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ED161-2: MIBOC CERTIFICATION OF RELIABILITY PRACTITIONERS

Requirements for qualification and assessment of Reliability Practitioners

Part 2 – Classifications of Personnel for Asset Reliability Practitioners: Category A, E, L

Version 5
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1. Introduction

The Mobius Institute Board of Certification (MIBoC) Scheme is managed and administered by the Mobius Institute Board of Certification, which takes into consideration the needs of industry through advice and guidance provided by a Governing Body, Scheme Committee and Technical Committee. The charters of these groups are outlined in documents ED121 – *Governing Body Charter*, ED167 – *Reliability Scheme Committee Charter*, and ED168 – *Reliability Technical Committee Charter*, respectively. Membership of committees is open to the participation of individuals and organisations, and further information is available from the Certification Manager of the Mobius Institute Board of Certification.

The MIBoC Scheme provides a Mobius Institute Board of Certification standard and associated programme which is non-discriminatory and internationally available, for the certification of reliability practitioners according to the aims & context outlined in this document. The programme conforms to the requirements of *ISO/IEC 17024 - Conformity assessment — General requirements for bodies operating certification of persons*.

If further information or advice is required on any certification matter, please contact the Certification Manager of MIBoC on telephone number +61 3 5977 4606, or email certification.manager@mobiuscertification.org.

2. Scope

This document describes the classification of personnel and specific requirements of the MIBoC scheme for the certification of Reliability Practitioners.

Further documents provide general scheme requirements and other details of the classification of personnel within the scheme:

ED161-1: MIBOC CERTIFICATION OF RELIABILITY PRACTITIONERS: Requirements for qualification and assessment of Reliability Practitioners - Part 1: General Scheme Requirements

ED161-3: MIBOC CERTIFICATION OF RELIABILITY PRACTITIONERS: Requirements for qualification and assessment of Reliability Practitioners - Part 3: Classifications of Personnel for Asset Reliability Practitioners: Category Ex, Lx

The scheme will adopt new versions of these documents and normative references as they are published.

3. References

Normative References:

- ISO/IEC 17024, Conformity Assessment – General requirements for bodies operating certification of persons.
- ED161-1: MIBOC CERTIFICATION OF RELIABILITY PRACTITIONERS: Requirements for qualification and assessment of Reliability Practitioners - Part 1: General Scheme Requirements
- ED161-3: MIBOC CERTIFICATION OF RELIABILITY PRACTITIONERS: Requirements for qualification and assessment of Reliability Practitioners - Part 3: Classifications of

Personnel for Asset Reliability Practitioners: Category Ex, Lx

Other MIBoC Documents:

- *ED044 – Independent Invigilator Instructions*, Instructions for Independent (non-AEC) Invigilators
- *ED121 – Governing Body Charter*, Charter of MIBoC's Governing Body
- *ED167 – Reliability Scheme Committee Charter*, Charter of MIBoC's Reliability Scheme Committee
- *ED168 – Reliability Technical Committee Charter*, Charter of MIBoC's Reliability Technical Committee
- *ED169 - List of Approved Reliability Training Courses,* List of MIBoC Approved Reliability Training Courses
- *AEC015 - AEC Requirements*, Requirements for MIBoC Authorized Examination Centres
- *AEC016 – AEC Invigilator Requirements,* Requirements for MIBoC Authorized Examination Center Invigilators
- *ED044 - Invigilator Instructions (non-AEC)*, Instructions for the Invigilation of non-AEC examinations.
- *ED043 - Invigilation Application Form*, Application for invigilation of examination outside an AEC.
- *ED033 - Accommodation of Special Needs*, Procedure for the accommodation of Special Needs.
- *ED170 – Reliability Certification Renewal,* Process & application form for Reliability Certification Renewal.

4. Terms, definitions and abbreviations

For the purposes of this document, the definitions and abbreviations listed in ED161-1 apply.

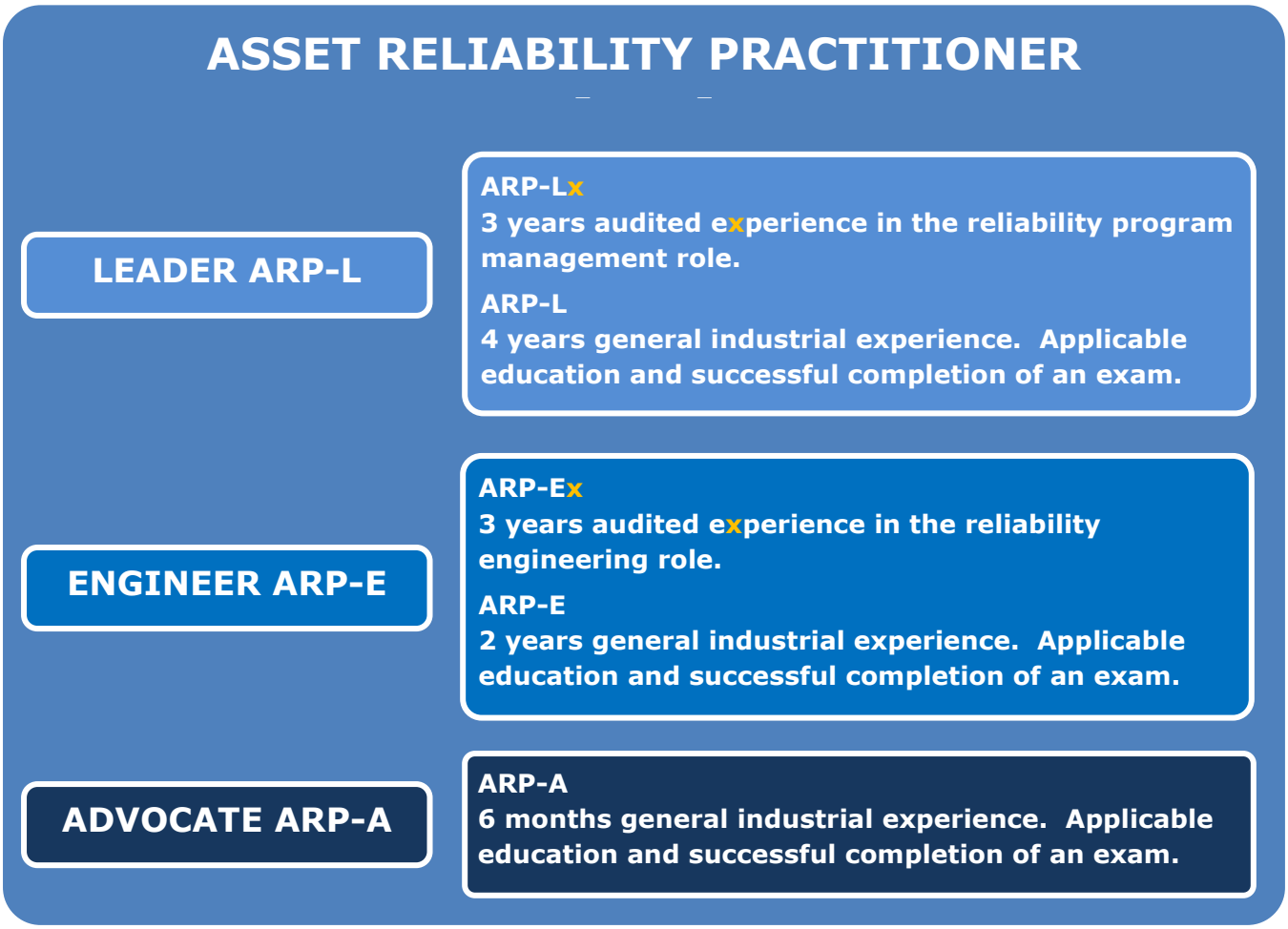
5. Classification of personnel - Overview

The scheme assigns one consistent title for any person certified by this program. That title is "Reliability Practitioner". Candidates certified under the scheme are classified as Asset Reliability Practitioners, or ARP's.

There are three categories of certification to recognize a Reliability Advocate (ARP-A) who contributes to reliability improvement (but that is not their main role), a Reliability Engineer (ARP-E) whose main role is in reliability improvement, and a Reliability Leader (ARP-L) who is the manager/leader of the reliability improvement initiative.

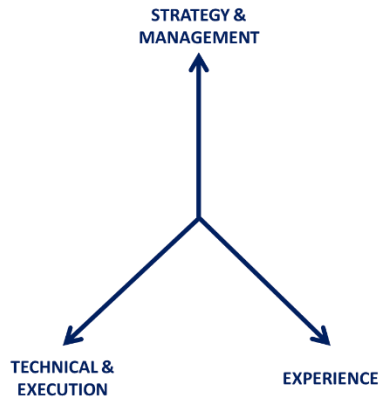
General certification at each of the three categories requires the individual to have general experience in an industrial facility of a duration outlined in sections 5.1, 5.2 and 5.3 of this document.

At Category ARP-E and ARP-LL, an optional level of certification has been defined that will recognize the candidate's experience and competence performing the activities defined in this scheme. These candidates will be certified Category ARP-Ex and ARP-Lx. Details of the certification requirements for these classifications are listed in document ED161-3.

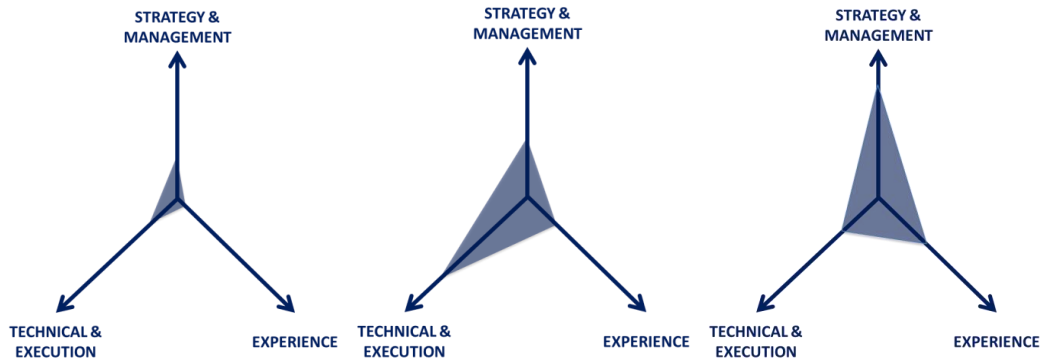


Authority to work as an Asset Reliability Practitioner shall be limited or specified by the employer or client and the limits of liability shall be agreed between the practitioner and their employer or client. The employer shall be fully responsible for the authorization to work, and the quality and results of such work.

Anyone certified as ARP will have the required level of capability in terms of program (strategy) compared with program (technical) execution. The person will also have the agreed level of experience. This will be represented below as a "trivector":



This reliability certification scheme will recognize three areas of capability in the field of industrial reliability improvement:



ARP-A, ARP-E and ARP-L respectively in relation to the required level of strategy & management knowledge, technical & execution knowledge, and actual experience and contribution to reliability improvement

The categories and their related qualifications are specified below.

5.1 Reliability Advocate: ARP-A

ARP-A is designed to create awareness and buy-in for all people working in an asset intensive organization. The goal is to create awareness and thus to transform the reliability culture – to make these people strong advocates/supporters for reliability and the reliability improvement initiative.

Candidates may be in a variety of roles including operations, electrical and mechanical maintenance, planning, scheduling, condition monitoring, spares management, procurement, engineering, and all levels of management. Their day-to-day actions influence reliability in many ways.

Reliability "advocates" must be knowledgeable in and fully understand how reliability and reliability improvement benefits the both organization and themselves personally.

Advocates must have a sufficiently broad and detailed understanding of the technical aspects of reliability and reliability improvement to promote the concepts to others, ensuring that methodology and philosophy becomes embedded in the culture of the organization just as safety is a core belief on the organization. Detailed knowledge in any of the specific topic areas is not required.

Advocates must also have a full understanding of how they personally must contribute to reliability and the success of the reliability improvement processes.

The ARP-A Reliability Advocate will:

1. Be aware of the root causes and results of poor reliability such as: safety and environmental violations, reduced quality and throughput, excessive cost, energy waste, etc. Actively contribute to identify anomalies, determine root cause and eliminate defects:
    a. Identify and report issues
    b. Suggest improvements
    c. Provide information when requested
    d. Contribute to the remedy (where possible)
2. Support efforts to identify anomalies and improvements:
    a. Cooperate with maintenance to assure maximum effectiveness and results from condition monitoring, operator care tasks, planned and proactive maintenance, spare parts stocking levels and similar efforts to assure safe, environmentally sound, reliable operation
    b. Assist with inspections, operator rounds, condition monitoring activities and like endeavors to assure optimal coverage and effectiveness
    c. Provide feedback regarding coverage, quality and effectiveness in areas such as safety and environmental compliance, operator inspections, condition monitoring and maintenance tasks and scheduling; the former to include job plans and history
3. Ensure their role is conducted and plant activities are accomplished in accordance to the highest standards of safety and reliability, for example:
    a. Identify and report safety violations, deviation from standard operating and maintenance procedures and/or where existing procedures may be deficient or ineffective
    b. Perform all assigned tasks, including maintenance, with precision and in full accordance with procedures. Identify any departures from procedure that may be necessary to complete a task for consideration of revision
    c. Evaluate life cycle cost compared to price when purchasing products and services. Make certain that greatest value is fully identified for consideration in any purchase decision
    d. Consistently endeavor to identify and report the root cause of anomalies and failures. Participate in root cause analysis teams. Detect the root cause of fault conditions, not just the failures, when performing condition monitoring testing

5.2 Reliability Engineer: ARP-E

The second level of certification is designed to ensure that a person, often referred to as a reliability engineer, is adequately educated to be able to identify the causes of unreliability, perform the tasks necessary to improve reliability, and also to recognize their experience via Category ARP-Ex in this role. A candidate may currently be employed as a reliability

engineer, or they may be involved in an associated area (e.g. condition monitoring) and wish to learn more about reliability engineering and be recognized for that knowledge.

The ARP-E Reliability Engineer may be involved in the following tasks:

1. Assist in the development of the master asset list (also known as the equipment register)
2. Assist in the development of the bill of materials (BOM)
3. Participate in the development of the asset criticality ranking (ACR)
4. Participate in the development of the asset reliability strategy utilizing a combination of the following techniques:
    a. Reliability Centered Maintenance (RCM)
    b. Preventive Maintenance Optimization (PMO)
    c. Failure Modes and Effects Analysis (FMEA)
5. Participate in the development and implementation of a comprehensive condition monitoring plan to include all applicable technologies applied to assets by criticality and effectiveness
6. Perform/participate in Root Cause Analysis (RCA) to identify cause and corrective action for safety and environmental incidents, failures and defects of all types, deviations from operating and performance objectives, etc.
7. Perform Weibull, Pareto or other forms of analysis on failure data to identify commonalities and cause
8. Participate in the costs analysis and reduction process, as defined by the Program Manager, and recommend actions that will reduce costs
9. Assist in the development of standards and procedures for all maintenance work including critical spares, time based preventive maintenance, comprehensive Job Plans and safety precautions
10. Assist in the development of proactive task identification and implementation with the aim of extending the asset life and performance. In the case of rotating machine it should include alignment, balancing, and lubrication management.
11. Work closely with the maintenance department to audit the quality and effectiveness of maintenance activities and ensure that proactive tasks are performed
12. Assist in the development of standard operating procedures
13. Work closely with design engineers to ensure that new equipment is designed for reliability, efficiency, operability and maintainability
14. Work closely with procurement to ensure a life cycle value comparison is included with an evaluation of purchase cost. Make every effort to ensure that life time reliability and cost histories with equivalents as well as the cost of retrofits should they become necessary are included in the evaluation.
15. Work closely with the condition monitoring department to ensure that the most critical assets are being tested with the most appropriate technology at the correct measurement period.
16. Work closely with all involved to ensure that the root causes of anomalies, failures and other abnormal events and conditions are being investigated with a proven RCA procedure; recommendations reported, tracked and implemented on a time schedule
17. Review spares storage including factors such as: temperature, potential contamination, orientation (horizontal, vertical), necessity for periodic Preventive Maintenance, etc. to ensure quality and condition when required for use
18. Contribute to the:
    a. Development and analysis of the benchmarking process
    b. Development and analysis of key performance indicators
    c. Development and analysis of reliability data

19. Participate in the training of other people in the organization to create awareness of the value, to the individual and the organization, when reliability and operating practices are improved.

5.3 Reliability Leader: ARP-L

The third level of certification is reserved for the reliability initiative program manager/leader - the person who will manage one or more ARP-E reliability engineers, possibly across multiple sites. This person must have a technical knowledge of reliability, maintenance, and the best practices in these areas. Knowledge will not need to be as detailed as the ARP-E reliability engineer's knowledge. However, they will require knowledge and skill in project management, people management, budgeting, continuous improvement, training and work culture change. They will need exceptional communication skills and must be able to communicate the financial and operating benefits to senior executives in management terms.

The ARP-L Reliability Leader job role will include a combination of the following:

1. Assess the needs of the business to best understand how reliability will add value
2. Assess the current state of reliability to determine where there are shortcomings
3. Work with the senior executive to create (when necessary) and maintain full support
4. Work with the reliability team to value and prioritize the gaps (opportunities to improve) between current state and best practices
5. Oversee the creation and operation of the reliability improvement steering committee (or equivalent)
6. Lead the design and review of the reliability improvement strategy
7. Ensure the reliability improvement strategy is strongly aligned with delivering business outcomes
8. Ensure the roles and responsibilities are fully defined (RASCI or equivalent) and clearly understood
9. Develop the vision and mission statements for the reliability improvement initiative
10. Establish metrics and KPIs to measure the benefits of the reliability improvement initiative
11. Work with the reliability improvement steering committee to coordinate, optimize and maximize the effectiveness of implementing the reliability improvement strategy.
12. Direct, manage and coordinate execution of the reliability improvement strategy at the working level.
13. Work with design/engineering and procurement to achieve the lowest life cycle costs on new purchases, upgrades, and capital projects
14. Monitor all audit/benchmarking/KPI/Pareto/bad-actor results and metrics in order to reduce costs and drive improved reliability and performance
15. Develop a communication plan to publicize results and gain enthusiastic support from senior executives, steering committee, program participants, uninvolved management and employees at large
16. Develop and manage the reliability improvement budget
17. Oversee the work culture change process
18. Oversee the training process and the knowledge/skills assessment process
19. Integrate vendors into the reliability strategy

6. Eligibility for certification

6.1. General certification for Category ARP-A, ARP-E and ARP-L

To be eligible for certification, candidates shall have completed sufficient training to ensure they understand the principles and procedures consistent with clause 5 above and Annex A, passed a knowledge-based examination and have verifiable general industrial experience.

Certification at the lower category is not a prerequisite for certification for ARP-E or ARP-L, provided all the other certification requirements are met.

The MIBoC Certification Manager shall review each candidate's certification prerequisites, including training, experience and the score obtained in the knowledge-based examination, to determine the candidate's general certification status.

6.1.1. Training

Candidates shall provide evidence of successful completion of approved training based on the requirements of Annex A or which is otherwise recognised by the MIBoC Reliability Technical Committee. A list of approved/recognised training courses can be found in document *ED169 – Approved Reliability Training Courses*. Training should be in the form of lectures, demonstrations, trainer-specified practical exercises or controlled self-study. The training could be achieved during one comprehensive course, or via multiple courses over an extended period. Total training time shall meet the minimum duration requirements given in Table 1 below, and shall include the topics identified in Annex A.

Table 1 – Minimum duration of training (hours)

ARP-A	ARP-E	ARP-L
16	32	32

6.1.2. Knowledge-based examination

For each category, the candidates shall be required to answer a fixed number of multiple-choice questions in a specified time duration as indicated in Table 2 below. The questions, covering topics shown in Annex A, shall be selected from a database of questions existing at the time of the examination. These questions have been generated or approved by the MIBoC Reliability Technical Committee.

Table 2 – Examination details

Category	Number of questions	Duration (hours)	Pass grade (%)
ARP-A	60	2	70
ARP-E	100	3	70
ARP-L	100	3	70

The knowledge-based examination shall be conducted as outlined in section 7 of this document.

6.1.3. General experience

The candidate must have relevant experience of the duration specified in Table 3 below. The nature of the experience varies according to the category level:

ARP-A candidates must have general industrial experience for a sufficient period that they should have experienced the consequences of failure in the areas of production targets missed, and/or performance targets, and/or quality goals missed, and/or risk of safety or environmental incidences, and/or excessive costs associated equipment failure.

ARP-E candidates must also have experienced the impact of poor reliability as per the ARP-A requirements, but they should have been directly involved with the reliability improvement process in at least two (2) of the following areas: performed maintenance tasks, operated equipment, performed condition monitoring tasks, participated in an RCA project, performed reliability analysis, performed RCM/FMEA analysis, or been actively involved in the role of reliability engineer as described in section 5.2.

ARP-L candidates should also have experienced the impact of poor reliability as per the ARP-A requirements, but they should also have been involved in the reliability improvement process, either as a reliability engineer (as described in section 5.2) or a program manager/leader (as described in section 5.3).

Candidates shall be required to provide details of their experience and the contact details of someone who can verify the experience.

The minimum duration of the experience described above are shown in Table 3 below.

Table 3 – Minimum duration of cumulative general industrial experience (months) required for general certification

ARP-A	ARP-E	ARP-L
6	24	48

7. Conduct and scoring of knowledge-based examinations

The general knowledge-based examinations may be conducted at

- an AEC and administered by a MIBoC authorised invigilator in accordance with document *AEC015 - AEC Requirements*; or
- administered by a MIBoC authorised non-AEC invigilator in accordance with document *ED044 – Invigilator Instructions (Non-AEC)*. Applications for such invigilated exams shall be submitted to MIBoC using document *ED043 – Invigilation Application Form.*

The exams shall be prepared by MIBoC and distributed to AECs or authorised non-AEC invigilators.

For each category, the candidate shall be required to answer a number of multiple-choice questions in a given time-period, as specified in section 6.1.2.

The examination shall be closed book, and the candidate shall not be in possession of any reference documentation during the examination, except for any materials which are enclosed in the exam envelope.

The examination may be presented in languages other than English. The translation of exams into languages other than English shall be managed by MIBoC.

At the time of examination, the candidate shall have in his or her possession valid proof of identification, showing a photographic image, which shall be shown to the invigilator upon request.

Provision is made for candidates with a disability which may affect their ability to complete the exam, in accordance with document *ED033 – Accommodation of Special Needs*.

The presence of mobile phones or any other electronic communication, image capturing or data storage devices is prohibited in examination rooms.

Once an examination has commenced, candidates found breaching the exam conditions will be considered to have cheated and their exam will be terminated. No exam results will be issued for those exam parts already completed and a letter will be sent to the candidate explaining why their exam was terminated. Candidates considered to have cheated in a MIBoC exam will be ineligible for another MIBoC exam for a period of 12 calendar months from the date of the exam in which cheating was considered to have taken place.

The exam shall be conducted in accordance with the requirements outlined in ED044 or AEC015 and AEC016.

Completed examination papers will be scored by an authorized person (Examination Scoring Administrator) at MIBoC by comparison with model answers.

To achieve qualification the Candidate shall obtain a minimum pass mark as specified in *section 6.1.2*.

8. Re-examination and re-assessment

8.1. Re-examination of knowledge-based exam

In the event that a candidate is unsuccessful in passing the knowledge-based examination, he/she can apply to re-sit the exam, provided that the re-sit takes place no sooner than 30 days after the previous exam date. MIBoC may use its discretion in allowing an earlier re-sit examination in the event that evidence of further training acceptable to MIBoC is undertaken. A candidate who fails three consecutive attempts will be excluded from further examinations for a period of 12 months.

A candidate whose examination results have not been accepted for reason of fraud or unethical behaviour shall wait at least 3 years before re-applying for examination.

8.2. Re-assessment of experience/competence assessment

In the event that a candidate is unsuccessful in passing the x-level experience assessment, he/she can apply to be re-assessed, provided that the re-sit takes place no sooner than 6 months after the previous assessment date. A candidate who fails three consecutive attempts will be excluded from further assessments for a period of 3 years.

A candidate whose assessment results have not been accepted for reason of fraud or unethical behaviour shall excluded from further assessments for a period of at least 3 years.

9. Validity of certification

The period of validity of a MIBoC certificate/wallet card is three years from the date of initial certification or renewal.

Certification shall be withdrawn or invalid:

- three years after certification unless the certificate holder applies for renewal;
- if the certificate holder becomes physically and/or mentally incapable of performing the duties;
- if a significant interruption takes place in the application of the competence for which the individual is certified;
- at the discretion of MIBoC, after reviewing evidence of unethical behaviour.

Certification of an individual can be checked and verified online at MIBoC's website, or by contacting the MIBoC Certification Manager at certification.manager@mobiuscertification.org.

Candidates whose certification has been withdrawn or become invalid will have their names removed from MIBoC's website list of certified individuals and their digital certificate, card & logo will be removed from MIBoC's digital certificate platform.

10. Certification renewal

At any time within 4 months of the certification's expiry date, the holder may renew his/her certificate for a further period of three years upon submission of satisfactory documentary evidence of ongoing asset reliability work experience which is relevant to the category of certification being applied for as well as ongoing personal and professional development in the area of reliability improvement during the current three-year certification period. To ensure continuity of certification, it is advisable to apply at least 6 weeks prior to expiry. Applications for renewal after a certificate has expired for more than 4 months may be considered at MIBoC's discretion, however a certificate which expired more than 9 months ago shall not be eligible for renewal.

The issue number of the renewed certificate will be incremented by one (i.e. issue 02, 03 etc.).

Individuals will be required to accumulate a total of 50 renewal credit points (1 hour = 1 credit point) from a combination of two or more of the following options:

a) Continued professional development in areas relevant to the skills outlined in the Body of Knowledge (BoK) as per Annex A of this document – actual hours spent in the classroom.
b) Complete educational workshops, seminars, on-demand education, or other online controlled self-learning training relevant to the subject areas in the BoK – actual hours spent in the workshop or seminar or viewing an online course.
c) Participate as an active member of the MIBoC Reliability Technical or Scheme Committees – actual hours spent on committee activities
d) Attend annual/executive/chapter meetings at organisations relevant to the subject areas in the BoK (such as SMRP, ASNT, CMVA, etc.) – actual hours spent in such activities
e) Attend conferences relevant to the subject areas in the BoK (e.g. CBM Connect Live, SMRP, ASNT, CMVA, IMC, Reliable Plant, Euromaintenance, vendor sponsored conferences, etc.) – actual hours spent in conference sessions, up to 6 hours for each day of attendance
f) Give presentations at conferences or seminars which are relevant to the subject areas in the BoK – actual hours spent developing and presenting the paper, up to 5 hours per presentation
g) Publish articles or papers in publications relevant to the subject areas of the BoK - actual hours spent developing the article or paper, up to 10 hours per article/paper
h) Author a book or a significant chapter of a book relevant to the subject areas in the BoK – 20 hours per chapter
i) Provide instruction in a course or workshop relevant to the subject areas in the BoK – actual hours spent delivering the course/workshop, plus up to 12 hours for development of each course/workshop hour (e.g. 6 hour course = 6 hours for delivery plus up to 12 hours if the individual also developed the course)
j) Participate in the development of questions for the MIBoC Reliability Certification exam – up to 1 hour per question submitted
k) Other activity or learning experience in the subject areas of the BoK, subject to the approval by the MIBoC Certification Manager – actual hours spent on the activity
l) Complete work hours relevant to the subject areas in the BoK – maximum of 10 renewal credit points for each year of full-time work experience within the three-year certification period.

Additionally, individuals will be required to provide verifiable details of ongoing asset reliability work experience in one of the following areas:

a) Work in an industrial facility in the field of condition monitoring, maintenance, reliability, engineering, or operations
b) Sales consultant in the field of CBM/reliability
c) Consultant in CBM/Reliability
d) Manager of sales and consulting people in CBM/Reliability
e) Instructor in CBM/Reliability

Application for renewal of certification is made on the Application for Certification Renewal form, which is Annex A of *ED170 – Reliability Certification Renewal*.

Whilst the renewal process is conducted on an honor system of reporting, MIBoC will audit five percent (5%) of applicants to verify the accuracy of reporting. The audit process will require the individual to provide documentary evidence to support the credit points claimed. Guidance on the evidence required is provided in *ED170*. It is the responsibility of the individual to collect and retain such documentation and promptly provide it to MIBoC when requested. Failure to do so may be grounds for denying the certification renewal.

If the criteria for renewal are not met, MIBoC will cancel the certificate upon its expiry date, and to regain the certificate concerned the individual will need to successfully complete the process for initial certification.

Annex A: Body of Knowledge for Reliability Practitioners

Table A.1 – Levels of knowledge required

STRATEGY AND IMPLEMENTATION			
Reliability improvement strategy topic	**ARP-A**	**ARP-E**	**ARP-L**
General overview	■	■■	■■■
Business process review	□	■	■■■
Business case	□	■	■■■
Asset management	□	■	■■■
Reliability improvement implementation	□	■■	■■■■
Operational excellence	□	■	■■
Project management		■	■■
Maintenance strategies	■	■■■	■■
Reactive maintenance	■	■	■
Condition Based Maintenance	■■	■■	■■
Preventive (interval based) maintenance	■	■■	■■
Run-to-failure maintenance	■	■	■
Preventive Maintenance Optimization	■	■■	■
Operator Driven Reliability	■	■■	■

PEOPLE MANAGEMENT			
People management topic	**ARP-A**	**ARP-E**	**ARP-L**
General overview	■	■	■■■
Leadership	■	■	■■■
Culture change	■	■■	■■■■
Project management	□	■	■■
Human error	■	■■	■■
Human relations		■	■■■
Knowledge and skills assessment			■■■■
Training and education	■	■■	■■■■
Certification	■	■	■■

DEFECT ELIMINATION

Defect elimination topic	ARP-A	ARP-E	ARP-L
General overview	■	■■	■■■
Design	■	■■	■■■
Purchasing	■	■	■■■
Transportation	■	■■	■■
Spares management	■	■■■	■■■
Storage	■	■■■	■■
Planning and Scheduling	■	■■	■■
Installation and commissioning	■	■■■	■■
Project management	■	■■	■■■
Operation	■	■■	■■■
Acceptance Testing	□	■■	■■
Root cause analysis	■	■■■	■

ASSET STRATEGY DEVELOPMENT

Asset strategy development topic	ARP-A	ARP-E	ARP-L
General overview	■	■■	■■
Master asset list	□	■■	■
Bill of materials	□	■■	■
Asset Criticality Ranking	■	■■■	■■
Failure Modes Effects Analysis	□	■■■■	■■
Reliability Centered Maintenance	■	■■■■	■■
Preventive Maintenance Optimization [PMO]	■	■■■■	■

RELIABILITY ENGINEERING

Reliability engineering topic	ARP-A	ARP-E	ARP-L
General overview		■■	■
Reliability block diagrams		■■	
Reliability analysis		■■■	
Lifecycle costing		■	■

WORK AND SPARES MANAGEMENT

Work and spares management topic	ARP-A	ARP-E	ARP-L
General overview	■	■■	■■■
Maintenance Repair and Overhaul (MRO) spares management	■	■■■	■■■
Maintenance planning	■	■■■	■■
Maintenance scheduling	■	■■■	■■
Managing break-in work	■	■■■	■
Shutdowns, turnarounds and outages	■	■■■	■■■
Computerized Maintenance Management Systems	■	■■■	■■■

PRECISION SKILLS (PRECISION AND PROACTIVE MAINTENANCE)

Precision skills topic	ARP-A	ARP-E	ARP-L
General overview	■■	■■■	■■
Shaft alignment	■	■■■	■
Balancing	■	■■■	■
Fastening	■	■■	■
Soft foot	□	■	■
Looseness correction		■■	■
Resonance correction	□	■■	■
Rolling element bearing installation	■	■■■	■
Journal bearing installation		■	■
Mechanical seal installation	□	■■	■
Electrical installations	■	■■■	■
Verifying electrical systems	■	■■■	■
Power quality	□	■■	■
Commissioning of electrical equipment	□	■■	■
General principles of installing mechanical components	■	■■■	■■
General principles of installing electrical components	■	■■■	■■
Grease lubrication	■■	■■■	■
Oil lubrication	■	■■■	■

CONDITION MONITORING

Condition monitoring topic	ARP-A	ARP-E	ARP-L
General overview	■■	■■■■	■■■
Vibration analysis	■■	■■■	■■
Ultrasound	■	■■■	■
Infrared analysis (thermography)	■	■■■	■
Oil analysis	■	■■■	■
Wear particle analysis	■	■■	■
Motor current/voltage/circuit analysis	■	■■	■
Non Destructive Testing (NDT)	□	■■	■
Process/performance monitoring	■	■■	■
Visual inspection	■	■	■
Electrical insulation testing		■	

CONTINUOUS IMPROVEMENT

Continuous improvement topic	ARP-A	ARP-E	ARP-L
General overview	■	■■	■■■
Business justification	■	■	■■■
PDCA/Kaizen/Lean	■	■ ■	■ ■■
Benchmarking	■	■	■■■
Key Performance Indicators	■	■■■	■■■
Communication	□	■■	■■■
Root Cause (Failure) Analysis	■■	■■■■	■■
Visual workplace & error proofing	■	■	■

Annex B: Body of Knowledge for Reliability Practitioners – Detailed Topics

Table B.1 – List of detailed topics & knowledge required

STRATEGY AND IMPLEMENTATION

Reliability improvement strategy topic	ARP-A	ARP-E	ARP-L
General overview	Understand the key strategies involved with reliability improvement and how they should be combined to create a successful and sustainable initiative	Understand the key components of the strategy and how the ARP-E Reliability Practitioner contributes towards the success of the strategy	Understand: ▪ how to develop the strategy that meets the business needs ▪ how to establish a plan so that the strategy can be implemented ▪ how to ensure that the strategy is implemented
Business process review	Understand: ▪ that the reliability improvement initiative is implemented to enable the business to meet its objectives ▪ understand how the priorities related to cost control, downtime reduction, capacity improvement, quality improvement, throughput improvement, or safety and environmental incident reduction will vary from industry to industry and even between different parts of the plant	Understand: ▪ how each of the steps in the implementation process must be aligned with the goals of the business ▪ how to express the benefits of each step in terms of the goals of the business ▪ how to incorporate the priorities revealed in the business process review into the asset criticality ranking	Understand: ▪ how to perform the business process review which must include an understanding of the corporate risk (including safety) analysis and identification process ▪ how to communicate the results of the business process review ▪ how to prioritize investments according to the results of the business process review ▪ how to assess risk in terms of the results all process review ▪ how elements of the reliability strategy directly impact the business needs, and how to form a tailored strategy
Business case	Understand: ▪ in general terms, how the business will benefit if reliability is improved ▪ how a business case will be required in order to justify the expense associated with reliability improvement	Understand: ▪ in greater detail, how the business will benefit if reliability is improved ▪ how a business case will be required in order to justify the expense associated with reliability improvement ▪ how to assist the program leader in developing the business case	Understand: ▪ how to quantify the benefits of a reliability improvement initiative ▪ how to measure the costs and returns of a reliability improvement initiative ▪ how to communicate the benefits of the initiative ▪ the principle of the "time value of money", and NPV and IRR
Asset management	Understand: ▪ the basic principles of asset management	Understand: ▪ the big picture of asset management ▪ the relationship between reliability improvement and asset management ▪ ISO 55000 standard and the certification process	Understand, in detail: ▪ the big picture of asset management ▪ the relationship between reliability improvement and asset management ▪ ISO 55000 standard and the certification process

Reliability improvement implementation	Understand: ▪ there must be a strategy in place that begins with an audit of the current state ▪ the strategy must include as a minimum culture change, condition monitoring, precision/proactive skills improvement, improvement to work management, and a general philosophy of defect elimination ▪ the strategy must also include metrics that make it possible measure progress and identify opportunities for improvement	Understand: ▪ how to assist in the development of an implementation "roadmap"	Understand: ▪ how to develop a "roadmap" strategy with defined goals and milestones ▪ how to avoid common roadblocks ▪ understand the relative importance of culture change versus the technical aspects ▪ understand the need for continuous improvement and communication
Operational excellence	Understand the importance of the "operational excellence" goal and the role reliability improvement plays	Understand the importance of operational excellence and that reliability decisions can have a direct impact on operational excellence	Understand how a reliability improvement initiative enables the organization to achieve "operational excellence"
Project management		Understand the key elements in successful project management	Understand: ▪ how to manage projects ▪ how to set milestones ▪ how to set budgets and manage costs ▪ how to measure and document progress ▪ how to report on the progress of the project
Maintenance strategies	Understand: ▪ common practices and strategies such as reactive maintenance, run to fail maintenance, condition-based maintenance, predictive maintenance, and "interval-based" maintenance a.k.a. preventive maintenance ▪ the basic logic that enables one to decide whether run-to-fail, condition-based, or interval-based maintenance (or a combination thereof) should be applied to an asset based on its failure modes	As per ARP-A, but with an understanding of how the principles of RCM can be used to determine how those strategies should be applied. Also understand the value and limitations of every maintenance strategy.	As per ARP-A, but utilize the principles of RCM to determine how those strategies should be applied
Reactive maintenance	Understand: ▪ the pros and cons of reactive maintenance ▪ the difference between reactive maintenance and intentional run-to-failure maintenance	As per ARP-A	Understand: ▪ the reasons why reactive maintenance is costly, dangerous, and environmentally harmful ▪ how to break out of the reactive maintenance cycle ▪ how to stop rewarding "breakdown maintenance heroes" and instead reward the "proactive quiet achievers"
Condition Based Maintenance	Understand:	Understand:	Understand:

	▪ the basic principle of condition-based maintenance ▪ the difference between condition monitoring and the condition-based maintenance strategy	▪ how to utilize the principles of FMEA & RCM to determine which condition monitoring technologies should be utilized and the measurement interval	▪ how to utilize the asset criticality ranking to determine if condition based maintenance is justified ▪ how to cost justify the condition based maintenance strategy ▪ the basic principles of starting a condition based maintenance program ▪ the technical, training and certification requirements for condition monitoring technicians and analysts ▪ how to document the benefits gained from condition-based maintenance
Preventive (interval based) maintenance	Understand: ▪ the basic principle of preventive (interval based) maintenance ▪ the risks that are taken when preventive maintenance is not applied correctly	Understand: ▪ how to utilize the principles of FMEA & RCM to determine which preventive maintenance tasks should be performed and the interval of those tasks	Understand: ▪ the conditions under which a preventive maintenance task would be performed ▪ how to utilize the asset criticality ranking to determine if preventive maintenance is justified
Run-to-failure maintenance	Understand: ▪ the basic principle of run to failure maintenance ▪ the risks that are taken when run to failure maintenance is not applied correctly	Understand: ▪ how to utilize the asset criticality ranking the principles of FMEA & RCM to determine it is justified to implement run to failure maintenance	As per ARP-A and ARP-E
Preventive Maintenance Optimization	Understand: ▪ that in most plants there are a large number of so-called preventive maintenance tasks that do not add value ▪ that through proper analysis unnecessary tasks can be identified	Understand: ▪ how to identify maintenance tasks that do not add value ▪ why it is necessary to also identify proactive and preventive tasks that are necessary but that may not be performed currently	Understand: ▪ that there could be a large number of maintenance tasks currently being performed that are unnecessary ▪ that by removing unnecessary tasks, critical resources are made available ▪ that some tasks may be required by OEMs that are actually unnecessary ▪ that some tasks may be required by regulators that through negotiation can be avoided
Operator Driven Reliability	Understand: ▪ that operators have a great deal to offer in the condition monitoring and reliability improvement process ▪ operators could perform basic maintenance tasks to improve reliability and free-up maintenance staff ▪ operators could perform basic inspections and condition monitoring tests	Be able to define the tasks that operators can perform in order to assist in the proactive maintenance and condition monitoring of the equipment they work with	As per ARP-A and ARP-E, and: ▪ be able to provide the justification for utilizing operators in order to assist in the proactive maintenance and condition monitoring of the equipment they work with

PEOPLE MANAGEMENT

People management topic	ARP-A	ARP-E	ARP-L
General overview	Understand: ▪ improving reliability is not simply a technical challenge - the key to success is through the people working in the plant ▪ everyone within an organization must contribute to, and participate in, the reliability improvement program ▪ the need for strong leadership ▪ the need for properly trained and informed people ▪ the need for independent certification	Understand: ▪ the importance of working with people and not simply telling people what they need to do to improve reliability ▪ to need for asking people for their suggestions and their assistance	Understand: ▪ how to engage senior management ▪ how to maintain the support of senior management ▪ the fundamentals of culture change ▪ how to deal with human error ▪ the need for properly trained and certified personnel ▪ that trades people need the appropriate skills
Leadership	Understand the essential role that leadership (throughout the organization) plays in the success of the program	Understand: ▪ the importance of leadership ▪ that leadership is not just reserved for senior management	Understand: ▪ what the difference is between a leader and a manager ▪ the critical importance of leadership in the reliability improvement process ▪ how to behave in order to send clear, consistent messages to the workforce ▪ how to inspire people to improve and change
Culture change	Understand: ▪ that everyone in the organization must contribute to the reliability improvement initiative ▪ That "front-line" staff have a high level of understanding of the root-cause and nature of failures and should contribute their knowledge ▪ How everyone in the organization will benefit if reliability is improved	Be able to provide support for the "culture change" process, including: ▪ providing "awareness" training ▪ participating in "brainstorming" sessions to identify problems and solutions. ▪ assisting those who lead the improvement projects ▪ provide data that indicates where opportunities for improvement exist, and where improvement is being made	Understand: ▪ the critical important of developing a culture of reliability ▪ the role senior management play ▪ the key elements of culture change program ▪ the steps necessary to create awareness and create a desire for change
Project management	Understand: ▪ the basics of the RACSI chart/concept	Understand: ▪ the concept and importance of the RASCI chart and process	Understand: ▪ the importance of defining who is Responsible, Accountable, Consulted, provides Support, and Informed – i.e. RASCI
Human error	Understand: ▪ people are susceptible to making simple mistakes without realizing they are making mistakes	Understand: ▪ the nature of human error ▪ the basics of "cognitive biases", blind-spots, and	Understand: ▪ how to identify where human error will lead to problems that will impact reliability,

		peer group pressure that can lead to error	throughput, quality and safety
Human relations		Understand: ▪ that the HR department has a critical role to play in the reliability improvement initiative ▪ the HR department may need to change people's titles and job descriptions	Understand: ▪ the need to involve the HR department in the reliability improvement program ▪ the need to review job descriptions ▪ the need to review bonus incentives ▪ the need to review workplace agreements ▪ the need to monitor the people who are directly involved in the reliability improvement initiative ▪ the need to coach HR in the specifics of roles and responsibilities in the reliability strategy
Knowledge and skills assessment			Understand: ▪ the need to assess the knowledge requirements of everyone involved improving reliability improvement initiative ▪ the need to assess the skills of everyone involved in the reliability improvement initiative ▪ the difference between knowledge and competence in the need for competence in each key role ▪ be able to develop a skills matrix so that skills are documented and so that gaps can be identified and managed
Training and education	Understand: ▪ that training will be involved in order to have the required level of knowledge in each person's specialist area ▪ that training will be involved in order to have a basic understanding of the entire reliability improvement initiative including the activities of the maintenance and operations groups	Understand: ▪ that training will be necessary in order to perform the role of reliability engineer ▪ that the people they interact with will require training to understand the benefits of reliability and the knowledge and skills required to perform their roles effectively ▪ prepare to provide in-house training to meet the previous goal	Understand: ▪ the need to provide detailed training so that people are competent in the roles ▪ the need for refresher training so that people remain competent ▪ the need for cross training so that everyone understands each other's roles ▪ the pros and cons of external classroom training, internal classroom training delivered by external companies, internal training delivered by company staff, and e-learning
Certification	Understand: ▪ the importance of certification ▪ the basic principles of accredited versus non-accredited certification ▪ the role played by the ISO	As per ARP-A	As per ARP-E, and to be able to develop a plan to ensure that all technical staff are trained and certified to the correct level.

DEFECT ELIMINATION

Defect elimination topic	ARP-A	ARP-E	ARP-L
General overview	Understand that Defect Elimination (DE) is a process of eliminating existing defects from a plant and keep defects from entering a plant in future.	Understand: ▪ that Root Cause Failure Analysis (RCFA) is often used to determine root causes or defects after a failure or undesirable reliability event has occurred ▪ that defects can be introduced in systems or processes not under the control of the reliability team ▪ that Failure Modes and Effects Analysis (FMEA) is often used to determine potential root causes of failures or defects, before failure has occurred ▪ what managerial systems to update or improve to ensure proper documentation and permanent elimination of defects	Understand: ▪ how DE fits into a Continuous Improvement (CI) cycle ▪ methods to estimate the value of different DE facets
Design	Understand: ▪ equipment design is typically a trade-off between operability, maintainability and reliability ▪ equipment may have design flaws (relative to the application it is used for) which could introduce reliability defects to a plant ▪ design flaws should be recognized and their effects mitigated	Understand: ▪ a deeper understanding of maintainability, operability and reliability ▪ what criteria should be specified in future design requirements for satisfactory operability, maintainability and reliability	Understand: ▪ what is required to mobilize designers to consider requirements for operability, maintainability and reliability in future designs ▪ a method to quantify the effect of inappropriate design on defects in the plant
Purchasing	Understand: ▪ purchasing decisions are often made on the minimum specification at the lowest cost basis ▪ purchasing decisions should instead value life cycle costs ▪ shortsighted purchasing practices may lead to the introduction of defects	Understand: ▪ a method to estimate the lifecycle cost of equipment	Understand: ▪ what is required to change purchasing policies from lowest purchase cost to optimum life cycle cost ▪ a method to illustrate the return on investment if purchasing is done on a lowest lifecycle basis in terms of NPV, EAC or IRR
Transportation	Understand: ▪ that equipment can be damaged when transported ▪ common reasons why equipment is damaged	Understand: ▪ how incorrect transportation of equipment can lead to the introduction of defects in a plant ▪ typical defects that are introduced by poor transportation practices ▪ techniques to ensure transported equipment is not damaged	Understand: ▪ how to implement good transportation practices in the purchasing process ▪ a method to quantify the contribution of poor transportation practices to defects in the plant
Spares management	Understand:	Understand:	Understand:

	▪ that spares should be installed in the same condition that it was manufactured ▪ any action taken during spares management that alters the condition of spares could introduce defects to the plant	▪ how to establish procedures and standards to ensure defects are not introduced whilst in stores	▪ a method to quantify the contribution of poor Spares management to defects in the plant
Storage	Understand: ▪ equipment and spares can deteriorate during storage (even over relatively short periods of time) ▪ spares that have been damaged or compromised during storage could introduce defects to the plant ▪ actions that could be taken to avoid damage of equipment during storage	Understand: ▪ how to develop storage practices and procedures for specific equipment	Understand: ▪ how to implement sound storage practices as part of Work Planning and Execution (housekeeping) ▪ a method to quantify the contribution of poor Storage practices to defects in the plant
Planning and Scheduling	Understand: ▪ that is planning and scheduling is not performed correctly defects can be introduced via damage to the parts, the wrong parts being used, the wrong tool being used, the person with inadequate skills being used, the job being rushed, and the commissioning not performed correctly.	Understand: ▪ in greater detail how poor planning and scheduling can introduce defects and how to avoid those defects	Understand: ▪ a method to quantify the contribution of poor planning and scheduling practices to defects in the plant
Installation and commissioning	Understand: ▪ installation and commissioning require a person with the right skills, the right tools and sufficient time to perform the installation task ▪ equipment should be aligned, balanced, lubricated and secured after installation using precision techniques ▪ installation tasks done with less than described above could lead to the introduction of defects in the plant	Understand: ▪ in greater detail how poor installation and commissioning can introduce defects and how to avoid those defects ▪ how to commission correctly to avoid production, quality, maintenance, and reliability issues	Understand: ▪ a method to quantify the contribution of poor installation and commissioning practices to defects in the plant
Project management	Understand: ▪ the definition of *projects* in the Defect Elimination (DE) context ▪ that project management is a structured template that is often used to execute projects to ensure maximum control over the project timing, budget, risk and final deliverable ▪ that project management pressures should not lead to the	Understand: ▪ in greater detail how poor project management can introduce defects and high costs and how to avoid those defects	Understand: a method to quantify the contribution of poor Project management practices to defects in the plant

	introduction of defects in the plant		
Operation	Understand: ▪ that operation of equipment outside of its optimal operating specifications can lead to the introduction of defects in the plant ▪ the value of Standard Operating Procedures (SOPs)	Understand: ▪ in greater detail how poor operating practices can introduce defects, inefficiencies, poor performance, and reduced quality ▪ how equipment can be harmed through poor operating practices	Understand: ▪ how to establish optimal operating procedures ▪ how to involve operators in the definition of SOPs ▪ how to establish standard operating procedures (SOPs) ▪ how to educate operators why their practices must change ▪ a method to quantify the contribution of poor operational practices to defects in the plant
Acceptance Testing	Understand: ▪ that despite the best preventive measures against the introduction of defects, defects will still be introduced ▪ that acceptance testing can be used as checkpoints or quality insurance after procurement, maintenance or operation of equipment ▪ that acceptance testing can be done in any sensible manner including through condition monitoring, non-destructive testing or performance testing	Understand: ▪ how to develop the acceptance testing standards for a plant in terms of vibrations levels, alignment, resonance testing, oil quantities/qualities, electrical testing of motors, etc.	Understand: ▪ how to establish acceptance testing as a standard part of the purchase and selection process ▪ how to implement the acceptance testing standards as part of work management and control ▪ a method to quantify the value of acceptance testing in eliminating defects the plant
Root cause analysis (RCA)	Understand: ▪ how to identify the root cause of the failures or unacceptable performance in order for those root cause to be eliminated ▪ how everyone can contribute to this process	Understand: ▪ how to determine the root causes of failure or unacceptance performance ▪ that it is necessary to follow a documented process ▪ it is necessary to work with others to ensure identified root causes are eliminated (when there is an appropriate value proposition)	Understand: ▪ the importance of root cause analysis in the defect elimination process ▪ The need for everyone to be empowered to conduct RCAs and contribute to RCAs

ASSET STRATEGY DEVELOPMENT

Asset strategy development topic	ARP-A	ARP-E	ARP-L
General overview	Understand: ▪ the goals of establishing an asset strategy ▪ the core components of an asset strategy ▪ the basic questions that must be asked in order to develop the asset strategy	Understand, in detail, the importance of establishing an asset strategy, based on criticality, which takes failure modes, time to failure, and the root causes of failure into consideration.	Understand: ▪ the critical importance of developing and maintaining an asset strategy ▪ the need to periodically review the asset strategy ▪ the importance of ensuring the asset

			strategy is being followed ▪ the need to learn from failures (via RCFA) in order to revise the asset strategy
Master asset list	Understand the importance of establishing a "master asset list" (aka "asset register"), the basic concept of using a structured naming system, and the need to maintain its accuracy.	Understand how to establish a master asset list. Be familiar with ISO 14224.	Understand the importance of establishing a "master asset list" in order to insist on its development and maintenance in order to ensure accuracy.
Bill of materials	Understand what a "bill of materials" (BOM) is and how it serves the work management function.	Understand what is involved in developing and maintaining a bill of materials.	Understand the importance of establishing and maintaining an accurate bill of materials (BOM) in order to insist on its development and maintenance.
Asset Criticality Ranking	Understand: ▪ the importance of establishing a risk ranking at the system and asset level ▪ the basic premise of the criticality ranking: consequences, reliability and detectability ▪ how the ACR can be used to prioritize investment and work activities	Understand how to: ▪ establish the criteria for defining the ACR (consequences, reliability and detectability) ▪ involve the key stakeholders in establishing the ACR ▪ utilizing the ACR in key decisions, including the design of the asset strategies	Ensure that the needs of the business are clearly understood to ensure that the ACR is aligned with those needs. Ensure that the right stakeholders are involved in establishing the ACR criteria and in setting the ranking.
Failure Modes Effects Analysis [FMEA]	Understand: ▪ that there is a systematic process for examining the failure modes, their consequences, there causes, their severity, and their detectability ▪ the FMEA process is normally only performed on highly critical equipment	Understand how to perform FMEA with the option of including criticality analysis in order to improve upon the asset criticality ranking	Understand the structure of the FMEA process and how it can be used, when the criticality requires, to establish which failures modes pose the greatest risk.
Reliability Centered Maintenance [RCM]	Understand: ▪ that there is a systematic process similar to FMEA that asks the same questions but also, considers the operating context where the goal is to establish an asset strategy ▪ the pros and cons of performing RCM on physical assets	Understand: ▪ how to utilize RCM to develop the reliability strategy ▪ under what conditions RCM should be utilized ▪ the risks associated with utilizing RCM	Understand: ▪ the basic premise of RCM ▪ The pros and cons of utilizing RCM
Preventive Maintenance Optimization [PMO]	Understand: ▪ that there is a process that can be undertaken to review the value gained for each existing PM task ▪ that tasks that do not add value, or that negatively impact asset reliability, must be eliminated	Understand: ▪ how to utilize PMO as part of the development of the reliability strategy ▪ under what conditions PMO should be utilized ▪ the risks associated with utilizing PMO	Understand: ▪ the basic premise of PMO ▪ The pros and cons of utilizing PMO

RELIABILITY ENGINEERING

Reliability engineering topic	ARP-A	ARP-E	ARP-L
General overview	Not required	Understand the principles of reliability engineering, including when and where it can be beneficial to utilize the named techniques below	Understand the circumstances under which it would be necessary to perform detailed reliability engineering analysis
Reliability block diagrams		Understand the basic premise of reliability block diagrams	
Reliability analysis		Understand how equipment failure data can be analyzed to determine failure patterns (infant mortality, random, age related) and to "predict" future availability	
Lifecycle costing		Understand: ▪ the principles of lifecycle cost versus purchase price, and ▪ the basic principles of performing lifecycle cost analysis	Understand: ▪ the importance of lifecycle costing the principles of life-cycle cost versus purchase price

WORK AND SPARES MANAGEMENT

Work and spares management topic	ARP-A	ARP-E	ARP-L
General overview	Understand that work management is the process of having the right work ready for execution by the right people at the right time. Understand the importance of work management to reliability improvement and cost management.	Have a detailed understanding of the work management cycle including work identification, planning, scheduling and closure. Appreciate the benefits of efficient shutdowns, turnarounds and outages and have a basic understanding of the details of engineering project management. Understand the details of common CMMS components.	Have a high level recognition of the importance of the work management cycle and the main elements including work identification, planning, scheduling and closure. Have a detailed understanding of engineering project management as it pertains to efficient shutdowns, turnarounds and outages. Understand the influence and reach of the CMMS.
Maintenance Repair and Overhaul (MRO) spares management	Understand: ▪ the importance of having the appropriate spares available in a plant ▪ the cost of having unnecessary spares in store ▪ why documenting spares received, spares issued or spares scrapped is important	Understand the details of: ▪ spares policy identification ▪ the definition of a "critical spare" ▪ spares sourcing ▪ inventory control ▪ spares issuance ▪ documentation and analysis In addition: ▪ understand the consequences of a poor MRO spares management	Understand: ▪ the main elements of a typical MRO spares management cycle that ensures both effectiveness and efficiency ▪ the strategic advantages in optimized MRO spares management ▪ the impact of MRO spares management on resource allocation systems such as the CMMS
Maintenance planning	Understand: ▪ the gains in efficiency available through job planning ▪ the key components of the planning cycle	Understand: ▪ how to correctly identify work ▪ how to develop a job plan, involving, at minimum: safety	Have working knowledge of what it entails to: ▪ correctly identify work ▪ allocate people to work

	▪ the information required for the planning cycle ▪ the need for feedback and the processing of information coming out of the planning cycle ▪ The need for job plans and standards ▪ The concept of "wrenchtime" and the importance of maximizing wrenchtime	precautions and procedures, tolerances, commissioning, and testing ▪ allocating people to work ▪ how to determine the time required to perform work ▪ how to identify spares, tools and special resources required for work ▪ how to process information captured during work for future planning purposes ▪ understand the benefits of high wrenchtime	▪ determine the time required to perform work ▪ develop detailed job plans ▪ Ensure that safety risks are understood and that procedures (e.g. lock-out tag-out, isolation, etc.) are understood and followed ▪ identify spares, tools and special resources required for work Be able to: ▪ estimate the value contribution of good planning ▪ know what management systems are utilized and influenced in the maintenance planning process ▪ calculate wrenchtime as a primary KPI of planning ▪ lead backlog management ▪ lead forward planning of resources, to optimize strategy implementation within budget constraints
Maintenance scheduling	Understand: ▪ the importance of coordinating with operations/production ▪ what information is required to accompany any task to enable efficient scheduling	Understand: ▪ what information is required to accompany any task to enable efficient scheduling ▪ task prioritization methods	Understand: ▪ what information is required to accompany any task to enable efficient scheduling ▪ task prioritization methods ▪ methods to quantify the value of efficient scheduling
Managing break-in work	Understand: ▪ the impact of break-in work on the planning and scheduling process, and on reliability and performance	Understand: ▪ how to create a priority system which caters for urgent break-in work	Understand: ▪ that break-in work must be managed and prioritized
Shutdowns, turnarounds and outages	Understand: ▪ the difference between regular maintenance and shutdowns, turnarounds and outages ▪ the factors that demand shutdowns, turnarounds and outages (plant expansion, major refurbishment, regulation, etc.) ▪ the importance of scope, cost and time management	Have sufficient knowledge of the following items to participate in a supportive role as it pertains to shutdowns: ▪ Scope management (planning, definition, verification and control) ▪ Time management (activity definition and scheduling) ▪ Cost management ▪ Quality management ▪ Human resource management ▪ Communications management ▪ Risk management ▪ Contractor management	Shutdowns, turnarounds and outages as per ARP-A. Have detailed knowledge of the following items as it pertains to shutdowns: ▪ Scope management (planning, definition, verification and control) ▪ Time management (activity definition and scheduling) ▪ Cost management ▪ Quality management ▪ Human resource management ▪ Communications management ▪ Risk management ▪ Contractor management

Computerized Maintenance Management Systems (CMMS)	Understand: ▪ what the purpose of a CMMS is ▪ how efficient use of a CMMS can benefit reliability ▪ the importance of correctly recording information in the CMMS, including failure codes Have a basic understanding of the common components in a typical CMMS.	Understand the various components of a typical CMMS and its associated application in reliability including: ▪ Labor force information (skills, availability, etc.) ▪ Asset data (name plate data, criticality, cost codes, drawings, etc.) ▪ Work management information (work order details, resource reservation, safety procedures, etc.) ▪ Materials management (store rooms, parts tracking, reordering, vendor management, etc.) ▪ Purchasing (requisitions, order tracking, approvals, etc.) Assist in the development of failure codes: ▪ a practical and manageable system ▪ a system that will provide data that can be analyzed	Have a general understanding of the common components of a typical CMMS. Understand: ▪ the interrelationships between the CMMS and other management systems in the organization ▪ methods to quantify the benefits of an efficient CMMS ▪ ensure there is a system of recording failure codes that is used by all maintenance staff

PRECISION SKILLS (PRECISION AND PROACTIVE MAINTENANCE)

Precision skills topic	ARP-A	ARP-E	ARP-L
General overview	Understand the importance of precision maintenance skills: ▪ how it benefits the organization if precision skills are utilized ▪ why the additional time required to perform the job correctly is warranted, ▪ why procedures should be documented and followed, ▪ why special tools are required and used, ▪ why training is required to use the tools properly Understand the importance of proactive maintenance: ▪ Avoiding future problems if proactive tasks are done today	Be able to specify how each of the precision skill tasks should be performed correctly: ▪ ensure that the maintenance and operations groups are aware that additional time will be required to perform the task correctly, ▪ develop (or provide existing) standard operating procedures for each of the tasks, Understand the proactive maintenance opportunities ▪ ensure the proactive maintenance tasks a well defined ▪ ensure the proactive maintenance tasks are performed	Understand the importance of the precision skills and ensure that: ▪ funding is provided to purchase the necessary tools ▪ funding is provided for training on how to operate those tools ▪ operations understands the importance of these practices so that time is made available for their use ▪ Operators are involved in the performance of certain proactive tasks, including cleaning ▪ maintenance understands the importance of these practices so they are always utilized ▪ the ARP -E Reliability Engineer is provided with adequate support and funding ▪ the business case for employing precision skills is documented
Shaft alignment	Understand the basic principles of precision shaft alignment:	Understand: ▪ the importance of following safety procedures	Understand the basic principles of precision shaft alignment as per Category I and understand the

	▪ a precision aligned machine is more reliable ▪ dial indicators and lasers can be used to perform precision shaft alignment ▪ it is not possible to precision align a machine using a straight edge	▪ the basics of how to perform dial indicator alignment and the key challenges to accuracy ▪ the basics of how to perform laser alignment and the key challenges to accuracy ▪ common challenges including becoming bolt-bound, base-bound, and dealing with thermal growth	basics of how precision alignment is performed
Balancing	Understand the basic principles of precision rotor balancing: ▪ a precision balanced rotor runs more smoothly ▪ a precision balanced machine has less vibration and therefore less stress on its components ▪ a rotor can be balanced when it is still in the machine or via a balance machine	Understand: ▪ the importance of following safety procedures ▪ the basics of how to perform rotor balancing ▪ the difference between single-plane and two-plane balancing ▪ the challenges associated with flexible rotor balancing ▪ the difference between in situ balancing and machine shop balancing ▪ the ISO 1940 balancing standards and the importance of balancing to G1.0 or better	Understand the basic principles of precision rotor balancing as per ARP-A, and the steps involved in balancing a rotor correctly as per ARP-E, and: ▪ ensure that standards are in place specifying how balance jobs will be performed ▪ ensure that acceptance testing is used to check rotors balanced by contractors
Fastening	Understand: ▪ the importance of using the right type of fastener ▪ importance of tightening fasteners in the correct sequence ▪ importance of tightening fasteners to the correct torque	Understand: ▪ the importance of using the right type of fastener ▪ importance of tightening fasteners in the correct sequence ▪ importance of tightening fasteners to the correct torque ▪ the basic operation of torque wrenches and why it is not possible to tighten to the correct tension without one ▪ develop (or utilize existing) procedures to ensure that fastening is performed correctly	Understand the importance of following precision fastening procedures
Soft foot	Understand: ▪ what soft foot is, how it affects the reliability of rotating machinery, how to test for it, and how to correct it	Understand: ▪ what soft foot is, how it affects the reliability of rotating machinery, how to test for it, and how to correct it ▪ develop (or utilize existing) procedures to ensure that soft foot is always corrected	Understand the benefits of correcting soft foot
Looseness correction		Understand: ▪ the nature of rotating looseness, loose bolts and fasteners, and weak/flexible foundations ▪ how looseness affects the reliability of rotating machinery, ▪ the basics of how to test for looseness, and how to correct it ▪ develop (or utilize existing) procedures to	Understand the benefits of eliminating looseness

		ensure that looseness is always corrected	
Resonance correction	Understand: ▪ that resonance amplifies vibration resulting in high vibration that could be damaging or affect quality	Understand: ▪ the basic principles of natural frequencies and resonance ▪ the basics of how to test for resonance ▪ how to avoid resonance ▪ the basic principles of how to modify the structure to avoid resonance	Understand the need to eliminate resonance
Rolling element bearing installation	Understand the importance of installing rolling element bearings correctly: ▪ a bearing can be damaged during the installation process ▪ an incorrectly installed bearing causes excessive load and wear and thus it will fail prematurely ▪ there are special tools and procedures for installing bearings correctly which must be followed	Understand: ▪ the different types of rolling element bearings and their application: deep groove ball bearings, cylindrical roller bearings, etc. ▪ the importance of mounting and de-mounting bearings correctly ▪ how to test that bearings are installed correctly ▪ develop (or utilize existing) procedures to ensure that bearings are installed corrected	Understand the importance of installing rolling element bearings correctly as per ARP-A
Journal bearing installation		Understand: ▪ the different types and principles of operation of journal bearings: cylindrical bearings, elliptical bearings, etc. ▪ the importance of installing journal bearings correctly ▪ develop (or utilize existing) procedures to ensure that bearings are installed corrected	Understand the importance of installing journal (plain) bearings correctly
Mechanical seal installation	Understand: ▪ the basic design of seals ▪ the importance of installing seals correctly	Understand: ▪ the basic design of seals ▪ the importance of installing seals correctly ▪ develop (or utilize existing) procedures to ensure that seals are installed corrected	Understand the importance of installing mechanical seals correctly
Electrical installations	Understand the importance of making proper electrical terminations and cable runs	Understand: ▪ the importance of crimping/terminations (fasteners, method, sizing) ▪ the importance of correctly installed cable runs (type, length, tray fastening/layout/earthing, conduit protection), and environmental issues (moisture, vibration, fugitive gas, dust)	As per ARP-A
Verifying electrical systems	Understand the need to verify the integrity of electrical systems	Understand the need to verify the integrity of electrical systems via: ▪ fault current ▪ earth loop ▪ impedance, ▪ insulation resistance, ▪ protection testing (trip curve)	As per ARP-A

Power quality	Understand the effects of poor power quality	Understand the effects and sources of poor power quality: ▪ earth loops ▪ power factor ▪ harmonics ▪ earthing/bonding ▪ EN60130 ▪ Electrical resonance (VFD and supply)	As per ARP-A
Commissioning of electrical equipment	Understand the importance of calibration tracking, loop tuning, and process data alarms	Understand the importance and the details of calibration tracking, loop tuning, and process data alarms	As per ARP-A
General principles of installing mechanical components	Understand the importance of installing all mechanical components, for example motors, pumps, gearboxes etc. in order to ensure that defects are not introduced and reliability is optimized	Ensure: ▪ safety practices are understood and followed at all times ▪ there are standard procedures provided to all mechanics when performing work on mechanical components ▪ the mechanics are properly trained on these procedures ▪ the mechanics have the appropriate tools to carry out these procedures ▪ the planner understands these procedures	Understand the importance of installing all mechanical components correctly as per ARP-A
General principles of installing electrical components	Understand the importance of installing all electrical components, for example circuit breakers, fuses, conductors etc. in order to ensure that defects are not introduced and reliability is optimized	Ensure: ▪ safety practices are understood and followed at all times ▪ there are standard procedures provided to all electricians when performing work on electrical components ▪ the electricians are properly trained on these procedures ▪ the electricians have the appropriate tools to carry out these procedures ▪ the planner understands these procedures	Understand the importance of installing all electrical components correctly as per ARP-A
Grease lubrication	Understand the importance of precision greasing and contamination control: ▪ the correct grease must always be used ▪ the same grease must always be used ▪ too much grease or too little grease will damage the bearing ▪ contaminated grease will damage the bearing	Ensure: ▪ bearings are precision lubricated to eliminate contamination and under or over greasing ▪ there is documentation specifying which grease should be used for each item of equipment ▪ there are standard procedures for how to apply grease Understand: ▪ the basic principles of grease lubrication ▪ the ways in which grease can become contaminated	Understand the importance of precision greasing and contamination control as per ARP-A. Provide strict guidelines on the management of lubricants and the focus that must be given to precision lubrication
Oil lubrication	Understand the importance of precision lubrication and contamination control:	Ensure: ▪ bearings and gears are precision lubricated to eliminate contamination	Understand the importance of precision lubrication and contamination control as per ARP-A

	▪ the properties of the oil are critically important to the reliable operation of the machine ▪ contamination can degrade the ability of the oil to do its job correctly ▪ contamination can harm the lubricated components ▪ understand the most common sources of contamination and how contamination can be avoided ▪ understand the importance of correct selection, receipt, storage, issue, and replenishment	▪ there is documentation specifying which lubricants should be used for each item of equipment ▪ there are standard procedures staring, dispensing, replacing and removing oil Understand: ▪ the fundamentals of oil lubrication ▪ the ways in which oil can become contaminated ▪ the basics of filtration Understand: ▪ importance of correct lubricant selection, receipt, storage, issue, and replenishment and the impact these issues have on contamination	Provide strict guidelines on the management of lubricants and the focus that must be given to precision lubrication

CONDITION MONITORING

Condition monitoring topic	ARP-A	ARP-E	ARP-L
General overview	Understand the importance of condition monitoring: ▪ how it benefits the organization if the health of mechanical and electrical equipment is known ▪ how condition monitoring can be used to determine when maintenance is required ▪ how observations made by operators, craftspeople and others provide valuable equipment health information ▪ that specialist equipment is far more sensitive than our human senses ▪ that a combination of condition monitoring technologies provides a clear picture than the use of just one technology	Ensure: ▪ All condition monitoring tests add value and can thus be justified ▪ the difference between "age related" and "random" failures is understood ▪ equipment criticality and failure modes are understood so that the correct technologies are utilized ▪ P-F interval is understood so that tests are performed at the correct interval ▪ condition monitoring tests are always performed correctly and understand the difference between repeatability and accuracy	Understand the importance of condition monitoring as per Category I and ensure that: ▪ the business case is understood so that technologies and monitoring methods can be applied as required ▪ funding is provided to purchase the necessary condition monitoring equipment and software ▪ funding is provided for training on the equipment and software ▪ condition monitoring technicians and analysts are correctly trained and certified according to ISO 18436 and ISO/IEC 17024 ▪ operations understands that certain condition monitoring tests require that equipment be run in a controlled state ▪ operators are involved in performing inspections and other basic condition monitoring tests ▪ maintenance understands the philosophy of condition-based maintenance ▪ the relationship between condition monitoring and risk management is understood

			▪ incidents of cost avoidance are documented and publicized ▪ the ARP-E Reliability Engineer is provided with adequate support and funding
Vibration analysis	Understand the basic principles of vibration analysis: ▪ how measurements are collected ▪ vibration provides an indication of the nature and severity of the fault condition in rotating machinery ▪ simple overall level readings only provide a basic (and late) indication of the nature and severity of the fault condition ▪ that spectrum analysis helps to pinpoint the source of vibration and the nature and severity of the fault condition	Understand: ▪ the basic principles of vibration analysis including the FFT, time waveform, and phase ▪ where spectra, phase, time waveforms, and other techniques should be used ▪ the basic spectral patterns of unbalance, misalignment, looseness, resonance, and rolling element bearing faults ▪ the limitations of overall level measurements ▪ the difference between routine data collection with portable instruments, automated online monitoring, continuous monitoring, and protection systems and we each should be used	Understand the basic principles of vibration analysis as per ARP-A. Understand that there can be economic benefits, and a risk reduction if on-line monitoring and optionally protection systems are utilized.
Ultrasound	Understand the basic principles of ultrasound analysis: ▪ how ultrasound measurements are collected ▪ applications include leak detection, ultrasound assisted greasing, mechanical and electrical fault detection, and other process fault identification applications	Understand: ▪ the basic principles of contact and noncontact ultrasound testing ▪ the strengths and weaknesses of ultrasound ▪ how ultrasound can be used when greasing bearings ▪ how ultrasound can detect mechanical faults that vibration analysis cannot detect ▪ the electrical applications of ultrasound ▪ the general process applications of ultrasound including detection of faulty steam traps ▪ how ultrasound can be used in combination with vibration analysis and infrared analysis	Understand the basic principles of contact and non-contact ultrasound testing as per ARP-A
Infrared analysis (thermography)	Understand the basic principles of infrared analysis: ▪ how infrared measurements are collected and the difference between a spot radiometer and a thermal imaging camera ▪ infrared analysis enables the analyst to	Understand: ▪ the basic principles of infrared analysis ▪ the strengths and weaknesses of infrared analysis ▪ the principle theory including emissivity, reflection, camera focus and resolution, and environmental test conditions to ensure	Understand the basic principles of infrared analysis as per ARP-A

	detect abnormal temperatures ▪ infrared analysis does not actually measure temperature and issues such as reflections and environmental conditions affect measurements ▪ temperature change can indicate the presence of a problem in mechanical, electrical and process equipment ▪ temperature change in mechanical equipment is a late stage indicator of a problem	data is collected correctly ▪ the electrical and mechanical applications of thermography ▪ the general process applications of thermography including detection of faulty steam traps ▪ how infrared analysis can be used in combination with vibration analysis and ultrasound	
Oil analysis	Understand the basic principles of oil analysis: ▪ how oil samples are collected ▪ how oil samples are tested (in very basic terms) ▪ oil analysis determines if the chemistry of the oil is correct ▪ oil analysis detects contamination ▪ oil analysis detects wear ▪ oil analysis can be used to determine when oil changes are required	Understand: ▪ the basic principles of oil analysis sampling and testing ▪ key properties including viscosity ▪ key testing including spectrometric analysis, FTIR, particle counting, and the PQ index. ▪ how critically important it is that the lubricant has the correct chemical properties and is not contaminated ▪ the tests that can be performed on-site versus at an oil lab ▪ how to take oil samples correctly ▪ the limitations of the human to detect water or particles in oil ▪ the limitations of oil analysis when it comes to particle detection ▪ how to interpret the key data on an oil analysis lab report	Understand the basic principles of oil analysis as per ARP-A
Wear particle analysis	Understand the basic principles of wear particle analysis: ▪ how oil samples are collected ▪ how the samples are prepared and tested under a microscope (in very basic terms) ▪ wear particle analysis detects contaminants as well as wear particles ▪ the shape size and color of wear particles indicate the source of the particles and the nature and severity wear	Understand: ▪ the basic principles of wear particle analysis ▪ the difference between wear particle analysis and the testing techniques performed under oil analysis ▪ the need to perform wear particle analysis on gearboxes and hydraulic equipment ▪ that wear particles are useful for root cause failure analysis	Understand the basic principles of wear particle analysis as per ARP-A
Motor current/voltage/circuit analysis	Understand the basic principles of electric motor testing: ▪ the current can be analyzed to detect certain faults within the motor	Understand: ▪ the difference between motor current analysis and electrical signature analysis ▪ the types of faults that can be detected by	Understand the basic principles of electric motor testing as per ARP-A

	▪ the voltage can be analyzed to detect problems with supply ▪ off-line tests can be performed which test the electrical properties of motors in order to detect defects	analyzing the motor current ▪ the types of faults that can be detected by analyzing the supply voltage ▪ the basic details of motor circuit analysis and the faults that can be detected ▪ the application of motor circuit analysis as part of an acceptance testing process	
Non Destructive Testing (NDT)	Understand: ▪ the basics of the NDT techniques ▪ the relationship between the NDT techniques and safety	Understand: ▪ the basic principles of magnetic particle testing, liquid penetrant testing, radiographic testing, ultrasound testing, and visual testing ▪ the relationship between the NDT techniques and safety	Understand the basic principles of NDT testing as per ARP-E
Process/performance monitoring	Understand: ▪ that changes in process provide useful information, possibly indicating an underlying problem ▪ the need to also monitor the performance	Understand: ▪ the importance of monitoring the performance of rotating machinery as a condition monitoring technique ▪ that performance monitoring provides an indication of whether an asset has functionally failed ▪ that operating rotating machinery incorrectly will lead to reduced life	Understand the basic principles of performance monitoring as per ARP-E
Visual inspection	Understand: ▪ the importance of using sight, sound and smell in order to detect problems ▪ the importance of reporting observations that indicates that an asset is not functioning normally	Understand: ▪ the difference between intrusive and nonintrusive tests and the risk posed to equipment and safety when intrusive tests are performed ▪ the importance of seeking the cooperation of operators, mechanics and electricians so that observations are reported	Understand the basic principles of nonintrusive visual inspection as per ARP-E & ARP-E. Understand the importance of involving operators in the condition monitoring process.
Electrical insulation testing		Understand: ▪ the basic principles of testing insulation, including partial discharge, surge testing, polarization index, inductive testing, capacitive testing, and microOhm testing ▪ the application of partial discharge to transformers and switchgear	

CONTINUOUS IMPROVEMENT

Continuous improvement topic	ARP-A	ARP-E	ARP-L
General overview	Understand that the process of proactively improving reliability is a long-term process and thus requires continuous improvement.	Understand: ▪ reliability improvement is not a short-term project ▪ all activities must add value ▪ it is necessary to document the returns achieved from each reliability improvement activity ▪ when failure occurs, or when problems exist, root cause analysis is an effective tool to solve those problems and eliminate reoccurrence	Understand: ▪ continuous improvement is key to long-term success ▪ all reliability improvement activities must add value ▪ it is necessary therefore to understand the goals of the organization ▪ it is necessary to develop KPIs in order to measure progress and identify opportunities for improvement ▪ benchmarking can also be used to assess opportunities for improvement ▪ it is necessary to continually seek to improve as long as all activities continue to add value
Business justification	Understand: ▪ that the only reason we seek to improve reliability is to enable the organization to achieve its goals ▪ the goals of the organization will place varying priority on downtime avoidance, capacity improvement, cost reduction, throughput improvement, quality maximization, safety and environmental incident reduction	As per ARP-A.	Understand: ▪ how to assess the relative importance of downtime avoidance, capacity improvement, cost reduction, throughput improvement, quality maximization, safety and environmental incident reduction in an organization ▪ that priorities may differ in different parts of the plant/facility
PDCA/Kaizen/Lean	Understand: ▪ the basic principles and importance	Understand: ▪ the need to follow PDCA ▪ the Lean techniques that reduce waste and improve efficiency ▪ the Kaizen principles	Understand: ▪ the importance of following PDCA ▪ the application of Kaizen ▪ the relationship between Lean and the reliability improvement initiative ▪ the opportunity to reduce waste using Lean techniques
Benchmarking			Understand: ▪ the need to benchmark ▪ different types of benchmarking (and their pros and cons) including the use of documented industry benchmarks, benchmarking against and organizations "best day", and benchmarking against design capacity
Key Performance Indicators	Understand: ▪ the basic concept of KPIs	As per ARP-A but in more detail	Understand: ▪ the basic concept of utilizing KPIs ▪ the difference between leading and lagging KPIs

	▪ that KPIs provide an indication of the success of the program ▪ the difference between leading and lagging KPIs ▪ how KPIs can be used to identify opportunities for improvement ▪ that it is more important to measure the KPI successfully instead of solely seeking to achieve KPI goals		▪ the importance of measuring what needs to be improved ▪ the pitfalls of establishing employment incentives based on KPIs ▪ how to calculate the following common KPIs: OEE, availability, capacity, schedule compliance
Communication	Understand the importance of collecting and communicating reliability performance indicators	Understand the importance of recording the status of projects, failures and successes, and accurate performance and KPI data, and reporting that information to the team leader (ARP-L) who will communicate that information to the rest of the company	Understand: ▪ how important it is to communicate both success and failure ▪ the types of information that should be communicated ▪ how to assess the best means and frequency of communication
Root Cause (Failure) Analysis	Understand: ▪ that root cause analysis can be used to solve a wide range of problems ▪ that root cause failure analysis can be used to identify why a problem occurred and to eliminate the reoccurrence of the problem ▪ that there are multiple RCA techniques ▪ the basics of the "five why" method	Understand: ▪ the importance of the Failure Reporting, Analysis, and Correct Action Systems (FRACAS) ▪ the basic RCA and RCFA processes ▪ the following techniques: five why, fault tree analysis, Ishikawa (fishbone) ▪ the need to establish a logical process for determining which technique should be used ▪ most common reasons why the RCFA process will fail ▪ the need to deal with the root cause and not just the symptom	Mandate the use of the FRACAS so that RCA projects are common (but well structured) throughout the organization. Ensure that the focus is on root cause *elimination*, not just *identification*.
Visual workplace & error proofing	Understand: ▪ that mistakes can be made due to the work environment ▪ the basics of error proofing and the visual workspace	Understand: ▪ the importance of error proofing the workplace, to avoid mistakes ▪ the basics of the visual workspace	As per ARP-A