



## **NATIONAL WELDER TRAINING STANDARD**

### **DOCUMENT NO. NWTS-CP2-1-09**

### **Code of Practice 2: Training of Craftsman Welders**

### **Part 1: Theoretical Knowledge**

2<sup>nd</sup> Edition – July 2015

Issued under the authority of:



**The  
Welding  
Institute**

The Welding Institute, Professional Division under the guidance of the



Association for Welding and Fabrication Training and Education

The Welding Institute, Professional Division  
Granta Park  
Great Abington  
Cambridge  
CB21 6AL  
United Kingdom

Tel: +44 1223 899000

Fax: +44 1223 894219

Email: [professional@twi.co.uk](mailto:professional@twi.co.uk)

Web: [www.theweldinginstitute.com](http://www.theweldinginstitute.com)

# 1 General

## 1.1 Structure of the Standard

This Code of Practice is one of three which together will form a national standard for the training of welders, covering practical training for skills, essential job knowledge, welder approval and requirements for training organisations. The three codes are:

- CP1 Training of Welding Operatives**
- CP2 Training of Craftsman Welders**
- CP3 Training of Master Welders**

For the purpose of this Code, a Craftsman Welder is defined as a person who has undergone a programme of theoretical and practical training in arc welding; and has demonstrated theoretical knowledge and practical skills in accordance with recognised standards, in a range of welding positions.

All NWTS document are downloadable from [www.cswip.com](http://www.cswip.com).

## 1.2 Structure of CP2

CP2 is in three parts:

- Part 1 Theoretical knowledge
- Part 2 Fillet welding practical
- Part 3 Plate welding practical

The route to achieving a qualification under CP2 is shown in Figure 1. It can be seen from Figure 1 that there is a direct link between CP2 and the International Welder qualification under the International Institute of Welding (IIW) scheme<sup>1</sup>. Therefore, the outcome from the CP2 programme is both the NWTS and the IIW qualification. The latter ensures that the welder's knowledge and skills is recognised throughout the world.

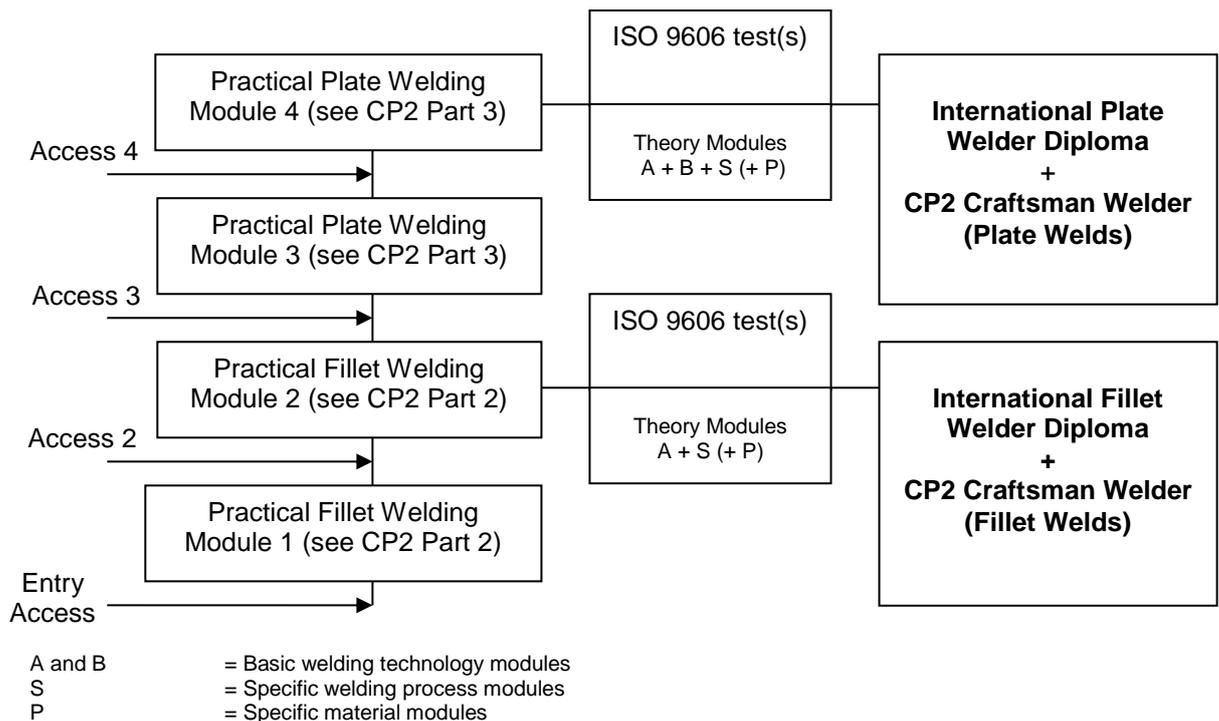
The NWTS is implemented under the authority of TWI Certification Ltd, the UK Authorised National Body (ANB) for IIW and EWF.

Both CP2 and IIW qualifications are issued for specific welding processes and materials according to the precise content of the course and examinations taken by the candidate.

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<sup>1</sup> The IIW scheme is exactly the same as the pre-existing European Welding Federation (EWF) scheme. Successful participants receive diplomas from both schemes





**Figure 1** The overall structure of the training and examination under CP2.

Where indicated ISO 9606 (or equivalent) qualification certificates are issued to successful candidates.

### 1.3 Access to the Course

Only training providers approved by TWI Certification Ltd via the Certification Scheme for Welder Training Organisations (see [www.cswip.com](http://www.cswip.com)) are permitted to conduct NWTs courses and course attendance is mandatory.

Applicants must possess sufficient knowledge of, or education in, metalworking to follow the course. They must also have a level of health, and physical and mental capability, to undergo the training for which they are applying.

Successful completion of one module qualifies for participation in the next module. With existing knowledge and proven skill, the program may be entered at a higher level, provided that the candidate demonstrates a capability (practically and theoretically) to meet the entry requirements as described below.

- Access to 2: Demonstrate the required level of skill by passing the tests as described in module 1.
- Access to 3: Demonstrate the required level of skill by passing the full examination as described in module 2.
- Access to 4: Demonstrate the required level of skill by passing the full examination as described in module 2 and passing the tests as described in module 3.

Practical skill may be proven by adequate and valid ISO 9606 or equivalent certificates. As an option to normal welder qualification tests, training organisations can offer the alternative of a 'test object'. This requires candidates to produce a small fabricated structure containing the test geometries and materials required. These test objects have some similarities to fabrications that are used to test candidates in welding skill competitions and therefore may be advantageous if any of the training organisation's students are considering entering a welding competition. For more details, please contact TWI Certification Ltd at Granta Park, Great Abington, Cambridge, CB21 6AL, email: [twicertification@twi.co.uk](mailto:twicertification@twi.co.uk).

This document, CP2 Part 1, covers only the Theoretical Modules shown in Figure 1.

## **1.4 IW Diploma via the Alternative Route**

The Alternative Route allows those who have gained the knowledge and expertise of the instruction programme in this Guideline and who can demonstrate their capability in all respects, to proceed to examination without compulsory attendance at an approved training course.

### **1.4.1 Entry requirements**

- Any candidate who can show a welder qualification (e.g. ISO 9606) valid under the scope for the Diploma he/she wants.
- Three years of experience as a welder.

### **1.4.2 Evaluation process**

- To perform the theoretical examinations, related to the level of the IW Diploma that the candidate is seeking
- To perform the practical examinations that are defined in this Guideline for the level of the IW Diploma that the candidate is applying for, including the lower levels examinations. See Figure 1.

Re-examination in the case of candidate failure in the theoretical examination(s) or in the practical exam(s):

For theoretical examinations candidates are allowed to have two more attempts (in total three attempts). In case of failure on the third attempt the candidate must take the theoretical module(s) that they failed.

For practical exams candidates are allowed to have one more attempt. In case of failure on the second attempt the candidate must take the practical module they has failed.

## **2 Theoretical Education**

The theoretical education given to the students aims at a basic understanding of the appropriate welding process and the materials behaviour including standards and safety regulations. The themes and keywords are given as 'scope' in the module descriptions, together with the 'objective' and the 'Learning outcomes'. After each module a theoretical examination is required.

The recommended periods of time given in the tables A, B, P and S represent the average time required to attain the expected level of knowledge. The time needed may vary individually according to the capability of the student. A teaching hour will contain at least 50 minutes of direct teaching time. It is not obligatory to follow exactly the order of the topics given in this guideline.

The CP2 theory course consists of modules A and B supplemented by specific modules per welding process and material. The modules A and B provide basic theoretical knowledge in welding.

### **2.1 Module A – Items for the Theoretical Education**

Module A provides theoretical education to the level of the International Fillet Welder. The matters to be dealt with and the recommended hours devoted to them are listed below.

#### **2.1.1 Using electricity for arc welding**

**(2hr)**

##### **Objective**

- Know the principle of arc welding.

## Scope

- Basics of electricity
- Nature of the electric arc
- The arc as heat source
- Arc power
- Basic terminology for welds. (eg run, layer, top, root, penetration)
- Welding processes (MMA, MIG/MAG, TIG)
- Welding consumables
- Metal transfer; weld metal
- Formation of the weld pool.

## Learning outcomes

1. Describe the principle of arc welding
2. Understand the basic terms in welding
3. Brief explanation of the heat generation in the arc
4. Brief explanation of material transfer through the arc
5. Brief explanation of the formation of the weld pool.

### 2.1.2 Welding equipment

(2hr)

#### Objective

- Know the operating principles of welding equipment for arc welding.

#### Scope

- Distribution of electricity; mains supply
- Converting mains to welding power; welding power source
- Transformers; use of AC
- Rectifiers for DC
- Open circuit and arc voltage; welding current
- Type of welding current and polarity
- Duty cycle
- Shielding gas supply
- Welding parameters.

#### Learning outcomes

1. Describe the major components of welding equipment and their function
2. Describe polarity and change of polarity
3. Name the essential parameters for arc welding.

### 2.1.3 Health and safety

(2hr)

#### Objective

- Know and understand hazards and basic safety requirements when welding.

#### Scope

- Electric shock
- UV- and heat radiation
- Eye hazards
- Burns and fires, fire prevention, fire fighting
- Welding fumes
- Respiratory hazards
- Personal protective equipment and clothing
- Fire prevention
- Noise hazards
- Specific rules and regulations.

### **Learning outcomes**

1. Know dangerous situations in relation to electricity, humidity, DC and AC
2. Know the health risks of welding fumes
3. Know the signals for escape routes
4. Name adequate means of personal protection
5. Know measures to be taken to prohibit fire
6. Know measures to prevent noise hazards.
7. Know the specific rules and regulations.

#### **2.1.4 Safe working in the fabrication shop**

**(2hr)**

##### **Objective**

- Know how to perform welding activities in the fabrication shop in a safe manner.

##### **Scope**

- The working environment of the fabrication shop; general hazards, dust, heavy and hot material, electrical cables.
- Welding in the fabrication shop; protection of other workers from welding hazards.
- General ventilation to minimise background pollution levels from welding hazards.
- Control of the welder's local environment; fume disposal.
- Safety measures in case of personal accident; monitoring of operations; escape procedures.
- Working in confined spaces; build-up of pollutants; risk of explosion; enrichment of gases like argon, helium, etc.
- Handling gas cylinders.

### **Learning outcomes**

1. Know the general hazards in a fabrication shop.
2. Know the need for ventilation.
3. Know the risk of explosions.
4. Know safe handling of gas cylinders.

#### **2.1.5 Welding consumables**

**(2hr)**

##### **Objective**

- Understand the basic principles of the use of welding consumables.

##### **Scope**

- Principle of welding consumables and functions of each type of welding consumable (electrodes, rods and gases)
- Shielding gases
- Backing gases
- Classification of welding consumables
- Storage, drying and handling.

### **Learning outcomes**

1. Know use, types and functions of welding consumables
2. Know why and how to dry, store and handle welding consumables
3. Know the designation of welding consumables as used on WPSs of the training program (e.g. according to EN 439, 440, 499, 758, 1599, 1600, 1668, 12070 – 12073, 12534 – 12536, ISO 636, 14175, ASME Code, etc.).

#### **2.1.6 Welding practice (1)**

**(4hr)**

##### **Objective**

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

### **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.

### **Learning outcomes**

1. Read welding details on a drawing and interpret welding symbols (ISO 2553)
2. Know the welding positions per ISO 6947
3. Identify the types of welded joints: "T", lap, corner, etc
4. Identify in the fillet weld: size, shape, tack weld, and excess weld metal
5. Know the use of a WPS in the production
6. Describe how to get the required parameters.

## **2.1.7 Welding practice (2)**

**(2hr)**

### **Objective**

- Know the effect of welding parameters on performance and their influence on the weld surface.

### **Scope**

- Introduction to weld imperfections, ISO 6520-1 and ISO 5817
- The control of welding parameters
- The effect of welding parameters on weld geometry
- The effect of magnetic arc blow
- Visual inspection.

### **Learning outcomes**

1. Describe the influence of the welding parameters on the weld surface
2. Describe the effect of incorrect welding parameters
3. Knowing the different types of imperfections according to ISO 6520-1
4. Perform visual inspection on a fillet weld and subsequently evaluate to ISO 5817
5. Brief explanation of magnetic arc blow
6. Describe methods how to avoid magnetic arc blow.

## **2.1.8 Introduction to steel**

**(2hr)**

### **Objective**

- Know the basics of welding steel.

### **Scope**

- Different types of steels
- Effects of welding on steel
- Adding elements to create alloys
- Basis of ISO/TR 15608. and ISO/TR 20172, ISO/TR/20173 and ISO/TR 20174 as appropriate

### **Learning outcomes**

1. Explain the influence of welding on steel
2. Understand the difference between non alloy, stainless steels and other alloy steels
3. Mention the influence of alloying elements on the properties of steel
4. Identify materials according to ISO/TR 15608.

## 2.1.9 Qualification of welders (2hr)

### Objective

- Know the basics of welder qualification according to ISO 9606.

### Scope

- Objectives of qualification tests
- Qualification of WPSs
- Welders qualification standard (ISO 9606)
- Essential variables; range of qualification; validity; test pieces and assessment of the welder.

### Learning outcomes

1. Know the range of qualification in a welder's certificate
2. Outline the essential variables for a welder qualification test.

**Total number of recommended hours for A:** 20hr

## 2.2 Module B – Items for Theoretical Education

Module B provides in addition to module A, theoretical education to the level of the International Plate Welder. The matters to be dealt with and the recommended hours devoted to them are listed below.

### 2.2.1 Methods of joint preparation for welding (2hr)

#### Objective

- Know the available methods for joint preparation for welding.

#### Scope

- Suitable cutting processes for different types of steel to achieve a suitable cutting surface
- Flame cutting: principles and parameters, cutting blow pipes, cutting machines; quality of cut surfaces (e.g. ISO 9013)
- Arc gouging and gas gouging principles
- Other cutting processes such as: plasma, laser, mechanical cutting.

#### Learning outcomes

1. Outline methods used for joint preparation and their specific application
2. Know essential parameters and results of thermal cutting (plasma and flame cutting)
3. Know suitable cutting and gouging processes for the main types of steel.

### 2.2.2 Welded joints in plates (2hr)

#### Objective

- Know the basics of welded joints and their terminology.

#### Scope

- Types of welds: butt and fillet
- Types of joints: butt, "T", lap and corner (ISO 17659)
- Characteristics of fillet welds; leg length, throat thickness, penetration, number of runs, surface finish
- Characteristics of butt welds; types of joint preparation; single and multi-run welds; excess weld metal; weld profile, penetration, surface finish, permanent and temporary backing
- Examples of welded joints in typical constructions using plates (eg structures, tanks, and pressure vessels).

### **Learning outcomes**

1. Know butt weld, fillet weld, butt joint, T-joint, lap joint and corner joint
2. Identify throat thickness, leg length, penetration, and number of runs
3. Identify single- and multi-run welds, excess weld metal, weld profile
4. Name different types of joint preparations and their main dimensions.

### **2.2.3 Weldability of steels**

**(2hr)**

#### **Objective**

- Know the specific effects of welding heat on steel.

#### **Scope**

- The concept of weldability
- Effects of composition, thickness and temperature (preheat and interpass)
- Heat input.

### **Learning outcomes**

1. Name the influence of alloying elements on the properties of weldable steel
2. Describe the effect of plate thickness on the properties of weldable steel
3. Mention the carbon equivalent and its use
4. Calculate the heat input and mention its use.

### **2.2.4 Shrinkage, residual stress, distortion**

**(2hr)**

#### **Objective**

- Know the effect of welding in terms of shrinkage, residual stresses and distortion. And know how to minimise distortion before, during and after welding.

#### **Scope**

- The thermal cycle in welding
- Development of residual stresses due to solidification, cooling and shrinkage
- Effects of restraint on residual stress
- Significance of residual stress
- Preheating, postheating
- Relationship between heat input and shrinkage, residual stress and distortion.
- Development of distortion; effect of heat input, weld size, penetration, and number of runs single- and double-sided fillet welded joints and in butt welds
- Corrective measures, procedure, welding technique, sequence, joint preparation, pre-setting
- Correction of distortion after welding.

### **Learning outcomes**

1. Describe the thermal cycle during welding
2. Describe distortion resulting from shrinkage
3. Describe residual stresses
4. Name measures to minimise distortion.
5. Describe the main causes for weld shrinkage
6. Outline the main effects on a weld due to residual stresses.

### **2.2.5 Weld imperfections**

**(2hr)**

#### **Objective**

- Know about imperfections in welds.

### **Scope**

- Origin of imperfections: parent metal; welding process; welder; joint preparation
- Survey of specific weld imperfections and their cause
- Influence of weld imperfections on product performance
- Influence of the weld geometry on the fatigue life of the product.

### **Learning outcomes**

1. Identify and describe the cause of: gas pores, incomplete penetration, lack of fusion and cracks (see also the specific modules “S” on welding processes.)

## **2.2.6 Overview of fusion welding processes (2hr)**

### **Objective**

- Have an overview of the most frequently used fusion welding processes.

### **Scope**

- Revision of the arc as heat source (2.1.1)
- Principles of arc welding equipment (2.1.2)
- Revision of MMA (111) welding
- Revision of MIG/MAG (13) welding
- Principles of Self Shielding Metal Arc (114) welding
- Revision of TIG (141) welding
- Principles of gas welding (311)
- Principles of plasma welding (151)
- Principles of submerged-arc welding (121).

### **Learning outcomes**

1. Describe different welding processes: 311, 111, 13, 114, 141, 151, 121.

## **2.2.7 Safe working on site (2hr)**

### **Objective**

- Know how to perform welding activities on construction sites in a safe manner.

### **Scope**

- The site environment; special problems of open air working; working at height for example gantries and fixed staging; poor ground conditions; extremes of heat and cold; wind and rain effects
- Welding in the site environment
- Earthing arrangements
- Protection of other workers from welding hazards.

### **Learning outcomes**

1. Identify the hazards for welding when working on site
2. Name basic precautions to be taken.

## **2.2.8 Inspection and testing (2hr)**

### **Objective**

- Know the principles of basic NDT methods used in welding.

### **Scope**

- Revision of weld imperfections (ISO 6520-1)
- Revision of quality levels (ISO 5817)
- Checking dimensions, surface and distortion

- Surface inspection of cracks and other surface imperfections by visual testing (VT), penetrant testing (PT) and magnetic particle testing (MT)
- Detectability of internal imperfections of welds by radiographic testing (RT) and ultrasonic testing (UT)
- Destructive tests to measure mechanical properties of weld.

#### **Learning outcomes**

1. Perform simple visual inspection of welds to ISO 17637 and subsequently evaluate to ISO 5817
2. Identify the following destructive and non-destructive methods: bend tests, hardness tests, tensile tests and impact tests, VT, MT, PT, RT and UT.

### **2.2.9 Quality assurance in welding (QA)**

**(2hr)**

#### **Objective**

- Have knowledge about the function of Quality Assurance (QA) in welding.

#### **Scope**

- Role of inspection and Quality control
- Key role of welders in assuring weld Quality
- Key role of inspection and NDT in identifying potentially dangerous weld defects
- Introduction of ISO 3834: Quality Requirements for Welding
- Introduction of ISO 14731: Welding Co-ordination and relationship to IIW qualifications.

#### **Learning outcomes**

1. Explain the need for quality assurance in welding
2. Know the position of ISO 3834 in connection with the standards for welding personnel and welding procedures.

**Total number of recommended hours for B:**

**18hr**

## **3 Modules S, Dedicated to One Specific Welding Process**

Modules S: dedicated to one specific welding process to be taught after or in parallel to theoretical modules per material required.

### **3.1 Module SG: Supplementary Theoretical Education for Gas Welding (311)**

#### **3.1.1 SG.1 Construction & maintenance of gas welding equipment & typical parameters (3hr)**

#### **Objective**

- Know about the basic construction of welding equipment for gas welding and the influence of the typical gas welding parameters on the final quality of welding.

#### **Scope**

- Properties and storage of acetylene and oxygen
- Supply of workshops with gases
- Standards for gas welding equipment
- Pressure regulators (ISO 2503 / ISO 7291)
- Safety devices (ISO 5175)
- Hoses / hose connections (ISO 3821, EN 559, EN 560, EN 561, EN 1256)
- Welding blowpipes; sizes and types. (ISO 5172)
- Care and maintenance of equipment
- Process of combustion
- Temperature profile
- Flame adjustment

- Typical welding parameters: choice of nozzle in function of weld thickness, welding position
- "Leftward" and "rightward" welding techniques
- Checking for safe operation
- Welding Procedure Specifications to ISO 15609-2
- Weld imperfections and possible problems specific to the process.

**Learning outcomes**

1. Check the safety precautions against the standards requirements
2. Describe the basics of required welding equipment for gas welding
3. Know the pressure regulators, gas cylinders, blowpipe and safety devices.
4. Describe the process of combustion
5. Explain the use of "leftward" and "rightward" welding techniques
6. Can determine and identify the correct nozzle and regulate the correct gas pressure
7. Identify the use of a WPS in production
8. Identify the most common imperfections and problems for this process and know how to avoid them.

**3.1.2 SG.2 Welding consumables (1hr)**

**Objective**

- Have basic knowledge about the specific consumables used with this welding process.

**Scope**

- Identification and selection of welding rods for gas welding
- Classification of rods and gases (EN 12536).

**Learning outcomes**

1. Know how to select a welding rod for a specific job.

**3.1.3 SG.3 Health and safety (1hr)**

**Objective**

- Have basic knowledge about the specific health and safety precautions related to gas welding process.

**Scope**

- Gases
- Decomposition of acetylene, cylinder fire, gas cylinder handling
- Fire guard
- Extinguishing substances, fire fighting.

**Learning outcomes**

1. Know how to protect the welder against the potential hazards of gas welding
2. Know what to do when accidents occur
3. Know how to prevent fires.

**Total number of recommended hours for SG: 5hr**

### **3.2 Module SA: Supplementary Theoretical Education for MMA Welding (111)**

#### **3.2.1 SA.1 Construction and maintenance of MMA welding equipment & typical parameters (3hr)**

##### **Objective**

- Know about the basics of a power source for MMA welding and the influence of the typical MMA welding parameters on the final quality of the weld.

##### **Scope**

- AC and DC
- Study of 'electric arc' and its characteristics
- The AC transformer; windings, core, temperature rise and control
- Primary and secondary circuits; mains protection
- Relationship between arc voltage and welding current; power source characteristics
- Control of welding current, instruments to be used and validation of measuring instruments
- Power sources for DC welding
- Arc starting aids
- Earthing arrangements, cables, electrode holders
- Maintenance of equipment; condition of cables and connections; cleanliness of contact faces; cleanliness of internal components
- Checking for safe operation
- Typical welding parameters and selection of electrode type and size
- Weld imperfections and possible problems specific to MMA welding.

##### **Learning outcomes**

1. Describe the basics of a power source for MMA welding
2. Know the transformer, electrode holder, earth cable, earth clamp
3. Know Open Circuit Voltage, AC, DC, polarity
4. Identify the most common imperfections for MMA welding and how to avoid them
5. Know how to select a proper type and diameter of covered electrode
6. Know the main safety requirements in MMA welding.

#### **3.2.2 SA.2 Covered electrodes (1hr)**

##### **Objective**

- Have basic knowledge about covered electrodes.

##### **Scope**

- Classification of covered electrodes according to the relevant standards
- Application of different types of covered electrodes.

##### **Learning outcomes**

1. Check the correct selection of a covered electrode for a specific job (e.g. according to the appropriate WPS).

#### **3.2.3 SA.3 Health and safety (1hr)**

##### **Objective**

- Have basic knowledge about the specific health and safety precautions related to the MMA process.

##### **Scope**

- Protection during slag removal
- Welding fumes
- Electrical safety (open circuit voltage (OCV), etc).

### **Learning outcomes**

1. Know how to protect the welder against the potential hazards of MMA welding.

**Total number of recommended hours for SA:**

**5hr**

### **3.3 Modules SM: Supplementary Theoretical Education for MIG/MAG Welding (13)**

#### **3.3.1 SM.1 Construction and maintenance of MIG/MAG equipment**

**(3hr)**

##### **Objective**

- Know about the basic construction of a power source for MIG/MAG welding and the influence of the typical MIG/MAG welding parameters on the final quality of the weld.

##### **Scope**

- The AC transformer; windings, core, temperature rise and control
- MIG/MAG power sources (DC)
- Primary and secondary circuits; mains protection
- Control of welding current, instruments to be used and validation of measuring instruments
- Earthing arrangements, cables, welding guns
- Maintenance of equipment; condition of cables and connections; cleanliness of contact faces; cleanliness of internal components; gas supply and control
- The wire feed unit and its proper operation
- Checking for safe operation
- Selection of wire type and size.

##### **Learning outcomes**

1. Describe the basics of a power source for MIG/MAG welding
2. Know different types of power sources, guns, earth cables and earth clamps
3. Explain how the welding current is controlled
4. Know the main safety requirements when MIG/MAG welding
5. Know how to select proper type and diameter of wire electrode.

#### **3.3.2 SM.2 Welding consumables**

**(1hr)**

##### **Objective**

- Have basic knowledge about the specific welding consumables used in MIG/MAG welding.

##### **Scope**

- Classification of welding consumables (wire electrodes and shielding gases)
- Chemical composition of wire electrodes
- Application of different types of wire electrodes and size
- Selection of shielding gases.

##### **Learning outcomes**

1. Check the correct selection of the welding consumables for a specific job (e.g. according to the appropriate WPS).

#### **3.3.3 SM.3 Health and safety**

**(1hr)**

##### **Objective**

- Have basic knowledge about the specific health and safety precautions related to the MIG/MAG welding process.

### **Scope**

- Fumes
- UV-radiation.

### **Learning outcomes**

1. Know how to protect the welder against the potential hazards of MIG/MAG welding.

## **3.3.4 SM.4 MIG/MAG welding characteristics and typical parameters (2hr)**

### **Objective**

- Know about the different metal transfer modes and the influence on the final quality of the weld.

### **Scope**

- Short arc, spray arc, globular arc, etc
- Typical welding parameters as eg distance contact tube / work piece, travel speed, gas flow rate, etc
- Weld imperfections and possible problems specific to MIG/MAG (eg lack of fusion for solid wire)
- Torch angle and technique (push and pull)
- Use of so called “synergic” equipment.

### **Learning outcomes**

1. Describe the types of metal transfer
2. Identify the most common imperfections for MIG/MAG welding and how to avoid them
3. Know the difference between push and pull technique
4. Set and check the parameters (e.g. as specified in the WPS).

**Total number of recommended hours for SM: 7hr**

## **3.4 Module ST: Supplementary Theoretical Education for TIG Welding (141)**

### **3.4.1 ST.1 Construction and maintenance of TIG welding equipment (3hr)**

### **Objective**

- Know about the basic construction of a power source for TIG welding and the influence of the typical TIG welding parameters on the quality of the weld.

### **Scope**

- The AC transformer; windings, core, temperature rise and control
- Primary and secondary circuits; mains protection
- Control of welding current, instruments to be used and validation of measuring instruments
- Rectifiers for DC welding
- Arc starting devices
- Earthing arrangements, cables, welding torches
- Maintenance of equipment; condition of cables and connections; cleanliness of contact faces; cleanliness of internal components; gas supply and control
- Checking for safe operation
- Grinding of tungsten electrodes
- Weld imperfections specific to TIG welding.

### **Learning outcomes**

1. Describe the basics of a power source for TIG welding
2. Know the transformer, torch, and earth cable, starting device
3. Know open circuit voltage (OVC), AC, DC

4. Describe how to grind a tungsten electrode
5. Identify the most typical imperfections for TIG welding.

### 3.4.2 ST.2 Tungsten electrodes and welding consumables (1hr)

#### Objective

- Have basic knowledge about the tungsten electrodes and the specific welding consumables used in TIG-welding.

#### Scope

- Classification of tungsten electrodes (ISO 6848)
- Classification of welding rods or wires used for TIG welding
- Classification of shielding and backing gases (ISO 14175)
- Size of rod or wire to be used.

#### Learning outcomes

1. Check the correct selection of tungsten electrode, welding rod or wire and shielding gas for a specific job (e.g. according to the appropriate WPS).

### 3.4.3 ST.3 Health and safety (1hr)

#### Objective

- Have basic knowledge about the specific health and safety precautions related to TIG welding.

#### Scope

- Sharpening and handling of tungsten electrodes
- Proper use of backing gases.

#### Learning outcomes

1. Know how to protect the welder against the potential hazards of TIG welding.

**Total number of recommended hours for ST: 5hr**

## 4 Modules P, Dedicated to One Specific Material

Modules P: dedicated to one specific material to be taught after or in parallel to theoretical modules if the sought qualification is for stainless steel or aluminium.

### 4.1 Module PSS: Instruction Items for Supplemental Theoretical Education for Stainless Steel

#### 4.1.1 PSS.1 Basics of stainless steel, welding processes and health aspects (2hr)

#### Objective

- Know the basics of stainless steel; appropriate welding processes and the health aspects related to welding of stainless steel

#### Scope

- Definition of stainless steel
- Identification of stainless steel
- Protective oxide film
- Welding processes
- Characteristics of stainless steel compared to no-alloy steel and aluminium alloys
- Grades of stainless steel and their characteristics: austenitic, ferritic, martensitic, duplex (austenitic-ferritic)
- Health aspects during welding of stainless steel, alloys in stainless steel and their effect on the health

- Methods for preventing health risks related to welding of stainless steel, breathing zone, welder's mask with fresh-air filters, hygiene
- Safety precautions for cutting.

#### **Learning outcomes**

1. Definition of stainless steel and brief explanation of the protective oxide film
2. Understand the difference of welding stainless steel compared to welding unalloyed steel and aluminium alloys
3. Outline the grades of stainless steel and their characteristics: austenitic, ferritic, martensitic, duplex (austenitic-ferritic)
4. Give examples of common welding processes for stainless steel
5. Knowing methods for preventing health risks related to welding of stainless steel.

#### **4.1.2 PSS.2 Weldability, welded joints and distortion of stainless steel (2hr)**

##### **Objective**

- Know the theoretical basics of welding stainless steel, the common welded joints and how to prevent distortion.

##### **Scope**

- Welded joints for stainless steel
- Methods for joint preparation in stainless steel
- Weldability of stainless steel, heat input, interpass temperature
- Effects of composition, temperature, heat input.
- Welding of dissimilar metals and clad metal (stainless steel-unalloyed steel) and control of dilution
- Distortion caused by welding stainless steel and the difference when compared to unalloyed steel
- Handling of stainless steel in the workshop and the use of tools for stainless steel.

##### **Learning outcomes**

1. Outline the commonly used welding joints and the methods of joint preparation regarding stainless steel
2. Know about the importance of controlling heat input and interpass temperature
3. Name the influence of alloying elements on weld properties.
4. Know the effect of heat input on material properties.
5. Describe the methods of welding dissimilar metals and clad metal
6. Knowing methods to confine distortion of stainless steel caused by welding
7. Know how to control the dilution.

#### **4.1.3 PSS.3 Welding consumables for stainless steel (2hr)**

##### **Objective**

- Know the basics of welding consumables and of backing gas.

##### **Scope**

- Welding consumables (filler metals and shielding gases) adequate for stainless steels, standards
- Measurements (ppm) of oxygen on backing gas, different requirements for grades of stainless steels
- Determination of required backing gas, density of gases compared to density of air
- Equipment for backing gas.

##### **Learning outcomes**

1. Know the main types and classification of welding consumables for stainless steel
2. Understand how to work with standards and manufacturers' recommendations
3. Determine and measure required backing gas

4. Know about equipment for backing gas.

#### **4.1.4 PSS.4 Corrosion, post weld treatment (2hr)**

##### **Objective**

- Know the basics of corrosion and post weld treatment of stainless steel.

##### **Scope**

- Use of protective means
- Corrosion types in stainless steel (pitting, intergranular, crevice corrosion)
- The influence on corrosion in stainless steel caused by welding and environment
- Post weld treatment: pickling, blasting, brushing and grinding
- Post weld heat treatment: austenitic, ferritic, martensitic, austenitic-ferritic (duplex).

##### **Learning outcomes**

1. Outline corrosion types in stainless steel
2. Know the key role of welding in corrosion of stainless steel
3. Describe post weld treatment: pickling, blasting and brushing, grinding
4. Brief explanation of post weld heat treatment of stainless steels).

**Total number of recommended hours for PSS:**

**8hr**

#### **4.2 Module PAL: Instruction Items for Supplemental Theoretical Education for Aluminium**

##### **4.2.1 PAL.1 Basics of aluminium, welding processes & health aspects (2hr)**

##### **Objective**

- Know the basics of aluminium, aluminium alloys, welding processes and the health aspects regarding welding of aluminium alloys.

##### **Scope**

- Grades of aluminium and aluminium alloys their characteristics and classification
- Characteristics of aluminium compared to mild steel and stainless steel
- Protective oxide film positive for welding?
- Welding processes for aluminium and aluminium alloys
- Health aspects during welding of aluminium and aluminium alloys
- Methods for preventing health risks during welding and joint preparation of aluminium, breathing zone, welder's masks with fresh-air filters, hygiene.

##### **Learning outcomes**

1. Brief explanation of the protective oxide film
2. Know the grades of aluminium and aluminium alloys their characteristics and classification
3. Understand the difference of welding aluminium alloys compared to welding unalloyed steel and stainless steel
4. Give examples of common welding processes for aluminium alloys
5. Knowing methods for preventing health risks related to welding and joint preparation of aluminium alloys.

##### **4.2.2 PAL.2 Weldability and welding technique (2hr)**

##### **Objective**

- Know the theoretical basics of welding aluminium alloys and common welding technique
- Know about weld imperfections, characteristic for welding of aluminium and its alloys.

##### **Scope**

- Weldability of aluminium heat input, preheating
- Post weld treatment

- Welding technique, TIG and MIG
- Handling of aluminium in the workshop
- Survey of specific imperfections and their cause (porosity, hot cracking, lack of fusion).

#### **Learning outcomes**

1. Outline the essentials of weldability of aluminium alloys, heat input, preheating, post weld treatment
2. Know about welding technique, TIG and MIG
3. Describe the correct handling of aluminium alloy material in workshop
4. Knowing how to avoid the imperfections characteristic to aluminium.

#### **4.2.3 PAL.3 Welding consumables for aluminium welding (2hr)**

##### **Objective**

- Know the basics of how to choose filler metals and gases for aluminium welding

##### **Scope**

- Filler metals for aluminium, standards, consumable manufacturers' recommendations
- Shielding gases for aluminium welding, standard, consumable manufacturers' recommendations
- Handling of welding consumables
- Consumables selection based on required properties of the weld (strength, weldability, corrosion properties and anodising properties.)

##### **Learning outcomes**

1. Identify the main types, and classification of welding consumables regarding aluminium alloys
2. Understand how to work with standards
3. Identify types of welding consumables in view of requested properties.

#### **4.2.4 PAL.4 Welding joints and distortion in aluminium alloys (2hr)**

##### **Objective**

- Know about different types of welded joints and distortion caused by welding

##### **Scope**

- Welded joints for aluminium alloys
- Methods of joint preparation in aluminium alloys
- Cleaning before welding
- Distortion caused by welding aluminium alloys compared to steel.

##### **Learning outcomes**

1. Outline the commonly used welding joints and the methods of joint preparation regarding aluminium alloys
2. Knowing methods to confine distortion of aluminium alloys caused by welding.

**Total number of recommended hours for PAL: 8hr**

## **5 Theoretical Examinations**

After the theoretical modules there are final theoretical examinations of the multi-choice type for the relevant level of diploma and covering the specific modules taken. It will be set under the authority of TWI Certification Ltd.

The hours to be allocated to the theoretical examination should be 3 h 15 minutes in total (for all modules). The examination duration for each module is shown in Table 1.

**Table 1** Maximum duration of each module harmonised written exam

Welding process Module (Duration)	Process 111	Process 141	Process 13X	Process 311
<b>General Theoretical Training</b>				
Module A (20 hours)	55 minutes (40 questions)			
Module B (18hours)	40 minutes (36 questions)			
Module C (7 hours) (See CP3)	15 minutes (14 questions)			
<b>Welding Process Theoretical Training</b>				
Module SA (5 hours)	10 min (10 questions)			
Module ST (5 hours)		10 min (10 questions)		
Module SM (7 hours)			15 min (14 questions)	
Module SG (5 hours)				10 min (10 questions)
<b>Materials Specific Theoretical Training</b>				
Module PSS (8 hours)	20 minutes (16 questions)			
Module PAL (8 hours)	20 minutes (16 questions)			
<b>Total Duration of the all above modules</b>	<b>3 hours 15 minutes (195 minutes)</b>			

The theoretical examinations pass mark is 60% for each module (A, B, C, PSS, PAL, SA, SM, ST and SG). Failure in theoretical parts of the examinations requires re-examination in the part failed. A third failure requires re-entry into the module leading to the examination.

The theoretical knowledge obtained in this training program may be transferred to another welding process or material group, as long as the examination date is not longer than 5 (five) years ago. The specific modules for materials and processes need to be studied and examined.

In order to be awarded a CP2 and IIW Diploma, successful completion of the relevant practical tests, see CP2 Parts 2 and 3, is required in addition to passing the theoretical examination.