EWF Guideline for
International Metal AM Operator: Directed Energy Deposition - Arc

PERSONNEL WITH QUALIFICATION FOR METAL ADDITIVE MANUFACTURING

Minimum Requirements for the Qualification and Examination

IAMQS

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MINIMUM REQUIREMENTS FOR
QUALIFICATION AND EXAMINATION

International Metal Additive Manufacturing Operator Directed Energy Deposition – Arc (I MAM O DED-Arc)

Guideline - General information for the public and organizations that implement this qualification

For more information regarding the Qualifications System, the Management Team or the IAMQS ANB should be contacted
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Preface

The present document consists in International MAM Operator DED-Arc Guideline, developed by EWF.

This guideline, for the European education, training, examination and qualification of additive manufacturing personnel, has been prepared, evaluated and formulated by the EWF International Additive Manufacturing Qualification Council (IAMQC). Contains general information for the public and organisations that implement this qualification.

Copies of this document can be downloded from EWF website: www.ewf.be, requested to IAMQS Authorized Nominated Bodies for Metal Additive Manufacturing (IAMQS ANBs) or Management Team.

MINIMUM REQUIREMENTS FOR THE EDUCATION, TRAINING, EXAMINATION AND QUALIFICATION OF PERSONNEL

Introduction

This guideline covers the minimum requirements for education and training, which have been agreed upon by all IAMQS ANB, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them. It will be revised periodically by EWF IAMQC to take into account changes that reflect the "state of the art".

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level.

The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	E O MAM DED-Arc	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	3,5	7
CU 01: DED-Arc Process	14	28
CU 02: Quality Assurance (QA) in DED-Arc	11	14
CU 03: Health, Safety and Environment (HSE) in DED-Arc	7	14
CU 04: Fit and set-up of DED-Arc systems	21	42
CU 05: Manufacturing of DED-Arc parts	7	14
CU 06: Post processing of DED-Arc parts	7	14
CU 07: Maintenance of DED-Arc systems	14	28
TOTAL	**84**	**161**

* Recommended Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall con-tain at least 50 minutes of direct teaching time.
** Expected Workload is calculated in hours, corresponding to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Although the hours indicated in the above table are merely recommended, it is mandatory that in total the qualification has a minimum of 40 contact hours.

Within EWF´s qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF´s Systems Framework levels (see Appendix I).

On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills. Recommended contact hours are distributed between theoretical (A), assigned pro-jects/exercises (B), practical workshop training (C), etc., as shown in the following example:

***Qualification:* Example 1**	
CONTACT HOURS	**X= (SUM A:C)**
Subject Contents	A + B + C

Professional Profile

I MAM O DED-Arc are the professionals with the specific knowledge, skills, autonomy and responsibility to operate metal AM machines using DED-Arc Process. His/her main tasks are to:

- Operate arc based DED machines for AM, including, fitting and setting up, maintenance and repair.

He/She will be able to:

- Verify arc related parameters and positioning in DED-Arc machines for AM;
- Self-manage the handling of feedstock (approval, storage, contamination, traceability);
- Develop solutions on basic and specific problems related with DED-Arc machines and processes for AM.

1 Routes to Qualification

Two distinct routes to gaining the qualifications described in this document have been agreed.

1. The Standard Route
2. Blended Learning Route

1.1 The Standard Route

The Standard Route requires successful completion of EWF approved courses which are designed to meet all the requirements in this Guideline. This is the route recommended by EWF as offering the fastest, most comprehensive manner in which the detailed knowledge may be covered.

1.2 Blended Learning Route

The Blended Learning Route will depend on the type of Competence Units (Cross-cutting or Functional). The Cross-Cutting Competence Units (theoretical knowledge and skills) may be taught using Distance Learning Programs under the control of the IAMQS ANB and all the Functional Competence Units (practical knowledge and skills) must be taught at the Authorized Training Bodies for Metal Additive Manufacturing (IAMQS ATB) facilities

2 General Access Conditions

The defined access conditions approved by IAMQC are given in detail for all countries participating in the EWF system.
The access conditions to International MAM Operator DED-Arc Qualification admission are the following:

- National compulsory school diploma

3 Special Requirements

3.1 Standard Route

Applicants shall satisfy the access conditions, to be accepted for the attendance of a training course conducted by an IAMQS ATB.

There will be written, oral and practical examinations (where applicable) for the award of the applicable EWF Diploma.

It is not obligatory to follow exactly the order of the Competence Units given in this guideline and choice in the arrangement of the detailed knowledge is permitted, with the exception that **the first Competence Unit to be provided must be CU 00: Additive manufacturing Process Overview.**

The rules to conduct the examinations by the IAMQS ANB are prescribed under Examination and Qualification in each Competence Unit guideline.

Complementary to the Competence Units that are required for the purpose of the International MAM Operator DED-Arc Diploma issuing, a set of optional Competence Units can be added. These can be of added value for the student and can be implemented by the AM ATB as a supporting training and education offer.

For these optional Competence Units, separate Records of Achievement will be issued after examination approval. Whenever these optional Competence Units are considered mandatory for a certain EWF Qualification, they can be recognized for the purpose of such Qualification Diploma.

In order to be awarded with the I MAM O DED-Arc Diploma, the trainee must successfully complete all the theoretical examinations described in each of the CUs referenced in the present document by achieving a minimum pass mark of 60% in each competency unit examination.

The trainee must successfully complete all the practical examinations described in each of the CUs referenced in the present document by achieving a minimum pass mark of 80% in each competency unit examination and a minimum mark of 60% for each of the assessment criteria included in the Practical Assessment Matrix.

The examination of any Competence Unit for the purpose of being validated individually, not included in a Qualification course, shall be completed within a period of 1 year from the starting day of the Competence Unit.

If the Competence Unit “A” is done as a part of a qualification course, the examination shall be completed within a period of 4 years from the date of the completion of the first Competence Unit from the qualification where Competence Unit “A” is integrated in. Failure in the examination shall require re-examination.

Each Competence Unit has a period of validity of 4 years. When applying for a Qualification course, the period of validity of the completed CUs are at discretion of the IAMQS ANB.

Note: For qualifying operators of equipment used in aerospace applications at least 80 % of the theoretical questions shall be answered correctly.

3.2 Section I: Theoretical and Practical Education – Qualification Descriptors and Learning Outcomes

I.1. Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSI-BILITY
International MAM Operator DED–Arc	**INDEPENDENT**	Factual and broad concepts in the field of DED–Arc metal additive manufacturing process.	Fundamental cognitive and practical skills required to develop proper solutions and application of procedures and tools on simple and specific of DED–Arc manufacturing problems	Self-manage of professional activities and simple standard applications of of DED–Arc manufacturing in predictable contexts but subject to change.

I.2. Mandatory Competence Units Learning Outcomes

Each of the following Competence Units has its Guideline with the Minimum Requirements for the Competence Unit and Examination, containing all the detailed knowledge to be covered and implementation and examination rules and procedures.

Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Directed energy deposition	0,5
Powder bed fusion	0,5
Vat photopolymerization	0,5
Material jetting	0,5
Binder jetting	0,5
Material extrusion	0,5
Sheet lamination	0,5
Total	3,5
WORKLOAD	**7**

Learning Outcomes – CU 00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Basic factual knowledge of theory, principles and applicability of: – Directed energy deposition – Powder bed fusion – Vat photopolymerization – Material jetting – Binder jetting – Material extrusion – Sheet lamination
SKILLS	Distinguish parts produced by different AM processes List the advantages and limitations of AM processes from a manufacturing process chain point of view Name the applicability of different AM processes, according to the characteristics of each process

Competence Unit 01: DED-Arc Process

CU01: DED-Arc Process	CONTACT HOURS
SUBJECT TITLE	
DED-Arc System (Hardware & Software)	5
DED-Arc Physical Principles, Processes and Parameters	5
DED-Arc Build platform, feedstock and other consumables	3
Post processing operations	1
Total	14
WORKLOAD	**28**

Learning Outcomes – CU01: DED-Arc Process	
KNOWLEDGE	Factual and broad knowledge of: – DED-Arc systems – Arc physics – Processable materials with DED-Arc – Processing atmosphere requirements with DED-Arc – Sensors and process controls with DED-Arc
SKILLS	Describe the DED–Arc systems, including the components and their functions Distinguish different types of feedstock Associate the interaction of the process heat source with the feedstock Recognise the DED–Arc parameters and the influence of their adjustment on the as built part (e.g. deformation) Recognise the characteristics of the DED–Arc build platform, feedstock and other consumables Identify the problems associated with inadequate preparation and set-up of the build platform, handling and storage of feedstock and application of the gases used in DED–Arc

Competence Unit 02: Quality Assurance (QA) in DED-Arc

CU 02: Quality Assurance in DED-Arc	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
General QA principles	3
AM Machine QA	2
AM Parts QA	2
Visual Inspection Overview	4
Total	**11**
WORKLOAD	**22**

LEARNING OUTCOMES – CU 02: Quality Assurance in DED-Arc	
KNOWLEDGE	Factual and broad knowledge of: – Quality Assurance in DED-Arc – Standard operating procedures – Overall overview of process flow from costumer purchase order to delivery of finished part – Receiving inspection of feedstock and build platform – Receiving inspection of non-consumable electrodes and constricting nozzles in DED-Arc – Material staging and preparation – Visual Inspection of DED-Arc
SKILLS	Recognise the broader use of QA within engineering Recognise the scope of the DED-Arc operator qualification within the AM industry Support the qualification and requalification procedures of DED-Arc equipment Identify the main procedures, equipment and their role Prepare test reports based on the requirements specified by the manufacturer Compare geometry and dimensions specified in the technical drawings with the as built parts Use simple measurement devices and techniques to carry out a basic visual inspection of the as built part Identify problems in the as build parts distinguishing between imperfections and defects Report defects suggesting either their removal with post processing operations or part disposal

Competence Unit 03: Health, Safety and Environment (HSE) in DED-Arc

CU03: HSE in DED-Arc	CONTACT HOURS
SUBJECT TITLE	
Health, Safety and Environment	7
Total	7
WORKLOAD	**14**

Learning Outcomes – CU03: Health, Safety and Environment (HSE) in DED-Arc	
KNOWLEDGE	Factual and broad knowledge of: – Health, Safety and Environment related to DED-Arc
SKILLS	Identify the main hazards and safety measures associated with DED-Arc systems Recall existing legislation and requirements on HSE procedures related to DED-Arc

Competence Unit 04: Fit and set-up of DED-Arc systems

CU04: Fit and set-up of DED-Arc systems	CONTACT HOURS
SUBJECT TITLE	
DED-Arc processes and systems requirements	5
Loading of files and Work Documentation	4
Operational Parameters	7
Materials handling and how it relates to the process	4
HSE procedures	1
Total	21
WORKLOAD	**42**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Fit and set-up of DED-Arc systems	**4 Independent**	Fit and set-up the DED-Arc system	Verifying the DED-Arc system set-up the procedure determined by the machine manufacturer and required operational conditions (e.g. electric arc power supply, gas supply, cooling system, torch)	**21**	**42**
			Preparing and verifying the build platform and feedstock		
			Performing Additive Manufacturing file loading and build jobs specs verification based on the AM procedure specification (includes inserting/verifying process parameters if needed)		
			Verifying parameter specifications (e.g. voltage, current, wire feed speed, travel speed, contact tip to work distance, positioning of the substrate)		
			Following HSE procedures for the fit and set-up of the DED-Arc system		
			Following and completing work documentation created by the DED-Arc Engineer		

Learning Outcomes – CU04: Fit and set-up of DED-Arc systems	
KNOWLEDGE	Factual and broad knowledge of: – Variables of DED-Arc and related operational conditions parameters – DED-Arc Equipment Requirements – Materials used for DED-Arc – Type of files and Work documentation – HSE procedures under DED-Arc
SKILLS	Prepare the system for operation, according to the Additive Manufacturing Procedure Specification Verify if the machine is working in accordance with the job specification, in terms of process parameters Prepare the feedstock, build platform and the machine in accordance to the used material Verify if the DED-Arc machine complies with the machine manufacturer and/or internal specifications Load files to DED-Arc machine Comply with HSE procedures associated to a DED-Arc machines Interpret technical information related to the DED-Arc processes and machines

Competence Unit 05: Manufacturing of DED-Arc parts

CU05: Manufacturing of DED-Arc parts	CONTACT HOURS
SUBJECT TITLE	
Machine functionalities and monitoring systems	5
Documentation	1
HSE procedures	1
Total	7
WORKLOAD	**14**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Manufacturing of DED-Arc parts	**4 Independent**	Manufacturing of DED-Arc parts	Performing a dry run and machine calibration at the beginning of the production run	**7**	**14**
			Ensuring that the layers are manufactured according to the quality requirements (i.e. first layers and periodically)		
			Monitoring the machine and the manufacturing process		
			Following HSE procedures when manufacturing DED-Arc parts		
			Following and completing work documentation according to the quality requirements		
			Reporting issues and implementing corrective or preventive actions based on parts' requirements feedback from the Engineer		

Learning Outcomes – CU05: Manufacturing of DED-Arc parts	
KNOWLEDGE	Factual and broad knowledge of: – Manufacturing of DED–Arc parts – DED–Arc machine functionalities and monitoring systems
SKILLS	Set-up the clamping system for the build platform characteristics according to the clamping plan (e.g. shape, thickness, material) Perform manufacturing of parts according to the build instruction applying HSE procedures Identify the main reasons for failure during the manufacturing process Interpret technical documentation related to the requirements of the as built parts Prepare reports on the manufacturing process, including identified issues

Competence Unit 06: Post processing of DED-Arc parts

CU06: Post processing of DED-Arc parts	CONTACT HOURS
SUBJECT TITLE	
Post build cycle operations including manual tools and methods	3
HSE procedures	4
Total	7
WORKLOAD	**14**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Post processing of DED-Arc parts	**4 Independent**	Prepare DED–Arc parts for post processing	Providing information from monitoring data about critical areas for extended testing	**7**	**14**
			Unclamping the part		
			Performing basic verification of as built parts		
			Applying manual operations to parts (cleaning, subtractive & other post processing)		
			Handing parts for post processing operations		
			Following applicable HSE procedures		

Learning Outcomes – CU06: Post processing of DED-Arc parts	
KNOWLEDGE	Factual and broad knowledge of: – Manual tools and methods for post-processing operations
SKILLS	Remove the as built parts from the machine applying the necessary HSE procedures Carry out simple manual preparation of the as built part for different post-processing methods

Competence Unit 07: Maintenance of DED-Arc systems

CU07: Maintenance of DED-Arc systems	CONTACT HOURS
SUBJECT TITLE	
Periodic maintenance aspects	5
Mechanical parts maintenance	5
Gas supply system maintenance	2
Auxiliary elements maintenance	2
Total	14
WORKLOAD	**28**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Maintenance of DED-Arc systems	**4 Independent**	Maintain and repair DED-Arc systems	Implementing equipment manufacturer's maintenance routines	**14**	**28**
			Cleaning and replacing components *(e.g. feedstock spool, electrode tip, nozzle, liner, coolant, gas supply components)*		
			Reporting problems to the Engineer		
			Following applicable HSE procedures		

Learning Outcomes – CU 07: Maintenance of DED-Arc systems	
KNOWLEDGE	Factual and broad knowledge of: – Maintenance aspects associated with DED-Arc systems
SKILLS	Assess the need to perform maintenance operations in DED-Arc system Perform maintenance operations in a DED-Arc system Identify the consumables for the different machine parts Report the need to execute specific maintenance Support other technicians during system maintenance Verify monitoring and calibration status (e.g. CNC/robot encoders) Verify the level of wear of a mechanical component (e.g. nozzles, rollers, contact tips) Replace, clean and repair mechanical components according to manufacturer/internal instructions Change filters in the shielding gas system Verify the welding gas and fume extraction system flows Verify the condition and make use of the personal protective equipment

Appendix I: EWF Systems Framework

FIELD OF ACTIVITIY		EQF LEVELS	EWF PROFICIENCY LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
COORDINATORS/MANAGERS	WELDERS & OPERATORS	7	EXPERT	Highly specialised and forefront knowledge including original thinking, research and critical assessment of theory, principles and applicability of metal additive manufacturing or welding related technologies.	Highly specialised problem- solving skills including critical and original evaluation, allowing to define or develop the best technical and economical solutions, when applying metal additive manufacturing or welding related technologies, in complex and unpredictable conditions	Manage and transform the metal additive manufacturing or welding and related technologies processes in a highly complex context. Fully responsible for the definition and revision of personnel's tasks.
		6	ADVANCED	Advanced knowledge and critical understanding of the theory, principles and applicability of metal additive manufacturing or welding and related technologies.	Advanced problem-solving skills including critical evaluation, allowing to choose the proper technical and economical solutions, when applying metal additive manufacturing or welding and related technologies, in complex and unpredictable conditions	Manage the applications of metal additive manufacturing or welding and related technologies in a highly complex context. Act autonomously in decision making and definition in the definition of the metal additive manufacturing or welding and related personnel's tasks.
		5	SPECIALIZED	Specialised, factual and theoretical of theory, principles and applicability of metal additive manufacturing or welding and related technologies	Specialised range of cognitive and practical skills, allowing to develop solutions or choose the appropriate methods, when applying metal additive manufacturing or welding and related technologies, in common/regular problems.	Manage and supervise common or standard metal additive manufacturing or welding applications and related technologies, in an unpredictable context. Take responsibility in standard work and supervise the metal additive manufacturing or welding and related personnel's tasks.
		4	INDEPENDENT	Factual and broad concepts in the field of metal additive manufacturing or welding technology	Fundamental cognitive and practical skills required to develop proper solutions and application of procedures and tools on simple and specific metal additive manufacturing or welding problems.	Self-manage of professional activities and simple standard applications of metal additive manufacturing or welding and related technologies in predictable contexts but subject to change. Supervise routine tasks and similar function workers, as well as take responsibility for decision making in basic work.
		3	BASIC	Basic facts, principles, processes and general concepts of welding, joining and related technologies	Be able to check and follow the information on the welding procedure specification, to produce butt and fillet welds in plates and or tubes, and or profiles in a variety of geometries and positions to the required quality and of specified dimensional accuracy	Work under supervision, taking personal responsibility for own actions and for the quality and accuracy of the work produced.
		2	ELEMENTARY	Elementary principles of welding, joining and related technologies	Able to check and follow the information on the welding procedure or adhesive bounding specification, and to produce weld/joints in a variety of geometries and positions to the required quality and of specified dimensional accuracy	Work under supervision.

General reference descriptors transversal to all qualifications. Each Qualification has its own specific descriptors in terms of Knowledge, skills, autonomy and responsibility.