# Welding codes and standards - WPS & PQR

**Objectives:** At the end of this lesson you shall be able to
- **describe the welding codes and standards**
- **explain about WPS & PQR**

**Welding procedure, Performance, Qualification and codes**

**Introduction**

'Code' is any set of standards set forth and enforced by a local government for the protection of public safety, health etc.. as in the structural safety of building, (building code) health requirements for plumbing, ventilation etc.... (Sanitary or health code) and the specifications for fire escapes or exits (Fire code)

'Standard' is defined as 'something considered by an authority or by general consent as a basis of comparison, an approved model'.

As a practical matter, codes tell the user what to do and when and under what circumstances to do it. Codes often legal requirements that are adopted by local jurisdictions that then enforce their provisions.

Standards tell the user how to do it and are usually regarded only as recommendations that do not have the force of law.

The uses of welding in Engineering Industries are Boilers, Heat Exchangers, Pressure Vessels, Bridges, Ships, Pipelines, Reactors, Storage tanks, Construction Structures and Equipment etc. When a design engineers designs a welding structure, the function of production & Quality control personnel is to translate that design in to a real component.

From a design point of view properties of the weld joint are designed as

1 Physical soundness (free from discontinuities)

2 Related Theory for Exercise 2.6.06 Metallurgical compatibility (Chemistry of weldment, base metal, gas etc.)

3 Mechanical Properties

The welding Procedure Specification (WPS) is written exactly to translate these property requirements on to relevant welding variables.

The procedure has to be testified on a test piece for its intented performance by a qualified welder. To draw a correct weld procedure, performance methods and qualification criteria, there are popular codes and standards are available.

All the codes specifies the rules for the preparation of welding procedures specification and the qualification of welding procedures, welders and welding operators. This code specifies the rules for all manual and machine welding processes.

**Reading of Welding Procedure specifications (WPS) & Reading of Procedure Qualification Record (PQR)**

Government as well as private organizations develop and issue standards that apply to a particular area of interest. Many standards with regard to the welding industry are prepared by the American Welding Society (AWS). Many countries have their own national standards on the subject of welding.

The following are examples of the various standards, and the bodies responsible for them.

| Standard codes | Country | Responsible bodies |
|---|---|---|
| IS | India | Bureau of Indian Standards (BIS) |
| BS | U.K | British Standard issued by British Standard Association |
| ANSI | U.S.A | The American National Standards Institute (ANSI) |
| AWS | U.S.A | American Welding Society |
| ASME | U.S.A | American Society of Mechanical Engineers |
| API | U.S.A | American Petroleum Institute |
| DIN | Germany | German standard issued by the Deutsches Institute fuer Normung |
| JIS | Japan | Japanese industrial standard issued by the Japanese standards Association |

There is also the International Organization for Standardisation (ISO). The main goal of ISO is to establish uniform standards for use in international trade.

The American Welding Society publishes numerous documents on welding and some of them are listed below:

**Welding procedure qualification**

A welding procedure qualification is the test to prove that the properties of a weld to withstand the service conditions as designed for particular/specific purpose.

**Welder performance qualification**

A welder's performance qualification is the test to certify a welder's or a welding operator's ability to deliver consistently quality welds. This performance qualification is always done in accordance with a qualified weld procedure specification.

**Weld procedure specification**

A WPS is deemed to have been qualified if through tests that are conducted on the weld test coupon meeting the requirements or the acceptance criteria. Acceptance criteria and the specification format may vary depending on the code of design and manufacture. The tests that are carried out on the weld test coupon are destructive tests, and they help to evaluate the mechanical properties of the weldment carried out in accordance with WPS.

The results of this qualification are generally recorded in a format and these are generally recorded in a particular format and this is usually referred to as an Procedure Qualification Record (PQR). Thus for every WPS there has to be at least ONE PQR and vice versa.

A performance qualification is generally done to evaluate the performance of a welder on a welding operator. It is done to evaluate the ability of a welder or operator to perform consistently and deliver sound and good quality welds. As this is done to a WPS which has already been qualified most codes of practice generally permit the evaluation to be done by the use of non destructive tests viz, radiography. Welders and operators who fulfill the requirements are deemed to be certified for welding to the specific WPS/WPSs.

ASME sections IX, AWS B2.1, API 1104 are some of the popular American codes specifying welding procedures and welder performance qualification.

BS 2633, BS 4870/4871, BS 4872, DIN 8560, AD Merkblatt HP 2 and HP 3, eN 288-2 and EN 287-1 are some of the European standards for welding procedures and performance qualification.

IBR chapter 13, IS 2825, IS 7307, IS 7310, IS 7318 are the major Indian codes on welding qualifications.

**Weld procedure specifications, variables and logic for requalification**

A WPS (Weld Procedure Specification) is a document which lists out all the essential characteristics for performing a weld. For purposes of qualifying for the WPS, a test coupon is welded adhering to all parameters as stated/listed in the WPS. A WPS is valid only when supported by a relevant PQR.

The characteristics listed in the WPS, those in this chapter, are otherwise known as variable. As the term signifies, these characteristics may be changed or varied. When these "variables" are changed we have a new WPS. Whenever a change in a particular "variable" is bound to influence the mechanical properties of the weld, then that "variable" is termed as an ESSENTIAL variable. The variable which do not have any impact on the mechanical properties of the weld are generally termed as NON-ESSENTIAL variables. However, under certain conditions, some of the variables could influence the mechanical properties of the weld. Such variables are termed as supplementary essential variables. A more detailed treatment of these is made in the code of manufacture and the same could be referred to.

Similarly those variable that have an influence on the welder's ability to produce sound welds are referred to as essential variables for purposes of Welder Performance Qualification. An example that comes to one's mind right way would be the position in which a weld is made.

**Introduction to ASME Sec.IX**

**Welding procedure and performance qualification**

Section IX of the ASME code specifies the rules for the preparation of welding procedure specification and the qualification of welding procedures, welders and welding operators.

This code specifies the rules for all manual and machine welding processes.

**Materials**

All the materials that can be used for pressure vessel manufacture have been grouped (Table 1) under different 'P' numbers. The object of grouping the base materials is to reduce the number of qualifications required. The 'P' numbers grouping of materials is based essentially on comparable metal characteristics such as composition, weldability and mechanical properties.

**Table 1**

**'P' Number grouping**

| | |
|---|---|
| P1 to P11 | Steel and steel alloy |
| P21 to P30 | Aluminium and aluminium based alloys |
| P31 to P35 | Copper and copper based alloys |
| P43 to P47 | Nickel and nickel based alloys |
| P51 to P52 | Titanium and titanium based alloys. |

**Filler metals**

The filler metals are grouped as both "F" numbers and "A" numbers.

**"F" numbers**

All the electrodes and filler metals are grouped under different "F" numbers. The object of the "F" number grouping (Table 2) is to reduce the number of welding procedures and performance qualifications.

**Table 2**

**"F" Number grouping**

| | |
|---|---|
| F1 to F6 | Steel and steel alloys |
| F21 to F24 | Aluminium and aluminium based alloys |
| F31 to F 37 | Copper and copper based alloys |
| F41 to F45 | Nickel and nickel based alloys |
| F51 | Titanium and titanium alloys |
| F61 | Zirconium and zirconium alloys |
| F71 to F72 | Hard facing weld metal overlay. |

The "F" number grouping is based essentially on their usability characteristics, with respect to coating. This fundamentally determines the ability of the welder to make a satisfactory weld with a given filler metal. For example, the low hydrogen electrodes have been grouped under "F" Number 4 and rutile steel electrode4s under "F" Number 2.

Obviously, a welder who is able to produce a sound weld with a E6013 (rutile) electrode may not be able to produce a sound weld with a low hydrogen lime powder coated electrode.

The skill required to use these electrodes is definitely not the same. "F" Number 1 is thus the easiest (iron powder) electrode used only in downhand fillet/butt and horizontal fillet positions.

**'A' Numbers**

A part from classifying the filler metals under "F" numbers, they are again classified under 'A' number as shown in Table 3. 'A' number classification of the filler metals is based on the weld metal chemical analysis whereas the 'F; number classification is based on the usability, or rather operation characteristics. With these definitions of 'P' numbers and 'A' numbers, we shall now see what the code says regarding welding procedures and welders qualification.

**Table 3**

**'A' number grouping**

| | |
|---|---|
| A 1 | Mild steel |
| A 2 | Carbon - Molybdenum |
| A 3 to A 5 | Chrome - Molybdenum |
| A 6 | Chrome - Martensitic |
| A 7 | Chrome - Ferritic |
| A 8 to A 9 | Chrome - Nickel |
| A 10 | Nickel - 4% |
| A 11 | Manganese-Molybdenum |
| A12 | Nickelchrome-Molybdenum |

**Welding procedures qualification**

The codes stipulate that all the details of the welding procedure should be listed in the 'Welding procedure specification' (WPS).

Each of these welding procedure specifications shall be qualified by the welding of test coupons, and the mechanical testing of the specimens cut from these coupons are required by this code. The welding date for these coupons and the results of these tests shall be recorded in a document known as 'procedure qualification record (PQR)'.

A WPS may require the support of more than one PQR, while alternatively, one PQR may support a number of WPSs. A WPS will be applicable equally for a plate, pipe and tube joints. The WPS should contain the following nine points in detail.

**1 Joints: details**

The groove design, the type of backing used etc. are to be specified in this. If a change in the type of edge preparation (Single Vee, Single 'U' or double Vee etc.) is made or if the joint backing is removed, a new WPS has to written but need not be qualified by a test.

**2 Base metals**

The base metal (P) number and the thickness ranges for which the procedure is applicable etc. have to be mentioned here. If the range of thickness has to be increased or a change of base metal from one 'P' number to another 'P' number is required, a new WPS should be prepared and supported by a PQR after due tests.

**3 Filler metals**

The details of the electrodes, and filler wires such as the 'F' number, 'A' number and the type of the filler metals have to be specified here. The electrodes, flux compositions, (basic, rutile, etc.) are also to be mentioned. A change in 'F' number or 'A' number shall require a new WPS and PQR. A change in the diameter of the electrode also requires a new WPS but need not be qualified by a test. The addition or deletion of filler metals requires a new WPS and PQR after re-tests.

**4 Position**

The positions in which the welding should be done shall be mentioned here. The qualification test can be done in any position but still the same procedure is applicable to all positions.

**5 Preheating**

The preheating temperature, interpass temperature etc. shall be clearly specified. If the preheat is to be decreased by more than 550C, then a new WPS has to be prepared and qualified by a test.

**6 Post - weld heat treatment**

The temperature and soaking time of the post-weld heat treatment shall be shown here. Any change in this shall require a new procedure qualification.

**7 Electrical characteristics**

The type of current, (AC or DC) polarity, amps and voltage etc. have to indicated here.

**8 Gas**

The shielding gases flow rate, details of gas purging etc. will be shown here. Change in gas composition will call for re-qualification.

**9 Technique**

The details of the welding techniques string or weave bead, method of initial and interpass cleaning, back gouging, single or multiple passes, root grinding etc., shall be written here. The test welding can be done either in a plate or pipe material and in any position. The maximum thickness for which the procedure is applicable is generally twice the thickness of the test plate or pipe. The welder who welds the test joint is also qualified for that procedure but only in that position in which he welds whereas the procedure is applicable to all positions. The results of the tests shall be recorded in the PQR including welding, NDT and mechanical test results.

**Welder's qualification**

The purpose of the welder's qualification is to determine the ability of the welder to make sound welds.

The welder may be qualified, based on the results of the mechanical test (two face bends and two root bend tests or four side bend tests) or by radiographic examination of a minimum length of 150 mm for a plate or the entire weld for a pipe. The position of the weld joint has been classified as 1G, 2G, 3G, 4G, 5G and 6G. Table 4 shows the positions qualifying for other positions.

**Table 4**

**Range of positions qualified**

| Test position | Also qualifies |
|---|---|
| 1G | 1G |
| 2G | 1G |
| 3G | 1G |
| 4G | 1G & 3G |
| 5G | 1G & 3G |
| 2G & 5G | All positions |
| 6G | All positions |

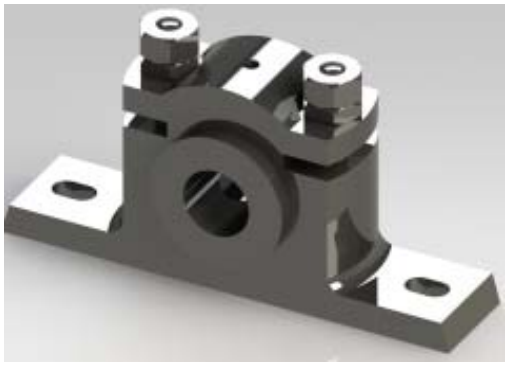
For positions 1G and 2G (flat and horizontal) qualification on a plate shall also qualify the welder in pipes. For all other positions, qualification on a pipe shall qualify for plate but not vice versa.

A qualification in a plate or pipe butt joint shall also qualify the welder for fillet welding in all plate thickness and pipe diameters.

## Reading of assembly drawing

**Objectives:** At the end of this lesson you shall be able to
- **identified the assemblled jobs.**

a bracket bearing



b bracket bearing

Bush

Bush

Slotting

Camp shaft

Internal bush bearing

Various types of bushes

Ball bearing