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SOUTH AFRICA

Discipline-specific Training Guideline for Candidate Engineers in Metallurgical Engineering

R-05-MET-PE

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ECSA

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DEFINITIONS

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

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

Ill-posed problem means problems whose requirements are not fully defined or may be defined erroneously by the requesting party.

Integrated performance means that an overall satisfactory outcome of an activity requires several outcomes to be satisfactorily attained, for example, a design will require analysis, synthesis, analysis of impacts, checking of regulatory conformance and judgement in decisions.

Level descriptor means a measure of performance demands at which outcomes must be demonstrated.

Management of engineering works or activities means the co-ordinated activities required to:

(a) direct and control everything that is constructed or results from construction or manufacturing operations;

(b) operate engineering works safely and in the manner intended;

(c) return engineering works, plant and equipment to an acceptable condition by the renewal, replacement or mending of worn, damaged or decayed parts;

(d) direct and control engineering processes, systems, commissioning, operation and decommissioning of equipment;

(e) maintaining engineering works or equipment in a state in which it can perform its required function.

Over-determined problem means a problem whose requirements are defined in excessive detail, making the required solution impossible to attain in all of its aspects.

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

Practice area means 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 means 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 means a category of registration for persons who must be licensed through the Engineering Profession Act or a combination of the Engineering Profession Act and external legislation as having specific engineering competencies at NQF 5, related to an identified need to protect the public safety, health and interest or the environment, in relation to an engineering activity.

BACKGROUND

The illustration below reflects the documents used as part of the Engineering Council of South Africa (ECSA) system for registration in professional categories. The illustration also locates the current document.

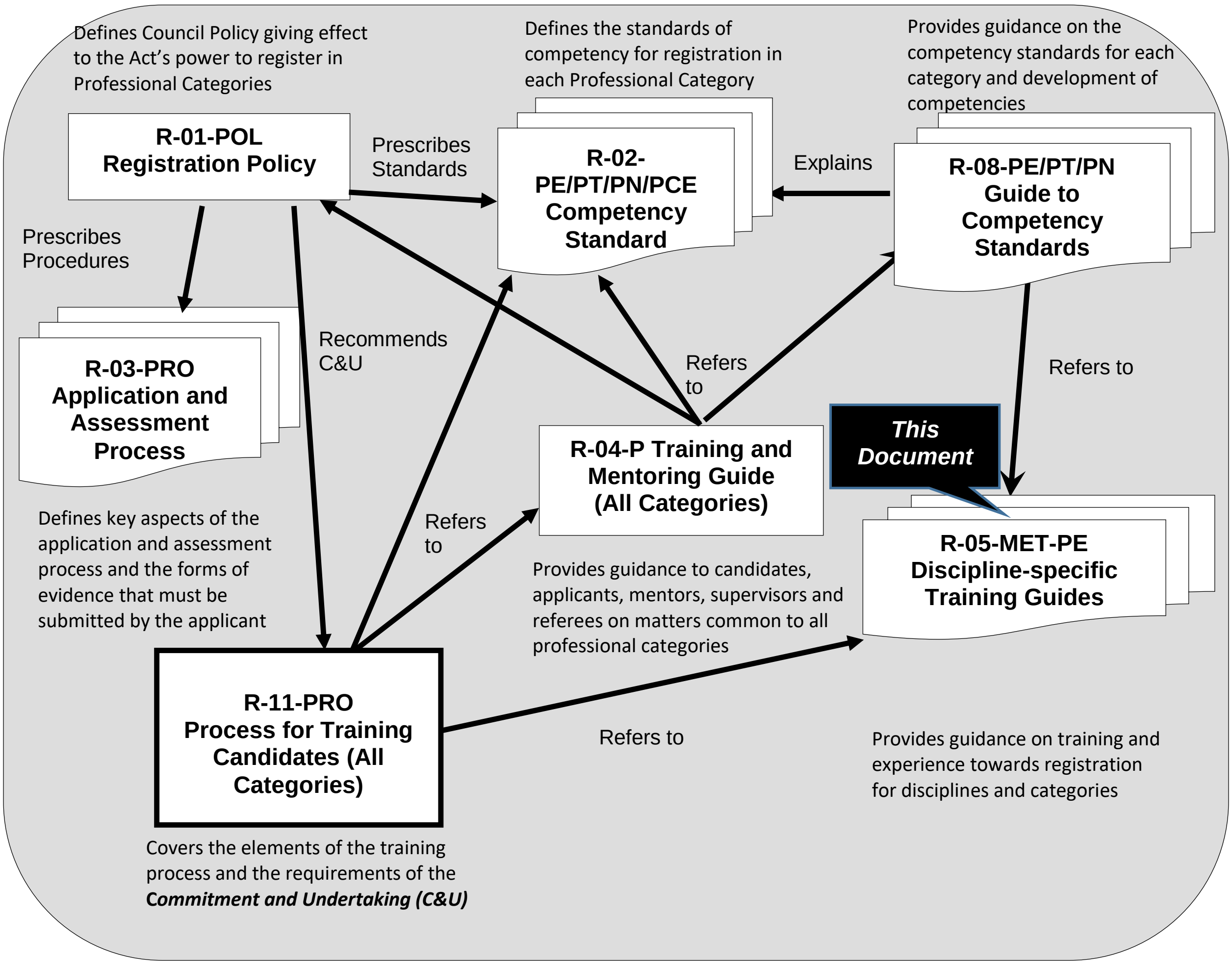

Figure 1: Documents defining the ECSA registration system

1. PURPOSE OF THIS DOCUMENT

All persons applying for registration as Professional Engineers are expected to demonstrate the competencies specified in document **R-02-PE** at the prescribed level, irrespective of the trainee's discipline, though work performed by the applicant at the prescribed level of responsibility.

This document supplements the generic Training and Mentoring Guide **R-04-P** and the Guide to the Competency Standards for Professional Engineers, document **R-08-PE**. In document **R-04 P** attention is drawn to the following sections:

- Duration of training and period working at level required for registration
- Principles of planning training and experience
- Progression of training programme
- Documenting training and experience
- Demonstrating responsibility.

The document **R-08-PE** provides both a high-level and an outcome-by-outcome understanding of the competency standards as an essential basis for this discipline specific guide.

This guide, as well as **R-04-P** and **R-08-PE**, are subordinate to the Policy on Registration, document **R-01-POL**, the Competency Standard (**R-02-PE**) and the application process definition (**R-03-PRO**).

2. AUDIENCE

This guide is directed to candidates and their supervisors and mentors in the discipline of Metallurgical Engineering. It is intended to support a programme of training and experience incorporating good practice elements.

This guide applies to persons who have:

- completed the education requirements by obtaining an accredited BEng type qualification, or a Washington-Accord Recognised qualification or through evaluation/assessment;
- registered as Candidate Engineers;
- embarked on a process of acceptable training under a registered Commitment and Undertaking (C&U) with a mentor guiding the professional development process at each stage.

3. PERSONS NOT REGISTERED AS CANDIDATES OR NOT BEING TRAINED UNDER COMMITMENT AND UNDERTAKING (C&U)

All applicants for registration must present the same evidence of competence and be assessed against the same standards, irrespective of the development path followed.

Application for registration as a Professional Engineer is permitted without being registered as a Candidate Engineer or without training under a C&U. Mentorship and adequate supervision are, however, key factors in effective development to the level required for registration. A C&U indicates that the company is committed to mentorship and supervision.

If the trainee's employer has no 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 (VA) for the discipline should be consulted for assistance in locating an external mentor. A mentor should be in place at all stages of the development process.

This guide is written for the recent graduate who is training and gaining experience towards registration. Mature applicants for registration may apply the guide retrospectively to identify possible gaps in their development.

Any applicants who have not been through mentorship programme are advised to request an experienced mentor (internal or external) to act as an application adviser while they prepare their applications for registration.

The guide may be applied in the case of a person moving into a candidacy programme at a later stage that is at a level below that required for registration (see Section 7.6 of this document).

4. ORGANISING FRAMEWORK FOR OCCUPATIONS

Metallurgical Engineering

Metallurgists normally work within the metal and mineral industry including mining and production in the concentrators and metal recovery operations, in smelters, metal refineries, foundries and research and development laboratories. Metallurgists use their knowledge of chemistry, physics, mineralogy, underlying process fundamentals and process engineering to control and improve processes that separate, concentrate and recover minerals and their valuable metals from natural ores. Three career paths are available to the Metallurgist: Mineral Processing Engineering, Extraction Engineering and Physical Engineering.

4.1 Extractive Metallurgical Engineering

Extractive Metallurgical Engineering: extraction of metals from their natural mineral deposits or intermediate compounds from ores by chemical or physical processes, including wet or hydrometallurgical process stages, high temperatures or pyro metallurgical process stages and electro-metallurgical process stages. The process may contain crude metal products that can be subjected to further processing called metallurgy or physical metallurgy that includes processes such as alloying, casting in foundry, rolling and extrusion; for example, copper, uranium vanadium and other metals produced by solvent extraction using a hydrometallurgical process.

Typical tasks an Extractive Metallurgical Engineer may undertake include but are not limited to the following:

- Conducting research and developing methods of extracting metals from their ores and advising on their application.
- Design, development and implementation of complex process projects.
- Operation and optimisation of process plants or commercial-scale processes.

Practising Extractive Metallurgical Engineers generally concentrate on one or more of the following fields:

- Metallurgy / Mineral Processing Researcher / Lecturer
- Extractive Metallurgist
- Metallurgy / Mineral Processing Consulting Engineer
- Pyro metallurgist
- Hydro metallurgist
- Electrometallurgist.

4.2 Mineral Processing Engineering

Mineral Processing Engineering: process by which valuable minerals are separated from worthless material or other valuable minerals by inducing them to gather in and on the surface of a froth layer using processing like flotation, jigging, milling, scrubbing, magnetic separation, Dense Medium Separation (DMS) or Heavy Medium Separation (HMS), etc. The process of froth flotation entails crushing and grinding the ore to a fine size. This fine grinding separates the individual mineral particles from the waste rock and other mineral particles. Valuable minerals such as gold, silver, copper, lead, zinc, molybdenum, iron, potash, phosphate and even sand for glass are often processed by froth flotation.

4.3 Metallurgical and Materials Engineering

Metallurgical and Materials Engineers perform research, analysis, design, production, characterisation, failure analysis and application of materials, including metals, for engineering applications based on an understanding of the properties of matter and engineering requirements.

Typical tasks that Metallurgical and Materials Engineers may undertake include:

- development, control and advice on processes used for casting, alloying, heat treating or welding of metals, alloys and other materials to produce commercial metal products or develop new alloys, materials and processes, evaluate and specify materials for engineering applications, and do quality control and failure analyses;
- investigating properties of metals and alloys, developing new alloys and advice on and supervising technical aspects of metal and alloy manufacture, processing, use and manufacturing;
- doing residual life evaluations, predictions and failure analyses, and prescribing remedial actions to avoid material failures.

Practising Metallurgical and Materials Engineers generally concentrate on one or more of the following areas:

- Metallurgy / Mineral Processing Researcher / Lecturer
- Physical Metallurgist
- Materials Engineer
- Welding Engineer
- Corrosion Engineer
- Quality Assurance Engineer
- Metallurgy / Mineral Processing Consulting Engineer: work on a variety of processes, plants and ores – maybe in research and development or project management area

- Mineral Process Engineer: work in all stages or ore processing.

5. NATURE AND ORGANISATION OF THE INDUSTRY

5.1 Investigation and problem analysis

Investigation and problem analysis involve the following:

- Demonstrating the theoretical and practical knowledge to solve problems utilising the well-proven analytical techniques and tools. This includes the ability to use trouble-shooting skills.
- Identifying problems / hazards and analysing the causes of process problems in a systematic manner using applicable models, frameworks and tools.
- Using of troubleshooting methodologies, literature surveys, data analysis and root cause analysis tools to identify or analyse problems.
- Demonstrating involvement in investigating properties of metals, ceramics, polymers and other materials, developing and assessing their commercial and engineering applications.
- Preparing reports on metallurgical operations and projects.
- Undertaking fault finding, root cause analysis, trouble shooting, data collection, etc.

Metallurgical and Mineral Process Engineers are involved in:

- metallurgical problem solving with application of modified or addition unit processes;
- management of process data collection and analysis.

Location of training in overall engineering lifecycle and functions performed

The areas within which Metallurgical Engineers work follow the conventional stages of the project life cycle:

Engineering lifecycle considerations

Since the Metallurgical Engineering industry encompasses a wide field of activities ranging from extractive metallurgy to physical metallurgy, it is unrealistic to expect that all training programmes cover the same field. However, it is recognised that a Metallurgical Engineer is usually employed in an organisation operating in one or more of the following fields:

- Research and development to develop new production from extraction metallurgy or to solve existing problems using laboratory or industry scale pilot plants.

- Undertaking or managing research and development studies to improve existing processes or to apply existing or possible processes to new ores or concentrates.
- Studying and applying the fundamentals of metallurgical processes to both aid control and improve their physical and economic operation.
- Metallurgical Plant Operation and Optimisation.
- Project Management: Specification, design, and commissioning of metallurgical plants / components.
- Metallurgy and mineral processing consulting (project management).

The levels of experience that Candidate Engineers must be exposed to in order to gain complex engineering experience are listed below:

Research, development, technology transfer and consulting would include any of the following sub-disciplines:

- Mineral Processing
- Hydrometallurgy
- Pyrometallurgy
- Materials engineering and other physical metallurgy sub-disciplines.

Graduate metallurgical engineers employed in research and development should gain experience in as many of the following aspects as possible:

- Developing a clear understanding of the complex problem / opportunity to be investigated by conducting a critical analysis of the literature and other relevant information and assembling the documentation on the subject in an organised manner.
- Motivation, planning and design of the complex research project and its associated equipment and/or plant.
- Complex theoretical or paper investigations and laboratory-scale investigation.
- Complex investigations on a pilot plant and/or industrial plant scale.
- Interpretation of results and ensuring that results are meaningful and have been correctly obtained in accordance with complex scientific principles.
- Data processing and analysis.
- Studies of technical and economic feasibility.
- Compiling the results into a written report and presentation of verbal reports.

- Technology transfer to ensure maximum benefit is obtained from the research and development effort.
- Metallurgy and Mineral Process Engineers investigate why and how metals and minerals behave the way they do or are the way they are, which involves looking at economic issues of how to extract metals and minerals from ore.
- Materials Engineers study the structure and properties of metals and other materials; investigate methods for shaping and fabricating materials and study methods for joining materials, improving existing materials and evaluating new ones.
- Hydrometallurgists study the nature and properties of different metals and materials and remove insoluble and toxic materials from metal using water-based solutions to find a purer form of ore.
- Extractive Metallurgical Engineers undertake research, develop, control and provide advice on processes used in extracting metals from their ores and the washing, crushing and grading of ore or refining metals.
- Minerals Process Engineers are involved in all stages of raw materials processing. They transform low value impure minerals, recycled materials and by-products of other processing operations into commercially valuable products. The main sources of these raw materials are low grade minerals, by-products of other processing operations and recycled materials.

5.2 Process optimisation, plant and equipment design

- The principles of complex metallurgical engineering practice, including the critical study of complex work methods and the development of more effective techniques for recognising real and significant problems and how to solve them.
- Process optimisation involves providing solutions to the problem identified; this might be through improving the system/equipment operating parameters by modifying or installing new equipment or systems.
- Equipment sizing and selection and application of instrumentation.
- Design plants or equipment by considering the following aspects: reliability, maintainability, usability, supportability, reducibility, disposability and affordability.
- Optimisation and control of a complex process to improve performance.
- Cost economic analysis for minimising cost and maximising throughput and/or efficiency of the plant operation or process.

- Design of mineral processing and extractive metallurgical plant.
- Process design and development.
- Equipment and process optimisation by improving operating parameters, sizing and selecting of appropriate equipment.
- Mineral process engineers improve or develop new processes and material; improve methods and equipment for extraction, filtration, distillation; design plants and specify equipment / processes and layouts; and test the quality of the process and product.

5.3 Risk management and impact mitigation

Metallurgists:

- coordinate the analysis of samples taken from metallurgical process streams to ensure safe and economic operation and they advise operations personnel on process changes required to obtain desired products, processes and quality control;
- improve environmental performance of metallurgical operations and ensure all environmental standards are met;
- Undertake risk assessments during plant operation and projects;
- ensure the OHS Act and other standards are followed.

5.4 Project management

Project management has a number of phases, stages and gates to be followed to solve industrial problems. Companies uses different project life cycles which include the following: project development (includes design specifications, concept design, basic design and detailed design); procurement management; contract management; plant construction; commissioning and hand-over; and decommissioning.

Applying the supporting project management process to solve the scientific problem may include the following:

- Integrated Project Controls: including cost control, estimating (resources, capital and operating and/or lifecycle costs), planning and scheduling, and project risk management.
- Stakeholder Management: Liaise with a wide variety of people on the job such as operators, maintenance and engineering staff, geologists, mining engineers and supporting specialists in process control, computing, technology provision and research.

- Metallurgists designing, developing, constructing, commissioning and handing over metal and mineral processing pilot and industry equipment and plants.
- Project Resource management.
- Managing project change and project risk.

5.5 Project development

- Integrated Project Controls: including cost control, estimating (resources, capital and operating and/or lifecycle costs), planning and scheduling, and project risk management.
- Stakeholder Management: including liaison and responsibility for communication and overall control of the engineering team and interfacing with client/legal entities.
- Project Resource Management.
- Managing project change and project risk.
- Undertaking project management tasks during all the project development phases including idea / problem analysis / definition need, conceptual design, basic and detailed engineering. The research and feasibility studies are undertaken to identify and select the preferred solution and develop the solution.
- Laboratory, pilot or full-scale plant work primarily aimed at obtaining engineering data for the specification and design of broadly-defined new metallurgical plants or the improvement of existing plants.
- Involvement in sound financial business concepts ranging from budgeting to feasibility studies.
- Plant Design: preparation of complex flow sheets and material and energy balances; appreciation of the operation of a drawing office and an engineering purchasing office; checking of working drawings for suitability with respect to the particular complex metallurgical operation; specification, design and selection of equipment and service requirements; consideration of the design with regard to materials used, economics, instrumentation, quality control, logistics, safety, acceptable operation conditions, spillage management and the effect on the environment.
- Pyro metallurgists design and develop high temperature heat-based processes and equipment to concentrate, extract and obtain pure metals and ore through various extractive processes such as refining, fusing and smelting metals.
- Responsibilities relating to procurement and contracts management include considering national treasury rules.

Plant construction, commissioning and hand over

- Plant construction – site establishment and management, assembling of plant equipment in accordance with drawings and installation designs.
- Preparation of operating – start up, shutdown and emergency procedures.
- Plant Commissioning – measurement and analysis of actual performance data versus design parameters, responsibility for performance of the plant, optimising plant performance, reviewing all safety standards, operability of the plant, sound labour relations and practices and managerial aspects.
- Plant hand-over – including 'as-built' documentation, construction, planning and execution of punch-out and hand over.

Plant decommissioning

Decommissioning involves the following:

- Dissembling equipment – this can be a process undertaken from one pilot plant to another depending on exploration period and requirements of the mineral processing or mining plant.
- Metallurgists evaluating and undertaking design and analysis of the new site requirements for optimum performance.
- Ensuring decommissioning strategy and safety procedures are followed by understanding the chemical and physical characteristics of the equipment or plant.
- Undertaking and compiling procedures for plant de-commissioning and consolidation for shutdown or closure.
- Ensuring the regulatory and statutory application and authorisation process is acquired.

5.6 Product / Manufacturing

- Application of physical and chemical methods to concentrate valuable minerals from their ores; processes can involve methods such as magnetic, electrostatic, gravity and flotation processes.
- Application of a combination of processes involving hydrometallurgy, electrometallurgy and pyrometallurgy to produce crude or refined product metal for market.

5.7 Plant operation and maintenance

One of the most useful ways in which the CET can gain experience is to be a member of a team responsible for commissioning a new or modified plant. Routine operation of existing plants will be considered sufficient training provided that as many as possible of the following aspects are covered, with emphasis on those that are particularly relevant to the operation:

- Measurement and analysis of performance plant or equipment data.
- Undertaking material and energy balances.
- Process plant operation, especially with direct and increasing responsibility for certain sections of the plant.
- Quality control in respect of measurement and specifications.
- Plant records and operating costs.
- Process control and management.
- Safety and acceptance of the principle that an engineer may not endanger the life and limb of people through negligence.
- Inter-relationships between engineering personnel and management, and among members of the engineering team, especially between production and maintenance.
- The impact the operation may have on the environment.
- Application of economic analysis of production processes to effect optimal performance.
- Management of the technical aspects metallurgical operations using tools such as on-line process monitoring, sampling, chemical analysis, data analysis and process modelling.
- Management and supervision of production staff in metallurgical operations.
- Application of chemical, metallurgical and process engineering fundamentals to production processes.
- Undertaking fault findings in plant equipment and taking corrective action to ensure safe operation.
- Pyro metallurgists: control temperature adjustments, change mixtures and other variables in operations such as blast-furnaces and steel-melting furnaces to obtain materials such as pig iron and steel of specified metallurgical characteristics and qualities.
- Ensuring that appropriate SHE systems and practices are implemented within the department / organisation.
- Ensuring that plant availability, utilisation and operability throughput and recovery targets are being met.

- Ensuring that all plant operations run efficiently against industry best practice and appropriate standards by updating, recording, archiving and analysing all plant related data.
- Ensuring that appropriate metallurgical input is provided for business plans and forecasts (e.g. monthly, quarterly and annual forecasts).
- Ensuring that cost and cash flow targets are met.
- Compiling or updating appropriate policies and procedures or work instructions to align with design bases. These include policies and procedures applicable to the following: main processing plant, final recovery, slimes dam and tailings dump, return water dam and plant water supply, and maintenance bases / system / equipment life cycle plans.

6. DEVELOPING COMPETENCY: DOCUMENT R-08-PE

6.1 Contextual knowledge

Candidates are expected to be aware of the engineering profession requirements. The VAs applicable to the Metallurgical Engineer and their functions and services to members, for example, provide a broad range of contextual knowledge for the Candidate Engineer through the full career path of the registered Professional Engineer.

The profession identifies specific contextual activities considered essential to developing the competence of Metallurgical Engineers. These include awareness of basic analytical, process and fabrication activities, as applicable, and the competencies required of the engineer, technologist, technician and artisan. Exposure to practice in these areas will be identified in each programme within the employer environment.

Chemical Engineers may find themselves gaining experience from diverse industries such as mining, metallurgy, etc. Chemical metallurgy uses chemical processing at high temperature or in solution to convert minerals from inorganic compounds to useful metals and other materials.

6.2 Functions performed

The functions in which all metallurgical engineers need to be proficient and are required to a greater or lesser extent in all the areas of employment that are listed below. The parallels with the complex generic competence elements required by the competency standard **R-02-PE** should be clear.

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

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

It is useful to measure progression of the candidate's competency by using the Degree of Responsibility, Problem Solving and Engineering Activity scales as specified in the relevant documentation.

Appendix A has been developed against the Degree of Responsibility Scale. Activities should be selected to ensure that the candidate reaches the required level of competency and responsibility.

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

The nature of work and degrees of responsibility defined in document **R-04-P**, Table 4, are used here (and in **Appendix A** below):

A: Being exposed	B: Assisting	C: Participating	D: Contributing	E: Performing
Undergoes induction, observes processes and work of competent practitioners.	Performs specific processes, under close supervision.	Performs specific processes as directed with limited supervision.	Performs specific work with detailed approval of work outputs.	Works in team without supervision, recommends work outputs, responsible but not accountable

A: Being exposed	B: Assisting	C: Participating	D: Contributing	E: Performing
Responsible to supervisor	Limited responsibility for work output	Full responsibility for supervised work	Full responsibility to supervisor for immediate quality of work	Level of responsibility to supervisor is appropriate to a registered person, supervisor is accountable for applicant's decisions

6.3 Statutory and regulatory requirements

The Candidate Engineer should be aware of the requirements for safety appointments in terms of the occupational Health and Safety Act for plant managers.

- SANS codes for Specification for Piping Design / Material (ANSI), see www.sabs.co.za.
- SANS 10248, 1023: Waste Classification and Management Regulations (e.g. tailings and waste spillage) from South Africa Constitution Act, 108 of 1996 and Hazardous Substance Act, 5 of 1973.
- Minerals and Energy Acts, e.g. Mineral and Petroleum Act, 28 of 2002.
- Mine and Safety Act, 29 of 1996, see www.dmr.gov.za: Design of underground dam walls, plugs and barricades; Regulations on use of water for mining.
- Project and Construction Regulations Management Professions Act, 48 of 2000.
- National Environmental Management Act, 107 of 1998.
- National Environmental Management Waste Act, 59 of 2008.
- Nuclear Energy Act, 46 of 1999.
- National Water Act, 36 of 1998: Various measures relating to pollution of a water resource; Waterworks process controller.
- National Water Act, 54 of 1956: Determination of persons permitted to design dams.
- Occupational Health and Safety Act and Regulations, 85 of 1993: Driven Machinery Regulations; Pressurised Equipment Regulations.
- ISO 9001: 2015.
- SAMREC (South African Code for Reporting of Exploration Results, Mineral Resources and Mineral Reserves) e.g. 10320:2004.
- SAMVAL (South African Code for Reporting of Mineral Asset Evaluations) from www.sans.co.za.

- Engineering Profession Act, 46 of 2000, its Rules, specifically the Code of Conduct.
- National Building Regulations and Building Standards Act, 103 of 1977: Certification of fire protection system.

6.4 Desirable formal learning activities

Attendance of relevant technical courses and conferences is recommended. Formal safety training should be mandatory. Register with relevant volunteer associations to access a list of training / conference / seminars and other relevant information e.g. SAIMM, PMI, PMISA, CESA, SACPCMP, etc. The following is the list of sample training / courses:

- Problem solving and analysis tools, e.g. brain storming, gap analysis, FMEA, Pareto analysis, root cause analysis, problem tree analysis, trade off tools, etc.
- Risk assessment and analysis techniques.
- Project management techniques and tools, including conditions of contract management, finance and economics, quality systems, stakeholder management and Project Management (planning, scheduling and project controls) tools and software's e.g. MS Project, Primavera, Project Risk Analysis tools, Earn Value Management (EVM), and other SAP tools.
- Modelling and simulation tools, e.g. for pumps, DMS, etc. from OEM or develop your own as the engineer as part of competency gained.
- Occupation Health and Safety including the OHS Act and 'safety in design'.
- Formally registered CPD courses in Metallurgical Engineering and associated disciplines.
- Value Engineering and other Value Improvement Practices (VIPs).
- Preparation of engineering design specifications.
- Environmental aspects of projects and plant operations.
- Waste management and treatment process.
- Professional skills such as report writing, presentations, facilitation and negotiation skills.
- Use of specific testing equipment / tools.
- Plant operations performance monitoring tools.
- Compilation of plant operation procedures.
- Plant commissioning, decommissioning and handover.
- Maintenance and reliability engineering.
- Metallurgy or Mineral processing specific equipment designs

7. PROGRAMME STRUCTURE AND SEQUENCING

7.1 Best practice

Best practice is the development process to assist applicants to become registered professional engineers. Best practice comprises the process for the candidate's continuous development. A number of courses (technical and management) must be attended to gain the IPD points required for registration requirements. On job learning from the organisation the candidate is employed in, refer to SAIMM (Southern African Institute of Minerals and Metals industry) for some best practice ideas. The applicant may register with these bodies to gain access to courses, articles and relevant information for their development. This may also open up opportunities to meet with experts during seminars.

It is suggested that candidates work with their mentors to determine appropriate projects to gain exposure to elements of the asset life cycle, to ensure their designs are constructible, operable, and are designed considering life cycle costing and long-term sustainability. A regular reporting structure with suitable recording of evidence of achievement against the competency outcomes and responsibility needs to be put in place.

The training programme should be such that candidate progresses through levels of work capability, which are described in **R-04-P**, such that by the end of the training period, the candidate must perform as individual and as a team member at the level of problem solving and complex engineering activity required for registration and exhibit at the degree of responsibility level E.

VIPs are out-of-the ordinary practices used to improve cost, schedule, and/or reliability of capital construction projects:

- Used primarily during front-end-loading
- Formal, documented practices involving a repeatable work process
- Almost always facilitated by specialists from outside the project team.

Examples are as follows:

- Technology selection
- Process simplification
- Classes of facility quality

- Waste minimisation
- Energy optimisation
- Process reliability modelling
- Customisation of standards and specifications
- Predictive maintenance
- Design to capacity
- Value engineering
- Constructability.

7.2 Realities

Document **R-08-PE** adequately describes what would be expected of persons whose formative development has not followed a conventional path, for example, academics, researchers and specialists.

No ideal training programme structure or unique sequencing constitutes best practice. The training programme for each candidate depends on the work opportunities available at the time for the employer to assign to the candidate. What is expected for ECSA registration is that in whatever area they are employed, applicants ensure they undertake tasks that provide experience in the three generic engineering competence elements: problem investigation and analysis, problem solution, execution/implementation. It should be possible, by judicious selection of work task opportunities with the same employer, to gain experience in all three elements.

Candidate Engineers are advised that although 3 years is the minimum period of experience following graduation, in practice metallurgical engineers seldom meet the experience requirements in 3 years, and then only if they have followed a structured training programme. Applicants are advised to gain at least 5 years of experience before applying.

7.3 Considerations for 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 and specialists.

The overriding consideration is that, irrespective of the route followed, the applicant must provide evidence of competency against the standard. To be able to become a professional engineer, a lecturer / researcher must become involved in applying engineering knowledge by way of applied research and consulting work under the supervision of a professional engineer.

For generalists and specialists, provided that the applicant's specialist knowledge is at least at the level of a Master's degree and provided the applicant has demonstrated the ability at a professional level to identify engineering problems and produce complex solutions which can be satisfactorily implemented, a degree of trade-off may be acceptable in assessing the experience. Where an applicant's experience is judged to be in a narrow specialist field, a minimum of 5 years' experience after obtaining the BEng in engineering is required, but each application will be considered on merit.

Applicants who studied chemical engineering may find themselves in a metallurgical environment and can undertake mineral processing duties. The candidate working towards being a professional engineer while in the academic environment needs to acquire the following broadly define engineering activities:

7.4 Recommended formal learning

Teaching/Lecturing/Facilitation:

- Reading in applicable fields of knowledge
- Curriculum development
- Selection and development of teaching materials
- Compilation of lecture notes
- Compilation of examination papers
- Demonstration of application of theory in practice
- Serve as supervisor for student projects.

Research or further studying:

- Literature survey
- Obtaining higher qualifications
- Advancement of the current state of the art of technology
- Theoretical research/development of analytical techniques

- Practical /experimental research
- Participation in international collaborative research.

Laboratory experiments activities:

- Experimentation
- Design and building of laboratories
- Experimental equipment design / construction
- Experiment design
- Development of new manufacturing techniques
- Development of non-destructive testing techniques
- Vibration testing
- Material / structural testing.

Conferences/Symposia/Seminars:

- Publishing papers (peer-review journals and international conferences)
- Public speaking, etc.

Consulting:

- Consulting to industry in solving real problems encountered in engineering practice
- Design of products / structure / systems / components.

Multi-disciplinary exposure

Interphase management among various disciplines needs to be formalised. Details of signed-off interface documents among different disciplines are essential.

Orientation requirements

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

7.5 Moving into or changing candidacy training programmes

This guide assumes the candidate enters a programme after graduation and continues with the programme until ready to submit an application for registration. It also assumes the candidate is supervised and mentored by persons who meet the requirements in document **R-04-P**. 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 be completed:

- The candidate must complete the Training and Experience Summary (TES) and Training and Experience Reports (TER) 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.
- On entering the new programme, the mentor and supervisor should review the candidate's development in the light of the past experience and opportunities and requirements of the new programme, and plan at least the next phase of the candidate's programme.

REVISION HISTORY

Revision number	Revision date	Revision details	Approved by
Concept A	2 Jul 2012	Initial draft in new template	
Rev 0: Concept B	1 Nov 2012	Standard sections 1–3 inserted. Formatted.	
Rev 1	12 Mar 2013		Registration Committee for Professional Engineers
Rev 2 Concept A	26 Oct 2017	Reviewed and checked	Z Zwane, J Cato
Rev 2	25 July 2019	Routine Review Approval	RPSC

Discipline-Specific Training Guideline for:

Candidate Engineers in Metallurgical Engineering

Revision 2 dated 25 July 2019 and consisting of 26 pages has been reviewed for adequacy by the Business Unit Manager and is approved by the Executive: Research, Policy and Standards **(RPS).**

.... 16/08/2019

Business Unit Manager — Date

.... 19/08/2019

Executive: **RPS** — Date

This definitive version of this policy is available on our website.

APPENDIX A: TRAINING ELEMENTS

Synopsis: A candidate engineer should achieve specific competencies at the prescribed level during his/her development towards professional registration, at the same time accepting more and more responsibility as experience is gained. The outcomes achieved and established during the candidacy phase should form the template for all engineering work performed after professional registration regardless of the level of responsibility at any particular stage of an engineering career:

1. Confirm understanding of instructions received and clarify if necessary;
2. Use theoretical training to develop possible solutions: select the best and present to the recipient;
3. Apply theoretical knowledge to justify decisions taken and processes used;
4. Understand role in the work team, and plan and schedule work accordingly;
5. Issue complete and clear instructions and report comprehensively on work progress;
6. Be sensitive about the impact of the engineering activity and take action to mitigate this impact;
7. Consider and adhere to legislation applicable to the task and the associated risk identification and management;
8. Adhere strictly to high ethical behavioural standards and ECSA's Code of Conduct;
9. Display sound judgement by considering all factors, their interrelationship, consequences and evaluation when all evidence is not available;
10. Accept responsibility for own work by using theory to support decisions, seeking advice when uncertain and evaluating shortcomings; and
11. Become conversant with your employer's training and development program and develop your own lifelong development program within this framework.

Complex engineering work is usually characterised by the application of novel technology deviating from standard procedures, codes and systems, the deviation verified by research, modelling and/or substantiated design calculations.

Responsibility Levels: A = Being Exposed; B = Assisting; C = Participating; D = Contributing; E = Performing.

Competency Standards for Registration as a Professional Engineer	**Explanation and Responsibility Level**
1. Purpose This standard defines the competence required for registration as a Professional Engineer. Definitions of terms having particular meaning within this standard are given in Appendix D.	Discipline Specific Training Guides (DSTGs) give context to the purpose of the Competency Standards. Professional Engineers operate within the nine disciplines ECSA recognises. Each discipline can be further divided into sub-disciplines and finally into specific workplaces as given in Clause 4 of the specific DSTG. DSTG's are used to facilitate experiential development towards ECSA registration and assist in compiling the required portfolio of evidence (Specifically the Engineering Report in the application form). **NOTE**: The training period must be utilised to develop the competence of the trainee towards achieving the standards below at a responsibility level E, i.e. Performing. (Refer to 7.1 in the specific DSTG)
2. Demonstration of Competence Competence must be demonstrated within *complex engineering activities,* defined below, by integrated performance of the outcomes defined in section 3 at the level defined for each outcome. Required contexts and functions may be specified in the applicable Discipline Specific Guidelines.	Engineering activities can be divided into (approximately): • 5% Complex (Professional Engineers) • 5% Broadly Defined (Professional Engineering Technologists) • 10% Well-defined (Professional Engineering Technicians) • 15% Narrowly Well-defined (Registered Specified Categories) • 20% Skilled Workman (Engineering Artisan) • 55% Unskilled Workman (Artisan Assistants) The activities can be in-house or contracted out; evidence of integrated performance can be submitted irrespective of the situation.
Level Descriptor: *Complex engineering activities* have several of the following characteristics: a) *Scope* of practice area is linked to technologies used and changes by adoption of new technology into current practice b) Practice area is located within a wider, complex *context,* requires teamwork, has interfaces with other parties and disciplines c) Involves the use of a variety *resources,* including people, money, equipment, materials, technologies	**Level Descriptor**: *BDEA* in the various disciplines are characterised by several or all of: a) *Scope* of practice area does not cover the entire field of the discipline (exposure limited to the sub-discipline and specific workplace). Some technologies used are well established and adoption of new technologies needs investigation and evaluation. b) Practice area varies substantially with unlimited location possibilities and an additional responsibility to identify the need for advice on complex activities and problems. *Complex activities* in the sub-discipline need interfacing with professional engineers, professional technicians, artisans, architects, financial staff, etc. as part of the team. c) The bulk of the work involves familiar, defined range of *resources,* including people, money, equipment, materials, but new technologies are investigated and implemented.

Competency Standards for Registration as a Professional Engineer	Explanation and Responsibility Level
d) Requires resolution of occasional problems arising from *interactions* between wide-ranging or conflicting technical, engineering or other issues e) Is *constrained* by available technology, time, finance, infrastructure, resources, facilities, standards and codes, applicable laws f) Has significant *risks* and *consequences* in the practice area and in related areas. *Activities* include but are not limited to the following: design; planning; investigation and problem resolution; improvement of materials, components, systems or processes; manufacture or construction; engineering operations; maintenance; project management; research; development and commercialisation.	d) Most of the impacts in the sub discipline are on wider issues, but some arise from conflicting technical and engineering issues that have to be addressed by the application of *complex* non-standard engineering principles; e) The work packages and associated parameters are *constrained* by operational context with variations limited to different locations only. (Cannot be covered by standards and codes). f) Even locally important minor risks can have far reaching consequences. *Activities* include but are not limited to the following: design; planning; investigation and problem resolution; improvement of materials, components, systems or processes; engineering operations; maintenance; project management. For engineers, research, development and commercialisation happen more frequently in some disciplines and are seldom encountered in others.

3. Outcomes to be satisfied:	Explanation and Responsibility Level
Group A: Engineering Problem Solving.	
Outcome 1: Define, investigate and analyse *complex* engineering problems	**Responsibility level E** Analysis of an engineering problem means the "separation into parts possibly with comment and judgement". *Broadly* means "not minute or detailed" and "not kept within narrow limits".
Complex engineering problems have the following characteristics: a) require coherent and detailed engineering knowledge, underpinning the technology area; *and one or more of:* b) are ill-posed, under- or over-specified, require identification and interpretation into the technology area; c) encompass systems within complex engineering systems;	a) coherent and detailed engineering knowledge for Engineers means the problem encountered cannot be solved without the combination of all the relevant detail including engineering principles applicable to the situation; b) the nature of the problem is not immediately obvious and further investigation to identify and interpret the real nature of the problem is necessary; c) the problem is not easily recognised as part of the larger engineering task, project or operation and may be obscured by the complexity of the larger system;

d) belong to families of problems which are solved in well-accepted but innovative ways; *and one or more of:* e) can be solved by structured analysis techniques; f) may be partially outside standards and codes; must provide justification to operate outside; g) require information from practice area and sources interfacing with practice area that is complex and incomplete; h) involve a variety of issues which may impose conflicting constraints: technical, engineering and interested or affected parties; *and one or both of:* i) require judgement in decision- making in practice area, considering interfaces to other areas; j) have significant consequences which are important in practice area but may extend more widely.	d) recognised that the problem can be classified as a falling within a typical solution requiring innovative adaptation to meet the specific situation; e) solving the problem needs a step-by-step approach adhering to proven logic; f) the standards, codes and documented procedures must be analysed to determine to what extent they are applicable to solve the problem and justification must be given to operate outside these; g) the responsibility lies with the Engineers to verify that some information received as part of the problem encountered may remain incomplete and solutions to problems may need justified assumptions; h) the problem handled by an Engineer may be solved by alternatives that are unaffordable, detrimental to the environment, socially unacceptable, not maintainable, not sustainable, etc. He/she will have to justify his/her recommendation; i) practical solutions to problems include knowledge and judgement of the roles displayed by the multi-disciplinary team and impact of own work in the interactive environment; j) Engineers must realise that their actions might seem to be of local importance only, but may develop into significant consequences extending beyond their own ability and practice area.
Assessment Criteria: A structured analysis of complex problems typified by the following performances is expected: 1.1 Performed or contributed in defining engineering problems leading to an agreed definition of the problems to be solved. 1.2 Performed or contributed in investigating engineering problems including collecting, organising and evaluating information. 1.3 Performed or contributed in analysis of engineering problems using conceptualisation, justified assumptions, limitations and evaluation of results	To perform an engineering task, an engineer will typically receive an instruction from a senior person (customer) to do a specific task, and must: 1.1 make very sure that the instruction is complete, clear and within his/her capability and that the person who issued the instruction agrees with his/her interpretation. 1.2 segregate the engineering problem and related information from the bulk of the information, investigate and evaluate. 1.3 ensure that the instruction and information to do the work is fully understood and complete, including engineering theory needed to understand the task and acceptance criteria, and to carry out and/or check calculations. If needed supplementary information must be gathered, studied and understood. Concepts and assumptions must be justified by engineering theory and calculations, if applicable.
Range Statement: The problem may be a design requirement, an applied Research and Development requirement or a problematic situation in an existing component, system or process. The problem is one amenable to solution by technologies known to the candidate. This outcome is concerned with the understanding of a problem: Outcome 2 is concerned with the solution.	**Please refer to clause 4 of the specific Discipline Specific Training Guideline.**

Outcome 2: Design or develop solutions to complex engineering problems	**Responsibility level C and D** Design means "drawing or outline from which something can be made". Develop means "come or bring into a state in which it is active or visible".
Assessment Criteria: This outcome is normally demonstrated after a problem analysis as defined in outcome 1. Working systematically to synthesise a solution to a complex problem, typified by the following performances is expected: 2.1 Designed or developed solutions to complex engineering problems. 2.2 Systematically synthesised solutions and alternative solutions or approaches to the problem by analysing designs against requirements, including costs and impacts on outside parameters. (requirements). 2.3 Drawing up detailed specification requirements and design documentation for implementation to the client's satisfaction.	After the task received is fully understood and interpreted a solution to the problem posed can be developed (designed). To synthesise a solution means "the combination of separate parts, elements, substances, etc. into a whole or into a system" by: 2.1 The development (design) of more than one way to solve an engineering task or problem should always be done, including the costing and impact assessment for each alternative. All the alternatives must meet the requirements set out by the instruction received, and <u>the theoretical calculations to support each alternative must be done and submitted as an attachment</u>. 2.2 The Engineer will in some cases not be able to support proposals with the complete theoretical calculation to substantiate every aspect and must in these cases refer his / her alternatives to an Engineer for scrutiny and support. The alternatives and alternative recommended must be convincingly detailed to win customer support for the alternative recommended. Selection of alternatives might be based on tenders submitted with alternatives deviating from those specified. 2.3 The best complete and final solution selected must be followed up with a detailed technical specification, supporting drawings, bill of quantities, etc., for the execution of work to meet customer requirements.
Range Statement: Solutions are those enabled by the technologies in the candidate's practice area.	Applying theory to do *complex engineering* work is mostly done in a way that has been used before, probably developed by engineers in the past and documented in written procedures, specifications, drawings, models, examples, etc. Engineers must seek approval of any deviation from these established methods, but also initiate and/or participate in developing and revising these norms.

Outcome 3: Comprehend and apply the knowledge embodied in widely accepted and applied engineering procedures, processes, systems or methodologies and those specific to the jurisdiction in which he/she practices.	**Responsibility level E** Comprehend means "to understand fully" the jurisdiction in which an Engineering practice is given in Clause 4 of the specific Discipline Specific Training Guideline.
Assessment criteria: This outcome is normally demonstrated in the course of design, investigation or operations. 3.1 Applied engineering principles, practices, technologies, including the application of BEng theory in the practice area. 3.2 Indicated working knowledge of areas of practice that interact with practice area to underpin teamwork. 3.3 Applied related knowledge of finance, statutory, safety and management.	Design work for Engineering s is based on BEng theory and is mostly the utilisation and configuration of manufactured components and selected materials and associated novel technology. Engineers develop and apply codes and procedures in their design work. Investigation would be on complex incidents and condition monitoring, and operations mostly on developing and improving engineering systems and operations. 3.1 Calculations at BEng theoretical level confirming the correct application and utilisation of equipment, materials and systems listed in Clause 4 of the specific Discipline Specific Training Guideline must be done on broadly-defined activities. 3.2 The understanding of complex procedures and techniques must be based on fundamental mathematical, scientific and engineering knowledge, as part of personal contribution within the engineering team. 3.3 The ability to manage the resources within legal and financial constraints must be evident.
Range Statement: Applicable knowledge includes: a) Technological knowledge that is well-established and applicable to the practice area irrespective of location, supplemented by locally relevant knowledge, for example, established properties of local materials. Emerging technologies are adopted from formulations of others. b) A working knowledge of interacting disciplines (engineering and other) to underpin teamwork. c) Jurisdictional knowledge includes legal and regulatory requirements as well as locally relevant codes of practice. As required for practice area, a selection of: law of contract, health and safety, environmental, intellectual property, contract administration, quality management, risk management, maintenance management, regulation, project and construction management.	a) The specific location of a task to be executed is the most important determining factor in the layout design and utilisation of equipment. A combination of educational knowledge and practical experience must be used to substantiate decisions taken including a comprehensive study of systems, materials, components and projected customer requirements and expectations. New ideas, materials, components and systems must be investigated, evaluated and applied accompanied by complex theoretical motivation. b) In spite of having a working knowledge of interacting disciplines, Engineers take responsibility for the multidisciplinary team of specialists like Civil Engineers on structures and roads, Mechanical Engineers on fire protection equipment, Architects on buildings, Electrical Engineers on communication equipment, etc. c) Jurisdictional in this instance means "having the authority", and Engineers must be aware of and decide on the relevant requirements applicable to each specific project that they are responsible for. They are usually appointed as the "responsible person" for specific projects in terms of the OHS Act.

Group B: Managing Engineering Activities.	Explanation and Responsibility Level
Outcome 4: Manage part or all of one or more *complex* engineering activities.	**Responsibility level D** Manage means "control".
Assessment Criteria: The candidate is expected to display personal and work process management abilities: 4.1 Manage self, people, work priorities, processes and resources in complex engineering work. 4.2 Role in planning, organising, leading and controlling complex engineering activities evident. 4.3 Knowledge of conditions and operation of contractors and the ability to establish and maintain professional and business relationships evident.	In engineering operations Engineers will typically be given the responsibility to carry out projects. 4.1 Resources are usually subdivided based on availability and controlled by a work breakdown structure and scheduling to meet deadlines. Quality, safety and environment management are important aspects. 4.2 The basic elements of managements must be applied to complex engineering work. 4.3 Depending on the project, Engineers can be the team leader, a team member, or can supervise appointed contractors. To achieve this, maintenance of relationships is important and must be demonstrated.

Outcome 5: Communicate clearly with others in the course of his or her broadly-defined engineering activities.	Responsibility level C
Assessment Criteria: Demonstrates effective communication by: 5.1 Ability to write clear, concise, effective technical, legal and editorially correct reports shown. 5.2 Ability to issue clear instructions to stakeholders using appropriate language and communication skills evident. 5.3 Oral presentations made using structure, style, language, visual aids and supporting documents appropriate to the audience and purpose.	5.1 Refer to Range Statement for Outcome 4 and 5 below. 5.2 Refer to Range Statement for Outcome 4 and 5 below. 5.3 Presentation of point of view mostly occurs in meetings and discussions with immediate supervisor.
Range Statement for Outcomes 4 and 5: Management and communication in *well-defined engineering* involves: a) Planning *complex* activities; b) Organising *complex* activities; c) Leading *complex* activities; and d) Controlling *complex* activities.	a) Planning means "the arrangement for doing or using something, considered in advance". b) Organising means "put into working order; arrange in a system; make preparations for". c) Leading means to "guide the actions and opinions of; influence; persuade". d) Controlling means the "means of regulating, restraining, keeping in order; check". e) Engineers write specifications for the purchase of materials and/or work to be done, recommendations on tenders received, place orders and variation orders, write work instructions, report back on work done, draw, correct and revise drawings, compile test reports, use operation and maintenance manuals to write work procedures, write inspection and audit reports, write commissioning reports, prepare and present motivations for new projects, compile budget reports, report on studies done and calculations carried out, report on customer requirements, report on safety incidents and risk analysis, report on equipment failure, report on proposed system improvement and new techniques, report back on cost control, etc.

Group C: Impacts of Engineering Activity.	Explanation and Responsibility Level
Outcome 6: Recognise the foreseeable social, cultural and environmental effects of *complex* engineering activities generally	Responsibility level B Social means “people living in communities; of relations between persons and communities”. Cultural means” all the arts, beliefs, social institutions, etc. characteristic of a community”. Environmental means “surroundings, circumstances, influences”.
Assessment Criteria: This outcome is normally displayed in the course of analysis and solution of problems. The candidate typically shows: 6.1 Ability to identify interested and affected parties and their expectations in regard to interactions between technical, social, cultural and environmental considerations shown. 6.2 Measures taken to mitigate the negative effects of engineering activities evident.	6.1 Engineering impacts heavily on the environment e.g. servitudes, expropriation of land, excavation of trenches with associated inconvenience, borrow pits, dust and obstruction, street and other crossings, power dips and interruptions, visual and noise pollution, malfunctions, oil and other leaks, electrocution of human beings, detrimental effect on animals and wild life, dangerous rotating and other machines, demolishing of structures, etc. 6.2 Mitigating measures taken may include environmental impact studies, environmental impact management, community involvement and communication, barricading and warning signs, temporary crossings, alternative supplies (ring feeders and bypass roads), press releases, compensation paid, etc.

Outcome 7: Meet all legal and regulatory requirements and protect the health and safety of persons in the course of his or her complex engineering activities.	**Responsibility level E**
Assessment Criteria: 7.1 Identified applicable legal and regulatory requirements including health and safety requirements for the engineering activity. 7.2 Circumstances stated where applicant assisted in, or demonstrated awareness of the selection of save and sustainable materials, components and systems and have identified risk and applied risk management strategies.	7.1 The OHS Act is supplemented by a variety of parliamentary acts, regulations, local authority by-laws, standards and codes of practice. Places of work might have standard procedures, instructions, drawings and operation and maintenance manuals available. These documents, depending on the situation (emergency, breakdown, etc.) are consulted before work is commenced and during the activity; 7.2 It is essential to attend a Risk Management (Assessment) course and to investigate and study the materials, components and systems used in the workplace. The Engineer seeks advice from knowledgeable and experienced specialists if the slightest doubt exist that safety and sustainability cannot be guaranteed.
Range Statement for Outcomes 6 and 7: Impacts and regulatory requirements include:	
a) Requirements include both explicit regulated factors and those that arise in the course of particular work;	a) The impacts will vary substantially with the location of the task, e.g. the impact of laying a cable or pipe in the main street of town will be entirely different to construction in a rural area. The methods, techniques or procedures will differ accordingly and may be complex and is identified and studied by the Engineering before starting the work.
b) Impacts considered extend over the lifecycle of the project and include the consequences of the technologies applied;	b) The Safety Officer and/or the Responsible Person appointed in accordance with the OHS Act usually confirm or check that the instructions are in line with regulations. The Engineer is responsible to see that this is done, and if not, establishes which regulations apply and ensures that they are adhered to. Usually the people working on site are strictly controlled w.r.t. health and safety, but the Engineer checks this is done and may authorise unavoidable deviation after setting conditions for such deviations. Projects are mostly carried out where contact with the public cannot be avoided, and safety measures like barricading and warning signs must be used and maintained.
c) Effects to be considered include direct and indirect, immediate and long-term related to the technology used;	c) Effects associated with risk management are mostly well known if not obvious, and methods used to address, clearly defined. Risks are mostly associated with elevated structures, subsidence of soil, electrocution of human beings and moving parts on machinery. The Engineer needs to identify, analyse and manage any long-term risks, and develop strategies to solve these by using alternative technologies.
d) Safe and sustainable materials, components and systems;	d) The safe and sustainable materials, components and systems must be selected and prescribed by the Engineer or other professional specialists must be consulted. It is the responsibility of the Engineer to use his/her knowledge and experience to confirm that prescriptions by others are correct and safe.
e) Regulatory requirements are explicit for the context in general.	e) Application of regulations associated with the particular aspects of the project must be carefully identified and controlled by the Engineer.

Group D: Exercise judgment, take responsibility, and act ethically.	**Explanation and Responsibility Level**
Outcome 8: Conduct engineering activities ethically.	**Responsibility level E** Ethically means "science of morals; moral soundness". Moral means "moral habits; standards of behaviour; principles of right and wrong".
Assessment Criteria: Sensitivity to ethical issues and the adoption of a systematic approach to resolving these issues is expected, typified by:	Systematic means "methodical; based on a system".
8.1 Conversance and operation in compliance with ECSA's Rules of Conduct for registered persons confirmed.	8.1 ECSA's Code of Conduct, as per ECSA's website, is known and adhered to.
8.2 How ethical problems and affected parties were identified, and the best solution to resolve the problem selected.	8.2 Ethical problems that can occur include tender fraud, payment bribery, alcohol abuse, sexual harassment, absenteeism, favouritism, defamation, fraudulent overtime claims, fraudulent expenses claimed, fraudulent qualifications, misrepresentation of facts, etc.

Outcome 9: Exercise sound judgement in the course of *complex* engineering activities	**Responsibility level E** Judgement means "good sense: ability to judge".
Assessment Criteria: Judgement is displayed by the following performance: 9.1 Judgement exercised in arriving at a conclusion within the application of technologies and their interrelationship to other disciplines and technologies. 9.2 Factors taken into consideration given, bearing in mind, risk, consequences in technology application and affected parties.	9.1 The extent of a project given to a junior Engineer is characterised by the several *complex* and a few *well-defined* factors and their resulting interdependence. He/she will seek advice if educational and/or experiential limitations are exceeded. 9.2 Taking risky decisions will lead to equipment failure, excessive installation and maintenance cost, damage to persons and property, etc. Evaluation includes engineering calculations to substantiate decisions taken, and assumptions made.
Range Statement for Outcomes 8 and 9*: Judgement* in decision making involves: a) taking several risk factors into account; or b) significant consequences in technology application and related contexts; or c) ranges of interested and affected parties with widely varying needs.	In Engineering, about 5% of engineering activities can be classified as *complex* where the Engineer uses standard procedures, codes of practice, specifications, etc., but develops variations and completely unique standards when needed. Judgement must be displayed to identify any activity falling inside the *complex* range, as defined above by: a) getting the work done in spite of numerous risk factors needs good judgement and substantiated decision making; b) consequences being part of the project e.g. extra cost due to unforeseen conditions, incompetent contractors, long term environmental damage, etc.; c) interested and affected parties with defined needs that may be in conflict e.g. need for a service irrespective of environmental damage, local traditions and preferences, etc. needs sound management and judgement.

Outcome 10: Be responsible for making decisions on part or all of all of one or more *complex* engineering activities	**Responsibility level E** Responsible means "legally or morally liable for carrying out a duty; for the care of something or somebody in a position where one may be blamed for loss, failure, etc.".
Assessment Criteria: Responsibility is displayed by the following performance: 10.1 Engineering, social, environment and sustainable development taken into consideration in discharging responsibilities for significant parts of one or more activities. 10.2 Advice sought from a responsible authority on matters outside your area of competence. 10.3 Academic knowledge of at least BEng level combined with past experience used in formulating decisions[1].	10.1 All interrelated factors taken into consideration are indicative of professional responsibility accepted working on complex activities. 10.2 The Engineer does not operate on tasks at a higher level than *complex* and consult professionals at engineer level if elements of the project to be done are beyond his/her education and experience, e.g. power system stability. 10.3 This is in the first instance of continuous self-evaluation to ascertain that the task given is done correctly, on time and within budget. Continuous feedback to the originator of the task instruction and corrective action if necessary form an important element. The calculations, for example, fault levels, load calculations, losses, etc. are done to ensure that the correct material and components are utilised.
Range Statement: Responsibility must be discharged for significant parts of one or more *complex* engineering activity.	The responsibility is mostly allocated within a team environment with an increasing designation as experience is gathered.
Note 1: Demonstrating responsibility would be under supervision of a competent engineering practitioner but is expected to perform as if he/she is in a responsible position.	

Group E: Initial Professional Development (IPD)	Explanation and Responsibility Level
Outcome 11: Undertake independent learning activities sufficient to maintain and extend his or her competence	Responsibility level D
Assessment Criteria: Self-development managed typically: 11.1 Strategy independently adopted to enhance professional development evident. 11.2 Awareness of philosophy of employer in regard to professional development evident.	11.1 If possible, a specific field of the sub-discipline is chosen, available developmental alternatives established, a programme drawn up (in consultation with employer if costs are involved), and options open to expand knowledge into additional fields investigated. 11.2 Record keeping must not be left to the employer or anybody else. The trainee must manage his/her own training independently, taking initiative and being in charge of experiential development towards Professional Engineering level.
Range Statement: Professional development involves: a) Planning own professional development strategy; b) Selecting appropriate professional development activities; and c) Recording professional development strategy and activities; while displaying independent learning ability.	a) In most places of work, training is seldom organised by some training department. It is up to the Engineer to manage his/her own experiential development. Engineers frequently end up in a 'dead-end street' being left behind doing repetitive work. If self-development is not driven by him/her, success is unlikely. b) Preference must be given to engineering development rather than developing soft skills. c) Developing a learning culture in the workplace environment of the Engineering is vital to his / her success. Information is readily available, and most senior personnel in the workplace are willing to mentor, if approached.

APPENDIX B: TRAINING ELEMENTS SCOPE

	Occupational		
	Tasks	**Contexts**	**Work Experience and Scope**
1	**Introduction**		
1.1		**Training Induction Programme**	**(Typically 1 to 5 days)**
1.1.1			Company structure
1.1.2			Company policies
1.1.3			Company Code of Conduct
1.1.4			Company safety regulations
1.1.5			Company staff code
1.1.6			Company regulations
1.2		**Exposure to engineering principles and processes**	**(Typically 6 to 12 months) and cover how things are:** **(Experience in one or more of these but not all)**
1.2.1		(Responsibility level A, B, C)	Manufacturing / Production
1.2.2			Laboratory and Testing
1.2.3			Project Management
1.2.4			Process Optimisation and Design
1.2.5			Plant Operations and Maintenance, Construction, Commissioning and Decommissioning
1.2.6			Heat treatment (Use of equipment e.g. furnace, spectrometer)

	Occupational		
	Tasks	**Contexts**	**Work Experience and Scope**
1.2.7			Mechanical testing of materials
1.2.8			Non-destructive testing of materials
1.2.9			Chemical analysis
1.2.10			Problem Investigation & Failure investigations
1.3		**Experience in design and application of design knowledge**	**(Typically 12 to 18 months) and would focus on planning, design and application**
1.3.1		(Responsibility level C&D)	Analysis of data and systems
1.3.2			Research and investigation
1.3.3			Preparation of specifications and associated documentation
1.3.4			System modelling and integration
1.3.5			System & Software Designs
1.3.6			Component / Product designs
1.3.7			Preparation of contract documents and associated documentation
1.3.8			Preparation of project management documents
1.3.9			Application of quality systems
1.3.10			Configuration and Documentation management (Quality Management Systems)
1.3.11			Development of standards and procedures

	Occupational		
	Tasks	Contexts	Work Experience and Scope
1.4		**Experience in the execution of engineering tasks**	**Rest of training period, focus should be on projects and project management.** **(Working in one or more of these but not in all)**
1.3.1		(Responsibility level E)	Plant & Process Design
1.3.2			Process Optimisation
1.3.3			Manufacture / Production
1.3.4			Construction and Installation
1.3.5			Project Management
1.3.6			Commissioning
1.3.7			Plant Operations and Maintenance
1.3.8			Modifications
1.3.9			Decommissioning
1.3.10			Safety Standards and Processes
1.3.11			Research and Development
	(Responsibility Level E)		
2	**Solving problems based on engineering and contextual knowledge**		
2.1		Conceptualisation of complex engineering problems	
2.1.1			Receive brief
2.1.2			Investigate / evaluate requirements

	Occupational		
	Tasks	**Contexts**	**Work Experience and Scope**
2.1.3			Develop preliminary solutions
2.1.4			Justify the preliminary design
2.2		Design or development processes for complex engineering problems	
2.2.1			Detailed design or development processes
2.2.2			Documentation development for Implementing complex engineering Solutions
3	**Implementing projects or operating engineering systems or processes**		
3.1		Planning processes for Implementation or Operations	
3.1.1			Develop business and stakeholder relationships
3.1.2			Scope and plan
3.2		Organising processes for Implementation or Operations	
3.2.1			Manage resources
3.2.1			Optimisation of resources and processes
3.3		Controlling processes for Implementation or Operations	
3.3.1			Monitor progress and delivery
3.3.2			Monitor quality
3.4		Close out Processes for Implementation or Operations	
3.4.1			Commissioning processes
3.4.2			Development of operational documentation

	Occupational		
	Tasks	**Contexts**	**Work Experience and Scope**
3.4.3			Handover processes
3.5		Maintenance and repair processes	
3.5.1			Maintenance planning and scheduling
3.5.2			Monitor quality
3.5.3			Oversee repairs and/or implement remedial processes
4	**Risk and Impact Mitigation**		
4.1		Impact and risk assessments	
4.1.1			Impact assessments
4.1.2			Risk assessments
4.1.3			Mitigation Plans
4.2		Regulatory compliance processes	
4.2.1			Health and Safety
4.2.2			Legal and regulatory
5	**Managing Engineering Activities**		
5.1		Self-Management Processes	
5.1.1			Manage own activities
5.1.2			Communicate effectively

	Occupational		
	Tasks	Contexts	Work Experience and Scope
5.2		Team Environment	
5.2.1			Participate in and contribute to team planning activities
5.2.2			Manage people
5.3		Professional communication and relationships	
5.3.1			Establish and maintain professional and business relationships
5.3.2			Communicates effectively
5.4		Exercising Judgement and Taking Responsibility	
5.4.1			Ethical practices
5.4.2			Exercise sound judgement in the course of complex engineering activities
5.4.3			Be responsible for decision making on part or all of complex engineering activities
5.5		Competency development	
5.5.1			Plan own development strategy
5.5.2			Construct initial professional development record