EWF Guideline

European Thermal Spraying Specialist

Minimum Requirements for the Education, Training, Examination and Qualification

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MINIMUM REQUIREMENTS FOR THE EDUCATION, TRAINING, EXAMINATION AND QUALIFICATION

EWF Guideline

EUROPEAN THERMAL SPRAYING SPECIALIST (ETSS)

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Section 0: Minimum Requirements for the Education of European Thermal Spraying Specialist

The use of this guideline is restricted to organizations approved by the Authorized National Body (ANB). The section II of this guideline covers the examination and qualification of European Thermal Spraying Specialists.

0.1. Introduction

This guideline for the European education and training of the Thermal Spraying Specialist has been prepared, evaluated and formulated by Members of the Subcommittee Thermal Spraying of the Committee for Education and Training of the EWF. It is designed to provide the basic core education in thermal spraying technology required for a number of thermal spraying personnel being active in job functions such as inspection, supervision, foremanship, instruction, technical sales etc.. It is possible that additional training and/or experience may be required by the thermal spraying personnel beyond the basis core education to lead to qualifications in the applicable job functions. Additional training programmes will be established as required.

The guideline covers the minimum requirements for education and training, agreed upon by all national welding societies, to which thermal spraying is allied in most cases, within the EWF, in terms of themes, keywords and times devoted to them. It will be revised periodically by the Subcommittee taking into account any changes that may have an effect on the "state of the art". Students having successfully completed this course of education will be expected of being capable of applying the thermal spraying technology as covered in this guideline. A subsequent document covers the examination and certification.

The contents are given in the following structure:

Theoretical Education teaching hours

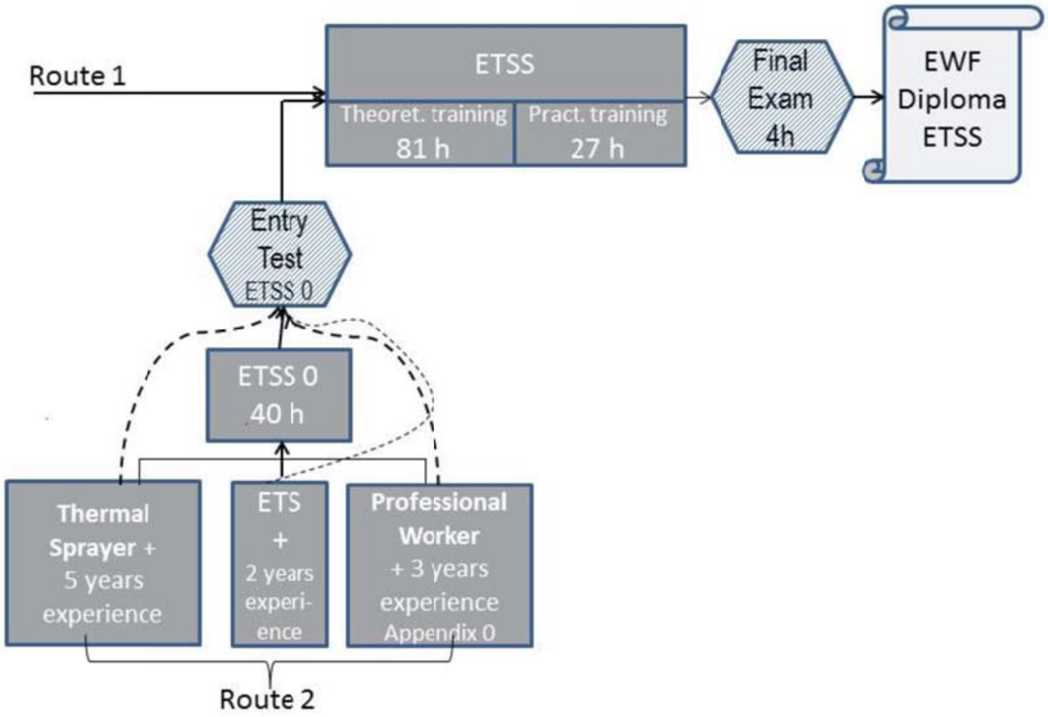
Thermal spraying processes: introduction and principle and environmental aspects	20
Spray material selection and bonding mechanisms	13
Working procedure, health and safety	15
Spray results and documentation	15
Application engineering and quality management	18
Practical training/demonstration	27
Examination	4
Total	112

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 and choice in the arrangement of the syllabus is permitted.

The depth to which each topic is dealt with is indicated by the number of hours allocated to it in the guideline. This will be reflected in the scope and depth of the examination.

0.2. Access to Education

For the entry to the programme three routes are available:



Access to ETSS via Route 1 and 2:

Any Candidate to the Route 1 and 2 to access the ETSS training first of all must comply with the access requirements mentioned on the guideline (see below statement) and shall also comply with the National Access Conditions defined on this Part (see Appendix 0 and 1).

ETSS Access Conditions requirements:

All candidates shall have a minimum of 2 years of job related experience.

Route 1:

For the access to the module ETSS the minimum requirements are:

- Specific technical qualifications, the national definitions are given in appendix 1

Route 2:

For access to the module ETSS part 0 minimum requirements are:

- ETS Qualification (European Thermal Sprayer - Guideline EWF Doc. 507) and a minimum of 2 years of experience in thermal spraying related activities.

or

- Thermal sprayer and 5 years of experience

or

- Qualification of a professional worker in metalworking professions and minimum of 3 years of experience in thermal spraying related activities, national definitions are given in appendix 0.

Students who enter from route 2 must pass an entry test. Those who feel they lack the necessary technical education may take the preparatory ETSS 0-course before the test. If a student fails in the entry test, he must take the full ETSS 0-course before the next test.

The rules for the conduct of the final examination by the ANB are prescribed under Examination and Qualification in this guideline.

Applicants not fulfilling the access conditions may follow the course as guests, but entry to the EWF examination is not permitted.

0.3. Theoretical Education ETSS 0 — in total: 40 hours

The module ETSS 0 aims at teaching basic technical knowledge, which in general is lacking with participants entering via route 2 and 3 in comparison to participants entering via route 1. It provides the chance for professional worker to be qualified as a European Thermal Spraying Specialist.

1. Introduction (2 hours)

Objectives: To guarantee a basic knowledge of the state of the art in education and applicable standards, related to thermal spraying.

Scope:

- Survey of the contents of this module, repetition of basic knowledge
- Information about the ETSS and its education and training system
- Job function of the ETSS in relation to EN standards

Learning Outcomes:

1. Understand objectives of the available education system, related to thermal spraying
2. Know about standards, related to thermal spraying

2. Units (2 hours)

Objectives: To guarantee a basic knowledge of metrology for an ETSS to be able to control the quality in thermal spraying operations. To acquire a working knowledge of the metric system of measurements, i.e. the International System of Units (SI), related to thermal spraying

Scope:

- Units - length and area
- Time and time dependent units

Learning Outcomes:

1. Understand objectives of the metrology.
2. List all SI base units and their symbols for length, mass, time, electric current, voltage, temperature, plane angle and other commonly used units related to thermal spraying.
3. List all SI derived units and their symbols for area, density, energy, force, frequency, power, pressure, volume, area, linear velocity, and other commonly used units related to thermal spraying.
4. List commonly used multiplication factors, prefixes and their symbols.

3. Technical Calculation (13 hours)

Objectives: To demonstrate how to make calculations related to thermal spraying involving various combinations of mathematical operations, powers, square roots, basic trigonometric functions, equations, variables including linear and angular measurements and time.

Scope:
- Addition, subtraction, multiplication, division
- Percentage calculation, rule of three
- Use of pocket calculators
- Equations, rearranging equations
- Calculation of length, area and volume
- Angular units, trigonometric functions

Learning Outcomes:
1. Show examples of mathematical operations of addition, subtraction, multiplication and division of whole numbers of different signs, decimals and fractions.
2. Show examples of linear equations and how the equations can be re-arranged, manipulated and solved.
3. Explain the definition of basic trigonometric functions of sine, cosine and tangent in terms of the ratios of the sides of a right-angled triangle.
4. Be able to calculate length, area, volume, speed and acceleration.
5. Show the use of pocket calculators for the above calculations and functions.

4. Technical Drawing (6 hours)

Objectives: To be able to read and understand basic technical drawings related to thermal spraying technology.

Scope:
- Formats, lines, fonts, scales, drawing aids
- Sketch of flat pieces
- Drawings, projections, cross sections
- Pieces with hidden lines
- Symbols, size lines
- Drawing of diagrams

Learning Outcomes:
1. Explain the purpose and importance of the technical drawing for the thermal spraying applications.
2. Know projection views.
3. Explain the use and indication of scales in engineering drawings.
4. Illustrate the various types of lines and their usage.

5. Basics of Electrical Engineering (3 hours)

Objectives: To acquire a basic knowledge of the industrial electricity in relation to the requirements of thermal spraying technology.

Scope:
- Direct current, alternating current
- Circuits, connection diagrams

Learning Outcomes:
1. Briefly describe sources of electricity.
2. Describe the major differences between DC and AC current and give examples of their individual applications.
3. Read connection diagrams and simple circuits.

6. Basics of Chemistry and Physics (4 hours)
Objectives: To acquire a basic knowledge of chemistry for the understanding of chemical reactions in thermal spraying processes and chemical analysis of thermal spray materials and thermal sprayed coatings.

Scope:
- Chemical elements
- Simple chemical reactions of reduction and oxidation (used in steel manufacturing, corrosion and combustion)

Learning Outcomes:
1. List basic chemical elements and their symbols in engineering steel, aluminium, nickel and copper, and their alloys.
2. Explain chemical reaction and its representation by the chemical equation with examples of chemical reactions in steel manufacturing.

7. Properties of Materials and Metal Products (6 hours)
Objectives: To be informed about main metallic materials used in thermal spraying. To know how they are classified according to their main physical properties, and how they influence material applications. To know different product form in which the metallic materials used in thermal spraying are commercially supplied and to have notions about methods of their production.

Scope:
- Basics of metals, non-metals
- Metal products: plates, profiles, bars, castings, forgings, extrusions

Learning Outcomes:
1. Description, application, types, physical properties of main metallic materials.
2. Know the difference between the main properties of steel, cast iron, aluminium and copper.
3. Be able to identify materials by their designation.

8. Machining of Materials (2 hours)
Objectives: To be informed about the different methods to machine metals and materials used tor thermal sprayed coatings

Scope:
- Sawing, cutting, stamping, drilling, shaping
- Milling, thermal cutting
- Turning, grinding, polishing

Learning Outcomes:
1. Know the most important machining methods.
2. Be able to describe the difference between cutting and abrasive machining.
3. Know the importance of detrimental effects due to false machining of thermal sprayed coatings

8. Survey of Thermal Spray Processes (2 hours)
Objectives: Get an overview of the most important thermal spray processes currently used

Scope:
- Flame-, HVOF (liquid and gas fuel), arc-, plasma spraying

Learning Outcomes:
1. Know the difference between the spray processes in general

Appendix 0

National definitions for the minimum requirements for the access to the Thermal Spraying Specialists' education and examination via the route 3 defined above:

Austria:
Professional worker in a metal working profession

Belgium:
Holders of a B.S.O. (Beroeps Secondair Onderwijs) or a E.S.P.
(Enseignement Secondaire Professionel) qualification plus demonstrated practical skill in two processes + three years of practical experience

Denmark:
Craftsman (diploma of skill) in metalworking professions (Faglaert med svendebrev)

Finland:
3 years at institute of vocational education or equivalent (mechanical line) or sufficient technical knowledge and 3 years of experience in metalworking professions (including at least 1 year of experience in thermal spraying)

France:

Germany:
Certificate of a professional worker in metalworking professions
(Facharbeiterbrief), obtained after successful examination by the chambers of industry or craft organisations

Italy:
National certificate (diploma) of professional worker obtained at public or private professional school recognized by the district education authorities ("Regioni" or "Provincie Autonome")

Ireland:

Luxembourg:
Certificate of a professional worker in metalworking professions (CATP = certificat d´aptitude technique et professionel), obtained after successful examination by the chambers of trade

Netherlands:
NIL/SOM diploma level 3 ("grounddiploma")

Norway:
Qualification as skilled worker - letter of skill - in:

Plate/welding, mechanical processes or electro-mechanical processes - according Norwegian education system (Grunnskole, GK Mekaniske fag, VK1 plate/sveise-sfag, fagprøve)
Min. 2 years of experience in Thermal Spraying

Portugal:
- Second cycle of basic education or,
- First cycle of basic education plus two years in a Professional Training Centre of the metalworking area (Profissional Qualificado)

Spain:
Professional worker in metalworking professions

Sweden:
Access is possible via three routes:

a) 2 years at Gymnasieskolans plat-och svetslinje (practical, upper secondary school). Prior to 1993

or

b) 3 years at Gymnasieskolans (practical, upper secondary school). After 1993

or

c) Older equivalent education with at least 2 years of technical education after the compulsory school leading to at least the same competence as alternatives a) and b) above

All ETSS-students must have minimum 3 years of industry practice in a metalworking profession

Switzerland:
Certificate of a professional worker in metalworking professions, obtained after successful examination by the craft organisation (Eidg. Fähigkeitsausweis)

United Kingdom:

Approved craft certificates in engineering subjects issued by, for example, City & Guilds of London Institute

or

Approved Level 2/3 National Vocational Qualifications or other nationally recognized vocational qualifications in engineering subjects

Section I: Theoretical Education ETSS – Syllabus and Performance Objectives

1. THERMAL SPRAYING PROCESSES: INTRODUCTION AND PRINCIPLES HOURS AND ENVIRONMENTAL ASPECTS TOTAL HOURS: 20

1.1 General

Objective: Understand the developments in thermal spraying and gain basic knowledge of the different thermal spraying processes including terminology, standards and abbreviations.

Scope: *(1 hour)*

- introduction, purpose of thermal spraying , definition of thermal spraying history, processes
- base and spray materials and combinations
- typical applications
- duties and responsibilities of the ETSS

Learning Outcomes:

1. Outline the major differences between each thermal spray process, e.g. flame, arc, plasma
2. Describe the different processes.
3. Identify a thermal spray process by the common abbreviations.

1.2 Mechanical, chemical, thermal attack of surfaces

Objective: Gain basic understanding of the fundamentals of wear.

Scope: *(2 hours)*

- mechanical attack
- chemical attack
- thermal attack
- combined attack

Learning Outcomes:

1. Outline wear situations that involve the mechanisms of the different types of wear.

1.3 Possibilities to protect surfaces

Objective: Gain basic knowledge of the principles and fields of application of the most common application techniques, the methods and materials of protective layers used.

Scope: *(1 hour)*

- Painting, galvanic plating
- vapour deposition (physical, chemical)
- hardening
- cladding
- typical advantages, limits, differences compared to thermal sprayed coatings

Learning Outcomes:

1. Recognise in general the various techniques for applying protective layers and the reasons for their choice.
2. Outline the limits associated to each method.

1.4 Thermal spraying processes: principles incl. spraying and handling equipment

Objective: Gain basic knowledge of the fundamentals of thermal spraying.

Scope: *(1 hour)*

- process principles
- kinds of heat sources

Learning Outcomes:
1. Outline the different TS process principles.
2. Outline the typical characteristics of each kind of heat source.

1.4.1 Oxygen fuel flame spraying

Objective: Understand in detail the fundamentals of oxy-gas combustion, characteristics of the different fuel gases, equipment, safety and typical applications (safety - see also chap. 3.5).

Scope: (3 hours)

- principles, gases, fuels, influence of properties,
  spray material and base material
  powder flame spraying, wire and rod flame spraying
- equipment for flame spraying
  gas supply, fuel, burning, oxygen
  cylinders, tanks, hoses, pressure regulators
  flow meters, safety devices
  exhaust systems
  principles, extracting, filtering - outside/inside workshop, spray booth etc.
- spray material feeder
  powder feeder - powder feeder systems:
  gravity, mechanical wheel, fluidized bed, pressurized disk, injector
  wire feeder systems:
  pull-, push-pull-system, wire table, straightener, pneumatic motor, electric motor
- gun: gun - powder spraying, gun - wire spraying
- HVOF spraying (1 hour)
  equipment for HVOF spraying, fuel supply, gas supply: speciality - tanks, pumps, vaporiser; heating, compressor
  control unit (flow meter, pressure regulators)
  gas flow, liquid flow , measurement, pumps
  liquid fuel supply - pumps, liquid flow measurement.
  guns - design (gas, fuel or liquid) water cooled, air cooled, hybrid
  nozzle lifetime, coating quality, modifications, extensions
  powder injection
  cooling system: primary and secondary cooling system
- cold spraying: Equipment. gas supply, guns, powder injection etc. (1 hour)
- detonation spraying (in short terms)

Learning Outcomes:
1. Outline the characteristics of the different fuel gases (see also chap. 3.5).
2. Identify the potential hazards and methods of safe handling, storage and working practices.
3. Outline the purpose and working principle of each component of the equipment.
4. Identify the limitations and the range of application of the different flame spray processes.

1.4.2 Arc spraying

Objective: Gain basic knowledge of an electric arc, its characteristics, limitations and application in thermal spraying. Understand in detail the purpose of the main components used for arc spraying, safety and typical applications (safety - see also chap. 3.5).

Scope: *(2 hours)*

- basics of electricity and power sources (current, resistance, AC/DC, Ohm´s law, polarity), and of the electric arc
- principle of process
  power sources (rectifier, transformers, characteristics)
- spray materials - wire - solid wire/cored wire
- gases - transportation and shielding of spray materials
- equipment for arc spraying
  - control unit
  - stability of process, duty cycles, voltage adjustment - material size
  - wire speed, spray rate
  - measuring and adjusting, current, voltage, gas pressure, wire feed
- gun

Learning Outcomes:
1. Describe an electrical arc and arc stability.
2. Outline the generation of heat in the arc.
3. Outline the purpose and working principle of each component of the equipment.
4. Identify the limitations and the range of application of the arc spray process.

1.4.3 Plasma spraying

Objective: Understand in detail the principles and the fields of application of plasma and the fundamentals of the process, including equipment, applications, main variables, safety (see also chap. 3.5) and common problems.

Scope: *(2 hours)*

- atmospheric plasma spraying - APS
- process principles - properties of plasma
- spray materials
- gases - mixtures, purity, properties and safety regulations for handling
- equipment for plasma spraying (closed loop control, advantages)
- power sources
- control unit - high frequency ignition
- gun, cooling water

Learning Outcomes:
1. Describe plasma.
2. Outline the purpose and working principle of each component of the equipment.
3. Identify the limitations and the range of application of the plasma spray process.

1.4.4 Vacuum plasma spraying (VPS) / Low pressure plasma spraying - LPPS

Objective: Gain basic knowledge of the fundamentals and the field of application of vacuum plasma spraying, including equipment, main variables and most common limits.

Scope: *(1 hour)*

- process principles
- chamber
- properties of coatings
- cleaning with transferred arc
- heating

Learning Outcomes:
1. Describe a transferred arc and its application.
2. Describe the working principle of the vacuum/low pressure plasma spray process.
3. Outline the purpose and working principle of each main component of the equipment.
4. Identify the limitations and the range of application of the vacuum/low pressure plasma spray process.

1.5 Handling the equipment for all processes

Objective: Gain basic knowledge of the principles and industrial applications of mechanisation and the use of robotics in in thermal spraying.

Scope: *(1 hour)*

- handling of the gun - manually, mechanised, robotized
- handling of the work-piece - fixed, turntables, automated - production line

Learning Outcomes:
1. Outline the advantages and disadvantages of robotics, automation and mechanisation of thermal spraying processes.
2. Recognise potential risks, hazards and methods of safe handling and working related with automatic, mechanised and robotics (in thermal spraying).

1.6 Environmental aspects and waste disposal

Objective: Gain basic knowledge of environmental aspects and waste disposal associated with thermal spraying, including national standards and regulations.

Scope: *(4 hours)*

- emission
- national standards for dust and noise
- dust: filter-cleaning-system, collector, changing filters, spreading
- waste disposal
- waste: dust, collecting, storage, recycling, treatment
- stripping waste

Learning Outcomes:
1. Identify – basically - appropriate methods to reduce dust pollution.
2. Describe correct waste disposal.

2. SPRAY MATERIAL SELECTION AND BONDING MECHANISMS TOTAL HOURS: 13

2.1 Coating functions and related materials

Objective: Understand in detail the different types of coating functions and the related materials.

Scope: *(4 hours)*

- mechanical resistance
  soft-, hard bearing coatings
- coatings resistant to:
  abrasive grains and hard surfaces at low/high temp.
  fretting at low/high temperatures
  cavitation
  particle erosion at low/high temperatures
- chemical resistance
- thermal resistance
- special functions:
  electrical conductivity or resistivity
  machine element clearance control
  abradable coatings
- material examples

Learning Outcomes:
1. Identify different types of coating functions.
2. Recognise the significance of appropriate spray material.

2.2 Spray material

Objective: Understand in detail the different types of spray material, the importance of the type of production and classification methods, as well as the importance of proper handling and storage.

Scope: *(5 hours)*

- powder
  production (atomized, agglomerated, coated –morphology)
- wire
  solid wire, cored wire, cords, rods
  production
- classification
  including for spray powders also: methods for measuring powder particle size distributions
- handling and storage

Learning Outcomes:
1. Identify different types of spray powders and their production methods.
2. Identify different types of spray wires and their production methods.
3. Recognise the significance of appropriate handling and storage of the spray material.
4. Describe the methods and purpose of proper classification.
5. Demonstrate the use of appropriate standards for consumables.

2.3 Bonding mechanism

Objective: understanding the theoretical background of bonding mechanisms, influences of spray parameters and material interaction.

Scope *(4 hours)*

- principles
  heat transfer, chemical reaction during flight
  splatting, diffusion, micro-welding, mechanical clamping
- influence of parameters on the particle,
- energy transfer
  from flame, arc and plasma to particle
  from particle to substrate
- particle velocity, particle temperature, differences in gas to particle velocity
- mechanical, physical and metallurgical bonding
- influence of parameters on the particle
  particle injection in flame
  size of particles
  particle in centre of the heat source
  particles at the edge of the heat source
- influence of the substrate
  surface - particle interaction
  mechanical bonding (shrinkage, clamping)
  physical bonding (physisorption), chemisorption
  metallurgical bonding (diffusion, alloying, micro-welding)

Learning Outcomes:
1. Recognise the bonding mechanisms of thermal sprayed coatings.
2. Outline the influences of spray parameters.
3. Outline the influence of the substrate.
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3. WORKING PROCEDURE, HEALTH AND SAFETY TOTAL HOURS: 15

3.1 Pre-spray conditions and preparation

Objective: becoming acquainted with the most common surface preparation processes used in industry. Understanding the importance of proper design of surfaces to be thermally sprayed.

Scope: *(3 hours)*

- shape and design
  geometrical influence, bores, edges, wall thickness
- surface preparation (EN 13507)
  behaviour of the material
  degreasing, cleaning activating
  mechanical, chemical, thermal treatment,
  masking,
  grit blasting: size/type of grit - materials, angle, pressure, distance
  nozzle size, activating, roughening, time influence)
- preheating

Learning Outcomes:

1. Describe and compare the principles of each pre-treatment and their applications.
2. Explain the selection of appropriate pre-treatment, according to the application and/or material.
3. Describe potential hazards and methods of safe handling and working of the above mentioned techniques.

3.2 Substrate, bond coats and intermediate layers

Objective: Gain basic knowledge of structure and properties of the different substrate materials. Gain basic knowledge on the fundamentals of delamination mechanisms in sprayed coatings, the function of bond coats, intermediate and other layers.

Scope: *(2 hours)*

- \- function and types of bond coats
  materials, properties, adhesion, diffusion, roughness
  thickness, corrosion resistance, geometrical compensation
- \- intermediate layers, graduated layers, buffer layers
  roughness
  thickness, geometrical compensation
- \- substrate materials and properties
  thermal conductivity, thermal expansion coefficient
  hardness, oxidation characteristics
  Ni-/ Co-base
  copper
  light metals and alloys
  non-metallics

Learning Outcomes:

1. Identify the basic mechanical properties of the different substrate materials.
2. Describe the causes for delamination.
6. Recognise alternatives that will reduce or eliminate the risk of delamination.

3.3 Working procedure

Objective: Gain basic knowledge of the effect of parameters on the thermal spray coating built up.

Scope: *(4 hours)*

- flame spraying: cold / warm spraying
- spraying and fusing/ fusing during / after spraying
  (self-fluxing alloys; flame, furnace induction)
- HVOF spraying
- arc spraying
- plasma spraying
- cooling of the substrate
- trouble shooting for all processes

Learning Outcomes:

1. Explain – basically - the factors/set-up parameters that might change the TS coating built up.
2. Recognise which parameters have to be set-up, and how to check them during thermal spraying, in accordance with the applicable thermal spray process.
3. Interpret procedures for the calibration of thermal spraying operations.

3.4 Post treatment

Objective: Gain basic knowledge on the fundamentals mechanical, thermal and chemical post treatment methods of thermal sprayed coatings.

Scope: *(2 hours)*

- post treatment - changing the properties of the coating (fusing)
- machining
  turning - dry grinding, wet grinding, polishing, tools and parameters
- sealing, impregnation, hipping

Learning Outcomes:

1. Recognise the risk factors that might lead to delamination or damaging of the TS coating due to inadequate post treatment methods.
2. Identify appropriate methods to reduce delamination or damaging of the coatings while applying post treatments.

3.5 Health and safety

Objective: Understand in detail the health and safety hazards associated with thermal spraying and fabrication processes, including techniques to minimise them.

Scope: *(4 hours)*

- Noise: noise levels, noise reduction, means for protection, standards
- radiation - light emission, heat emission
  effects on eye and skin
  protective measures, standards
- dust, fumes and gases
  AGW-values, health damaging effects
- electrical hazards: physiological effects, accidents, protection
- hazards in thermal spray technique: during preparation, during spraying
  safe handling of the whole system, dust explosions
  international and national standards

Learning Outcomes:

1. Recognise the risk factors associated with thermal spraying from electricity, gases, fumes, fire, radiation and noise.
2. Identify Health and Safety regulations with respect to the above hazards.
3. Identify appropriate methods to reduce each type of the above mentioned risk factors.
4. Describe correct use of protective clothing.

4. SPRAY RESULTS AND DOCUMENTATION **TOTAL HOURS:** 15

4.1 Spray results

Objective: Understand the principles of coating characteristics, structure and properties, acceptance criteria and fitness for purpose.

Scope: *(4 hours)*

- characteristics of thermal sprayed coatings,
- properties: porosity, hardness, adhesion strength, shear strength
- oxide content
- structure of coatings
- influencing properties

Learning Outcomes:
1. Explain the microstructure formed as a result of thermal spraying.
2. Explain the principle of metallographical preparation of thermal sprayed coatings.

4.2 Imperfections and defects:

Objective: Understand the fundamental aspects of how imperfections and defects in thermal sprayed coatings may be caused. Know the different types of defects and imperfections and how they may be avoided or eliminated.

Scope: *(3 hours)*

- causes and elimination, prevention (ISO14923)
- cracks, delamination
- excessive porosity
- excessive roughness
- uneven coverage, component distortion
- poor machinability (ISO 14924)
- coating chipping
- discoloration

Learning Outcomes:
1. Explain the principles of acceptance criteria.
2. Define the effects of imperfection size, morphology and position on structural integrity.

4.3 Measurement, recording, testing and documentation

Objective: Understand the fundamental aspects of testing materials. Understand the use of Non Destructive Testing and Destructive Testing applicable to thermal sprayed fabrications. Understand in detail the fundamentals of the various types of corrosion. Gain basic knowledge of the requirements for measurement, control and recording during thermal spraying and allied operations.

Scope: *(8 hours)*

- process, parameters, materials, shape, size - before spraying:
  mechanical measurement
  chemical analysis
  visual inspection - NDT
  - during spraying:
    parameter measurement
    dummies and blanks
    for testing (bending test, adhesion test, shear test, etc.)
    modern diagnostic procedures
- after spraying:
  mechanical measurement: roughness, dimensions

- DT - destructive testing:
  adhesion testing (EN 582), pull-off-testing (ISO 4624 - in case of application for corrosion protection)
  shear load resistance (EN 15340)
  testing of hardness, tensile, shear, bending
  hammer test, scratch hardness (in short terms)
  chemical testing: corrosion (wet environment), air oxidation (air/gas environment)
  metallographical testing, porosity
- NDT - non-destructive testing: (for industrial use or used in laboratories)
  visual inspection/testing, Penetration test (acc. to EN 571-1)
  eddy current method (thickness, bonding, cracks, delamination)
  ultrasonic, radiography/isotope, thermography
  coating thickness measurement (magnetic, inductive)

Learning Outcomes:
1. Outline in principal DT and NDT methods, their advantages and disadvantages, when applied to thermal sprayed fabrications.
2. Recognise imperfections of thermal sprayed coatings, their causes and avoidance and methods of detection.
3. Explain the methods of measurement used in the control of thermal spraying and allied operations.
4. Outline the chemical and electrochemical phenomena involved in corrosion.
5. Recognize and describe the most common types of corrosion.
6. Recognise the basis and results of tests to define wear resistance.

5. APPLICATION ENGINEERING AND QUALITY MANAGEMENT TOTAL HOURS: 18

5.1 Economics

Objective: Gain basic knowledge of the economics of thermal spraying operations applied to thermal sprayed fabrications.

Scope: *(2 hours)*

- analysis of coating process and spray costs:
  deposition efficiency and rate, costs of labour, quality control/inspection, consumable, equipment, energy
  spray time, preparation time, finishing costs etc.
  waste, disposal costs

Learning Outcomes:
1. Identify the elements of cost associated with thermal spraying.
2. Calculate the cost of thermal spraying operations.
3. Outline – basically - thermal spraying and handling procedures including mechanisation and automation to minimise production costs.

5.2 Quality management

Objective: Gain basic knowledge of the principles of quality assurance and quality control and recognise the related standards and their application to thermal sprayed fabrication as a special process.

Scope: (3 hours)

- (ISO 9000) basic information, acc. to ISO 14922:
- Standards, quality manual, quality system elements, certification
- material certificates, consumable certificate
- spraying procedure specification
- sprayer certificates
- heat treatment records, NDT and DT procedures and reports, dimensional reports

Learning Outcomes:
1. Describe the main differences between quality assurance, quality control and inspection systems.
2. Demonstrate effective writing of quality control procedures.
3. Demonstrate correct use of standards (e.g. ISO 9000, and ISO 14922ff.).
4. Recognise the basic factors related to personnel and equipment, which influence the quality in a thermal sprayed fabrication.
5. Outline the role of the Thermal Spraying Specialist in the fabrication industry.

5.3 Other processes and new developments

Objective: Gain basic knowledge of alternative surfacing processes and new developments in thermal spraying.
Scope: *(2 hours)*

- laser spraying, -melting
- condensor discharge
- high energy plasma spraying, wire plasma spraying

Learning Outcomes:
1. Outline the principles of the processes mentioned in the objective and their application.
2. Identify common applications of the above mentioned processes in the different industrial fields.

5.4 Typical applications and case studies

Objective: Understand and be able to handle thermal spraying related tasks in respect of the manufacture of specific thermal sprayed products. (The best way to give this education is a combination of experts from industry presenting special cases and project work to the students split up into groups, followed by a general discussion and comments by the experts. All of the following subjects have to be dealt with the depth to which, however, will depend on the national needs.)

Scope: (11 hours)

- typical applications according to coating function:
  standards and specifications
  design / construction
  different base and spray materials and processes
  pre- and post-treatment
  quality control, economics
- case studies:
  technical point of view
  economical point of view

Learning Outcomes:
Not Applicable

<u>Practical training/demonstration:</u> ETSS Part II Total hours: 27

This part does not aim at practical skills of the thermal spraying specialist but on gaining knowledge on the control of different thermal spraying processes. The students shall become as familiar as possible with the difficulties and typical defects associated with incorrect use of the different thermal spraying methods. During their exercises the students are guided by skilled thermal spraying personnel.

Practical training and demonstration	hours
P1. Practical demonstration entire equipment changing wear parts all processes automated processes	7
P2. Practical instructions one gas and one electrical process different base and spray materials different blast materials masking measuring, calibrating, testing recording trouble shooting maintenance	14
P3. Practical demonstration of fusion and post treatment fusion stages: right/wrong waxing/sealing machining polishing	3
P4. Visual inspection, testing and measuring metallographic preparation practical demonstration of hardness test, bending test, adhesion test practical training of geometrical measurement	3

Appendix 1

National definitions for the minimum requirements for the access to the Thermal Spraying Specialists' education and examination via route 1 defined previously:

Austria:
High craft or industry qualification in metal working professions.
(Meister im Gewerbe oder in der Industrie)

Belgium:
Holders of the B.S.O (Beroeps Secondair Onderwijs) or a E.S.P. (Enseignement Secondaire Professionel) qualification plus certificate of a "seventh" year of professional education plus demonstrated practical skill in two processes + two years of practical experience.

Denmark:
Master craftsman in metalworking. E.g. exam og autoriseret gas, sand og sanitetsmester

Finland:
3 years at institute of vocational education or equivalent (mechanical line) or sufficient technical knowledge and 3 years experience in metalworking professions

France:
High craft or industry qualification in metalworking professions

Germany:
High craft or industry qualification in metalworking professions.
(Meisterprüfung in Handwerk oder Industrie)

Italy:
Diploma of technical professional school (at least 3 years after middle school), recognized by the Minister of Education

Ireland:

Luxembourg:
Master craftsman in metalworking (Inhaber einer Meisterprüfung im metallverarbeitenden Handwerk)

The Netherlands:

NIL/SOM diploma level 4 ("vakdiploma")

or

MTS

Norway:
Qualification as skilled worker - letter of skill - in:
Thermal spraying - according Norwegian education system
(Grunnskole, GK Mekaniske fag, VK1 Mek.prosessfag, fagprøve)

Portugal:
- Third cycle of basic education;

or
- Second cycle of basic education plus three years in a professional center of metalworking area (Profissional Qualificado)

Spain:
High Technician (Technico superior) in metalworking professions or nationally recognized studies equivalent to the above

Sweden:
Access is possible via three routes:

a) 2 years at Gymnasieskolans plat- och svetslinje (practical, upper secondary school). Prior to 1993

or

b) 3 years at Gymnasieskolans (practical, upper secondary school. After 1993

or

c) Older equivalent education with at least 2 years of technical education after the compulsory school leading to at least the same competence as alternatives a) and b) above

Switzerland:
High craft qualification in metalworking professions.
(dipl. Meister oder Betriebsfachmann mit eidg. Fachausweis)

United Kingdom:

BTech/Scotvec, National Certificate in Engineering,

or

Approved City & Guilds of London Institute Part 3 Certificate in Engineering Subjects,

or

Approved Level 3 National Vocational Qualification in Engineering Subjects

Section II: Examination and Qualification

1. Introduction

This guideline seeks to achieve harmonization and a common standard in the examination and certification of professional Thermal Spraying Specialists in Europe. The national welding organisations, to which thermal spraying is allied, being members of the EWF, mutually acknowledge the Certificate awarded in any Member state to European Thermal Spraying Specialist, following examination conducted in accordance with this guideline.

Education must have followed this EWF guideline "European Thermal Spraying Specialist" Part I and II, and the examination must have been conducted by the national body authorized by the EWF for this purpose.

This "Authorized National Body" will normally be the National Welding Organization, to which thermal spraying is allied, but may be another organization with the agreement of the EWF Member.

2. Approval of the training course

Any training course leading to the EWF examination must be approved by the Authorized National Body. The number of teachers required to give the course shall be sufficient to ensure that the essential specialist knowledge and industrial experience to cover the syllabus, is adequately represented in the team of teachers and visiting lecturers.

3. Board of Examiners

The chairman and the members of the Board of Examiners shall be nominated by the Authorized National Body. The examining board shall consist of:

a) The Chairman, who shall be a representative of the Authorized National Body, and he shall be independent from the training school

and an adequate number of:

b) Main teachers of the subjects and/or

c) Experts from industry or other organizations

The responsibilities of the Board of Examiners are given in the Doc. EWF 416.

4. Admission to the examination

Admission to the examination leading to the award of the European Thermal Spraying Specialist certificate will be restricted to those:

a) Who comply with the access conditions already defined previously

and

b) Who have participated in a course, approved by the Authorized National Body, according to this guideline.

Admission to the examination shall be denied for those who failed to attend 90 % of the training programme. In case of special circumstances the board of examiners may use its discretion.

5. Examination procedures

The examination procedures described below are designed to simulate the different situations of a thermal spraying specialist active in industry. There will be examinations in each of the following subjects:

1. Thermal spraying processes, introduction and process principles, environmental aspects
2. Material selection and bonding mechanisms
3. Working procedure, health and safety
4. Spray results and documentation
5. Application engineering and quality management

5.1 Written examination

At the discretion of the Board of Examiners the examination shall consist of:

a) a series of essay questions covering the whole field of the subject

or

b) a series of multiple choice questions covering the whole field of the subject

or

c) a combination of a) and b) with equal marks allocated to each type

Time devoted to the written examination shall be a minimum of 45 minutes per subject, i.e. 4 hours in all.

5.2 Oral examination

The oral examination will be optional at the discretion of the Board of Examiners except in borderline cases where it will be mandatory.

6. Evaluation of performance

In order to pass the examination, candidates must achieve at least 60 % of the maximum possible marks in each subject.

Successfully completed individual parts of the examination will remain valid for a period of 3 years.

The examination in all five subjects shall be completed within a period of 3 years from the start of the course.

7. Re-examination and appeals

The procedure has to be in accordance to EWF-416 which refers also IAB 001 (latest edition).

Failure in any individual module of the examination shall require re-examination only in the module failed. Examinations shall be retaken within 15 months of the initial examination and, in the case of a second failure, one further attempt is permitted within 15 months from the date of the second examination. If a candidate fails three times, he/she has to retake the whole ETSS course.

In the case of re-examination, the 3 years validity period of the examination may be extended by decision of the Lead Assessor, if it has not been possible for the ANB to organize the necessary re-examinations within the relevant period.

In such circumstances, the following conditions shall be fulfilled:

i) The ANB must provide valid reasons for needing an extension.
ii) Any re-examinations taken after the first period must include oral examinations covering the whole syllabus.
iii) Under no circumstances shall the validity period exceed a total of six years.

Candidates who feel they have been unfairly treated during the examination procedure have the right to appeal to the Authorised National Body.

8. Appeal procedure

The procedure has to be in accordance to EWF-416, which – in this case - refers to IAB 001 (both guidelines of latest edition).

9. European Thermal Spraying Specialists' Diploma

After successful examination a Diploma is awarded to the candidate by the Authorized National Body. Those qualified as "European Thermal Spraying Specialist" may be called European Thermal Spraying Specialist in the national language and use the professional designation "ETSS" (invariable in all member countries).