
Leonardo da Vinci

# Course: Quality Assurance

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## MODULE 4

***Objective:***

***Know how to work to a WPS, knowing the use of welding parameters.***

***Have basic knowledge about the harmonised system of International Standards.***

***Scope:***

- ***Welding Procedure Specifications (ISO 15609-1).***
- ***Welding parameters, welding positions (ISO 6947).***
- ***Types of welds and joints: characteristics, size, surface finish.***
- ***Welding symbols according to ISO 2553.***
- ***Qualification of WPSs***
- ***Essential variables; range of qualification; validity; test pieces and assessment of the welder.***
- ***Role and operation of CEN and ISO; relationship with National Standards Organisations***
- Product Standards which contain welding requirements
- ***Standards for Quality and Co-ordination in welding***

***Expected results:***

- ***Read welding details on a drawing and interpret welding symbols (ISO 2553).***
- ***Identify the welding positions per ISO 6947.***
- ***Identify the types of welded joints: "T", lap, corner, etc.***
- ***Identify in the fillet weld: size, shape, tack weld, and excess weld metal.***
- ***Identify the use of a WPS in the production.***
- ***Describe how to get the required parameters.***
- ***Name the most important International and national standards for welding.***

For a given application, the main way of ensuring adequate weld quality is to specify the procedure and the skill level of the welding operator. Here, the alternative routes for welding procedure approval are described together with the requirements for welder or welding operator approval.

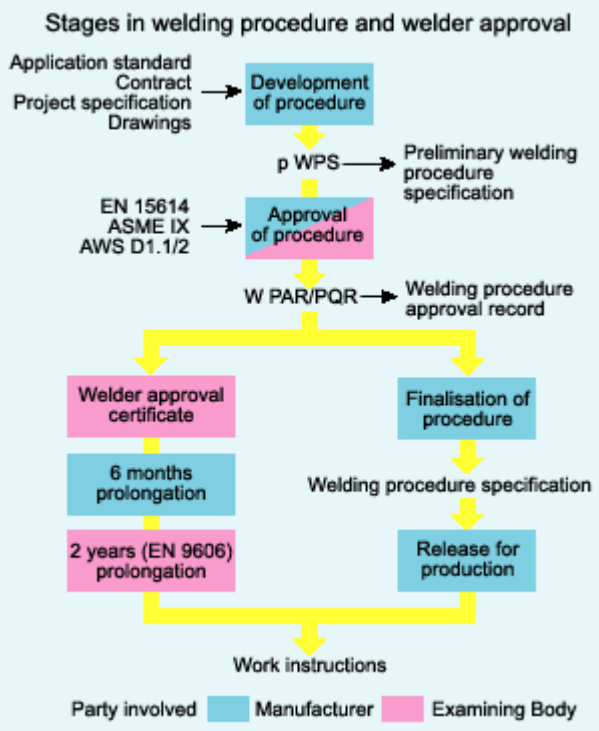
### Routes to welding procedure approval

The key document is the Welding Procedure Specification (WPS) which details the welding variables to be used to ensure a welded joint will achieve the specified levels of weld quality and mechanical properties.

The WPS is supported by a number of documents (eg, a record of how the weld was made, NDE, mechanical test results) which together comprise a welding approval record termed the WPAR (ISO 15614) .

In the European standards, there are a number of 'essential variables' specified which, if changed, may affect either weld quality or mechanical properties. Therefore, a change in any of the essentials will invalidate the welding procedure and will require a new approval test to be carried out. The essential variables are detailed in the relevant specification but include material type, welding process, thickness range and sometimes welding position.

### Stages in welding and welder approval




The route followed to produce a WPS in ISO15614 and the responsibilities of the manufacturer and the Examiner/Examining Body are shown in the figure

The most common method of gaining approval is to carry out an approval test as described in ISO 15614-1 (steels) and 15614-2 (aluminium and its alloys). The manufacturer initially drafts a preliminary welding procedure (pWPS) which is used by one of the manufacturer's competent welders to prove that it is capable of producing a welded joint to the specified levels of weld quality and mechanical properties. The welding procedure approval record (WPAR) is a record of this weld. If the WPAR is approved by the Examiner, it is used to finalise one or more WPSs which is the basis for the Work Instructions given to the welder.

It is noteworthy that the welder carrying out a satisfactory welding procedure approval test is approved for the appropriate range of approval given in the relevant standard .

The following options for procedure approval are also possible:

- Welding procedure test (ISO 15614)
- Approved welding consumable (ISO 15610)
- Previous welding experience (ISO 15611)
- Standard welding procedure (ISO 15612)
- Pre-production welding test (ISO5613)

The conventional procedure test (as specified in ISO 15614) does not always need to be carried out to gain approval. But alternative methods have certain limits of application regarding, for example, welding processes, materials and consumables as specified in the appropriate application standard or contract agreement.

The welding procedure test method of approval is often a mandatory requirement of the Application Standard. If not, the contracting parties can agree to use one of the alternative methods. For example, a welding procedure

specification can be approved in accordance with the requirements of ISO 15611 (previous experience) on condition that the manufacturer can prove, with appropriate documentation, that the type of joint has previously been welded satisfactorily.

**Welder approval**

The welder approval test is carried out to demonstrate that the welder has the necessary skill to produce a satisfactory weld under the conditions used in production as detailed in the approved WPS or Work Instruction. As a general rule, the test piece approves the welder not only for the conditions used in the test but also for all joints which are considered easier to weld.

As the welder's approval test is carried out on a test piece which is representative of the joint to be welded, it is independent of the type of construction. The precise conditions, called 'essential variables', must be specified in the approval test, eg material type, welding process, joint type, dimensions and welding position. The extent of approval is not necessarily restricted to the conditions used for the test but covers a group of similar materials or a range of situations which are considered easier to weld.

It is important to note that a number of Amendments and Corrigenda have now been issued which affect the range of approval (see list of Relevant Standards).

In EN 287/EN 9606, the certificate of approval testing is issued under the sole responsibility of the Examiner/Examining Body. The welder approval certificate remains valid subject to the requirements of the application standard. In EN 287/EN 9606, it can be extended at six monthly intervals by the employer for up to two years provided the welder has been successfully welding similar joints. After two years, prolongation of the welder's qualification will need approval of the Examiner who will require proof that his or her performance has been of the required standard during the period of validity. As the Examiner will normally examine the company's records on the welder's work and tests as proof that he has maintained his skill, it is essential that work records are maintained by the company.

It should also be noted that EN 287/EN 9606 requires records of tests, ie half yearly documentation about X-ray or ultrasonic inspections or test reports on fracture tests must be maintained with the welder's approval certificate (tests on production welds will satisfy this requirement). Failure to comply will necessitate a retest.

American standards have similar requirements although the extent of approval of the welding variables are different to those of EN 287/EN 9606.

**Welding operator approval**

When required by the contract or application standard, the welding operators responsible for setting up and/or adjustment of fully mechanised and automatic equipment must be approved but the personnel operating the equipment do not need approval. In clarifying the term 'welding operator', personnel who are using the equipment (loading and unloading robotic equipment or operating a resistance welding machine) do not require approval.

As specified in EN 1418, approval of operators of equipment for fusion welding and resistance weld equipment setters can be based on:

- welding a procedure test
- pre-production welding test or production test
- production sample testing or a function test.

It should be noted that the methods must be supplemented by a functional test appropriate to the welding unit. However, a test of knowledge relating to welding technology which is the equivalent of 'Job knowledge for welders' in EN 287/EN 9606 is recommended but not mandatory.

Prolongation of the welding operator approval is generally in accordance with the requirements of EN 287/EN 9606. The welding operator's approval remains valid for two years providing the employer/welding co-ordinator confirms that there has been a reasonable continuity of welding work (period of interruption no longer than six months) and there is no reason to question the welding operator's knowledge.

The validity of approval may be prolonged for further periods of two years by the examiner / examining body providing there is proof of production welds of the required quality, and appropriate test records maintained with the operator's certificate.

**Welding procedures and instructions.**

The Manufacturer shall prepare the Welding Procedure Specification(s) (WPS) and shall ensure that these are used correctly in production.

The welding procedures applied during production shall be as specific as possible, in order to clearly identify actions and parameters to be used for the required joint. However, if the relevant WPS contains data too detailed and not useful for the welder, dedicated work instructions may be used directly derived from such a WPS containing only the necessary data. These instructions have to refer directly to the welding procedure specification they derived from, e.g. by referring to the relevant WPS number.

Considering that welding is a special process and that the quality of the welded joint cannot be properly controlled only by final tests, the welding procedures significant for the final product quality shall be qualified precisely prior to production. As a consequence, those Welding Procedure Specifications should be prepared in accordance with a Welding Procedure Approval Record (WPAR). Normative references to the specification and to the qualification of welding procedures are given in the table.

| Welding process | Standard | Material | Scope | Field of application |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| All fusion welding processes | ISO 15607 | All | WPS, WPAR | General Rules |
| | ISO 15610 | | WPAR | Qualification based on tested welding consumables |
| | ISO 15611 | | | Qualification based on previous welding experience |
| | ISO 15612 | | | Qualification by adoption of a standard welding procedure |
| | ISO 15613 | | | Qualification based on pre-production welding test |
| Gas Welding | ISO 15609-2 | Steels | WPS | Compiling |
| | ISO 15614 - 1 | | WPAR | Qualification based on welding procedure test – Steels |
| Arc welding | ISO 15609-1 | All | WPS | Compiling |
| | ISO 15614 - 1 | Steels and Nickel alloys | WPAR | Qualification based on welding procedure test |
| | ISO 15614 - 2 | Aluminium, Magnesium | WPAR | Qualification based on welding procedure test |
| | ISO 15614 - 3 | Steel castings | WPAR | Qualification based on welding procedure test |
| | ISO 15614 - 4 | Aluminium castings | WPAR | Qualification based on welding procedure test |
| | ISO 15614 - 5 | Titanium and zirconium | WPAR | Qualification based on welding procedure test |
| | ISO 15614 - 6 | Copper | WPAR | Qualification based on welding procedure test |
| | ISO 15614 – 7 | All applicable | WPAR | Qualification based on welding procedure test – corrosion resistance overlay, cladding restore and hardfacing |
| | ISO 15614 – 8 | All applicable | WPAR | Qualification based on welding procedure test - Welding of tubes to tube-plate joints |
| Electron beam welding | ISO 15609 – 3 | All | WPS | Compiling |
| | ISO 15614 – 11 | All applicable | WPAR | Qualification based on welding procedure test |

| | | | | |
|---|---|---|---|---|
| Laser Welding | ISO 15609 – 4 | All | WPS | Compiling |
| | ISO 15614 – 11 | All applicable | WPAR | Qualification based on welding procedure test |
| Underwater Arc Welding – Wet Hyperbaric | ISO 15614 – 9 | All applicable | WPAR | Qualification based on welding procedure test |
| Underwater Arc Welding – Dry Hyperbaric | ISO 15614 – 10 | All applicable | WPAR | Qualification based on welding procedure test |

*Standards for the qualification of welding procedures*

Different methods for the qualification of welding procedures are available:

- *welding procedure test* **–** this method consists in welding a standardised test piece on which destructive and non-destructive tests are carried out in order to verify the achievement of required properties;
- *use of approved welding consumables* **-** this method of approval may be used if the welding consumables and the base material are not particularly affecting the welding quality, provided that heat inputs are kept within specified limits;
- *previous welding experience* - a welding procedure may be qualified by referring to previous experiences in welding if the Manufacturer is able to prove, by appropriate authentic documentation of an independent nature, that he has previously satisfactorily welded the same joint with reliable results;
- *use of a standard welding procedure* – a procedure is qualified if it is issued as a specification in the format of a WPS or WPAR based on appropriate qualification (e.g based on the relevant part of EN ISO 15614), not related to the Manufacturer and qualified by an examiner or examining body;
- *Pre production Test* - this method is the only reliable method of qualification for those welding procedures in which the resulting properties of the weld strongly depend on certain conditions such as: components, special restraint conditions, heat sinks etc., which cannot be reproduced by standardised test pieces; it is mostly used when the shape and dimensions of standardised pieces do not adequately represent the joint to be welded.

Even if different qualification methods are considered, the most commonly used are qualification by welding procedure test and pre-production test; however the applicable method of qualification is generally specified in either manufacturing codes, standards or contracts.

In order to demonstrate the achieved quality of the welded product, all the welding related documents shall be properly controlled.

This involves the preparation and maintenance of a procedure for the management of such documents, in order to identify issuance responsibilities, distribution methods, availability, and method for withdrawing obsolete documents. Even if it is not a normative requirement, a commonly adopted method to control documentation is the production of a written procedure, produced or approved by the welding coordinator, to be kept by the Manufacturer quality assurance department or directly by the welding coordinator himself.

In the next page a typical WPS form is reported, produced according to EN ISO15609-1.

| *COMPANY NAME OR LOGO* | **WELDING PROCEDURE SPECIFICATION (WPS)** | **WPS n°** _____ **Rev.** ___ **Supp. WPQR** **Date** |
|---|---|---|

| | | | |
|---|---|---|---|
| Welding process(es) | a) | b) | c) |
| Type(s) | a) | b) | c) |

**JOINTS –**

Joint Type _____

Backing _____

Backing material _____

Weld preparation

Method of preparation & Cleaning

**PARENT METAL**

Group n° To group n°

Spec. Type & grade _____

To Spec. Type & grade _____

Thickness _____

Outside Diameter _____

Other

Joint drawiing

**WELDING CONSUMABLE**

| | a) | b) | c) |
|---|---|---|---|
| Specification n° | | | |
| Designation | | | |
| Size | | | |
| Trade name | | | |
| Manufacturer | | | |
| Flux design. EN | | | |
| Flux Trade name | | | |
| Weld deposit | | | |

Other

**GAS(ES)**

| | | Gas(es) | Mixture | Flow Rate |
|---|---|---|---|---|
| Plasma | | | | l/min |
| Shielding | a) | | | l/min |
| Shielding | b) | | | l/min |
| Trailing | | | | l/min |
| Backing | | | | l/min |

Other

**ELECTRICAL CHARACTERISTIC -**

Current _____

Polarity _____

Mode of Metal Transfer

Tungsten Electrode Type & size

**WELDING POSITION**

Position

| | |
|---|---|
| Welding Progression<br>Other | Electrode wire feed speed range<br>Other |
| **PREHEAT**<br>Preheat Temperature<br>Interpass Temperature<br>Preheat maintenance<br>Other | **TECHNIQUE**<br>String or weave beads<br>Orifice or gas cup size<br>Initial & interpass cleaning<br>Method of back gouging<br>Oscillation Amplitude Freq.<br>Distance contact tube – work piece<br>Multiple, single pass (for side)<br>Single or multiple electrodes<br>Torch angle direction of welding<br>Other |
| **PWHT and/or AGEING**<br>Temperature Range<br>Time Range (hour)<br>Heating rate<br>Cooling rate<br>Other | |

| Run(s) or Layer(s) | *Welding process* | Filler metal | | Current | | Voltage V | Travel Speed mm/min | Heat input KJ/mm | Other |
|---|---|---|---|---|---|---|---|---|---|
| | | *EN designation or trade name .* | Size (mm) | Type & polarity | Amperage A | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| **MANUFACTURER** | **APPROVED BY** |
|---|---|
| | |

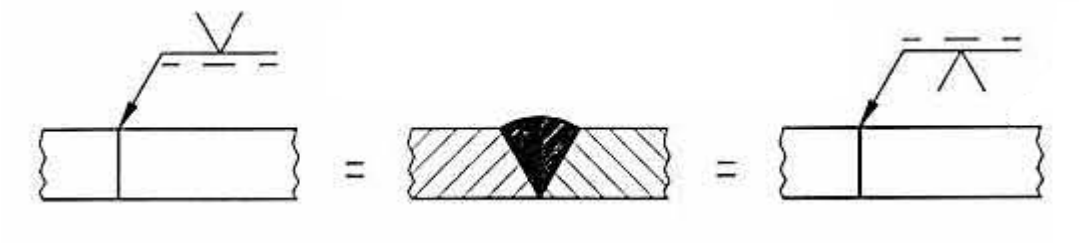
*Welding Procedure Specification*

**Welding symbols according ISO 22553**

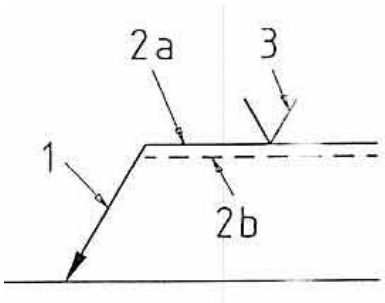
The **weld joint** is where two or more metal parts are joined by welding. The five basic types of weld joints are the butt, corner, tee, lap, and edge.

Special symbols are used on a drawing to specify where welds are to be located, the type of joint to be used, as

well as the size and amount of weld metal to be deposited in the joint.

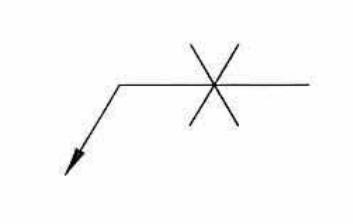


A standard welding symbol consists of a reference line, an arrow, and a tail. The reference line becomes the foundation of the welding symbol. It is used to apply weld symbols, dimensions, and other data to the weld. The arrow simply connects the reference line to the joint or area to be welded. The direction of the arrow has no bearing on the significance of the reference line. The tail of the welding symbol is used only when necessary to include a specification, process, or other reference information.

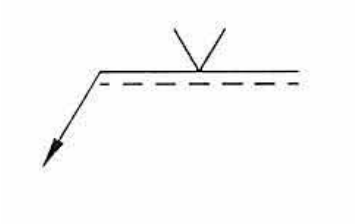



The term *weld symbol* refers to the symbol for a specific type of weld: fillet, groove, surfacing, plug, and slot are all types of welds. Some of basic weld symbols are shown in the next figures.

**Types of butt welds**

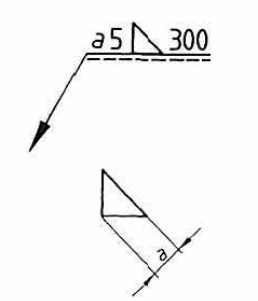


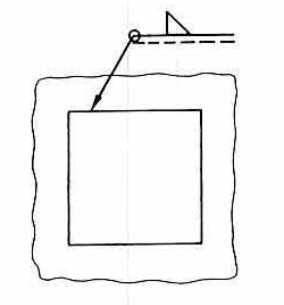
Single V preparation



Double V preparation

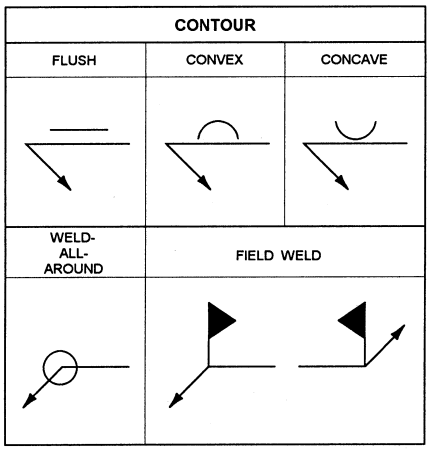
**Types of fillet welds**



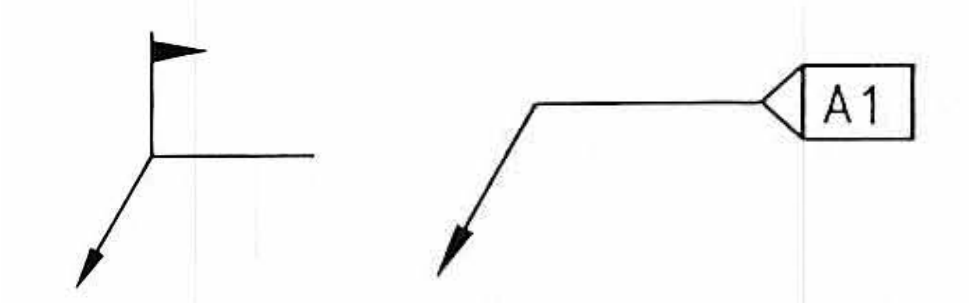



The leg length of a fillet weld is located in front of the weld symbol (triangle). The dimension is in millimeters preceded with the letter Z or by the letter ”a”.
In addition to basic weld symbols, a set of supplementary symbols may be added to a welding symbol.

Some of the most common supplementary symbols are shown in the following figure.



**Supplementary symbols**




Weld this joint on site Inspect by NDT, Weld, Paint, etc.

**ISO**

ISO is a network of the national standards institutes of 157 countries, on the basis of one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system.

ISO is a non-governmental organization: its members are not, as is the case in the United Nations system, delegations of national governments. Nevertheless, ISO occupies a special position between the public and private sectors. This is because, on the one hand, many of its member institutes are part of the governmental structure of their countries, or are mandated by their government. On the other hand, other members have their roots uniquely in the private sector, having been set up by national partnerships of industry associations.

Therefore, ISO is able to act as a bridging organization in which a consensus can be reached on solutions that meet both the requirements of business and the broader needs of society, such as the needs of stakeholder groups like consumers and users.

The national delegations of experts of a technical committee meet to discuss, debate and argue until they reach consensus on a draft agreement. This is then circulated as a Draft International Standard (DIS) to ISO's membership as a whole for comment and balloting. Many members have public review procedures for making draft standards known and available to interested parties and to the general public. The ISO members then take account of any feedback they receive in formulating their position on the draft standard. If the voting is in favour, the document, with eventual modifications, is circulated to the ISO members as a Final Draft International Standard (FDIS). If that vote is positive, the document is then published as an International Standard.

**CEN**

CEN, the European Committee for Standardization, was founded in 1961 by the national standards bodies in the European Economic Community and EFTA countries.

CEN supports the policies of the European Union and EFTA, in particular for free trade, but also the safety of

workers and consumers, interoperability of networks, environmental protection, exploitation of research and development programmes, and public procurement.

Standardization diminishes trade barriers, promotes safety, allows interoperability of products, systems and services, and promotes common technical understanding.

All standards help build the 'soft infrastructure' of modern, innovative economies. They provide certainty, references, and benchmarks for designers, engineers and service providers.

In addition, regional or European Standards are necessary for the Single Market and support the Union's policies for technical integration, protection of the consumer, and promotion of sustainable development.

***CE Marking*** is the symbol CE as shown. The letters "**CE**" are the abbreviation of French phrase "**C**onformité **E**uropéene" which literally means "European Conformity". The term initially used was "EC Mark" and it was officially replaced by "CE Marking" in the Directive 93/68/EEC in 1993. "CE Marking" is now used in all EU official documents. "CE Mark" is also in use, but it is NOT the official term.

1. CE Marking on a product is a manufacturer's declaration that the product complies with the **essential requirements** of the relevant European health, safety and environmental protection legislations, in practice by many of the so-called **Product Directives.***

   ***Product Directives** contains the "essential requirements" and/or "performance levels" and "Harmonized Standards" to which the products must conform. Harmonized Standards are the technical specifications (European Standards or Harmonization Documents) which are established by several European standards agencies (CEN, CENELEC, etc).
   **CEN** stands for European Committee for Standardization.
   **CENELEC** stands for European Committee for Electro technical Standardization.
2. CE Marking on a product indicates to governmental officials that the product may be **legally placed on the market** in their country.
3. CE Marking on a product ensures the **free movement of the product** within the EFTA & European Union (EU) single market (total 28 countries), and
4. CE Marking on a product permits the **withdrawal of the non-conforming products** by customs and enforcement/vigilance authorities.

Along with more directives' becoming effective, more and more products are required to bear the CE Marking for gaining access to the EFTA & European Union market.