test requirements, it should be indicated in the welding procedure specification. It is important to remember that this includes surface finish requirements for non-destructive test inspection. The fabricator could, through ignorance, make welds that fail to meet quality or finish inspection requirements.

Postheat Treatment: When materials or structures require heat treatment after welding to develop required mechanical properties, dimensional stability, or dependability, such treatment should be delineated in the welding procedure specification and be applied to all procedure qualification test welds. This may include a full description of the heat treatment in the actual welding procedure or in a separate fabrication document, such as a shop heat-treating procedure or a shop drawing. With heat-treated alloy steels, the postheat treatment should not exceed the final tempering temperature used to heat treat the base metal.

Marking: If identification of the welder is required, individual identification marks should be adjacent to each weld or a controlled identification system employed. The mark is usually made with low stress steel die stamps rather than sharp-edged stamps.

64 / WELDING INSPECTION

Records: If detailed records of the welding of the joints are required, the specific requirements for these records should be included in the welding procedure specification.

Summary of Important Details

Not all of the preceding applies to every process or application. Also, there may be some not listed.

The various items are listed only for illustration to provide guidance in preparing and reviewing welding procedure specifications. They are not unalterable patterns or rules. As a matter of fact, due to the diversity of welding methods and application requirements, many of the items could be of major consequence in one application and of minor influence—if applicable at all—in another. In considering or reviewing welding procedure specifications, inspectors should weigh these points accordingly.

Certain important factors are classed as essential variables; if changed, requalification is necessary. Much the same situation exists in connection with welder and welding operator qualifications. Some variables that are considered essential and require requalification are outlined in Chapter 12.

Application

Welding procedure specifications are sometimes required by the purchaser to govern fabrication of a given product in a fabricator's shop. More often, however, the purchaser will simply specify the properties he desires in the weldment

in accordance with a code or specification, leaving the fabricator to use a welding procedure that will produce the specified results. In other cases, the purchaser will prescribe that the fabricator establish definite welding procedure specifications and test them, to prove that the resulting welds will meet certain requirements specified by the purchaser, and then follow those welding procedures in production.

The AWS Structural Welding Code employs the concept of prequalified weld joints. By following a number of well defined variables, the user of this code does not have to qualify the procedure. Instead, he must only record the values of the specific variables used. Qualification is required only if any of these variables are changed beyond their specified limits. Records of such procedures are maintained using the form shown in Fig. 11.1.

Examples of Welding Procedure Specifications

Welding procedure specifications of either the general or individual joint types may be prepared in many different ways and may be either quite brief or very long and detailed. Many organizations such as ASME have suggested standard forms which provide sufficient information but are not excessively complex and are not mandatory. Naturally, more complex and critical applications warrant and should have more detailed procedure specifications; regardless, the applicable code, rules, or purchase specifications govern. An example of a welding procedure specification form is shown in Figure 10.1.

QW-482 WELDING PROCEDURE SPECIFICATION (WPS)
 (See QW-201.1, Section IX, 1974 ASME Boiler and Pressure Vessel Code)

Company Name _____	
Welding Procedure Specification No. _____	Date _____ Supporting PQR No. _____
Revisions _____	
Welding Process(es) _____	Type(s) _____
JOINTS (QW-402) Groove Design _____ Backing: Yes _____ No _____ Backing Material (Type) _____ Other _____	POSTWELD HEAT TREATMENT (QW-407) Temperature _____ Time Range _____ Other _____
BASE METALS (QW-403) P No. _____ to P. No. _____ Thickness Range _____ Pipe Dia. Range _____ Other _____	GAS (QW-408) Shielding Gas(es) _____ Percent Composition (mixtures) _____ Flow Rate _____ Gas Backing _____ Trailing Shielding Gas Composition _____ Other _____
FILLER METALS (QW-404) F No. _____ Other _____ A No. _____ Other _____ Spec No. (SFA) _____ AWS No. (Class) _____ Size of Electrode _____ Size of Filler _____ Electrode-Flux (Class) _____ Consumable Insert _____ Other _____	ELECTRICAL CHARACTERISTICS (QW-409) Current AC or DC _____ Polarity _____ Amps (Range) _____ Volts (Range) _____ Other _____
POSITION (QW-405) Position of Groove _____ Welding Progression _____ Other _____	TECHNIQUE (QW-410) String or Weave Bead _____ Orifice or Gas Cup Size _____ Initial & Interpass Cleaning (Brushing, Grinding, etc) _____ Method of Back Gouging _____ Oscillation _____ Contact Tube to Work Distance _____ Multiple or Single Pass (per side) _____ Multiple or Single Electrodes _____ Travel Speed (Range) _____ Manual, Semi-Automatic, or Machine Automatic _____ Other _____
PREHEAT (QW-406) Preheat Temp. _____ Interpass Temp. _____ Preheat Maintenance _____ Other _____	

This form may be obtained from the Order Dept., ASME, 345 E. 47th St., New York, N.Y. 10017

Fig. 10.1—QW-482 welding procedure specification form

TABLE 10.1
WELDING PROCEDURE SPECIFICATION AND WELDER QUALIFICATION FACTORS
WHICH MAY REQUIRE REQUALIFICATION

NOTE: This table is shown FOR ILLUSTRATION PURPOSES ONLY to indicate the general nature of code requirements governing requalification of welding procedures, welders, and operators. It cannot be used by an inspector to determine whether requalification is required in a specific instance. For that information reference must be made to the particular code or specification applicable to the work being inspected.

Procedure Factor	Procedure Requalification May Be Required When the Welding Practices Are Changed to the Extent Indicated Below	Welder or Welding Operator Requalification May Be Required for the Practice Changes Indicated Below
Type, composition, or process condition of the base material	When the base metal is changed to one not conforming to the type, specification, or process condition qualified. (Some codes and specifications provide lists of materials which are approximately equivalent from the standpoint of weldability and which may be substituted without requalification).	Usually not required, unless a marked change is made in the type of filler metal used or covering thereon, e.g., ferritic to austenitic or non-ferrous metal; cellulosic to low-hydrogen type electrode covering, etc.
Thickness of base metal	When the thickness to be welded is outside the range qualified. (The various codes and specifications may differ considerably in this respect. Most provide for qualification on one thickness within a reasonable range; e.g., 3/16" to 2T, 1/2 T to 2T, 1/2T to 1.1T, etc. Some may require qualification on the exact thickness or on the minimum and maximum).	When the thickness to be welded is outside the range qualified.
Joint design	When established limits of root openings, root face, and included angle of groove joints are increased or decreased; i.e., basic dimensions plus tolerances. (Some codes and specifications prescribe definite upper and lower limits for these dimensions, beyond which requalification is necessary. Others permit an increase in the included angle and root opening and a decrease in the root face without requalification. Requalification is also often required when a backing or spacer strip is added or removed or the basic type of material of a backing or spacer strip is changed).	When changing from a double-welded joint or a joint using backing material to an open root or to a consumable insert joint.
Pipe diameter	Usually not required. In fact, some codes permit procedure qualification on plate to satisfy the requirements for welding to be performed	When the diameter of piping or tubing is reduced below specified limits. (It is generally

on pipe.		recognized that smaller pipe diameters require more sophisticated techniques, equipment, and skills).
Type of current and polarity (if dc)	Usually not required for changes involving electrodes or welding materials adapted for the changed electrical characteristics, although sometimes required for change from ac to dc, or vice versa, or from one polarity to the other.	Usually not required for changes involving similar electrodes or welding materials adapted for the changed electrical characteristics.
Electrode classification and size	When electrode classification is changed or when the diameter is increased beyond that qualified.	When the electrode classification grouping is changed and sometimes when the electrode diameter is increased beyond specified limits.
Welding current	When the current is outside of the range qualified.	Usually not required.
Position of welding (For definitions, see Appendix A)	Usually not required, but desirable.	When the change exceeds the limits of the position(s) qualified is only required by some codes; others only when employing impact-tested welding procedures in the vertical-up position.
Deposition of weld metal	When a marked change is made in the manner of weld deposition; e.g., from a small bead to a large bead or weave arrangement or from an annealing pass to a no annealing pass arrangement, or vice versa.	Usually not required.
Preparation of root of weld for second side welding	When method or extent is changed.	Usually not required.
Preheat and interpass temperatures	When the preheat or interpass temperature is outside the range for which qualified.	Usually not required.
Postheat treatment	When adding or deleting postheating or when the postheating temperature or time cycle is outside the range for which qualified.	Usually not required.
Use of spatter compound, paint, or other material on the surfaces to be welded.	Usually not required, but desirable when employing unproven materials.	Usually not required.