ENSURING THE EXPERTISE TO GROW
SOUTH AFRICA

Discipline-Specific Training Guide for Registration as a Professional Engineer in Mechanical Engineering

R-05-MEC-PE

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DEFINITIONS

Certification: Formal recognition awarded to an education or training programme through a quality assurance procedure specifying that it meets the criteria laid down for the type of programme.

Competency Standard: Statement of competency required for a defined purpose.

Complex engineering work: This work is characterised by the following:

(a) Scope of activities may encompass entire complex engineering systems or complex subsystems.
(b) A context that is complex and varying, is multidisciplinary, requires teamwork, is unpredictable and may need to be identified.
(c) It requires diverse and significant resources: including people, money, equipment, materials, technologies.
(d) Significant interactions exist among wide-ranging or conflicting technical, engineering or other issues.
(e) It is constrained by time, finance, infrastructure, resources, facilities, standards and codes, and applicable laws.
(f) It has significant risks and consequences in a range of contexts.

Engineering problem: A problematic situation that is amenable to analysis and solution using engineering sciences and methods.

Engineering science: A body of knowledge that is based on the natural sciences and uses mathematical formulation where necessary, which extends knowledge and develops models and methods to support its application, to solve problems and to provide the knowledge base for engineering specialisations.

Ill-posed problem: Problems for which the requirements are not fully defined or may be defined erroneously by the requesting party.

Integrated performance: An overall satisfactory outcome of an activity requires several outcomes to be satisfactorily attained. For example, a design requires analysis, synthesis, analysis of impacts, checking of regulatory conformance and judgement in decisions.

Level descriptor: A measure of performance demands at which outcomes must be demonstrated.
Management of engineering work or activities: The co-ordinated activities required are to:

- directly and control everything that is constructed or results from construction or manufacturing operations
- operate engineering works safely and in the manner intended
- return the engineering works, the plant and the equipment to an acceptable condition by the renewal, replacement or mending of worn, damaged or decayed parts
- direct and control the engineering processes, systems, commissioning, operation and decommissioning of equipment
- maintain engineering works or equipment in a state in which it can perform its required function.

Mentor: A professionally registered person who guides the competency development of a candidate in an appropriate category.

Over-determined problem: A problem for which the requirements are defined in excessive detail, making the required solution impossible to attain in all its aspects.

Outcome: A statement of the performance that a person must demonstrate to be judged competent at the professional level.

Practice area: A generally recognised or distinctive area of knowledge and expertise developed by an engineering practitioner by virtue of the path of education, training and experience followed.

Range statement: The required extent of or limitations on expected performance stated in terms of situations and circumstances in which outcomes are to be demonstrated.

Specified category: A category of registration for persons registered through the Engineering Profession Act, 46 of 2000 or through a combination of the Engineering Profession Act and external legislation with specific Engineering competencies at NQF Level 5 regarding an identified need to protect the safety, health and interest of the public and the environment, in relation to an engineering activity.

Supervisor: A person who oversees and controls engineering work performed by a candidate.
**ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbr.</th>
<th>Description</th>
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<tbody>
<tr>
<td>BEng</td>
<td>Bachelor of Engineering</td>
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<tr>
<td>BSc Eng</td>
<td>Bachelor of Science in Engineering</td>
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<tr>
<td>C&amp;U</td>
<td>Commitment and Undertaking</td>
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<tr>
<td>DSTG</td>
<td>Discipline-Specific Training Guide</td>
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<tr>
<td>EIAs</td>
<td>Environmental Impact Assessments</td>
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<tr>
<td>HVAC</td>
<td>Heating, Ventilating and Air-Conditioning</td>
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<tr>
<td>MEng</td>
<td>Master of Engineering</td>
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<tr>
<td>OFO</td>
<td>Organising Framework for Occupations</td>
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<tr>
<td>PCE</td>
<td>Professional Certificated Engineer</td>
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<td>PE</td>
<td>Professional Engineer</td>
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<tr>
<td>PGDip</td>
<td>Post-graduate Diploma</td>
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<tr>
<td>PFD</td>
<td>Process Flow Diagram</td>
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<tr>
<td>PLC</td>
<td>Programmable Logic Controllers</td>
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<tr>
<td>PLM</td>
<td>Product Lifecycle Management</td>
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<tr>
<td>PN</td>
<td>Professional Engineering Technician</td>
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<tr>
<td>PT</td>
<td>Professional Engineering Technologist</td>
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<tr>
<td>QA</td>
<td>Quality Assurance</td>
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<td>QC</td>
<td>Quality Control</td>
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<td>QMP</td>
<td>Quality Management Plan</td>
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<td>RPS</td>
<td>Research, Policy and Standards</td>
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<tr>
<td>SCADA</td>
<td>Supervisory Control and Data Acquisition</td>
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<td>SEMP</td>
<td>Systems Engineering Management Plan</td>
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<td>SOW</td>
<td>Statements of Work</td>
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<tr>
<td>TES</td>
<td>Training and Experience Summary</td>
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<td>TERs</td>
<td>Training and Experience Reports</td>
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<tr>
<td>WBS</td>
<td>Work-breakdown Structures</td>
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BACKGROUND

The illustration below defines the documents that comprise the Engineering Council of South Africa (ECSA) system for registration in professional categories. The illustration also locates this document.

Figure 1: Documents defining the ECSA Registration System
1. PURPOSE OF THIS DOCUMENT

All persons applying for registration as Professional Engineers are expected to demonstrate the competencies specified in the Competency Standard for Registration in Professional Categories (document R-02-STA-PE/PT/PCE/PN) through work performed at the prescribed level of responsibility, irrespective of the trainee’s sub-discipline. This document supplements the generic ‘Training and Mentoring Guide for Professional Categories’ (document R-04-T&M-GUIDE-PC) and the ‘Guide to the Competency Standards for Professional Engineers’ (document R-08-PE).

In document R-04-T&M-GUIDE-PC, attention is drawn to the following sections:

- Duration
- Planning principles
- Progression of training programme
- Documenting training and experience
- Demonstrating responsibility.

Document R-08-PE provides a high-level, outcome-by-outcome understanding of the competency standards that form an essential basis for this Discipline-specific Training Guide (DSTG).

Documents R-04-T&M-GUIDE-PC and R-08-PE are subordinate to the ‘Policy on Registration in Professional Categories’ (document R-01-POL-PC), the Competency Standard (document R-02-STA-PE/PT/PCE/PN) and the ‘Processing of Applications for Registration of Candidates and Professionals’ (document R-03-PRO).

2. AUDIENCE

This DSTG is directed towards Candidates and their Supervisors and Mentors in the discipline of Mechanical Engineering. The guide is intended to support or applies to persons who have:

- completed the tertiary educational requirements in Mechanical Engineering by obtaining an accredited:
  - BEng/BSc(Eng)/BIng-type programmes (document E-02-PE) listed on the ECSA website

CONTROLLED DISCLOSURE

When downloaded for the ECSA Document Management System, this document is uncontrolled and the responsibility rests with the user to ensure that it is in line with the authorised version on the database. If the ‘original’ stamp in red does not appear on each page, this document is uncontrolled.

QM-TEM-001 Rev 0 – ECSA Policy/Procedure
3. PERSONS NOT REGISTERED AS A CANDIDATE AND/OR NOT TRAINED UNDER COMMITMENT AND UNDERTAKING.

Irrespective of the development path followed, all applicants for registration must present the same evidence of competence and be assessed against the same standards as prescribed in document R-02-STA-PE/ PT/PCE/PN. Application for registration as a Professional Engineer is permitted without being registered as a Candidate Engineer and without training under C&U. Mentorship and adequate supervision are, however, key factors in effective development to the level required for registration.

If the trainee’s employer does not offer C&U, the trainee should establish the level of mentorship and supervision the employer is able to provide. In the absence of an internal Mentor, the services of an external Mentor should be secured. The Voluntary Association for the discipline may be consulted for assistance in locating an external Mentor. A Mentor should keep abreast of all stages of the development process.

This DSTG is written for the Candidate/applicant who is training and gaining experience towards registration. Applicants who have not enjoyed mentorship are advised to request an experienced Mentor (internal or external) to act as an application adviser while they prepare their applications for registration.
4. ORGANISING FRAMEWORK FOR OCCUPATIONS

Mechanical Engineering – Organising Framework for Occupations (OFO) 214401

Mechanical Engineering is concerned with the design, development, installation, operation and maintenance of just about anything that has movable parts. It involves the production, transmission and use of mechanical power. Mechanical Engineers work in different industries and job opportunities within these industries include:

- **Design**: turning plans into new products or revising existing ones.
- **Production**: planning and designing new production processes; maintaining equipment.
- **Research and development**: continually trying to find solutions to engineering problems, using new technologies when they become available.

Mechanical Engineering involves the planning, design, construction, operation and maintenance of materials, components, machines and plants, including systems for lifting, hoisting and handling of materials as an example. The discipline is concerned with turbines, pumps and fluid power, heating, cooling, ventilating and air-conditioning, fuels, combustion, engines and gas turbines in addition to steam, petrochemical and food processing plants. Mechanical Engineering also focuses on automobiles, trucks, aircraft, ships, special vehicles, lifts and escalators as well as fire protection and nuclear energy power generation. Mechanical Engineers advise on the mechanical aspects of materials, products and processes through the application of the engineering sciences of mechanics, solid mechanics, thermodynamics, fluid mechanics, physics, chemistry, applied mathematics and computational techniques.

Typical tasks a Mechanical Engineer may undertake include the following:

- Advising on and designing machinery and tools for manufacturing, mining, construction, agricultural and other industrial purposes.
- Advising on and designing steam, internal combustion and other non-electric motors and engines, gear boxes and drive trains used for propulsion of railway locomotives, road vehicles and aircraft and systems for driving industrial and other machinery.
- Advising on and designing hulls, superstructures and propulsion systems of ships, mechanical plants and equipment for the release, control and utilisation of energy in addition
to heating, ventilation and refrigeration systems, steering gear, pumps, pipe work, valves and other associated mechanical equipment.

• Advising on and designing airframes, undercarriages and other equipment for aircraft suspension systems, brakes, vehicle bodies and other components of road vehicles.

• Advising on and designing non-electrical parts of apparatus or products such as word processors, computers, precision instruments, cameras and projectors.

• Establishing control standards and procedures to ensure efficient functioning and safety of machines, machinery, tools, motors, engines, industrial plants, equipment and systems.

• Ensuring the operation and maintenance of equipment complies with design specifications and safety standards.

Practising Mechanical Engineers generally specialise in expert fields as one or more of the following:

• Fire Protection and Detection Engineer (includes air-conditioning, heating and ventilation)
• Automotive Engineer
• Diesel Engineer
• Fluid Mechanics Engineer
• Forensic Engineer
• Heating and Ventilation Engineer
• Machine Design and Development Engineer
• Maintenance Management Engineer
• Mechanical Engineer – Mining industry
• Mechatronics Engineer
• Piping Engineer
• Power Generation Engineer (Mechanical Systems)
• Pressurised Vessels Engineer
• Propulsion System Engineer
• Rotating Equipment Plant Engineer
• Structural Steel Engineer
• Thermodynamics Engineer
• Transportation Systems Engineer
• Applied Mechanics Engineer
5. NATURE AND ORGANISATION OF THE INDUSTRY

Mechanical Engineers may be employed in either the private or the public sector. In the private sector, Mechanical Engineers are typically involved in consulting and contracting, and work in supply and manufacturing organisations. Engineering consultants are responsible for planning, designing, documenting and supervising the construction of projects on behalf of their clients. Engineering contractors are responsible for project implementation and their activities include design, planning, construction, plant erection, commissioning and labour, and resource management. Mechanical Engineers working in supply and manufacturing companies are involved in production, supply, product certification and quality assurance and control, and may be engaged in research and development.

The public sector is responsible for service delivery and is usually the client. However, in some departments, design and construction are also carried out. Mechanical Engineers are required at all levels of the public sector, including at national, provincial and local government levels, and in state-owned enterprises and public utilities. The public sector largely handles planning, specifying and overseeing implementation of infrastructure projects in addition to engaging in operations and maintenance of infrastructure. An extension of the public sector includes tertiary academic institutions and research organisations.

Depending on where the Candidate is employed and the nature of the enterprise, there may be situations where the in-house opportunities are insufficiently diverse to develop all the required competencies noted in groups A and B in document R-02-STA-PE/PT/PCE/PN. For example, the opportunities for developing problem-solving competence (including designing and developing solutions) and for managing Engineering activities (including implementing and constructing solutions) may not be available to Candidates through their direct employers. In such cases, employers are encouraged to implement a secondment system, enabling Candidates to obtain
experience in a specific category of training. It is fairly common practice that for situations in which organisations are unable to provide training in certain areas, secondments are arranged with other organisations so that Candidates are able to develop all the competencies required for registration. Problem-solving of mechanical systems in design, operation, construction and research environments is the core of Mechanical Engineering. It is a logical thinking process that requires engineers to apply their minds diligently in bringing solutions to technically complex problems. This process involves analysis of systems or the assembly of mechanical components and the integration of various elements of Mechanical Engineering through the application of basic and engineering sciences.

Problem-solving experience may be obtained in the following work categories that are linked to the lifecycle of the product, system, plant or equipment.

5.1 Investigation
The Candidate may be tasked to perform specific investigations, literature studies, process evaluations, defect or failure investigations, product performance evaluations and manufacturing or production baseline studies. The technical information thus gathered may then be used in design improvement, process optimisation, performance enhancement and product, system and plant efficiency upgrades. The type of work outputs can generally be used as inputs for mechanical engineering processes further along the value chain. The investigation phase of a project, which may be labelled formally as pre-feasibility, concept or feasibility, is a significant part of the Mechanical Engineering design process. Investigation in its most fundamental form is a process whereby a stated objective or mandate is explored in terms of the parameters of the specific situation, perhaps more aptly referred to as ‘Investigation of the Engineering Problem’.

Candidates are often exposed to the detailed area of the investigation under the supervision of an experienced, professional Mechanical Engineer.

It is useful for the purpose of this guide to separate the investigation phase into two distinct categories:
- Optimisation or modification of existing projects
- New projects.
Candidates could either be expected to design or develop a solution for improving or modifying an existing (brownfield) process or to design/develop a solution for a new (greenfield) project that has a more open-ended mandate.

The Candidate Mechanical Engineer needs to consider many aspects and follow certain steps in the investigation process to interrogate the given scope of work. The analysis must define and investigate the given scope of work to identify the characteristics of a 'complex engineering problem' as defined under R-08-PE.

This should include but not be limited to:

- defining the assumptions and limitations for the design basis considered
- choosing a combination of applicable fundamental principles of Mechanical Engineering to formulate a technical design basis
- defining the most appropriate integrated technical design basis (fundamental principles) and legislative design basis (appropriate legislative requirements)
- developing empirical models where specific design conditions/parameters cannot be estimated with theoretical models/defined fundamental models
- providing for innovation, safety and cost benefit analysis (Opex & Capex)
- investigating how the solution will improve the lives of the affected communities, society and the surrounding environment.

The investigation phase is critical to the development of Candidate Mechanical Engineers because it provides an opportunity to identify real-world scenarios. Employers often test Candidates by assigning them low-risk or non-critical items that could be solved in the space of a few weeks or months. This is insufficient.

5.2 Research and development

This type of work is carried out in the research and product-development centres of business organisations and academic institutions. Candidates undertake research and development work that is predominantly of a Mechanical Engineering nature, and this work involves an in-depth application of the various aspects of Mechanical Engineering, including product or system testing under controlled experimental conditions.
While Mechanical Engineers gain a vast amount of fundamental and first-principle knowledge in their tertiary education, industry problems require taking that knowledge one step further. After having identified a problem and investigating it, the research and development phase is the next step towards implementing a rational design to solve the problem.

Research/development is often assumed to be a task reserved for academic researchers or industry-partnered research institutions. However, the Candidate Mechanical Engineer will be confronted with the development of solutions based on collecting the information during the investigation phase, irrespective of the environment. It is important that the research and development work presented by the Candidate is original in nature and solely undertaken by the Candidate applying for registration as a Professional Engineer in a personal capacity. Candidates may not submit work undertaken by their peers/research students, whereby the Candidate’s role was supervision.

Research/development includes many available options, depending on the industry and application, for example:

- Consulting peer-reviewed academic journals in respect of novel technology.
- Conferring with technical representatives of industry associations.
- Consulting with industry specialists who may be equipment vendors and sometimes development requires test work to be done to verify the concepts identified in the research.

Many clients insist on proving a process on the bench or on a pilot scale since ultimately, vast amounts of money may be spent on the construction.

5.3 Process design

Process design in this guide refers to the synthesis of a solution to an engineering problem. A complex engineering problem has been posed and investigated, and all available tools are utilised to obtain a solution to it. The success of the engineering approach to this step is directly dependent on the preceding investigation and development/research steps.

The process synthesis would naturally follow the sequence:
• Block Flow Diagram – define fundamental process steps involved including applicable legislative requirements.
• Process Flow Diagram (PFD) – select the unit operations and define the inputs and outputs of the process as well as assumptions based on specific conditions.
• Mass and energy balance in conjunction with the PFD – reagent consumption, utility requirements, economics of the plant.
• Piping and instrumentation diagrams – the process is defined in detail and accurate pricing can be obtained.

Examples of acceptable designs include:
• complex fluid systems, incorporating rotating and reciprocating machines
• complex machines and equipment or major parts thereof
• complex energy systems, involving heat and/or power transfer
• complex pressure systems (heating, ventilating and air-conditioning (HVAC) systems)
• complex structures of:
  o vehicles
  o boats
  o trains
  o aircraft structures
  o conveying equipment
  o piping systems
  o transmissions, drive trains, gearboxes
  o defence equipment
  o chemical process plants
  o equipment for handling materials
  o mine processing plants
  o pressurised systems, vessels, valves, equipment
  o buildings, hospitals, mechanical systems in public centres
  o process manufacturing plants.
Acceptable complex design reviews include reviews of major machine systems such as turbines and compressors with their auxiliary systems, power station systems and their major components, complex refrigeration systems, petrochemical plants and other production and manufacturing plant systems.

5.4 Risk and impact mitigation
Risk and impact mitigation mainly deal with the investigation of failure or under-performance of major equipment and systems and the synthesis of implemented and proven solutions to avoid recurrence of the problem. In addition, this category of work involves improvement projects that are necessary for optimising operational efficiencies. In risk and impact mitigation, engineers must apply professional engineering judgement to all work done. This includes the ability to assess design work against the following criteria:

- Conformance to design specifications and health and safety regulations
- Ease of fabrication and assembly
- Constructability
- Maintainability
- Conformance to environmental requirements
- Ergonomic considerations
- Lifecycle costs
- Alternative solutions.

5.5 Engineering project management
The Candidate Engineer must be granted the opportunity to manage an engineering project or facets thereof to gain integration experience relating to the product, system, equipment or plant in accordance with the enterprise’s project management methodology. Various standards and software are deployed in industry that are linked to international specialised knowledge and expert systems.

ECSA is not prescriptive in this regard, but aspects of the following should be included in the Candidate’s experience base of Engineering Project Management as far as practically possible:

- Engineering task formulation, work-breakdown structures (WBS), Statements of Work (SOW)
- Time-based scheduling, budgeting, personnel allocation, project staffing
• Equipment, facilities and site selection, preparation and planning
• Sub-contracting, procurement and supplier monitoring
• Financial budgeting, management, costing, value engineering
• Product lifecycle management (PLM) and planning
• Engineering change procedures, product baseline management, configuration control
• Technical documentation and reports management
• Technical staff training support and technical assistance and project support
• Project status and progress management, control and reporting
• Identification, planning and implementation of corrective action.

Examples of Engineering Project Management include setting up/establishing a Systems Engineering Management Plan (SEMP) or setting up/establishing a Project Management Plan (PMP) for a specific project or a specific phases of a project within the employer’s enterprise.

5.6 Implementation/Commissioning
Ideally, the Candidate Engineer gains exposure in an integration responsibility role, interfacing with other engineering disciplines related to the project, product, system or plant. This normally occurs when higher-level systems, equipment or plants are built, constructed or assembled on site and followed by commissioning and acceptance-test processes. Elements in which the Candidate may gain experience include the following:

• Assembly and compilation of build instructions, fits and clearances, build-record sheets
• Acceptance methods (means of compliance) (define, analyse, inspect, demonstrate, test)
• Planning and execution of commissioning process, preparation of ‘punch lists’
• Plant or equipment assembly, commissioning, pass-off testing, certification (in conjunction with inspection and/or quality assurance (QA) departments and inspectors)
• Environmental impact assessments, compliance, plant measurements during commissioning
• Mechatronics:
  o Plant control and automation (control and instrumentation (C&I) interfacing), condition and performance monitoring, measurements
  o Installation of control systems, commissioning, upgrade of hardware and software control systems
Plant performance monitoring, data acquisitioning (e.g., Scada, plc systems), digital systems and automation.

5.7 Production

Producibility of a product design in accordance with stipulated quality standards and specified acceptance criteria is a major element of a product’s lifecycle. The Candidate Engineer needs to obtain experience in product realisation either during the early development of models or prototypes or during the development of various models in the phases of the project (e.g., prototype, experimental, advanced, engineering development, pre-production or serial production).

Focus areas in which the applicant can obtain exposure include:

- material selection, raw material sourcing and certification
- processing techniques (computer numerical control (CNC) machining, milling, turning)
- special processes (welding, vacuum brazing, laser piercing, cutting, heat treatment, shot-peening, surface treatment, electro-discharge machining (EDM), cladding)
- surface coatings (nitriding, carburising, chromising, aluminiumising, plasma spray thermal coatings, plating, anodising)
- manufacturing process selection and optimisation (collaboration with Industrial/Process Engineers)
- manufacturing trials
- rapid prototyping, 3D additive manufacturing
- product acceptance (demonstration, test, inspect, measure) (digital coordinate measuring machine (CMM), fluid flow measurements)
- non-destructive testing (NDT) (dye penetrant, magnetic particle inspection, ultra-sonic, X-ray, tooling and fixture design, manufacture, tool proving
- manufacturing verification and validation procedures, quality assurance / quality control (QA/QC)
- first article acceptance, factory acceptance test
- quality audits, technical assistance in compilation of Quality Management Plan (QMP)
- quality inspection reports.
5.8 Operations and maintenance

Candidate Engineers may expect possible work involvement in Operations and Maintenance.

The phases of a product, system or plant lifecycle include:

- providing technical support for scheduled and planned maintenance actions
- safety, health, environment and quality (SHEQ) studies (evacuation, emergency and safe shutdown procedures, security systems, safeguards)
- prevention of hazardous material spillage, containment, risks identification
- plant site / system hazard identification and mitigation processes and procedures
- process hazard analysis (PHA)
- reliability, availability, maintainability (RAM) studies
- maintenance optimisation, plant shutdown and start-up procedures/sequences
- equipment monitoring (health and usage, condition monitoring), interfacing with C&I
- plant vibration, critical temperatures, pressures, mass flow monitoring
- radiation safeguards, plant zoning, ‘design for nuclear safety’ (e.g., for nuclear power plant)
- hazardous environments, operations, failure event studies (e.g., Hazard and operability [HAZOP], failure modes, effects and criticality analysis [FMECA])
- plant control and automation (C&I interfacing), performance monitoring, measurements, tests
- development of repair technology/techniques, salvaging schemes
- maintenance, repair and overhaul (MRO) of mechanical products, systems and plants
- logistics support analysis (LSA)
- lifecycle analysis, component lifing/endurance studies
- plant or system de-commissioning, decontamination, disposal, re-cycling of materials
- reversion in alloys, re-processing, alternative use
- plant site close-out, site rehabilitation, recovery.

6. DEVELOPING COMPETENCY: ELABORATING ON SECTIONS IN THE GUIDE REGARDING COMPETENCY STANDARDS (DOCUMENT R-08-PE)

Applicants are required to demonstrate insight and the ability to use and interface various design aspects through verifiable work carried out in providing engineered and innovative solutions to practical problems experienced in their operating work environments. In addition, applicants must
develop the skills required to demonstrate the advanced use of Mechanical Engineering knowledge in optimising the efficiency of operations or the constructability of projects.

Candidates must be able to demonstrate that they have been actively involved in a mechanical workshop environment and have participated in the execution of practical work to the extent that they have learnt sufficient details regarding basic mechanical procedures to be able to exercise judgement in the workplace. Applicants must also show evidence of adequate training in this function through complex project work carried out in the analysis of problems and the synthesis of solutions.

Evidence is required in the form of a separate comprehensive engineering report (design report may be required if not included in the engineering report) that must accompany the application. This report should describe synthesised solutions to sufficiently complex engineering problems to demonstrate that applicants have had the opportunity to apply their technical knowledge and engineering expertise gained through university education and practical work experience.

In applying technical and scientific knowledge gained through academic training, the applicant must also demonstrate the financial and economic benefits of engineered solutions synthesised from scientific and engineering principles at a sufficiently advanced level.

What is a sufficiently complex engineering problem?

According to ECSA, the definition of complex in complex engineering problems can be defined as: Composed of many inter-related conditions; requiring first principle empirical judgment to create a solution within a set of originally undefined circumstances.

Mechanical Engineering forms an integral part of broader engineering systems and infrastructure in technologically complex environments such as manufacturing, processing, mining, construction, product-development and research. Applicants are required to undertake mechanical engineering projects that significantly enhance the operability and constructability of integrated engineering systems and infrastructures. Such project work should not be stand-alone assignments but should form part of the solutions to integrated engineering systems that require a broad
application of various theoretical aspects of Mechanical Engineering ranging from fluid systems and energy systems to structures and machines.

Engineering design is a logical thinking process that requires engineers to apply their minds carefully in bringing solutions to technically complex problems. This process involves the analysis of systems or the assembly of mechanical components and the integration of various elements of Mechanical Engineering through the application of basic and engineering sciences. Simple and straightforward calculation exercises and graphical representations from computer-generated data are not considered sufficiently complex engineering designs since anybody with qualifications in basic science and engineering science is able to perform this type of work. Professional registration requires advanced application of engineering knowledge in complex design problems.

In demonstrating advanced application of theoretical knowledge in regard to these systems, it is advisable that applicants incorporate calculations with clearly defined inputs of the formulae used and detailed interpretation of the results obtained as this will be advantageous for application. In addition, applicants must demonstrate how the calculated results have been used to provide the solution to the problem at hand and indicate the economic benefit to the project or the operating work environment (e.g., improved efficiency, reduced environmental footprint, capacity enhancement and simplification of system).

Candidate Engineers must obtain experience in solving a variety of problems in their work environment, and the solutions to these problems must involve the use of the fundamental and advanced Mechanical Engineering knowledge obtained at university. Problems that require a scientific and engineering approach to their solution may be encountered in any engineering work environment that consists of integrated engineering systems, equipment, machinery and infrastructure. From early in their training years, Candidates must actively seek opportunities to obtain experience in synthesising solutions to real-life engineering problems encountered in the workplace.

A suitable length of time and degree of practical participation should be sought in the workshop environment, learning the basic practices that are the essence of the mechanical discipline so that the Candidate can judge the efficacies of such practices in the general workplace thereafter.
6.1 Contextual knowledge

Candidates must be aware of the requirements of the engineering profession. The Voluntary Associations applicable to the Mechanical Engineer and their functions and services to members provide a broad range of contextual knowledge for the Candidate Engineer that continues through the full career path of the Registered Engineer.

The profession identifies specific contextual activities that are considered essential to the development of competence of the Mechanical Engineer. These include participation in basic workshops, manufacturing and fabrication activities and awareness of the competencies required of the technologist, technician and artisan. These areas of practice are identified in each programme within the employer environment.

6.2 Functions performed

Special consideration in the discipline, sub-discipline or speciality must be given to the competencies specified in the following groups:

- Knowledge-based problem-solving (this should be a strong focus)
- Management and communication
- Identifying and mitigating the impacts of engineering activity
-Judgement and responsibility
- Independent learning.

It is useful to measure the progression of the Candidate’s competency by using the scales for Degree of Responsibility, Problem Solving and Engineering Activity as specified in the relevant documentation. The attached Appendix was developed against the Degree of Responsibility Scale.

It should be noted that the Candidate working at Responsibility Level E carries the responsibility appropriate to that of a registered person except that the Candidate’s supervisor is accountable for the Candidate’s recommendations and decisions.

6.3 Statutory and regulatory requirements

The Candidate Engineer who aspires to become professionally registered must be familiar with all the legal requirements of practising as a Professional Engineer in the Republic of South Africa. In
executing Engineering Work, Candidates must comply with all relevant legislation and amendments thereto, among others:

- Engineering Profession Act, 46 of 2000
- Occupational Health and Safety Act, 85 of 1993
- National Building Regulations and Building Standards Act, 103 of 1977
- National Environmental Management Act, 107 of 1998

All Engineering Work must be carried out in accordance with the norms of the profession. Such norms are generally represented by national and international standards, industry standards, codes of practice and best practice guidelines.


- Mine Health and Safety Act, 29 of 1996
- Specific work instructions, standards and/or specifications of enterprise.

Other Acts not listed here may also be pertinent to a Candidate’s specific work environment. Candidates are expected to have a basic knowledge of the relevant Acts and to investigate whether any Acts are applicable to their particular work environment. All Engineering Work must be carried out in accordance with the norms of the profession. Such norms are generally represented by national and international standards, industry standards, codes of practice and best practice guidelines.

ECSA has established a document known as the ECSA Code of Conduct titled ‘Code of Conduct for Registered Persons: Engineering Profession Act, 46 of 2000’ and the ‘Overarching Code of Practice for the Performance of Engineering Work’ (document R-01-CoP). The ECSA Code of Conduct sets out the ethical rules of conduct for professionally registered persons in terms of the following categories:

- Competency
- Integrity
- Public Interest
• Environment
• Dignity of the Profession.

Further administrative considerations and practice requirements are set out in the Code of Conduct and the Overarching Code of Practice for the Performance of Engineering Work, respectively. The onus is on Candidates and their Mentors/Supervisors to familiarise themselves with these documents.

Depending on the working environment, the provisions of the Occupational Health and Safety Act, 85 of 1993 (OHS Act) and/or the Mine Health and Safety Act, 29 of 1996 (MHS Act) must be followed by employers and employees. Candidates should obtain a functional understanding of these provisions in their specific workplaces.

Industry-specific regulations and requirements may or may not be applicable in all fields of Mechanical Engineering. However, Candidates may find that each industry or aspect of design has developed ‘good engineering practices’ or has mandated statutory requirements. The onus is, once again, on Candidates and their Mentors/Supervisors to familiarise themselves with these practices in the South African industry-specific context or country specific legislation when they are undertaking projects abroad.

6.4 Recommended formal learning activities
The following includes useful courses for formal learning:
• Continuing Professional Development (CPD) courses on specific disciplines
• Project Management
• Value Engineering
• Standard Conditions of Contract (NEC, FIDIC, etc.)
• Preparation of specifications
• Negotiation skills in Engineering
• Finance risk analysis
• Quality assurance systems
• Occupational health and safety
• Energy efficiency
• Maintenance Engineering
• Environmental impact management
  o HAZOP study methods and techniques
  o Layer of protection analysis (LOPA)
  o Root cause analysis (RCA)
  o Training in the use of simulation tools
  o Training in safety-related legislation such as the OHS Act and the MHS Act
  o Initial Professional Development (IPD) activities
  o Value Engineering and other Value Improvement Practices (VIPs)
  o Preparation of specifications
  o Environmental aspects of projects
• Report writing
• Planning methods.

Training and courses that do not carry official CPD points are also appropriate, such as courses or training offered within the employer organisation or by other organisations.

7. PROGRAMME STRUCTURE AND SEQUENCING

7.1 Best practice
No ideal training programme structure or unique sequencing constitutes best practice. The training programme for each Candidate depends on the available work opportunities assigned to the Candidate by the employer at the time.

It is suggested that Candidates work with the appointed Mentors to determine appropriate projects to gain exposure to elements of the asset cycle and to ensure that their designs are constructible, operable and are designed considering lifecycle costing and long-term sustainability.

The training programme should be such that the Candidate progresses through the levels of work capability described in document R-04-T&M-GUIDE-PC so that by the end of the training period, the Candidate exhibits the degree of responsibility allocated during the particular period of training and is able to perform individually and as a team member at the level of problem-solving and engineering
activity required for registration. The Mentor and Candidate must identify the level of responsibility that is required for an activity to be compliant and demonstrate the various exit level outcomes (ELOs). Evidence of the Candidate’s activities and their acceptance by the Mentor are recorded on the appropriate system to meet the requirements of the Training Elements Appendix.

The onus is on Candidates and their Mentors/Supervisors to take responsibility for their own development.

7.2 Realities

ECSA prescribes the minimum period for the Candidacy Phase to be 3 years. The likelihood, however, is that the period of training will be longer. The time frame is determined by the availability of opportunities and the exposure to various functions in the actual work environment. Irrespective of the route followed, the overriding consideration is that the applicant must provide evidence of competence against the standard and provide objective evidence of meeting the 11 specified outcomes.

7.3 Generalists, specialists, researchers and academics

Document R-08-PE adequately describes what is expected of persons whose formative development has not followed a conventional path, for example, academics, researchers, specialists and applicants who have not followed a Candidate training programme. Each Candidate must undertake a unique programme in which the various activities carried out at the discipline-specific level are linked to the generic competency requirements stated in document R-08-PE.

7.4 Multi-disciplinary exposure

Due to the complexity of today’s modern systems, it is advisable that the Candidate Engineer gains experience in interfacing and interacting with other relevant engineering discipline tasks. This is naturally dependent on the employer’s enterprise, and it requires the Candidate Mechanical Engineer to work under the direct supervision of the alternative discipline engineer. Two examples are presented below.
Example 1:

In a steel processing plant, the Candidate Engineer assists in specifying the control instrumentation and data acquisitioning system for the plant’s mechanical systems. The Candidate works with the plant C&I Electronic Engineer and/or assists in developing the control system software under the supervision of the Plant Process Engineer (Metallurgist/Chemical Engineer).

Example 2:

At a coal post-processing plant that converts coal to coke as raw material for a steel refinery, the Candidate Engineer performs Environmental Impact Assessments (EIAs) together with subject-matter experts (scientists, environmental biologists, air quality specialists) to assess emission levels of the by-products of the processing plant (contaminated water, waste gas, waste heat). The Candidate Engineer is supervised by the Mechanical Engineer of the plant process.

7.5 Orientation requirements

For the Candidate Engineer starting a career with an employer, the basic introduction to the company’s functions is usually performed during the first months of employment. The induction process usually includes the following aspects:

- Introduction to the company
- Company safety regulations
- Company code of conduct
- Company staff code and regulations
- Typical functions and activities
- Hands-on experience and orientation in each of the major company divisions.

7.6 Moving into or changing candidacy training programmes

This DSTG assumes that the Candidate enters a programme after graduation from the tertiary institution and continues with the programme until ready to submit an application for registration. It also assumes that the Candidate is supervised and mentored by persons who meet the requirements stated in document R-04-T&M-GUIDE-PC.
In the case of a person changing from one candidacy programme to another or moving into a candidacy programme from a less structured environment, it is essential that the following steps are completed:

- The candidate must complete the Training and Experience Summary (TES) and the Training and Experience Reports (TERs) for the previous programme or unstructured experience. In the latter case, it is important to reconstruct the experience as accurately as possible. The TERs must be signed off by the responsible Supervisor or Mentor.
- On entering the new programme, the Mentor and Supervisor should review the Candidate’s development while being mindful of the past experience and the opportunities and requirements of the new programme. At minimum, the Mentor and Supervisor should plan the next phase of the Candidate’s programme.
## REVISION HISTORY

<table>
<thead>
<tr>
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<th>Revision date</th>
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<tr>
<td>Rev 0: Concept A</td>
<td>16 Sep 2011</td>
<td>Initial Draft</td>
<td>PAC Mech</td>
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<td>Rev 0: Concept B</td>
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| Rev 3: Draft 0  | 29 June 2021  | The document has been revised to include definitions, abbreviations and to update document numbers of referenced documents. The working group further added additional information under the following headings:  
- Investigation  
- Research and Development  
- Process design  
- Statutory and regulatory requirements | Executive: RPS |
| Rev 3           | 15 July 2021  | Approval        | RPSC        |
The Discipline-specific Training Guide for:

Registration as a Professional Engineer in Mechanical Engineering

Revision 3 dated 15 July 2021 and consisting of 31 pages was reviewed for adequacy by the Business Unit Manager and is approved by the Executive: Research, Policy and Standards (RPS).

.....................................      .................................
Business Unit Manager      Date

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Executive: RPS       Date

This definitive version of this policy is available on our website.
APPENDIX A: TRAINING ELEMENTS

<table>
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<th>1</th>
<th>Introduction</th>
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<td>1.1</td>
<td>Induction programme (typically 1–5 days)</td>
</tr>
<tr>
<td>1.1.1</td>
<td>Company structure</td>
</tr>
<tr>
<td>1.1.2</td>
<td>Company policies</td>
</tr>
<tr>
<td>1.1.3</td>
<td>Company Code of Conduct</td>
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<td>1.1.4</td>
<td>Company safety regulations</td>
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<td>1.1.5</td>
<td>Company staff code</td>
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<td>1.1.6</td>
<td>Company regulations</td>
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</tbody>
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<table>
<thead>
<tr>
<th>1.2</th>
<th>Exposure to Practical Aspects of Engineering (typically 6–12 months) and covers how things are: (Responsibility Levels A–B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2.1</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>1.2.2</td>
<td>Construction</td>
</tr>
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<td>1.2.3</td>
<td>Erection</td>
</tr>
<tr>
<td>1.2.4</td>
<td>Field installation</td>
</tr>
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<td>Testing</td>
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<td>Commissioning</td>
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<tr>
<td>1.2.7</td>
<td>Operation</td>
</tr>
<tr>
<td>1.2.8</td>
<td>Maintenance</td>
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<tr>
<td>1.2.9</td>
<td>Fault location</td>
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<tr>
<td>1.2.10</td>
<td>Problem investigation</td>
</tr>
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</table>

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<tr>
<th>2</th>
<th>Design or develop solution</th>
</tr>
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<tbody>
<tr>
<td>2.1</td>
<td>Experience in design and application of design knowledge (typically 12–18 months). Focus is on planning, design and application (Responsibility Levels C–D)</td>
</tr>
</tbody>
</table>

In one or more of the above sectors:

| 2.1.1 | Analysis of data and systems |
| 2.1.2 | Planning of networks and systems |
| 2.1.3 | System modelling and integration |
| 2.1.4 | System design |
| 2.1.5 | Network/circuit design |
### 2.1.6 Component/product design

### 2.1.7 Software design

### 2.1.8 Research and investigation

### 2.1.9 Preparation of specifications and associated documentation

### 2.1.10 Preparation of contract documents and associated documentation

### 2.1.11 Development of standards

### 2.1.12 Application of quality systems

### 2.1.13 Configuration Management

### 3 Engineering tasks

#### 3.1 Experience in the execution of engineering tasks (rest of training period). Focus should be on projects and project management (Responsibility Level E)

- **3.1.1** Working in one or more of these sectors but not all
  - Design or develop solution
  - Manufacture
  - Construction
  - Erection
  - Installation
  - Commissioning
  - Maintenance
  - Modifications

#### 3.2 Organising for implementation of 3.1 (Responsibility Level E)

- **3.2.1** Manage resources
- **3.2.2** Optimisation of resources and processes

#### 3.3 Controlling for implementation or operation of 3.1 (Responsibility Level E)

- **3.3.1** Monitor progress and delivery
- **3.3.2** Monitor quality

#### 3.4 Completion of 3.1 (Responsibility Level E)

- **3.4.1** Commissioning completion
- **3.4.2** Documentation completion
- **3.4.3** Documentation handover

#### 3.5 Maintenance and repair of 3.1 (Responsibility Level E)
### 3.5.1 Planning and scheduling maintenance

### 3.5.2 Monitor quality

### 3.5.3 Oversee maintenance and repair

#### 4 Risk and impact mitigation

##### 4.1 Impact and risk assessments (Responsibility Level E)

##### 4.2 Regulatory compliance (Responsibility Level E)

- **4.2.1** Health and safety
- **4.2.2** Codes and standards
- **4.2.3** Legal and regulatory

#### 5 Managing engineering activities

##### 5.1 Self-management (Responsibility Levels C–D)

- **5.1.1** Manages own activities
- **5.1.2** Communicates effectively

##### 5.2 Team environment (Responsibility Levels C–D)

- **5.2.1** Participates in and contributes to team planning activities
- **5.2.2** Manages people

##### 5.3 Professional communication and relationships (networking) (Responsibility Levels C–D)

- **5.3.1** Establishes and maintains professional and business relationships
- **5.3.2** Communicates effectively

##### 5.4 Exercising judgement and taking responsibility (Responsibility Level E)

- **5.4.1** Ethical practices
- **5.4.2** Code of Conduct
- **5.4.3** Exercises sound judgement in the course of complex engineering activities
- **5.4.4** Is responsible for decision-making in some or all engineering activities

##### 5.5 Competency development (Responsibility Level D)

- **5.5.1** Plans own development programme
- **5.5.2** Constructs initial professional development record

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