Most of the people consider the welding qualifications as totally theoretical and hence it is not very uncommon to see people totally ignoring this aspect in a manufacturing set-up. One would often meet several people in the related industries unaware of difference between a welding procedure qualification and a welder qualification. This paper is prepared with the intent of throwing light on aspects related to the welding qualifications.

When an item is designed for a particular application, the material used for the construction of such an item is assumed to have certain properties. Mechanical strength and chemical composition are the two such properties that are considered very commonly in almost all the engineering designs. Naturally a weld joint which forms a part of the component also is assumed to have these properties. Due to the advancements in the Welding Technology and NDT methods it has been possible to obtain weld joints which are as strong as the parent material. Hence, these days, in most cases welds are considered to have the strength same as that of base material.

To check that they have the desired properties, one can carry out any type of tests (either destructive or non-destructive) for the parent metals, in most of the cases. But same is not the case with the weld metals. In most of the cases NDTs are the only methods available for testing the properties. But with NDTs one cannot determine the strength of the weld. Hence one would think of making a sample of the weld and test for the required properties. This would call for a testing, for every new job and every new joint. This is where the concept of welding procedures helps one to reduce the number of tests and hence the cost.

**Welding procedure**

A welder/ welding engineer must know several details before starting the welding, such as base material composition, thickness, process to be used, etc.. These details which a welder/ welding engineer must know before commencing welding are called **Welding Variables**.

A document showing all the applicable welding variables is called **WPS (Welding Procedure Specification)**.

It is not enough if one has only the WPS. One must ensure that the weld made as per WPS meets all the requirements, which are nothing but the properties of the material of construction assumed by the designer while designing the item. Normally, the properties assumed are mechanical strength and chemical composition. Additionally it may also include notch toughness, hardness, corrosion resistance etc.

**How to ensure that the weld made have these properties?**

Weld a coupon as per WPS and test, if it meets the requirements one can assume that weld similarly made also will have similar properties. The document in which the actual values of the
variables and the results of the test are recorded is called a **PQR (Procedure Qualification Record)**. In other words, PQR is a record, which serves as a proof for the satisfactory performance of the weld made as per the specific WPS within the specific ranges permitted.

The above process of testing to ensure the properties is called **Procedure Qualification Test**.

The **WPS & PQR** together constitute a **Qualified Welding Procedure** or in short a **procedure**.

**Whether it is required to carry out the testing for every new joint?**

**No.**

It has been established that a change in the value of the variable need not necessarily change the properties. Accordingly the variables are classified under two groups.

1. Variables, Whose change results in the change in the properties are called as **Essential Variables**
2. Variables, Whose change does not have any effect on the properties are called as **Non Essential Variables**

Variables are listed under one more head known as **Supplementary Essential Variables**. These become essential variable when notch toughness is required for the weld as per applicable code.

Now we have understood 'what a welding procedure is', 'what is meant by the qualification of the welding procedure'. One must notice that welding procedure is only a mock up that can represent welding done in a shop under similar conditions. But, in certain cases where lesser factor of safety is considered this may not be sufficient. Hence, most of the codes call for a production weld coupons as an additional measure. One must note that these production coupons themselves also act as qualification tests for the welding procedures.

**Welder qualification**

Welder qualification is the second type of qualification in the welding.

It is very much similar to a driving licence issued to the drivers. This authenticates a person to perform welding. Just as a person capable of manipulating the steering wheel, brakes, clutch etc., can act as a driver, a person capable of depositing sound weld metal can become a welder. What is required for a welder is skill to deposit sound weld metal by properly interpreting the welding procedure. A document similar to driving license authorizing the driver to drive is the **WPQ (Welder Performance Qualification record)** for the welder.

The process of testing the capability of the welder is known as **"Welder Performance Qualification test"**

One must notice that most of the codes allow welder qualification on the job signifying the fact that what is important is the soundness of final weld. Hence, one must view Welder Qualification more as a tool to get a repair free joint in the first instance.
**Introduction to SEC IX of ASME**

Throughout this paper a reference is made to ASME boiler and pressure vessel code for the sake of convenience. But the discussions are normally valid for any codes.

SEC IX of ASME *covers various aspects relating to the welding qualifications*. The following points must clarify some of the doubts/confusions commonly seen in the beginners.

1. This section must be referred only when the design code (such as SEC VIII div.1), cross-refers to this section
2. This section does not guide in the selection of electrode
3. This section does not guide in the design of joints
4. This section does not specify the type and extent of radiography/ NDT to be used
5. This section does not specify the acceptance criteria (i.e. types and extent of discontinuities acceptable).
6. This section does not specify Energy value for impact testing

For points specified in 3, 4, 5 and 6 one must refer the Design code.

Knowledge of how the contents (and their organization) of SEC IX should greatly help the readers to solve the commonly seen starting trouble.

This section has two parts, welding and brazing. Under Welding there are 4 chapters (Article I to IV), in addition to initial introduction.

**Article I: General.** Mainly covers
- Positions of welding
- Examinations (Various Types of Tests, Testing Procedures, Specimen Details, Acceptance Criteria) etc.

**Article II - Welding Procedure Qualifications**
- WPS, PQR
- Their contents, Format
- List of variables
- Qualified ranges
- Type and number of examinations required

**Article III - Welding Performance Qualifications**
- WPQ
- List of Variables
- Qualified ranges
- Type and number of examinations required

**Article IV - Compiled welding data meant for using with articles I, II, III**

Hence, for example, one who wants to qualify a welder can directly refer article III.
Following Tips must help reader when reading the welding data:

- Never read the welding data given in article IV unless called upon to do so by articles I, II or III.
- Normally adding "a new qualification shall be done when …" before reading data against essential variable given in the tables of Article II and III (such as QW 253/6), makes the reading easy.
- Normally adding "a new qualification is not required when …" before reading the data against non-essential variable given in the tables of article II (such as QW 253/6), makes the reading easy.

**Thickness of the test coupon**

Thickness selection is the important and mostly confused parameter.

**Welding procedure**

Following parameters shall be considered in the selection of thickness:
- Test coupon thickness - governs the range
- Impact requirement - governs the lower limit
- Normalizing requirement - governs the upper limit

Appendix-I describes thickness selection in more detail.

**Welders qualification**

One must preferably qualify a welder with a coupon of 20mm thickness or more which will qualify him to weld deposit of any thickness.

**Grouping of materials**

Base materials and electrodes / filler materials are grouped variously due to their similarity of composition, mfg., Practice etc., to reduce the number of qualification tests to be carried out. Below we will discuss few of them.

**Base metals**

**P number**

This is the grouping of Base Materials based on their chemical composition, weldability, mechanical properties etc. P stands for Parent metal. Table QW422 lists the P numbers of various materials. QW422 and QW424 describe the rules for using the P numbers of qualifications. With the help of P numbers the number of qualification tests required are greatly reduced. For example all plain carbon steels (SA105, SA106, SA515, SA516 etc.) are assigned a P number of 1.

**G number**

This is a sub-grouping of ferrous Base Materials having specified impact test requirements, within a P number. G stands for Group. Table QW422 lists the G numbers of various materials. This will be an additional restriction on P number when impact testing is required for the base/weld metal in the job specification.

A simple example of usage of P number and group number is as follows.
A procedure qualified using a plates confirming to SA516 Gr.60 can be used to weld a joint between the pipes confirming to SA106 Gr.B assuming that all other parameters remain unaffected.

In the WPS it is enough if only P number and group number are specified. When they are not known, material specification shall be written (ex.. if base material IS2062). When specification also is not known, chemical composition shall be written. The latter options actually reduce the range qualified

**Filler materials**

**F number**
This is the grouping of electrodes and filler materials based on their usability characteristics mainly governed by flux or shielding medium used (which also govern their electrical characteristics). F stands for F Filter metal. These are described in QW430

**A number**
This is the grouping of electrodes and filler materials based on the weld metal chemical composition. 'A' stands for weld metal Analysis. These are described in QW440

**Some facts relating to WPS, PQR, WPQ**

- A double welded (welded from both the sides) joint is considered as a joint with backing. Weld metal becomes the Backing material.
- Size of base metal, normally designated as T and size of weld deposit normally designated as t must be considered separately.

**WPS/PQR**

- A procedure qualified using plates can be used for welding the pipes, provided the P number - G number criteria is met.
- A procedure qualified in any one position can be used to weld in any other position provided job specifications do not specify impact test.
- A procedure qualified using groove welds can be used for fillet welds of any size.
- One must always carry out impact testing at the lowest possible temperature, in the procedure qualification test. This can be used for the jobs having impact requirement or not
- Technically, a procedure qualification test, which has failed to meet the required tensile strength can be used for jobs with materials of lower strength. For example, if the tensile test results showed a value of 65 ksi when tested with a coupon material of SA516 Gr.70, E7018 electrode, on normalizing can be used for welds made on equipment of SA516 Gr.60, provided, all other parameters remain same
- A test coupon of thickness 40mm used for procedure qualification test covers largest range from 5 mm to 200mm (without heat treatment or impact requirements).
- The format recommended by SEC IX, commonly used for WPS/ PQR, is common for processes SMAW, GTAW, SAW and GMAW. Hence, one must be careful when using them, since, some of the points are not applicable for some processes.

**WPQ**

- Normally a welder can be qualified using only a radiographic test.
- A change of filler metal (F number) needs a re-qualification of welder
- Presence or absence of impact test or normalizing does not affect the welder's skill and hence the qualification.
- A small diameter pipe requires more skill for welding. Hence, a welder qualified on lower diameters can always weld higher diameters (plate is a pipe with infinite diameter).
Appendix I

Determination of test coupon thickness for welding procedure qualification

Ideally one must start with tables such as QW-253/256, proceed to welding data such as QW-403.8 (as specified in the tables) and then proceed to QW-451 (as specified in the data) and select the thickness in such a way as to cover the largest range.

Let us take an example to illustrate the above point. For the joint configuration shown on the right, various steps to be followed to arrive at the optimum thickness are as follows.

Step 1: Start with thickness same as the job.
But, code does not permit dissimilar thickness for the test coupon

Step 2: choose 16mm (arbitrary), This will qualify us for,

<table>
<thead>
<tr>
<th>Reference</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>As per QW-450 (Based on Thickness of the coupon)</td>
<td>5</td>
</tr>
<tr>
<td>As per QW-407.4 (due to normalizing)</td>
<td>-</td>
</tr>
<tr>
<td>As per QW-403.6 (due to impact test requirement)</td>
<td>16</td>
</tr>
<tr>
<td>Result</td>
<td>16</td>
</tr>
</tbody>
</table>

Step 3: choose 32 mm (arbitrary). This will qualify us for

<table>
<thead>
<tr>
<th>Reference</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>As per QW-450 (Based on Thickness of the coupon)</td>
<td>5</td>
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<tr>
<td>As per QW-403.6 (due to impact test requirement)</td>
<td>16</td>
</tr>
<tr>
<td>Result</td>
<td>16</td>
</tr>
</tbody>
</table>

One must note that the step 3 gives us the largest range. One may, however, choose any thickness higher than 32 mm, but this would not yield any additional benefit due to the presence of normalizing in the job requirement in this example. Additionally QW407.2 indirectly restrains us from choosing a thickness varying too much from that of job.

What happens when a production weld has two dissimilar metal thicknesses?
This shall be arrived at in two steps
1. Thickness of the thinner member shall be as permitted by QW-451
2. Thickness of the thicker member shall be
   i. Unlimited for specified material provided
      a) material are of same P number.
      b) qualification is made on >½".
   ii. limited within the range of qw-451

Process (assumption) - 2 layers (root and hot pass) of GTAW and rest by SMAW (fill-up and final).
Heat treatment - Normalizing
Min. design temperature. - 48°C