EWF Guideline for
International Metal AM Operator Powder Bed Fusion - Electron Beam

PERSONNEL WITH QUALIFICATION FOR METAL ADDITIVE MANUFACTURING

Minimum Requirements for the Qualification and Examination

IAMQS

EWF-AM-QUAL-008r1-21

MINIMUM REQUIREMENTS FOR
QUALIFICATION AND EXAMINATION

International Metal Additive Manufacturing Operator
Powder Bed Fusion - Electron Beam
I MAM O PBF-EB

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 the International MAM Operator PBF-EB 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 ANBs, 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 to 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	I O PBF-EB	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	3,5	7
CU 22: PBF-EB Process	14	28
CU 23: Quality Assurance (QA) in PBF-EB	7	14
CU 24: Health, Safety and Environment (HSE) in PBF-EB	3,5	7
CU 50: Hardware, software and build file set-up for PBF-EB	14	28
CU 51: Monitoring and managing the manufacturing of PBF-EB parts	3,5	7
CU 52: Post-processing of PBF-EB parts	7	14
CU 53: Maintenance of PBF-EB systems	7	14
Subtotal (without optional CUs)	**60**	**119**
CU 48: Powder Handling	7	14
Total	**67**	**133**

* Recommended Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain 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 projects/exercises (B), practical workshop training (C), etc., as shown in the following example:

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

Professional Profile

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

- Operate electron beam powder bed fusion machines for AM, including fitting and setting up, maintenance and repair.

He/She will be able to:

- Remove parts and prepare them for post-processing steps;
- Self-manage the handling of powder (approval, storage, contamination, traceability);
- Develop solutions on basic and specific problems related with electron beam powder-bed fusion machines

1 Routes to Qualification

Two distinct routes to gain the qualification 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 course which is 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 European PBF-EB Operator 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 listed below in this guideline.

Complementary to the Competence Units that are required for the purpose of the I MAM O PBF-EB 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 IAMQS 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 PBF-EB 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 AM 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 RESPONSIBILITY
International MAM Operator PBF-EB	**INDEPENDENT**	Factual and broad concepts in the field of PBF-EB 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 PBF-EB manufacturing problems	Self-manage of professional activities and simple standard applications of PBF-EB manufacturing in predictable contexts but subject to change.

I.2. Mandatory Competence Units Learning Outcomes

Each of the following Competence Units has it´s 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 ernergy 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 22: PBF-EB Process

CU 22: PBF-EB Process	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Applications	2
Process Principles	1,5
System – Hardware and Software	3
Parameters	3
System – Software	0,5
Feedstock	2
Consumables	1
Post Processing	1
Total	14
WORKLOAD	**28**

Learning Outcomes – CU22: PBF-EB Process	
KNOWLEDGE	Factual and broad knowledge of: – EB systems – EB characteristics – Build platform – Wire /Powder – Vacuum pressure – Advantages and limitations of the process – Processable materials with EB
SKILLS	Describe the EB systems, including the components and their functions Outline the main advantages and limitations of EB over conventional and other AM processes, namely based on Electron beam Recognise the characteristics of the EB build platform, feedstock and other consumables Recognise the EB parameters and the influence of their adjustment on the as built part Recognise the interaction of the process heat source with the feedstock Identify the problems associated with inadequate preparation and setup of the build platform, handling and storage of feed-stock used in EB

Competence Unit 23: Quality Assurance (QA) in PBF-EB

CU 23: Quality Assurance (QA) in PBF-EB	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
General QA principles	2,5
AM Machine QA	1,5
AM Parts QA	1
Visual Inspection Overview	2
Total	7
WORKLOAD	**14**

Learning Outcomes – CU23: Quality Assurance (QA) in PBF-EB	
KNOWLEDGE	Factual and broad knowledge of: – Quality Assurance in PBF-EB – Visual Inspection
SKILLS	Recognise the broader use of QA within engineering Recognise the scope of the PBF-EB operator qualification within the AM industry Support the qualification and requalification procedures of PBF-EB equipment Identify the main procedures, equipment and their role Prepare test reports based on the requirements specified by the manufacturer Read a manufacturing plan 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, further inspection or part disposal

Competence Unit 24: Health, Safety and Environment (HSE) in PBF-EB

CU24: Health, Safety and Environment (HSE) in PBF-EB	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Health, Safety and Environment	3,5
Total	3,5
WORKLOAD	**7**

Learning Outcomes – CU24: Health, Safety and Environment (HSE) in PBF-EB	
KNOWLEDGE	Factual and broad knowledge of: – Health, Safety and Environment related to PBF-EB
SKILLS	Identify the main hazards and safety measures associated with PBF-EB systems

Competence Unit 50: Hardware, software and build file set-up for PBF-EB

CU 50: Hardware, software and build file set-up for PBF-EB	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
PBF-EB machine set-up requirements	4
Pre-build check list	3
Consumables, feedstock & substrate	3
Build files	1
Work documentation	2
Practical implementation of HSE procedures (while fit and set up the machine)	1
Total	**14**
WORKLOAD	**28**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Hardware, software and build file set-up for PBF-EB	**4 Independent**	Hardware, software and build file set-up for PBF-EB	Verifying the PBF-EB system set-up according to the procedure determined by the machine manufacturer and required operational conditions	**14**	**28**
			Preparing and verifying the build substrate and feedstock conditions		
			Performing: build file loading, process preparation, process starts, in process observation and mal function detection and mitigation		
			Build observation		
			Following HSE procedures during machine and build file set-up		

Learning Outcomes – CU 50: Hardware, software and build file set-up for PBF-EB	
KNOWLEDGE	Factual and broad knowledge of: – Variables of PBF-EB and related operational conditions parameters – PBF-EB equipment requirements – Materials used for PBF-EB – Type of files and work documentation – HSE procedures under PBF-EB
SKILLS	Prepare the machine for operation, according to the AM procedure specification Prepare the feedstock, build platform and the machine in accordance to the material being used Verify if the PBF-EB machine complies with the machine manufacturer and/or internal specifications Load files to PBF-EB machines Verify if the PBF-EB machines are working in accordance with the job specification, in terms of process parameters Comply with HSE procedures associated to PBF-EB machines Interpret technical information related to the PBF-EB process and machines

Competence Unit 51: Monitoring and managing the manufacturing of PBF-EB parts

CU 51: Monitoring and managing the manufacturing of the PBF-EB parts	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
Machine functionalities and monitoring systems	2
HSE Procedures	0,5
Documentation	1
Total	**3,5**
WORKLOAD	**7**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Monitoring and managing the manufacturing of PBF-EB parts	**4 Independent**	Monitoring and managing the manufacturing of PBF-EB parts	Following HSE procedures when printing AM parts	**3,5**	**7**
			Following and completing work documentation according to quality/parts requirements		
			Reporting issues and implementing corrective or preventive actions based on parts' requirements feedback from the Engineer		

Learning Outcomes – CU 51: Monitoring and managing the manufacturing of the PBF-EB parts	
KNOWLEDGE	Factual and broad knowledge of: – Manufacturing of PBF-EB parts – Machine functionalities and monitoring systems
SKILLS	Load powder following mandatory safety procedures Apply HSE procedures when manufacturing parts Interpret technical documentation related to the requirements of the as built parts Identify the main reasons for failure during the manufacturing process Prepare reports on the manufacturing process, including identified issues

Competence Unit 52: Post processing of PBF-EB parts

CU 52: Post processing of PBF-EB parts	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
Powder and parts removal processes	4
Manual tools and methods for post-processing operations	3
Total	**7**
WORKLOAD	**14**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Post processing of PBF-EB parts	**4 Independent**	Prepare PBF-EB parts for post processing	Providing information from monitoring data about critical areas for extended testing	**7**	**14**
			Applying simple manual operations to parts (cleaning, subtractive & post processing)		
			Handing parts for post processing operations		
			Following applicable HSE procedures		

Learning Outcomes – CU 52: Post processing of PBF-EB parts	
KNOWLEDGE	Factual and broad knowledge of: – Powder removal processes – Manual Tools and Methods for subtractive operations – Procedures for different post-processing methods and materials
SKILLS	Remove the as build parts and base plates from the machine applying the necessary HSE procedures Carry out simple manual preparation of the as built part for different post-processing methods Remove powder from the powder bed and parts following mandatory safety procedures Separate the as built parts from base plates distinguishing the base plate from the part based on the technical drawing and specifications using simple manual processes

Competence Unit 53: Maintenance of PBF-EB systems

CU 53: Maintenance of PBF-EB systems	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
General maintenance aspects	2
Optical elements	0,5
Parts maintenance	1,5
Auxiliary elements maintenance	0,5
Application driven material change	1,5
HSE procedures	1
Total	**7**
WORKLOAD	**14**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Maintenance of PBF-EB systems	**4 Independent**	Maintain and repair the PBF-EB system	Implementing equipment manufacturer's maintenance routines	**7**	**14**
			Cleaning and replacing materials components (e.g. powder bed, cleaning agent, filters)		
			Reporting problems to the Engineer		
			Following applicable HSE procedures		

Learning Outcomes – CU21: Maintenance of PBF-EB systems	
KNOWLEDGE	Factual and broad knowledge of: – Maintenance aspects associated with PBF-EB systems
SKILLS	Clean the nozzle Assess the need to perform maintenance operations in PBF-EB system Perform maintenance operations in PBF-EB system Identify the consumables for the different machine parts Report the need to execute specific maintenance Support other technicians during system maintenance Verify the cleanliness of the system Monitoring and calibration status Verify the level of wear of a mechanical component Verify the system gas flow Adequate maintenance routines to the material type Verify the condition and make use of the personal protective equipment

Competence Unit 48: Powder Handling

CU 48: Powder Handling	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
Overview of Powder Manufacturing Processes	1
Chemical Composition and Physical Properties	2
Particle Size Distribution	0,5
Powder storage, handling, ageing and documentation	1,5
Powder reusability	1
HSE procedures	1
Total	**7**
WORKLOAD	**14**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Power Handling	**4 Independent**	Manage powders for Metal AM	Implementing procedures for powder delivery and storage	**7**	**14**
			Preparing and analysing powder according to technical documentation		
			Performing powder reconditioning (e.g. sieving) after build cycle		
			Following HSE procedures		

Learning Outcomes – CU 48: Powder Handling	
KNOWLEDGE	Factual and broad knowledge of: – Powder handling, storage and reconditioning
SKILLS	Complete technical documentation related to powders for metal AM Characterise powders according to instructions from the engineer Ensure powder conditioning according to the AM Procedure Specification Control the reusability of powders Handle powders according to HSE procedures

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.