CERTIFICATION RULES

GRUPPO
ISTITUTO ITALIANO DELLA SALDATURA

RULES FOR THE QUALIFICATION OF PROFESSIONAL CAREERS
- METALLOGRAPHIC TECHNICIAN
- METALLOGRAPHIC ANALYST
- DIAGNOSTICIAN OF METALLURGICAL DEFECTS

Document n° CER_QAS 060 R

CONTENTS

1 PURPOSE AND FIELD OF APPLICATION

These Rules define the qualification methods, issued by IIS CERT, of the following professionals:

a) Metallographic Technician,
b) Metallographic Analyst,
c) Diagnostician of metallurgical defects.

The application of the Rules is subject to the monitoring of the Committee to Safeguard Impartiality, in which the members interested in the certification are represented.

Note 1 *The general contract terms and conditions relative to the activities covered by these rules are listed in the document CER_QAS 017 R (see § 2).*

Note 2 *The EWF provides for the qualification of professionals in the field of metallography through the EWF-627 guideline (see § 2). IIS CERT has established in the CER_QAS 022 R rule (see § 2) and in the certification sheet cited therein the requirements to access that qualification. Below please find the following correspondences:*

- *the professional figure of the Metallographic Technician defined in these rules includes the Basic level defined in the CER_QAS P47 S certification (see § 2);*
- *the professional figure of the Metallographic Analyst defined in these rules includes the Comprehensive level defined in the CER_QAS P47 S certification.*

2 REFERENCES

CER_QAS 002 R	Rules for the use of the IIS CERT marking
CER_QAS 011 P	Management of appointments and assignments to certify
CER_QAS 017 R	Rules for the systems, personnel, product certification- General Contract Conditions
CER_QAS 022 R	Rules for the qualification and certification of EWF/IIW professional figures
CER_QAS 047 S -	Requirements sheet for qualification as: Metallographic Examination Personnel
UNI CEI EN ISO/IEC 17024	Evaluation of conformity – General requirements for bodies that provide certification of individuals
UNI EN ISO 9000	Quality Management Systems - Foundations and terminology
EWF-627-07	EWF Special Course – Personnel with the responsibility for Macroscopic and Microscopic Metallographic Examination of Structural Materials and their Joint Prepared/Produced by Welding and Allied Techniques

The documents cited above are applicable in the latest valid and/or revised edition.

3 DEFINITIONS

The terminology used in standard UNI EN ISO 9000 shall apply, integrated with the following:

Metallographic Technician: person who has the proven ability to prepare macro and micrographic samples of various metals and perform the metallographic tests defined in the current standards and in the specifications or internal corporate procedures (for example, the determination of the granulation size, the depth of cementation, the inclusion level, etc.), with preparation of the test report.

Metallographic Analyst: person who, in addition to the proven ability of the Metallographic Technician, also has in-depth knowledge of metallurgy and metallography of ferrous and/or non-ferrous alloys, to permit the correct and independent macro and microstructural interpretation and the ability to formulate opinions on the conformity of the products in metallographic test reports.

Diagnostician of Metallographic Defects: person who, in addition to the proven ability of the Metallographic Analyst, has proven metallurgical, metallographic and technological knowledge and proven powers of observation and analysis of damages, fractures or metallurgic defects of various kinds and origin in order to diagnose them and recommend solutions and remedies to eliminate the causes or reduce the probability of such events.

4 QUALIFICATION REQUIREMENTS

4.1 Metallographic Technician

Applicants for the qualification must demonstrate that:

- have a professional technical education in the field of mechanics, or a professional education in another field and 2 years work experience in the subject of the course;
- have attended a special course of metallography at a School recognized by IIS CERT (see § 5);
- have taken and passed the theoretical-practical qualification examination (see § 6).

4.2 Metallographic Analyst

Applicants for the qualification must demonstrate that:

- have a secondary technical education in the field of mechanics, or a secondary education in another field and 3 years work experience in the subject of the course, or a professional technical education of at least 2 years and 3 years of work experience in the subject of the course;
- have attended a special course of metallography at a School recognized by IIS CERT (see § 5);
- have taken and passed the theoretical-practical qualification examination (see § 6).

4.3 Diagnostician of Metallurgical Defects

Applicants for the qualification must demonstrate that:

- they have a diploma from a secondary school;
- have at least 3 years of laboratory experience in destructive and non-destructive controls of metallic products;
- have attended the course and passed the final examination of Metallographic Analyst at a School recognized by IIS CERT (see also § 5) or have sufficient provable knowledge of metallography with presentation of curriculum vitae or by undergoing a preliminary admission interview;
- have taken and passed the theoretical-practical qualification examination (see § 6).

4.4 Application for qualification

For qualification the applicant must send the application to IIS CERT, completed on the specific form together with the following attachments:

- certified copy of the original diploma held;
- certificate of attendance in the scheduled course issued by a Training Organization approved by IIS CERT.

5 COURSES

The courses can only be taken at a School of Metallography recognized by IIS CERT.

The metallography courses must have the following minimum durations:

- Metallographic Technician: 64 hours,
- Metallographic Analyst: 124 hours,
- Diagnostician of metallurgical defects: 108 hours.

Attachments A, B and C list the educational programmes of the three courses with the duration for each.

6 EXAMINATION

An Examination Commission (hereinafter referred to only as the Commission) specifically appointed by IIS CERT will examine the candidate through a theory test and a practical examination, as described in the following points.

The Commission is composed of at least two members who are experts in the field of metallurgy, one of whom represents IIS CERT and assumes the role of Chairman of the Commission, and a representative of the School of Metallurgy, who must not however have conducted, as possible teacher, over 25% of the anticipated course.

The members of the Commission must meet the following requirements:

- high school certificate;
- 10 years of experience in the field of metallic structures;
- 10 years of experience in the field of metallographic tests;

The members of the Commission are approved by IIS CERT according to the CER_QAS 011 P procedure (see § 2) and then entered in the special management software.

6.1 Metallographic Technician

6.1.1 Theoretical test

The Metallographic Technician must pass a written test which consists in answering a questionnaire of 15 questions with ready-made answers and an open question.

The written test is successfully passed if the candidate answered correctly at least 70% of the questionnaire and adequately performs the theme of the open question.

6.1.2 Practical test

The practical test for Metallographic Technician consists in:

- a practical macrographic test, performed in the presence of an examiner who will report to the Commission, with preparation of the test piece in accordance with a standard or technical specification of reference and chosen at random (preferably different from student to student) amongst the practical exercises provided in the metallographic course attended;
- writing the corresponding test report in accordance with the standard or specification reference;
- a practical micrographic test, performed in the presence of an examiner who will report to the Commission, with preparation of the test piece in accordance with a standard or technical specification of reference and chosen at random (preferably different from student to student) amongst the practical exercises provided in the metallographic course attended;
- writing the corresponding test report in accordance with the standard or specification reference .

The results of the test shall be decided by the examiner and the Commission and will take into account of the skills of the candidate and the accuracy and presentation of results.

6.2 Metallographic Analyst

6.2.1 Theoretical test

The Metallographic Analyst must pass:

The Metallographic Technician must pass a written test which consists in answering a questionnaire of thirty questions with multiple ready-made answers and two open questions;

The written test is successfully passed if the candidate answered correctly at least 70% of the questionnaire and adequately discusses the theme of at least three of the four open questions.

The candidate passes the oral test if he correctly interprets at least three of the four macro/micro images submitted by the examiner.

In both cases, the adequacy of the answers to the open questions and the macro and microstructural interpretations is irrevocably judged by the examiner and the Commission.

6.2.2 Practical test

The practical test for the Metallographic Analyst consists in:

- a metallographic interpretation test, consisting in correctly interpreting three images of macrographic structures and three images of micrographic structures, presented by the examiner and taken from metallographic atlases or similar publications, pertaining to the subjects discussed during the course;
- two practical macrographic tests, with preparation of the test pieces in accordance with standards or technical specifications of reference and chosen at random (preferably different from student to student) amongst the practical exercises provided in the metallographic course attended, performed in the presence of an examiner, who reports to the Commission (the preparation can be reduced to a single test piece if it permits the assessment of at least two macrostructural characteristics);
- writing the corresponding macrographic test reports, in accordance with the standard or specification of reference, which can be reduced to one if a single test piece is prepared.
- two practical micrographic tests, with preparation of the test pieces in accordance with standards or technical specifications of reference and chosen at random (preferably different from student to student) amongst the practical exercises provided in the metallographic course attended (assessment of inclusions or granulation size, measurement of the surface layers, structural interpretation), performed in the presence of an examiner, who reports to the Commission (the preparation can be reduced to a single test piece if it permits the assessment of at least two microstructural characteristics);
- writing the corresponding micrographic test reports, in accordance with the standard or specification of reference, which can be reduced to one if a single test piece is prepared;
- the writing of a procedure for the preparation of one of the four preceding samples.

The results of the test shall be decided by the examiner and the Commission and will take into account of the skills of the candidate and the accuracy and presentation of results.

6.3 Diagnostician of Metallurgical Defects

6.3.1 Theoretical test

The Diagnostician of Metallurgical Defects must pass:

- a written test which consists in answering a questionnaire with multiple ready-made answers and open questions;
- an oral examination.

The written test anticipates the answer to:

- a questionnaire of 90 questions (5 for each of the 18 macro subjects of the programme), with four ready-made answers of which only one is correct or more complete than the others;
- two open questions.

The written test is successfully passed if the candidate answers correctly at least 80% of the questions on the questionnaire and adequately discusses the theme of both the open questions.
The adequacy of the answers to the open questions is irrevocably judged by the Commission.

The oral test consists in submitting to the candidate a case of damage, fracture or defect in a component or metallic structure, complete with information on design, materials used and operating conditions (if known), with macro and/or micrographic images of the damage or defect: he must then interpret the data, discuss them before the Commission and formulate the most probably hypothesis of the cause of the damage or defect submitted, providing one or more suggestions to remedy or eliminate the causes.

The outcome of the oral examination is considered positive if the candidate:

- provides a hypothesis of the causes of the damage considered reasonable in the indisputable opinion of the Commission;
- provides a hypothesis of the causes of the damage considered reasonable in the indisputable opinion of the Commission;

The Commission will assess the skill of the candidate also based on the logical development of the reasoning in the interpretation of the data and in the formulation of the hypothesis of the damage and the relative remedies proposed.

6.3.2 Practical test

There is no practical test anticipated for the Diagnostician of Metallurgical Defects.

7 MINUTES AND FINAL REPORT

At the end of the tests, a report is drafted signed by all the members of the Examination Commission. The following must be included in this report:

- the names of the candidates taking the examinations;
- the duration of the examination;
- the results of the single tests and the final judgment.

The results of the test are communicated verbally and privately by the President of the Board of Examiners.

8 REPEATING THE EXAMINATION

The candidate who fails the examination must repeat only for the section(s) that were failed.
The examination for each part failed can be repeated no earlier than two weeks and no later than 15 months after the date of the initial examination.
In the case a second failure, a third exam can be taken no earlier than one month and no later than 15 months from the date of the second test.
After the third failure in any of the parts, the candidate must attend the course again.
The registration fee paid at the first examination also includes two (any) subsequent repetitions of the test, but not the third repetition or re-entry to the training course. In these final cases the fees must be paid again.

9 DIPLOMA

The candidate who has passed the qualification tests required is issued with a Diploma, numbered and signed, no later than 4 weeks after the date of the examination.
In case of theft, loss or destruction, by request and following reimbursement of the costs, the bearer can obtain a duplicate with the same number as the original.

10 CONFIDENTIALITY

Records (documents, letters, minutes) relating to the activities of certification, beginning with the application, shall be considered confidential and therefore access to them is limited to persons involved in this activity.
The personnel, IIS CERT employees and the members of the Commission, who during the implementation of their duties become aware of the contents of these documents, are bound by professional secrecy.

11 DOCUMENTATION

The qualification documentation is filed in the CFP Area of IIS CERT.

12 CONTRACTUAL CONDITIONS

The information listed in the CER_QAS 017 R document applies for the contractual conditions (see § 2).

ANNEX A Educational programme for Metallographic Technician

Sheet 1/1

MACROGRAPHY	duration (h)
Aim and field of application of macrography. Identification and care in the handling of the samples. Basic techniques of visual examination. Collection techniques and instrumentation for the preparation of the macrographic samples (machine tools, cutting off machines, grinders, honing machines, etc.).	4
Practical exercises of preparation, identification of the samples.	4
Macrographic connection: techniques and reactive attachments. Examination at low magnification (examination by eye or with magnifying lenses). The stereoscopic microscope. Preparation of the photographic documentation and description of the macrographic observations.	4
Practical exercises of macrographic tests. Macrographic attachment and highlighting of macrostructures (dendritic, bands, fibres, hardened areas, burns from grinding, etc.).	4
UNI ISO 4968: Steel. Macrographic examination by sulphur printing (Baumann Method).	4
Partial total (hours)	**20**

MICROGRAPHY	duration (h)
Aim and field of application of micrography. Tools and materials for the preparation of the micrographic test pieces (cutting-off machine, honing machine, dressing machines, papers, cloths, alternative technologies). The optical microscope. The microdurometer.	4
Practical exercises. Cutting off machines, honing machines, dressing machines, papers, cloths. The optical microscope: adjustments, focusing, use of the accessory devices. Observations on the metallographic optical microscope.	4
Theory of abrasion and mechanical dressing of micrographic test pieces. Mechanical preparation and identification of the test pieces. Electrolytic in-process dressing. Micrographic connection: techniques and reactive attachments.	4
Practical exercises. Preparation of the micrographic samples until the mechanical and electrolytic in-process dressing. Micrographic attachment and observations on the optical microscope.	8
Preparation of the samples for replica. UNI 6327: Microscopic examination of metallic materials. Examination method through replica with paints or with film. UNI 9993: Welded joints. Replicas in process for the microscopic examination.	1
Practical exercises. Preparation and examination of a metallographic replica.	3
Micrographic tests. UNI EN ISO 6507: Vickers Hardness and Microhardness. UNI 4839: Measurement decarbonization depth. UNI 4847: Measurement hardened layer thicknesses.	2
Practical exercises micrographic tests. UNI EN ISO 6507: Microhardness measurements. UNI 4839: Measurement depth of surface decarbonization. UNI 4847: Measurement hardened layer thicknesses.	6
Micrographic tests. UNI 3244 and ASTM E45: Assessment of the inclusions.	1
UNI 3244 and ASTM E45 Assessment of the inclusions.	3
Micrographic tests. UNI 3245 and ASTM E112: Austenitic or ferritic grain assessment (direct and McQuai Ehn).	1
UNI 3245 and ASTM E112: Assessment of the austenitic or ferritic grain (direct and McQuai Ehn).	3
Micrographic tests. UNI EN ISO 945: Graphite classification. ASTM 562: Determination of the volumetric fraction and manual count of the phases.	1
UNI EN ISO 945: Classification of graphite in cast iron. ASTM 562: Determination of the volume and manual count of the phases.	3
Partial total (hours)	**44**

ANNEX B Educational program for Metallographic Analyst

Sheet 1 / 2

INTERPRETATIVE METALLURGY AND METALLOGRAPHY	Duration (h)
Summary of the physics of the solid state	
The atom. The metallic state. Metallic crystals. Allotropic transformations. The mechanical characteristics of crystals. Displacements. Auto-diffusion. Alloys.	2
Thermal analysis. Diagram of the status of two completely soluble components in the liquid state and completely soluble in the solid state. Microstructures that can be obtained at the end of solidification and cooling.	2
Diagram of the status of two completely soluble components in the liquid state and totally insoluble in the solid state. Microstructures that can be obtained at the end of solidification and cooling.	2
Diagram of the status of two completely soluble components in the liquid state and partially soluble in the solid state. Microstructures that can be obtained at the end of solidification and cooling.	2
Diagram of the state with peritetic. Microstructures that can be obtained at the end of solidification and cooling.	1
Iron-Carbide [Cementite] diagram and Graphite-Iron diagram. Microstructures that can be obtained at the end of solidification and cooling.	3
Transformations of imbalance	
Solidification. The solidification phenomenon. Subcooling, nucleation and increase. Dendritic crystallization. Micro-segregation and band structure. Macro-segregation. Non-metallic inclusions.	2
Macro and microstructures of crude metals of solidification. Microstructure of non-metallic inclusions.	2
Ferrous alloys. Kinetics of transformation of austenite. Kinetics of transformation of austenite. Influence of the cooling speed. Microstructural changes with the change in the cooling speed. Microstructures that can be obtained (ferrite, lamellar pearlite, toostite, upper and lower bainite, tetragonal martensite).	5
Non-ferrous alloys. Kinetics of cooling (quenching of solubilization) and ageing phenomena.	3
Quenching and hardenability of steels. Techniques of quenching and phenomena committed. Definition of hardenability. Influence of the extinguishing means. Diameter and critical hardness. Assessment methods of the quenchability. Jominy Test. Microstructures of a Jominy test piece. Structures of evolution of tetragonal martensite (cubic martensite, sorbitol and globular pearlite).	4
Metallographic aspects of metallic products - Loaves, ingots, casting, forged, moulded, laminated and welded products.	
Ferrous alloys. Production of cast iron (blast furnace and cupola) Casting of steel (converter, electric furnace, casting in ingots and continuous). Loaves, jets and ingots. Macro and microstructures of crude ferrous products.	2
Non-ferrous alloys. Production of loaves and casting of non-ferrous alloys. Macro and microstructures of crude non-ferrous products.	2
Hot and cold deformed metallic products. Forging, moulding and lamination. Macro and microstructures of hot and cold deformed metallic products.	4
Welding and weldability of steels. Termology of welding and metallurgical weldability of steels. Macro and microstructures of welded joints.	4
Metallographic aspects of heat-treated metallic products	
Ferrous alloys. Steels. Soft or subcritical annealing. Complete annealing. Globular annealing: subcritical globular annealing; pendulum globulization annealing. Stress relieving annealing. Crystallization annealing. Readjustment. Recrystallization. Homogenizing annealing. Microstructures which can be obtained after the respective heat treatments.	2
Normalization. Direct quenching. Interrupted or scalar quenching. Discovery of stress relieving. Discovery of softening.	2
Isothermal annealing: globular isothermal annealing; normal isothermal annealing. “White and black” annealing. Patenting. Bainitic quenching. Microstructures which can be obtained after the respective heat treatments.	2
Superficial hardening. Induction quenching. Flaming. Laser quenching. Metallographic measurements to control products superficially hardened (gradients of hardness, depth of hardness and microstructures).	2
Thermochemical treatments	
Carburizing. Theory of the process. The potential of carbon. Gunnarson Index. Absorption and diffusion of carbon. Absorption of the carbon in gaseous cementation. Diagrams of equilibrium for gaseous cementation. Diffusion of carbon. The process of gas carburizing. Carburizing cycles. Quenching. Subcooling. Discovery of stress relieving. Finishing treatments. Microstructural characteristics of carburized steels. Microstructure of the carburized layers. Hypercementation. Decarbonization. Oxidation. Micro-cracks. Microstructure of the nucleus.	4
Carbonitriding, nitriding, other cementation processes. Theory and practice of the carbonitriding process. Carbonitriding atmosphere. Antinitrocarburant protections and finishing treatments. Carbonitriding under A1. Microstructures of the carbonitride layers.	4
Carbonitriding and nitriding. Conventional gas nitriding. Parameters that affect the process. Chemical composition of steel. Preliminary treatments. Degree of dissociation of the ammonia. Temperature of nitriding. Duration of nitriding treatment. Anti-nitriding protection. Practice of the gas nitriding process. Furnaces for gas nitriding. Microstructures of the nitride layers. Abnormalities of nitriding and their causes. Dimensional changes and deformations. Insufficient depth or hardness. Coloring of items. Chipping. Excessive white blanket. Excessive variation in the degree of dissociation. Nitriding in salt baths. Composition of the bath. Temperature of the bath. Duration of the treatment. Furnaces for saline nitriding. Microstructures of the nitride layers in salt baths.	4
Partial total (hours)	**60**

ANNEX B Educational program for Metallographic Analyst

Sheet 2 / 2

MACROGRAPHY	duration (h)
Aim and field of application of macrography. Identification and care in the handling of the samples. Basic techniques of the visual examination. Collection techniques and instrumentation for the preparation of the macrographic samples (machine tools, cutting off machines, grinders, honing machines, etc.).	4
Practical exercises of preparation, identification of the samples.	4
Macrographic connection: techniques and reactive attachments. Examination at low magnification (examination by eye or with magnification lenses). The stereoscopic microscope. Preparation of the photographic documentation and description of the macrographic observations.	4
Practical exercises of macrographic tests. Macrographic attachment and highlighting of macrostructures (dendritic, bands, fibres, hardened areas, burns from grinding, etc.).	4
UNI ISO 4968: Steel. Macrographic examination by sulphur printing (Baumann Method).	4
Partial total (hours)	**20**

MICROGRAPHY	duration (h)
Aim and field of application of micrography. Tools and materials for the preparation of the micrographic test pieces (cutting-off machine, honing machine, dressing machines, papers, cloths, alternative technologies). The optical microscope. The microdurometer.	4
Practical exercises. Cutting off machines, honing machines, dressing machines, papers, cloths. The optical microscope: adjustments, focusing, use of the accessory devices. Observations on the metallographic optical microscope.	4
Theory of abrasion and mechanical dressing of micrographic test pieces. Mechanical preparation and identification of the test pieces. Electrolytic in-process dressing. Micrographic connection: techniques and reactive attachments.	4
Practical exercises. Preparation of the micrographic samples until the mechanical and electrolytic in-process dressing. Micrographic attachment and observations on the optical microscope.	8
Preparation of the samples for replica. UNI 6327: Microscopic examination of metallic materials. Examination method through replica with paints or with film. UNI 9993: Welded joints. Replicas in process for the microscopic examination.	1
Practical exercises. Preparation and examination of a metallographic replica.	3
Micrographic tests. UNI EN ISO 6507: Vickers Hardness and Microhardness. UNI 4839: Measurement decarbonization depth. UNI 4847: Measurement hardened layer thicknesses.	2
Practical exercises micrographic tests. UNI EN ISO 6507: Microhardness measurements. UNI 4839: Measurement depth of surface decarbonization. UNI 4847: Measurement hardened layer thicknesses.	6
Micrographic tests. UNI 3244 and ASTM E45: Assessment of the inclusions.	1
UNI 3244 and ASTM E45 Assessment of the inclusions.	3
Micrographic tests. UNI 3245 and ASTM E112: Austenitic or ferritic grain assessment (direct and McQuai Ehn).	1
UNI 3245 and ASTM E112: Assessment of the austenitic or ferritic grain (direct and McQuai Ehn).	3
Micrographic tests. UNI EN ISO 945: Graphite classification. ASTM 562: Determination of the volumetric fraction and manual count of the phases.	1
UNI EN ISO 945: Classification of graphite in cast iron. ASTM 562: Determination of the volume and manual count of the phases.	3
Partial total (hours)	**44**

ANNEX C Educational programme for Diagnostician of Metallurgical Defects

Sheet 1/3

	Subjects	duration (h)
1	**Failure Analysis**	
1.1	**General principles for failure analysis in service of metallic components**	8
	General procedures for the diagnosis of the defects. Phases of the diagnosis of defects. Collection of the information and the tests. Registration of the history of the components. Photographic documentation. Selection of the tests. Conditions of abnormal operation. Preliminary tests, visual examination. Study of the fracture. Non-destructive tests. Magnetoscopic examination. Examination with penetrating liquids. Examination with induced currents. Examinations with ultrasound. Radiography. Tensional analysis. Mechanical tests. Hardness test. Traction test. Resilience test. Protection of the fracture surfaces. Precautions for the sampling and storage. Cleaning of the surface in the laboratory. Preparation of the sections. Secondary breaks. Protection of the fracture surfaces. Microscopic examination of the fracture surfaces. Metallographic tests. Micrographic tests. Classification of the fractures. Ductile fractures. Characteristics of the ductile fracture. Fragile fractures. Transgranular fracture or cleavage. Intergranular fracture. Fatigue fracture. Stress corrosion fracture. Embrittlement through liquid metals. Hydrogen embrittlement. Fracture from hot flow. Complex defects. Chemical analysis. Analytical techniques. Gravimetry. Volumetry. Colorimetry and Spectrophotometry of visible molecular (VIS) or ultraviolet (UV) absorption. Spectrophotometry of infrared molecular absorption (IR). Spectrophotometry of atomic absorption (AAS). Plasma emission spectrometry (ICP). Emission spectrography or quantometry (ES). Fluorescent spectrography to X-rays (FRX). X-ray diffraction (DRX). Analysis of surfaces and deposits. Mechanics of the fracture applied to the diagnosis of defect. Simulation tests. Formulation of the conclusions. Writing of the final report. Diagnosis of defect in the field.	
1.2	**Genesis and classification of failures in service of metallic components.**	16
	The possible causes of failure in service for components manufactured with metallic materials. Failures due to overload, excessive elastic deformation, fragile behaviour, fatigue, corrosion, viscous flow, wear. Conditions of load, overload, impact, etc. Uniaxial, biaxial and triaxial stresses. Temporary or elastic deformations. Permanent or plastic deformations. Classification of the fractures. Macroscopic features of the fractures. Microscopic features of the fractures. Ductile fractures and dimples. Fragile fractures due to intergranular cleavage. Fatigue fractures and streaks. Stress corrosion fractures and trigger and propagation mechanisms. Fractures from viscous flow. Summary of the mechanics of the fracture. Speed of propagation of fractures.	
1.3	**Failures due to fatigue. Genesis of failures due to fatigue. Macro and micrographic aspects of the fracture due to fatigue.**	12
	Historical overview. Genesis of breaks due to fatigue. First stage: Onset. Second stage: propagation. Third stage: final break or crash. Microscopic features of fatigue fracture. Streaks. Macroscopic features of fatigue fracture. Lack of deformation. Beach marks. Ratchet marks. Similarities between streaks and beach marks. Differences between streaks and beach marks. Relationship between stress and resistance to fatigue. Wöhler curve and limit of fatigue. Subcortical sources of fatigue. Fatigue under compression loads. Thermal fatigue. Corrosion fatigue. Fatigue due to contact. Superficial and subcortical pitting. Spalling.	
1.4	**Damage from wear. Metallographic theory and practice.**	8
	Definition of wear. Classification of the types of wear. Abrasive wear, adhesive wear, fretting, wear due to fatigue, wear due to erosion, corrosive wear. Analysis of the mechanisms of damage due to wear.	
1.5	**Damage due to corrosion in damp environment. Theory of corrosion. Damage from use at high temperature (oxidation or direct metal gas reactions).**	16
	Definition of corrosion. Factors that influence corrosion. External factors: pH, inhibitors or activators, saline concentration, temperature, motion of the electrolyte, impressed or stray currents. Internal factors: chemical stability of the metal (immunity, passivity, activity), effect of the structure, effect of the internal stresses and tensions, effect of the surface status. Guide to the diagnosis of industrial corrosion: uniform corrosion, punctiform localized corrosion (pitting), dealloying, intergranular corrosion, corrosion under tension with creation of cracks (stress corrosion), fatigue corrosion. Corrosion of steel in concrete. Principal causes of corrosion in plumbing systems. The reaction of oxidation. The mechanisms of growth in the oxidized layer. Influence of the chemical composition of steel on the temperature of formation of the flake. Effect of the temperature and the composition of the atmosphere.	
1.6	**Damage due to use at high temperature (hot viscous flow).**	4
	Introduction to the damage to metals used at high temperature. Viscous flow (creep). Fatigue at high temperature. Thermal fatigue. Metallurgic stability. Transition of a ductile fracture to a fragile fracture. Recrystallization. Ageing and hyperageing. Embrittlement at high temperature and precipitation of fragilizing phases: damage from hydrogen and from secondary phases. Precipitation and reactions of carbides: sensibilization, reactions of carbides. Damage induced by the environment: oxidation, corrosion and corrosion erosion, carbonization and decarbonization, contact with liquid metals. Prevention of the damage at high temperature. Examples of damage of metals used at high temperature.	

ANNEX C Educational programme for Diagnostician of Metallurgical Defects

Sheet 2/3

1.7	**Damage in service of forged and moulded metals**	4
	Introduction. Manufacture of forged and moulded products. Behaviour of the metal during forging and moulding. Defects of forged products and their origin. Defects stemming from ingots: segregation, shrinkage cones, flakes, non metal inclusions. Defects from forging and moulding: strip and weaving structure, tears, scoring and double-folding, grooves, internal irregularity. Causes of the defects in forged and moulded products: design defects; incorrect choice of materials; defects in the materials; defects in forging and moulding; defects in the operations that following the forging and moulding; failures due to operating conditions.	
1.8	**Damage in service of casting of cast iron and steel.**	4
	Introduction. Errors in the chemical composition and the mechanical characteristics. Typical defects of the foundry. Surface defects: shrinkage of casting and welding; lacerations or hot cracks; cold cracks; surface cavities containing sand; surface blowing; surface porosity; pin points; bubbles and blisters; erosion; sacks or thin layers; false sacks or boxes; incomplete casting and cold drops; crushing or failures of the forms and the cores; drops in the earth; defects of adherence; rough appearance of the surface; penetration; vitrification; force fitting; protrusions; failures; shifts; metal leaks from the forms. Internal defects: porosity due to shrinkage; porosity due to gas; inclusions. Defects attributable to other causes. Microstructure, chemical composition, heat treatments; concentration of stresses; operating conditions.	
1.9	**Damage in service of welded and brazed joints.**	4
	Introduction. Cracks. Fused zone (ZF) Solidification; Hot cracking in ZF. Factors that affect cracking. Thermally altered zone (ZTA). Materials without allotropic transformation. Materials without allotropic transformation. Areas close to the fused zone (under weld seam): liquation. Cracks in the thermally altered zone. Effects of hydrogen. Effects of hydrogen in fused zone. Flakes. Micro-cracks due to hydrogen. Effects of hydrogen in the thermally altered zone. Cold cracks in fused zone. Precautions to avoid cold cracks forming. Lamellar tears. Influence of the welding method. Characteristics of the base material. Lack of penetration or melting. Bonding. Inclusions. Porosity. External and profile defects. Excess machine allowance. Incomplete filling of the joint. Angle bead too convex. Marginal incisions. Superficial irregularities. Changes in the butts. Sprays and spitting. Arc welding. Brazing defects: Cracks, Staining, Distortions, Flow Inclusion, Intermittent union, Lack of filling.	
1.10	**Damage in service of tools and moulds.**	4
	Introduction. Characteristics of the tools and the moulds. Principal causes of the defects: design; heat treatments; machining and finishing; EDM; welding. Damage to the tools for hot processing; Damage to the lamination cylinders; Damage to the cutting tools.	
1.11	**Damage in service of shafts and bearings.**	4
	First part: fractures in the transmission shafts. Nature and causes of the principal fractures in the shafts. General procedures for the diagnosis of defects. On the types of stresses which are applied to the shafts. Fractures of shafts due to fatigue. Fractures due to wear and fatigue from contact. Ductile and fragile fractures. Deformations in operation. Fractures tied to corrosion. Overview on the intensification factors of the stresses. Metallurgical or process factors (construction or finishing processes of the shafts). Purely metallurgical factors. Breaks produced by errors in the surface treatments. Breaks produced by errors in the repair weldings. Second part: breaks in the bearings. Breaks in the sliding bearings. General information and classification of the sliding bearings. Materials for sliding bearings. Lubrication with fluid film. Load that can be supported. Surface roughness. Contamination and incisions. Lubricants. Polluting particles. Procedure for specific diagnoses of defect. Breaks in the sliding bearings. Breaks in rolling bearings. General information on the rolling bearings. Materials for rolling bearings. Type of breaks in rolling bearings.	
1.12	**Damage in service to the gears.**	4
	Contact of the teeth of the gears. Loads applied. Influence of the lubricant film. Causes of the damage to the gears. Fatigue from flexure and play. Damage due to impact. Surface conditions. Other causes. Classification of the damages to the gears. Wear, surface fatigue, plastic flow, breaks. Wear: lubrication and wear, normal wear, moderate and destructive wear, causes of the destructive wear, scoring, wear due to interference between gears, abrasive wear, wear and corrosion, flaking, burning. Surface fatigue: mechanisms, pitting, spalling, damage due to plastic deformation, rolling and shot peening, plastic deformations and pitting, cracks and pitting, shattering of the surface layer. Fractures: breaks due to fatigue, positions of the fractures of the teeth, fracture from fatigue due to overloads, fractures from overload and excessive wear. Design to avoid breaks. Defects due to manufacturing. Cracks from adjustment and quenching.	

ANNEX C Educational programme for Diagnostician of Metallurgical Defects

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1.13	**Damage in service of mechanical fastening systems**	4
	Types of mechanical fastening systems. Threaded components, rivets, armouring, plugs. Origins of the defects. Causes of the damage. Fatigue of the threaded components, concentration of the stresses, resistance of the material. Damage from fretting. Corrosion due to crack, galvanic and live. Effect of compression stresses, Effect of impurities. Damage due to hydrogen. Protection against corrosion: zinc-coating, cadmium plating, coating with aluminium. Threaded components at high temperature. Rivets: cutting the stem, Damage to the support surface. Armouring. Semi-permanent mechanical plugs, elastic plugs, etc. Procedure for examining the damage of the fastening systems.	
1.14	**Damage in service of boilers and heat exchangers**	4
	Damage to the boilers and the connected systems. Causes resulting from defects in the materials. Fractures from overheating of thick and thin sections; effect of incrustation, causes of overheating. Fractures from embrittlement: damage from hydrogen, graphitization. Damage due to corrosion or oxidation. Corrosion water side, Corrosion of components exposed to steam. Corrosion of the condensers and hot water generators. Corrosion smoke side: slag from coal and fuel oil. Corrosion at low temperature. Damage due to fatigue. Oligocyclic fatigue. Thermal fatigue. Corrosion fatigue. Erosion. Abrasion. Erosion from steam bubbles, Cavitation. Cracks due to stress corrosion. Damage due to several causes in the components of the boilers. Damages of the heat exchangers. Operating conditions. Resistance to corrosion. Causes of the damage. Secondary manufacturing techniques. Effect of the inspection procedures. Damage due to Corrosion. Corrosion from slot, dealloying, erosion-corrosion. Stress corrosion. Corrosion fatigue. Appearance of the fractures. Correlation between thermal and mechanical stresses. Effect of the welding procedures. Preparation of the joint. Design of the joint. Effect of the high temperature.	
1.15	**Damage in service of pressurized containers and pipes**	4
	Causes of the damage to the pressurized equipment (containers and pipes). Procedure for the analysis of the damage. Effect of the metallurgical irregularities. Effect of the production technique. Heat treatments. Overheating. Effect of the heterogeneity of cooling. Inspection procedures. Damage related to the operating conditions. Cracks due to stress corrosion from hot chlorides. Hydrogen embrittlement. Fragile fractures. Ductile fractures. Hot viscous flow and breaks due to mechanical stress. Damage due to fatigue.	
1.16	**Damage in service of components made of aluminium alloy**	4
	Introduction. Most common defects in extruded and laminated products. Defects of extruded materials: Flames or strips; Stopping and restarting extrusion; Transversal cracks; Seizing; Binding; Extrusion tears; Extrusion scoring; Surface bubbles; Deep bubbles; Signs of straightening; Dents; Corrosion. Defects of laminated materials: Blistering; Chaff; Imprints of the cylinders and incrustations; Black points; Dirty bottom; Scoring; Rubbing; Tears; Spreading of the plating; Quenching stains; Oxidation (water spots). Most common defects in pressurised poured aluminium casting (diecast): The mould; The most frequent defects in diecasting; Incomplete casting; Porosity; Surface bubbles; Welding; Cracks; Defects in the seal;	
1.17	**Damage in service of copper alloy components**	4
	Total (hours):	**108**