ECSA

ENGINEERING COUNCIL OF SOUTH AFRICA

An Effective Regulator Assuring Engineering Excellence

Discipline-specific Training Guide for Registration as a Professional Engineer, Technologist or Technician in Chemical Engineering

R-05-CHE-PE/PT/PN

REVISION 0: 25 JUNE 2024

ENGINEERING COUNCIL OF SOUTH AFRICA
Tel: 011 6079500 | Fax: 011 6229295
Email: engineer@ecsa.co.za | Website: www.ecsa.co.za

TABLE OF CONTENTS

INTRODUCTION......6
DEFINITIONS......7
ABBREVIATIONS......12
BACKGROUND......15
1. PURPOSE OF THIS DOCUMENT......16
2. AUDIENCE......16
2.1 Persons registered with ECSA as a Candidate......17
2.2 Persons not registered with ECSA as a Candidate......18
3. TYPE OF ENGINEERING WORK......18
3.1 Chemical Engineering Professionals Organising Framework for Occupations......18
3.2 Typical tasks a Chemical Engineering Professional may undertake......20
3.3 Areas of Chemical Engineering......23
4. DEVELOPING ENGINEERING COMPETENCIES......24
4.1 Training for registration as a Professional Engineer......34
4.1.1 Outcome 1: Define, investigate and analyse complex engineering problems (Responsibility Level E)......34
4.1.2 Outcome 2: Design or develop solutions to complex engineering problems (Responsibility Levels C and D)......36
4.1.3 Outcome 3: Comprehend and apply advanced and local knowledge of the widely applied principles underpinning good practice that is specific to the jurisdiction in which the Engineer practices. (Responsibility Level E)......38
4.1.4 Outcome 4: Manage part or all of one or more complex engineering activities (Responsibility Level D)......39
4.1.5 Outcome 5: Communicate clearly using multiple media and collaborate inclusively with a broad range of stakeholders in the course of engineering activities. (Responsibility Level C)......40
4.1.6 Outcome 6: Recognise the reasonably foreseeable economic, social, cultural, and environmental effects of complex engineering activities seeking to achieve sustainability. (Responsibility Level B)......41

4.1.7 Outcome 7: Meet all legal and regulatory requirements and protect the health and safety of persons during all complex engineering activities. (Responsibility Level E) 43

4.1.8 Outcome 8: Conduct engineering activities ethically (Responsibility Level E) 44

4.1.9 Outcome 9: Exercise sound judgement by evaluating the outcomes, impacts and alternatives in the course of complex engineering activities. (Responsibility Level E) 46

4.1.10 Outcome 10: Be responsible for making decisions on part or all of complex engineering activities. (Responsibility Level E) 48

4.1.11 Outcome 11: Undertake sufficient professional development activities to maintain, extend competence and enhance the ability to adapt to emerging technologies and the ever-changing nature of work (Responsibility Level D) 49

4.2 Training for registration as a Professional Engineering Technologist 50

4.2.1 Outcome 1: Define, investigate and analyse broadly defined engineering problems (Responsibility Level E) 50

4.2.2 Outcome 2: Design or develop solutions to broadly defined engineering problems (Responsibility Levels C and D) 52

4.2.3 Outcome 3: Comprehend and apply knowledge that is embodied in established engineering practices that is specific to the jurisdiction in which the Engineering Technician practices. (Responsibility Level E) 53

4.2.4 Outcome 4: Manage part or all of one or more broadly defined engineering activities (Responsibility Level D) 54

4.2.5 Outcome 5: Communicate clearly using multiple media and collaborate inclusively with a broad range of stakeholders in the course of engineering activities. (Responsibility Level C) 56

4.2.6 Outcome 6: Recognise the reasonably foreseeable economic, social, cultural, and environmental effects of broadly defined engineering activities seeking to achieve sustainability (Responsibility Level B)....57

4.2.7 Outcome 7: Meet all legal and regulatory requirements and protect the health and safety of persons during all broadly defined engineering activities (Responsibility Level E) 59

4.2.8 Outcome 8: Conduct engineering activities ethically (Responsibility Level E) 62

4.2.9 Outcome 9: Exercise sound judgement by evaluating the outcomes, impacts and alternatives in the course of broadly defined engineering activities. (Responsibility Level E) 63

4.2.10 Outcome 10: Be responsible for making decisions on part or all of broadly defined engineering activities. (Responsibility Level E)....65

4.2.11 Outcome 11: Undertake sufficient professional development activities to maintain, extend competence and enhance the ability to adapt to emerging technologies and the ever-changing nature of work. (Responsibility Level D) 66

4.3 Training for registration as a Professional Engineering Technician 67

4.3.1 Outcome 1: Define, investigate and analyse well-defined engineering problems (Responsibility Level E) 67

4.3.2 Outcome 2: Design or develop solutions to well-defined engineering problems (Responsibility Levels C and D) 68

4.3.3 Outcome 3: Comprehend and apply knowledge that is embodied in established engineering practices that is specific to the jurisdiction in which the engineering technician practises. (Responsibility Level E)....69

4.3.4 Outcome 4: Manage part or all of one or more well-defined engineering activities. (Responsibility Level D) 71

4.3.5 Outcome 5: Communicate clearly using multiple mediums and collaborate inclusively with a broad range of stakeholders in the course of engineering activities. (Responsibility Level C) 71

4.3.6 Outcome 6: Recognise the reasonably foreseeable economic, social, cultural and environmental effects of well-defined engineering activities seeking to achieve sustainability. (Responsibility Level B)....72

4.3.7 Outcome 7: Meet all legal and regulatory requirements and protect the health and safety of persons during all well-defined engineering activities. (Responsibility Level E) 73

4.3.8 Outcome 8: Conduct engineering activities ethically (Responsibility Level E) 73

4.3.9 Outcome 9: Exercise sound judgement by evaluating the outcomes, impacts and alternatives in the course of well-defined engineering activities. (Responsibility Level E) 74

4.3.10 Outcome 10: Be responsible for making decisions on part or all of well-defined engineering activities. (Responsibility Level E) 75

4.3.11 Outcome 11: Undertake sufficient professional development activities to maintain, extend competence and enhance the ability to adapt to emerging technologies and the ever-changing nature of work. (Responsibility Level D) 75

5. FUNCTIONS PERFORMED 76

5.1 Degrees of responsibilities 76

5.2 Recommended learning 81

APPENDIX A: TRAINING ELEMENTS 87

APPENDIX B: TRAINING ELEMENTS 103

INTRODUCTION

All persons applying for registration as a Professional Engineer, Technologist or Technician are expected to demonstrate the competencies specified in document **R-02-STA-PE/PT/PN** through work performed at the prescribed level of responsibility, irrespective of the Applicant's/ Candidate's discipline.

The *Training and Mentoring Guide for Professional Categories* (document **R-04-T&M-GUIDE-PC**) provides key aspects of training. These are as follows:

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

It is therefore important to standardise the framework for all engineering disciplines to ensure that all ECSA registration categories are aligned.

DEFINITIONS

Applicant: A person applying to the ECSA for registration in any of the categories according to Section 18 of the Engineering Profession Act, 46 of 2000.

Broadly defined engineering problems: Composed of many inter-related conditions and requiring underpinning methods, procedures, and technical judgement to create a solution within a set of originally broadly defined circumstances

Broadly defined engineering work is characterised by the following:

- It is constrained by available technology, time, finance, infrastructure, resources, facilities, applicable laws, standards and codes.
- It involves a variety of resources, including people, money, equipment, materials and technologies.
- It requires the resolution of occasional problems arising from interactions among wide-ranging or conflicting issues such as technical and engineering issues.
- It has significant risks and consequences in the practice area and related areas.
- The practice area is located within a wider, complex context; it requires teamwork and has interfaces with other parties and disciplines.
- The scope of the practice area is linked to the technologies used and the changes due to the adoption of new technology into current practice.

Candidate means a person who is registered with ECSA in a candidate category of registration.

Complex engineering work is characterised by the following:

- Scope of activities may encompass entire complex engineering systems or complex subsystems.
- A context that is complex and varying, is multidisciplinary, requires teamwork, is unpredictable and may need to be identified.

- It requires diverse and significant resources including people, money, equipment, materials, technologies.
- Significant interactions exist among wide-ranging or conflicting technical, engineering or other issues.
- It is constrained by time, finance, infrastructure, resources, facilities, standards and codes, and applicable laws.
- It has significant risks and consequences in a range of contexts.

Competency standard means a statement of competency required for a defined purpose.

Engineering problem means problem that requires the application of engineering theories, principles, knowledge and skills to find a solution. These problems typically arise in various fields of engineering. Engineering problems can range from designing and building structures, developing new technologies or products, optimising processes and/ or systems, improving efficiency, solving complex mathematical equations, troubleshooting technical issues and addressing safety concerns, among many others. The goal of solving an engineering problem is to create innovative and practical solutions that meet specific requirements, adhere to applicable regulations and standards and utilise techniques such as cost benefit analysis, risk analysis and technical evaluations to arrive at a cost-effective and sustainable solution.

Engineering science means a branch of science that applies scientific principles and methods to solve engineering problems. It involves the study and application of various scientific disciplines, such as physics, chemistry, mathematics, and materials science, to design and develop innovative solutions to address engineering problems. Engineering science focuses on understanding the fundamental principles underlying engineering systems and processes, and uses this knowledge to analyse, predict and optimise the behaviour and performance of engineering systems. It provides the theoretical foundation for various engineering disciplines and plays a crucial role in advancing technology and driving innovation in engineering

Ill-posed problem means a problem in which the requirements are not fully defined or may be defined erroneously by the requesting party.

Integrated performance refers to the evaluation and optimisation of various aspects of a system or product to ensure its overall efficiency, effectiveness, and reliability. It involves considering multiple performance factors, such as functionality, safety, durability, maintainability, cost-effectiveness, and environmental impact, and integrating them into a cohesive design. It considers the interactions and trade-offs among different components, subsystems and functions within a system. It aims to achieve a balance between conflicting requirements and constraints to create a well-rounded and high-performing solution. This holistic approach helps ensure that all aspects of the design work together harmoniously, resulting in a successful and optimised engineering solution.

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

Management of engineering works or activities refers to the process of planning, organising, coordinating and controlling various engineering projects or tasks. It involves overseeing the activities of engineers and other personnel involved in the design, development, construction and maintenance of engineering projects for the successful execution of engineering projects, ensuring that they are completed on time, within budget and to the desired quality standards.

Key responsibilities of engineering management may include:

- **Planning**: Defining project objectives, scope and deliverables, and creating a detailed plan to achieve them.
- **Resource management**: Determining the required resources, such as personnel, equipment and materials, and allocating them appropriately to ensure smooth execution of engineering work.
- **Team coordination**: Managing and leading a team involved in the activities of performing engineering work and ensuring effective communication, collaboration and coordination among team members.
- **Risk management**: Identifying potential risks and developing strategies to mitigate them.

- **Quality control**: Implementing quality assurance processes to ensure that engineering works meet the required standards and specifications.
- **Budget and cost control**: Monitoring project expenses, tracking costs, and ensuring that projects are completed within the allocated budget.
- **Stakeholder management**: Engaging with clients, contractors, suppliers and other stakeholders to address their concerns, manage expectations and maintain positive relationships.
- **Executing engineering work**: Direct and control engineering processes and systems, including commissioning, operating and decommissioning equipment, while maintaining safety at all times, and ensuring timeous completion.

Mentor means a professionally registered person who guides the competency development of a Candidate in an appropriate category.

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

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

Practice area means a generally recognised or distinctive area of knowledge and expertise developed by an engineering practitioner through following the path of education, training and experience.

Range statement means the required extent or the limitations of 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 are licensed through the Engineering Profession Act, 46 of 2000 or a combination of external legislation and the Engineering Profession Act and who have specific engineering competencies at the level of NQF 5 that are associated with an identified need to protect the public safety, health and interest or the environment in relation to an engineering activity.

Supervisor means a person who oversees and controls engineering work performed by a candidate.

Well-defined engineering problems: Problems composed of inter-related conditions and requiring underpinning methods, procedures, and techniques to create a solution within a set of originally well-defined circumstances.

ABBREVIATIONS

AI	Artificial Intelligence
AR	Augmented Reality
APC	Advanced Process Control
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
BEng Tech	Bachelor of Engineering Technology
BEng	Bachelor of Engineering
BTech (Eng)	Bachelor of Technology Engineering
BDEA	Broadly Defined Engineering Activities
CAPEX	Capital Expenditure
C&I	Control and Instrumentation Engineering
C&U	Commitment and Undertaking
CPD	Continuing Professional Development
DCS	Distributed Control System
DSTG	Discipline-Specific Training Guide
ECSA	Engineering Council of South Africa
EPCM	Engineering Procurement Construction Management
EIAs	Environmental Impact Assessments
FIDIC	Fédération Internationale des Ingénieurs-Conseils (The International Federation of Consulting Engineers)
GCC	General Conditions of Contract
HAZOP	Hazard and Operability
FEED	Front End Engineering Design
FMCG	Fast Moving Consumable Goods
ICI	Imperial Chemical Industries
ICT	Information and Communication Technology

IDoEW	Identification of Engineering Work
IPD	Initial Professional Development
IT	Information Technology
LOPA	Layer of Protection Analysis
MHS	Mine Health and Safety
N.Dip	National Diploma
NEC	New Engineering Contract
NEMA	National Environmental Management Act
NWA	National Water Act
NQF	National Qualification Framework
OFO	Organising Framework for Occupations
OPEX	Operating Expenses
OHS	Occupational Health and Safety
PCE	Professional Certificated Engineer
PFD	Process Flow Diagram
PID	Piping and instrumentation diagrams
Pr Eng Tech	Professional Engineering Technologist
PROCSA	Professional Consultants Services Agreement Committee
PGDip	Post-graduate Diploma
PE	Professional Engineer
PLC	Programmable Logic Controller
PN	Professional Engineering Technician
PT	Professional Engineering Technologist
RCA	Root Cause Analysis
SCADA	Supervisory Control and Data Acquisition
TEMA	Tubular Exchanger Manufactures Association
TES	Training and Experience Summary

TERs	Training and Experience Reports
VIPs	Value Improvement Practices
VR	Virtual Reality
4IR	Fourth Industrial Revolution

BACKGROUND

Figure 1 defines the documents that comprise the Engineering Council of South Africa (ECSA) system for registration in professional categories. The illustration also locates the current document.

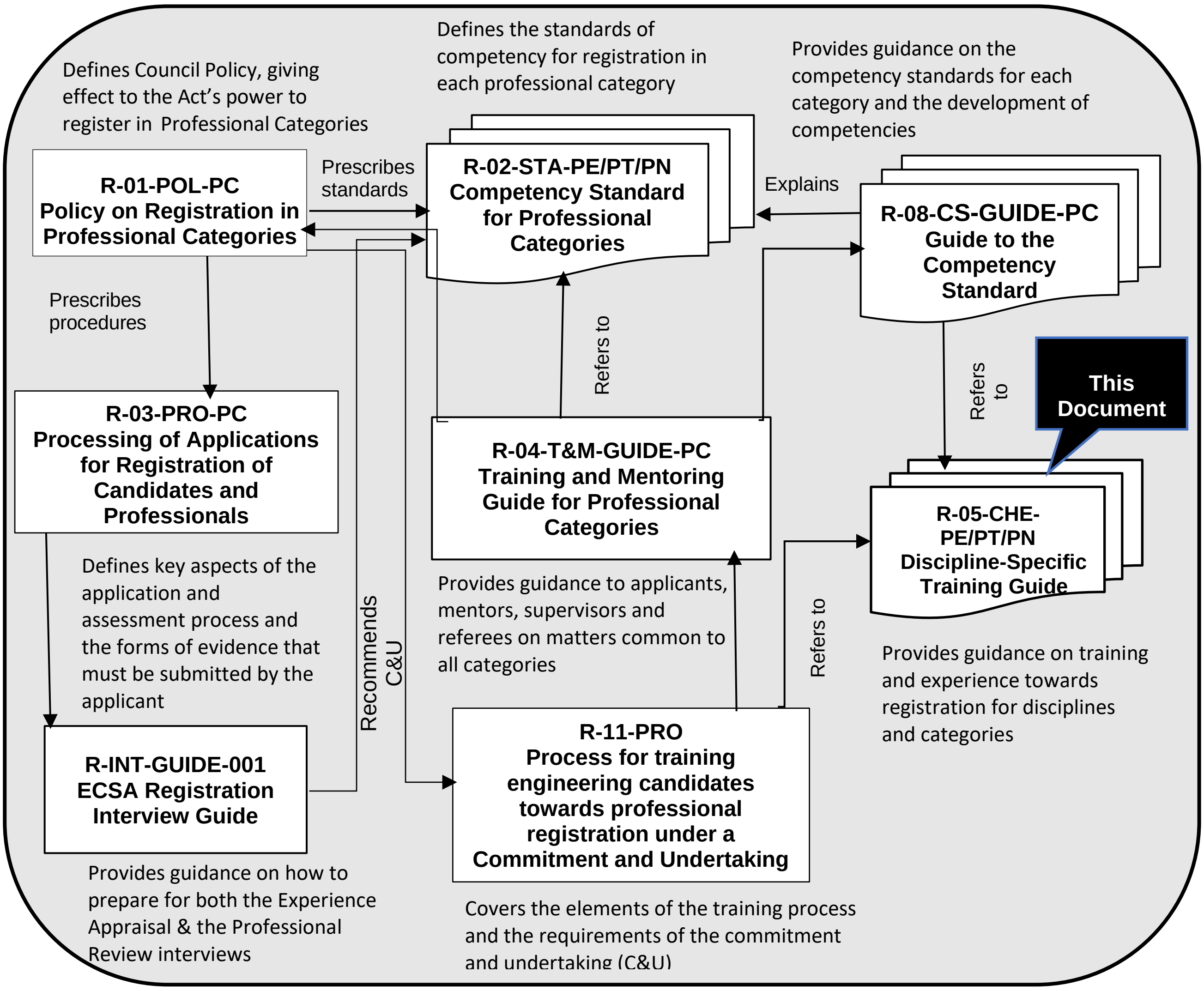

Figure 1: Documents defining the ECSA Registration System

1. PURPOSE OF THIS DOCUMENT

All persons applying for registration as Engineering Professionals are expected to demonstrate the competencies specified in document R-02-STA-PE/PT/PN through work performed at the prescribed level of responsibility, irrespective of the 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 Registration* in *Professional Categories* (document **R-08_CS-GUIDE-PE/PT/PN**) for Applicant Chemical Engineers, Technologists and Technicians or any other person who intends to register as a Professional with the ECSA in the respective discipline.

This document must be read in conjunction with the following documents:

- Policy on Registration in Professional Categories (document **R-01-POL-PC**)
- Processing of Applicants for Registration of Applicants and Professionals (document **R-03-PRO-PC**)
- Training and Mentoring Guide for Professional Categories (document **R-04-TM-GUIDE-PC**).

2. AUDIENCE

This Discipline-specific Training Guide (DSTG) provides guidance and support to those interested in applying for registration to become professionals through ECSA in the field of Chemical Engineering. Additionally, supervisors and mentors of these aspiring applicants can also benefit from this guide, as it offers best practices and elements necessary for a comprehensive training and experience programme.

This guide applies to persons who:

- are registered as a Candidate Engineer, Technologist, or Technician and/or embarked on a process of training under a registered mentor guiding the professional development process at each stage
- are not registered as a candidate, but deem it fit based on experience specified in this document to apply to become a professional

- hold an ECSA-accredited qualification or an acceptable combination of accredited qualifications prescribed for the category
- have met the minimum education in a specific category through ECSA educational qualification evaluation or assessment
- have qualifications recognised by the Washington, Sydney and Dublin Accords for which the ECSA is a signatory thereof
- hold a qualification or combination of qualifications recognised under an international academic agreement relevant to the category; or
- hold a qualification or a combination of qualifications that has been determined on a case-by-case evaluation to satisfy criteria for substantial equivalence to an accredited qualification for the category by virtue of:
    - the qualifications being awarded in a jurisdiction or a quality assurance system by the ECSA; or
    - examination of detailed documentation on the qualifications reflecting substantial equivalence.

2.1 Persons registered with ECSA as a Candidate

Candidate engineering practitioners refer to persons registered with the ECSA after completing the relevant engineering undergraduate programme as accredited or substantially assessed to be equivalent by the ECSA. Training and development can be done under a Commitment and Undertaking (C&U) candidacy programme according to document **R-11-PRO-PC** or through a training academy's programme as outlined in document **A-01-POL**.

The training under a C&U or through a training academy is structured to align with the ECSA standard competency outcomes for the benefit of the Candidate. The professional Mentor, Supervisor, Coach and the Candidate must ensure that the training covers all developmental aspects aligned with the competency outcomes required for registration as a professional. Mature applicants for registration may apply the guide retrospectively to identify possible gaps in their development.

2.2 Persons not registered with ECSA as a Candidate

Individuals who meet the qualifications and competence requirements outlined in **R-02-STA-PE/PT/PN** can apply for professional registration without going through the Candidate route. However, it is still essential for these individuals to have mentorship and supervision to ensure effective development towards meeting the competency requirements for professional registration. If the employer does not offer C&U, the aspiring applicant should seek mentorship. If no internal mentor is available, an external mentor can be sought. The individual can consult the Voluntary Association (VA) for the discipline to assist in locating an external mentor. The mentor should stay updated on the development process and the ECSA registration requirements.

This document is intended for Applicants/Candidates undergoing training and gaining experience in preparation for registration. Applicants who have not had mentorship are advised to seek the guidance of an experienced mentor (internal or external) when preparing their registration applications.

Document **R-08-CS-GUIDE-PE/PT/PN** guides individuals with unconventional developmental paths, such as academics, researchers and specialists.

3. TYPE OF ENGINEERING WORK

The engineering professional is responsible for ensuring that the work is carried out competently and in accordance with the relevant engineering standards and regulations. In terms of Section 27(1) of the Engineering Profession Act, 46 of 2000, the Council must draw up a Code of Conduct for Registered Persons and may draw up a Code of Practice in consultation with the Council for the Built Environment, VAs and registered persons

3.1 Chemical Engineering Professionals Organising Framework for Occupations

Chemical Engineering is concerned with the design, development, installation, operation and maintenance of chemical processes and systems. It involves the production and use of chemical substances to convert input materials into outputs, while controlling waste and maintaining the balance of the system. It interfaces with many engineering disciplines, including mechanical, electrical, civil, construction, industrial and materials engineering, among others. Chemical Engineering Professionals work in various industries to perform tasks such as the following:

- **Design:** Developing plans for new chemical products or modifying existing ones.
- **Production:** Planning and designing new production processes or maintaining equipment used in chemical manufacturing.
- **Research and development:** Continuously seeking innovative solutions to engineering problems using new technologies and scientific advancements.

Chemical Engineering practitioners must have a strong understanding of mathematics, science and engineering principles. They also need excellent problem-solving skills and attention to detail. Chemical Engineering Professionals undertake the planning, design, construction, operation and maintenance of materials, components, machinery, plants and systems related to chemical processes, including reactors, separators, distillation columns, heat exchangers and other equipment used in chemical production. In addition, Chemical Engineering Professionals provide expertise and advice on the chemical aspects of specific materials, products or processes. This involves applying engineering sciences such as chemical kinetics, thermodynamics, fluid mechanics, mass transfer and process control. They may work on projects related to pharmaceuticals, petrochemicals, polymers, food processing, environmental engineering and many other areas.

The levels of engineering problems for the different categories of registration in Chemical Engineering are outlined as follows:

- **Professional Engineer:** Solves complex engineering problems and performs advanced engineering activities.
- **Professional Engineering Technologist:** Solves broadly defined engineering problems and performs specialised engineering activities.
- **Professional Engineering Technician:** Solves well-defined engineering problems and performs technical engineering activities.

The characteristics and details of each level descriptor can be found in the Competency Standard for Registration, document **R-02-STA-PE/PT/PN**, which defines the competencies required for each category.

3.2 Typical tasks a Chemical Engineering Professional may undertake

Engineering professionals can be involved in various types of work. Some common types of engineering work include the following:

Research and development:

- Conducting research, advising on and developing broadly defined, commercial-scale processes to produce substances and items such as petroleum derivatives, chemicals, food and drink products, pulp and paper, pharmaceuticals and synthetic materials such as polymers, plastics and cement, in addition to incorporating energy and mineral processing and water treatment.
- Performing tests throughout stages of production to determine degree of control over process variables, which include composition, temperature, density, specific gravity and pressure.
- Performing laboratory studies of steps in the manufacturing of new products and testing proposed processes by employing small-scale operations such as a pilot plant. This type of work may be performed in research and product- development centres of business organisations or at academic institutions. Applicants must undertake research and development work that is predominantly Chemical Engineering in nature, and this work should include an in-depth application of the various aspects of Chemical Engineering.

Safety Engineering:

- Participating in and leading risk assessment studies such as hazard and operability (HAZOP) studies during phases of design or operation of equipment, systems and plants.
- Establishing control standards and procedures to ensure the safety of production operations and the safety of workers operating equipment or working in close proximity to on-going chemical reactions or processes.

- Developing and implementing safety protocols and procedures to ensure compliance with regulatory standards.

Process Design and Development

- Designing process plants and equipment and devising processes for manufacturing products while meeting targeted efficiencies.
- Optimising processes for efficiency, safety and sustainability.
- Specifying chemical production methods, equipment, materials and quality standards and ensuring that all conform to specifications and accepted industry practices and standards.
- Collaborating with cross-functional teams, including engineers, scientists and technicians within Chemical Engineering and within other engineering disciplines to develop and implement process improvements.
- Conducting economic evaluations and feasibility studies for new projects or process modifications.

Product Development and Quality Control

- Performing laboratory studies of steps in the manufacturing of new products and testing proposed processes by employing small-scale operations such as a pilot plant.

Plant Operation and Management

- Developing operating procedures to be employed during design and operating phases, including start-up, shutdown and emergency procedures, preparing of cost estimates such as (CAPEX, OPEX and lifecycle) and production progress reports for management.
- Overseeing plant operation and/or management.
- Optimising processes and products for improvement of prescribed performance indices such as profitability, sustainability, energy consumption, environmental sustainability and carbon efficiency.
- Conducting process troubleshooting and problem-solving to identify and resolve operational issues.

- Providing technical support and guidance to production personnel to ensure efficient and safe operation of chemical processes.
- Developing and implementing process optimisation strategies to improve product quality, yield and efficiency.
- Monitoring and analysing process data to identify trends, deviations, and opportunities for improvement.
- Developing and managing budgets and costs associated with engineering works.
- Training and mentoring junior staff members.
- Evaluating social, environmental, statutory and legal considerations or the modification of existing plants.

Environmental Protection

- Conducting environmental impact assessments and developing strategies for waste management and pollution prevention.

Process Control and Optimisation

- Developing broadly defined process control philosophies and/or advanced process control systems.

Consulting and Entrepreneurship

- Managing projects, including coordinating, and overseeing the work of technicians, operators, and other external service providers such as suppliers to ensure adherence to project timelines and budgets.
- Conducting economic evaluations and feasibility studies for new projects or process modifications.

Construction and Project Management

- Construction process, managing projects and ensuring that designs are implemented correctly according to scope. This can involve coordinating with contractors, conducting site inspections, and managing budgets and timelines.

The above are just a few examples of the types of chemical engineering work that professionals can be involved in. The specific nature of the work can vary depending on the specific industry.

3.3 Areas of Chemical Engineering

Chemical Engineering Professionals generally concentrate on one or more of the following areas:

- **Process engineering:** designing and optimising chemical processes, such as those used in the production of chemicals, pharmaceuticals and fuels.
- **Heat transfer and fluid mechanics:** transport of heat and fluids in various systems, including heat exchangers, reactors and pipelines.
- **Environmental impact studies:** designing and implementing processes to minimise the environmental impact of chemical manufacturing and waste treatment.
- **Materials engineering:** development and selection of materials for various applications, such as polymers, composites and catalysts.
- **Energy systems:** design and optimisation of energy systems, such as power plants, including renewable energy technologies and energy storage.
- **Process control and optimisation:** development and implementation of control systems to ensure the efficient and safe operation of chemical processes.
- **Safety:** identifying and mitigating potential hazards in chemical processes and ensuring the safety of workers and the surrounding environment. This also entails developing and implementing safety management systems to prevent and mitigate accidents in chemical plants.
- **Chemical reaction:** studying and optimisation of chemical reactions, including kinetics, reactor design and catalyst development.
- **Process modelling and simulation:** usage of computer-based tools to model and simulate chemical processes, aiding in process design and optimisation.
- **Separation plant:** working on separation processes, such as distillation, absorption and adsorption, involve the separation of components in a mixture based on their different

physical or chemical properties, crystallization and membrane filtration to separate and purify different components in mixtures.

- **Process equipment design:** design and selection of equipment used in chemical processes, such as reactors, separators and pumps.
- **Chemical plant design and construction:** design and construction of chemical plants, ensuring that they are safe, efficient and meet regulatory requirements.
- **Chemical process economics:** evaluation of the economic viability of chemical processes and making decisions regarding investment, production costs and profitability.
- **Research and Development:** Engineering professionals may work on developing new technologies, materials or processes. This can involve conducting experiments, analysing data and designing prototypes.

4. DEVELOPING ENGINEERING COMPETENCIES

Chemical Engineering professionals are employed in a wide range of sectors and industries. Their expertise is in demand due to factors such as globalisation, technological advancements, environmental considerations, government policies and market demands for sustainable products and services.

Table 1 provides an overview of the sectors and industries in which chemical engineering professionals may be employed, as well as the application of their expertise. For example, in the energy sector, they work on processes related to oil and gas exploration, production, refining and transportation. They also design and optimise processes for electricity production. In the manufacturing sector, they are involved in iron and steel production, steelmaking processes, casting and solidification, and heat treatment of steel. They also work in the chemical industry, food and beverage processing, industrial machinery, rubber formulation, and pulp and paper production. In the health sector, they contribute to pharmaceutical manufacturing. They are also involved in construction engineering, risk management, project management and providing professional services. In the public sector, they work on infrastructure planning, policy development and providing municipal services. In the ICT sector, they use data analysis and modelling techniques to optimise processes and implement control systems. They also provide consulting services and contribute to academic research and education. In the water sector, they work on water and wastewater management, treatment and infrastructure design.

While Chemical Engineering cuts across various sectors and industries, it is important to note that legal and regulatory bodies govern the Chemical Engineering profession in those industries. These will be dealt with in section 4, under the statutory and regulatory requirements outcome. In executing Engineering Work, Chemical Engineering professionals must comply with the relevant overarching legislation and amendments, 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
- Employment Equity Act, 55 of 1998
- Hazardous Substance Act, 5 of 1973
- Minerals and Energy Acts, (e.g., Mineral and Petroleum Act, 28 of 2002)
- Mine Health and Safety Act, 29 of 1996
- Project and Construction Management Professions Act, 48 of 2000
- National Environmental Management Act, 107 of 1998
- National Radioactive Waste Disposal Institute Act, 53 of 2008
- National Nuclear Regulatory Act, 47 of 1999
- Nuclear Energy Act, 46 of 1999
- National Water Act, 36 of 1998
- Occupational Health and Safety Act, 85 of 1993 and Regulations
- Construction Industry Development Board Act, 38 of 2000
- Construction Regulations 2014
- Pressure Equipment Regulations 2016
- Specific work instructions, standards, and/or specifications of the enterprise
- Protection of Personal Information Act, 2013

- Any other relevant codes and standards applicable to the relevant industry of practice

Some of the listed acts are used in daily operations and failure to comply with these acts can result in the operations being stopped or the responsible individuals in the company being subject to legal consequences, such as imprisonment or fines. Here is an explanation of what some of these Acts entail:

- **Occupational Health and Safety Act, 85 of 1993**: This legislation sets out health and safety requirements for workplaces, including chemical engineering facilities, to protect employees and other individuals from work-related hazards.
- **Engineering Profession Act, 46 of 2000:** This legislation governs the engineering Profession in South Africa. It establishes the regulatory framework for the engineering profession and aims to promote high standards of professional conduct, ethical practice and competency among engineers in South Africa.
- **National Environmental Management Act, 107 of 1998:** This Act provides the legal framework for environmental management in South Africa, including regulating activities that may have an impact on the environment, such as chemical engineering processes.
- **Hazardous Substances Act, 15 of 1973:** This Act regulates the handling, storage, transportation, and disposal of hazardous substances, including chemicals used in chemical engineering operations.
- **National Water Act, 36 of 1998:** This legislation governs the sustainable use and protection of water resources in South Africa, including regulations related to water pollution prevention from chemical engineering activities.
- **Air Quality Act, 39 of 2004:** This Act aims to protect air quality and human health by regulating emissions of air pollutants, including those from chemical engineering processes.
- **Mine Health and Safety Act, 29 of 1996:** This legislation focuses on health and safety standards in the mining industry, which may be relevant to chemical engineering activities in mining operations.

- **Regulations under the Occupational Health and Safety Act**: These regulations provide detailed requirements for specific industries and activities, including chemical engineering, to ensure compliance with health and safety standards.

As the field of chemical engineering offers numerous routes, in different sectors and industries, this document underscores the crucial competencies required for individuals aspiring to register as Chemical Engineering professionals. These competencies, regardless of the work sector, are essential for success in the field. The 11 outcomes specified in document **R-08-CS-GUIDE-PE/PT/PN** are the pillars of these competencies. In some instances, these competencies may not be readily available within an individual's current role, project or position. In such cases, secondment to another employer or seeking guidance from an external mentor is recommended.

Progression throughout the candidacy period presented in document **R-04-T&M-GUIDE-PC** and **Table 2** (see Section 5) refers to the gradual increase in the degree of responsibility (DoR) Applicants are exposed to during their professional training. The required level of responsibility is included in brackets under each sub-heading for ease of reference.

Applicants or Mentors who are unsure whether the engineering work they are considering is complex, broadly defined or well-defined, should refer to document **R-02-STA-PE/PT/PN**, the Competency Standard for Registration. Document **R-02-STA-PE/PT/PN** provides detailed information about the characteristics and requirements of each level descriptor, defining the competencies needed for each category.

Table 1: Sectors and Industries in which Chemical Engineering Professionals Practice.

Sector	Industry	Application
Energy	Oil and Gas	• Petro chemical processes related to the exploration, production, refining and transportation of oil and gas. Designing and optimising processes for extraction, separation, and purification of hydrocarbons. • Distillation.

Sector	Industry	Application
	Electricity	• Production of electricity from coal, gas, hydro, nuclear, renewables. • Design, monitor and improve the production processes for plants related to electricity production such as boiler, turbines and other auxiliary systems such as heat exchangers, pumps, portable water, demineralised water, condensation, ash, coal, cooling. • Monitor performance of plant by performing laboratory analysis of water, coal, oil, gases. • Calculate the required dose of chemicals to achieve desired optimal quality of water and electricity.
Manufacturing	Iron and Steel, Ferroalloys, and Aluminium products	• Production of iron from iron ore through processes like blast furnaces or direct reduction. Optimising the chemical reactions, designing the process equipment and ensuring efficient operation. • Steelmaking process, which involves refining iron and adding alloying elements to produce different types of steel. • Basic oxygen furnace, electric arc furnace or other secondary refining methods. • Casting and solidification of steel to achieve desired properties using techniques like continuous casting, ingot casting or specialty casting. • Heat treatment processes used to modify the microstructure and properties of steel using processes like annealing, quenching, tempering or surface hardening. • Corrosion control using coatings, inhibitors or other protective measures to mitigate corrosion
	Chemical	• Selecting appropriate raw materials, designing reactors and separation units,

Sector	Industry	Application
		and optimising process conditions to maximise efficiency and product quality. • Instruments and control systems to monitor and control process variables such as temperature, pressure, flow rates and composition. • Analyse reaction kinetics, design reactors and optimise reaction conditions to achieve desired product yields and selectivity. • Separation processes, such as distillation, extraction, crystallisation and membrane filtration.
	Food and Beverages	• Food processing. Design and optimisation of processes for converting raw materials into food products. Processes such as mixing, blending, heating, cooling, drying and packaging. • Optimising fermentation conditions, monitoring and controlling the growth of microorganisms, and ensuring product consistency and quality of fermented food and beverages, such as beer, wine, yogurt and cheese. • Extraction and separation of valuable components from raw materials for processes such as extraction of oils, flavours and aromas from plants, as well as the separation of different components in beverages. • Developing and implementing processes to ensure food safety and quality, such as cleaning and sanitation procedures, implementing quality control measures and developing methods for detecting and controlling contaminants. • Treatment of wastewater, recovery of valuable by-products from waste streams and design of sustainable waste disposal methods.

Sector	Industry	Application
		• Food process optimisation and automation using advanced control systems, data analysis techniques and modelling and simulation tools.
	Industrial Machinery	• Materials selection of suitable materials for the construction of machinery components considering factors such as chemical compatibility, mechanical properties, sustainability, environmental impacts and cost-effectiveness. • Develop process flow diagrams, specify equipment, and optimise process parameters to ensure efficient and safe operation. • Maintain effective heat transfer in heat exchangers, calculating heat transfer rates and optimising thermal management to ensure proper functioning of the equipment. • Apply knowledge of fluid mechanics to design pumps, piping systems and fluid handling equipment to ensure efficient and reliable operation. • Develop algorithms, specify sensors and actuators, and optimise control strategies to ensure equipment operates within desired parameters.
	Rubber	• Formulating rubber compounds with desired properties such as strength, flexibility and durability. Selecting and optimising the composition and processing conditions. • Polymerisation process to transform natural rubber or synthetic elastomers into polymers. Optimising reaction conditions, controlling molecular weight and ensuring product consistency.

Sector	Industry	Application
		• Vulcanisation of process parameters, such as temperature, time and curing agents, to achieve the desired physical properties of the rubber. • Mixing and processing using equipment such as internal mixers or extruders, to ensure proper dispersion of additives and uniformity of the rubber compound.
	Pulp & Paper	Pulping, bleaching, refining, forming, pressing and drying to achieve the desired properties and quality of the paper. Chemical recovery, digestions, reaction, filtration, sedimentation, effluent treatment.
Health	Pharmaceutical	• Designing and optimising chemical reactions and synthesis routes to produce active pharmaceutical ingredients. Formulation development, drug delivery systems and process scale-up for manufacturing. • Regulatory compliance.
Construction	Engineering	• Designing water or wastewater plants and utility distribution. Performing calculations of input material and desired outputs. Materials selection and evaluation to select construction materials based on their properties, durability, and environmental impact. Handling and managing materials such as concrete, polymers, metals and composites. • Risk Management. • Contracts Management. • Project management. • Budget and Cost Management. • Bill of Material. • Quality Control.
Professional Services	Project Management	• Process economics and project management. Evaluating the economic

Sector	Industry	Application
		feasibility of chemical processes and projects. Analysing costs, performing economic evaluations. Decision-making based on financial considerations, risk, technical, and social and sustainability factors. • Scoping of services. • Managing the project life cycle including initiation, planning, execution, monitoring and control and closure.
Public Sector	National, provincial, national government & state-owned entities, municipalities	• Sector infrastructure planning, policy development. • Provision of municipal services such as purified water, wastewater treatment and sanitation. • Developing regulations and frameworks such as environmental policies and implementation, health and safety policies governing the building, operations and maintenance for all industries.
ICT	Software, IT services and E-Commerce.	• Data analysis and modelling using statistical analysis and modelling techniques and software tools like MATLAB, Python, or R to analyse data and develop models for process optimisation to understand and optimise processes. • Developing business processes, value chains, and advisory services to aid in digital transformation of production or manufacturing or operating processes for industries. This includes the use of AI to improve processes, systems, control inputs and outputs used in production. • Designing and implementing control systems to monitor and regulate industrial processes using technologies like distributed control systems (DCS), programmable logic controllers (PLC) and

Sector	Industry	Application
		supervisory control and data acquisition (SCADA) systems to automate processes. • Virtual reality (VR) and augmented reality (AR) technologies to visualise and interact with simulated processes, aiding in design, training and troubleshooting. • Consulting to help with predictive analytics and make data-driven decisions for process optimisation, quality control and resource management.
Academic	Education and Training	Develop knowledge through research and publication. Compiling training strategies. Developing new skills based on latest technology and 4IR such as digital transformation, AI, robotics for improving engineering processes and systems.
Water	Water and Wastewater	• Water and wastewater management. Chemicals for Treating water. Water infrastructure design. Treatment solutions. Coagulation and flocculation. Sedimentation and clarification. Filtration. Advances Treatment processes such as activated carbon adsorption, membrane filtration, and advanced oxidation. Sludge treatment such as dewatering, digestion and drying. • Pumping, storage, thermal evaporation, anaerobic/aerobic digestion, waste-to-energy, thermal evaporation, anaerobic/aerobic digestion. • Water Quality. Water use. Water standards. Water Testing. Laboratory Testing.

4.1 Training for registration as a Professional Engineer

4.1.1 Outcome 1: Define, investigate and analyse complex engineering problems (Responsibility Level E)

According to the ECSA outcomes, engineers are expected to be able to define, investigate, and analyse complex engineering problems by identifying systems and sub-systems in resolving complex problems and using data and information technologies where applicable. The complex engineering problem may be defined as a design requirement, an applied research and development requirement or a problematic situation in an existing component, system or process.

Typical tasks in defining, investigating and analysing complex engineering problems may include the following:

Defining the engineering problem

- Identify the problem by clearly articulating what the problem is, including its scope and boundaries (or battery limits).
- Determine the requirements by establishing the criteria and constraints the solution must meet.
- Contextualise the engineering problem by understanding the context in which the problem exists, including any relevant background information.

Investigating the problem

- Research by gathering information from various sources to understand the problem more deeply. This includes data collection, case studies and literature reviews in some instances.
- Explore alternatives by looking into different approaches and methods that could potentially solve the problem.

Analysing the problem

- Model the problem by creating mathematical or computational models to simulate the problem and its various components.
- Evaluate the solutions by assessing different alternative solutions against the defined criteria and constraints, considering factors such as feasibility, efficiency and cost.
- Draw conclusions by synthesising the findings to determine the most viable solution and understand the implications of each.

Example in the Petrochemical Industry

Problem: Cracking furnace efficiency optimisation

Defining the problem

- Cracking furnaces are critical in converting heavy hydrocarbons into lighter products like ethylene and propylene. The challenge is to optimise furnace efficiency to maximise output while minimising energy consumption and emissions.

Investigating and analysing solutions

- **Data collection**: Collect Operational data by gathering historical and real time data on furnace temperatures, feedstock properties and product yields. Look at energy consumption by studying fuel usage and energy efficiency metrices. Look at emission data by measuring NOx, CO_2 and other emissions.
- **Problem analysis:** Analyse the problem by employing thermodynamics – assess the heat transfer efficiency and identify hotspots or areas of poor thermal performance. Kinetic modelling can be used by developing models to understand the reaction kinetics and optimise conditions for maximum yield. Finally, the engineer can perform a mass balance to track the conversion rates and losses.

Chemical engineering Professional Applicants/Candidates must note the following with regards to complex problems:

Occasionally, the issue might extend beyond typical standards and regulations. In such cases, it is incumbent upon Chemical Engineering professionals to rely on reliable sources and apply sound engineering principles. This entails corroborating information from diverse channels and providing rationale for any assumptions made.

Engineering challenges often present themselves with intricate and diverse contexts, encompassing multidisciplinary aspects and necessitating collaborative efforts. These problems can be unpredictable and may require careful identification. Moreover, addressing such challenges often demands a wide array of resources, both in terms of diversity and magnitude

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., and the Engineers have to justify their recommendations.

4.1.2 Outcome 2: Design or develop solutions to complex engineering problems (Responsibility Levels C and D)

The engineering design of the solution to a complex engineering problem includes having a detailed requirements specification that aligns with the required design and having potential solutions or methods that can be used to approach and resolve the complex problem. The preferred option or way forward is influenced by factors that best fit the solution, taking into consideration cost, practicability, innovation and any impact outside the requirements.

After the received task 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 the following:

- The development (design) of more than one way to solve an engineering task or problem should always be done and should include the costing and impact assessment for each alternative. All the alternatives must meet the requirements set out by the instructions that are received, and theoretical calculations to support each alternative must be done and submitted as an attachment.

- In some cases, the Engineer will not be able to support proposals with the complete theoretical calculation to substantiate every aspect. The alternatives and particularly the recommended alternative must be convincingly detailed to win customer support. The selection of alternatives might be based on tenders submitted with alternatives deviating from those specified.
- The complete and final solution that is selected must be followed up with a detailed technical specification and supporting drawings.

Example in the Petrochemical Industry (*continued from outcome 1* using the example Cracking Furnace Efficiency Optimisation scenario)

After defining, investigating and analysing the complex engineering problem, the chemical engineering professional might be required to design or develop solutions to the complex engineering problem.

Solution exploration

- **Advanced control systems:** Implement predictive control systems that optimise temperature and feed rates in real time.
- **Heat recovery:** Design and install a recovery system to capture waster heat and reuse it within the process.
- **Retrofit and upgrade:** Evaluate and implement technological upgrades to existing furnace infrastructure for better performance.

Simulation, testing and Implementation

- Use computational fluid dynamics (CFD) and process simulation software to model various scenarios and predict the impact of proposed changes.
- Conduct pilot testing of new catalysts or control systems under real operating conditions
- Gradually implement the optimised control systems and heat recovery solutions
- Monitor performance continuously and adjust parameters as necessary to ensure optimal operation.

In the above example, by systematically defining the problem, collecting and analysing data, exploring potential solutions and implementing the most effective strategies, a chemical engineering professional can significantly optimise the efficiency of a cracking furnace in the petrochemical industry, leading to increased production, reduced energy consumption and lower emissions.

4.1.3 Outcome 3: Comprehend and apply advanced and local knowledge of the widely applied principles underpinning good practice that is specific to the jurisdiction in which the Engineer practices. (Responsibility Level E)

Applicant/Candidate Engineers should be able to provide evidence that they have comprehended and mastered the engineering principles and technologies for their practice areas and that they apply first-principle analytical thinking in demonstrating this competency for the associated complex programme. This includes the application of fundamental principles, practices, sound testable assumptions or previously encountered techniques the applicant has used to solve the problem.

Example in distillation column design

A Chemical Engineering professional specialising in distillation column design should actively engage with technological advancements and emerging developments within the field. Adherence to engineering standards is paramount to ensuring the integrity and reliability of design outputs. Particularly in distillation equipment, meticulous attention to pressure regulations is essential, notably during Hazard and Operability (HAZOP) studies. For instance, Chemical Engineers must possess a comprehensive understanding of the foundational principles outlined by organisations such as the Tubular Exchanger Manufacturers Association (TEMA) for heat exchanger design, as well as comply with the stipulations of ASME VIII Div.1 and API 520 concerning pressure safety requirements and design considerations. It is incumbent upon candidates to actively participate in their respective industries, thereby upholding professional standards and contributing to the advancement of the field.

The theoretical knowledge gained from completing a BEng/BSc degree should also be applied in addition to knowledge of applicable engineering standards, codes of practice, legislation and regulations.

4.1.4 Outcome 4: Manage part or all of one or more complex engineering activities (Responsibility Level D)

In engineering operations, Engineers are typically given the responsibility to carry out projects. This typically involves:

- Planning, coordinating and overseeing engineering projects to ensure they are completed on time, within budget and to the required quality standards.
- Defining the project objectives, organising resources, scheduling activities, managing risks and communicating with stakeholders.

Chemical engineering Professional Applicants/Candidates must note the following regarding engineering project management:

- 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.
- The basic elements of management must be applied to complex engineering work.
- Depending on the project, Engineers can be team leaders or team members or they can supervise appointed contractors. To achieve this, maintenance of relationships is important and must be demonstrated.
- Chemical Engineers bring technical expertise to the project, interfacing with other disciplines to ensure the project meets the intended design objectives. In this role, the Chemical Engineer acts an Engineering Manager.

The training elements of a training scheme (see **Appendix A**) indicate the functions in which an applicant should be competent when carrying out the various phases of a project. The functions include:

- solving problems based on engineering and contextual knowledge

- implementing and operating engineering projects, systems, products, and processes
- mitigating risk and impact
- managing engineering activities.

These functions are aligned with the overall competency of the outcomes expected from the applicants. In addition, applicants must state the requirement of the project in terms of delivery, refer to the initial production requirements for the project and state whether they obtained results, and if not, why they were unsuccessful.

4.1.5 Outcome 5: Communicate clearly using multiple media and collaborate inclusively with a broad range of stakeholders in the course of engineering activities. (Responsibility Level C)

Chemical engineers are expected to communicate professionally by making use of the effective exchange of information among other engineers/disciplines, stakeholders and the team to ensure clarity and efficiency. This entails demonstrating the ability to write clear, concise, effective and technically, legally and editorially correct reports using a structure and a style that meet communication objectives and user/audience requirements.

Chemical Engineers must learn to communicate effectively for several reasons:

- **Collaboration:** Chemical Engineering professionals work in multidisciplinary teams including other engineering disciplines, scientists, technologists/technicians and management, so clear communication ensures that everyone understands their roles and responsibilities.
- **Safety:** Chemical Engineering professionals often involves handling hazardous materials and complex processes. Effective communication is critical to convey safety protocols and emergency procedures to prevent accidents and ensure a safe working environment.
- **Problem solving:** Engineers frequently need to explain complex problems and solutions to colleagues, clients and stakeholders. Effective communication helps in accurately conveying technical information and facilitating collaborative problem-solving.

- **Documentation**: Clear and precise documentation of processes, experiments and results is vital for maintaining records, ensuring reproducibility and complying with regulations and standards
- **Client relations**: Chemical engineers often interact with clients and non-engineering stakeholders. Effective communication helps in explaining technical concepts in an understandable way, building trust and ensuring client satisfaction.
- **Project management:** Successful project management requires clear communication to coordinate tasks, timelines, and resources, as well as to provide updates and reports to stakeholders.
- **Innovation and knowledge sharing**: Sharing knowledge and innovative ideas effectively can lead to better collaboration and advancements within the field. Good communication skills facilitate dissemination of new research and best practices.
- **Professional growth**: Effective communication enhances engineers' ability to lead teams, present at conferences and publish research, contributing to their professional development and career advancement.

For this outcome, Chemical Engineering Professional Applicants/Candidates are expected to:

- Provide clear instructions to subordinates using suitable language and communication tools, ensuring that any language or communication barriers are addressed.
- Deliver oral presentations that utilise structure, style, language, visual aids and supporting documents suitable for the audience and purpose.

4.1.6 Outcome 6: Recognise the reasonably foreseeable economic, social, cultural, and environmental effects of complex engineering activities seeking to achieve sustainability. (Responsibility Level B)

Complex engineering problems may have an impact on the social, environmental and cultural components. Applicants should be able to recognise and address the impact of their complex engineering activities on these components and where there are negative effects, provide mitigating measures.

- **Social effects** encompass all issues that affect people and their livelihoods, directly or indirectly. Engineering activities may affect people's way of life, their political system, their health and well-being, and their personal and property rights.
- **Environmental effects** include the effects on people's environment (i.e., air and water quality, dust and noise exposure, and adequacy of sanitation) and the effects on large ecosystems. These may include disruption of ecosystems, disruption of fauna and flora, and increased land temperatures.
- **Cultural effects** include people's customary beliefs, religion, language and norms, for example, the ceremonies and customs of a particular group or society.

Chemical Engineering has a heavy impact on the environment, for example:

- **Air pollution**: Chemical engineering processes such as combustion, chemical reactions, and industrial emissions can release harmful pollutants into the air, contributing to air pollution and climate change. For instance, emissions from chemical plants can release pollutants like sulphur dioxide, nitrogen oxides and greenhouse gases.
- **Water pollution:** Chemical engineering facilities may discharge wastewater containing toxic chemicals and pollutants into water bodies, leading to water pollution. For example, improper disposal of chemicals by chemical plants can contaminate rivers, lakes and oceans, affecting aquatic ecosystems and public health.
- **Soil contamination:** Improper handling and disposal of hazardous chemicals in chemical engineering activities can lead to soil contamination. Accidental spills, leaks or improper waste disposal practices can introduce harmful substances into the soil, affecting soil quality and posing risks to plants, animals and humans.
- **Deforestation:** Some chemical engineering processes require the extraction of resources such as wood for fuel, leading to deforestation. Clearing forests for industrial activities can disrupt ecosystems, reduce biodiversity and contribute to habitat loss for native species.
- **Energy consumption:** Chemical engineering operations often require significant energy inputs, leading to high energy consumption and greenhouse gas emissions. Fossil fuel-based energy sources used in chemical processes contribute to climate change and air pollution.

These are just a few examples of the heavy impacts of chemical engineering on the environment. It is important chemical engineers adopt sustainable practices, implement pollution control measures and prioritise environmental protection to mitigate these impacts.

Risk and impact mitigation must include the probability and impact of all the risks connected with the project. Mitigating measures taken may include environmental impact studies, environmental impact management, community involvement and communication, barricading and warning signs, and press releases.

4.1.7 Outcome 7: Meet all legal and regulatory requirements and protect the health and safety of persons during all complex engineering activities. (Responsibility Level E)

The gazetted Identification of Engineering Work (IDoEW) promotes safety and the protection of the public and the environment by ensuring that registered professionals in the different categories of registration have demonstrated the required competence and academic qualifications and have performed engineering work or have taken responsibility for engineering work performed per category. Applicants wishing to register with ECSA as Professional Engineers are expected to have a working knowledge of the related regulations and Acts and to be able to demonstrate how this legislation affects their complex engineering activities at Responsibility Level E (performing). Refer to the list at the beginning of section 4 of most common Acts and regulatory standards in the Chemical Engineering profession. Other Acts not listed here may also be pertinent to the Applicant's/Candidate's specific work environment. Applicants 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.

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. Applicants 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 Chemical Engineering. The onus is, once again, on Applicants and their Mentors/Supervisors to familiarise themselves with these practices in the South African industry.

4.1.8 Outcome 8: Conduct engineering activities ethically (Responsibility Level E)

Applicant Chemical Engineers are involved in tender evaluations and adjudications, and contract management. Ethical problems such as tender fraud and corruption, bribery payments, favouritism, defamation, alcohol abuse, sexual harassment, absenteeism, fraudulent overtime claims, fraudulent expenses claimed, fraudulent qualifications, misrepresentation of facts and overstating of compensation events may occur. Applicant Engineers are expected to identify ethical problems, affected parties and the best solution to resolve the problem at Responsibility Level E (i.e., performing).

Most engineering projects are multidisciplinary in nature, with many role players performing speciality work that could result in individuals conducting engineering activities for which they have no education, training or competency.

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 also set out in the *Code of Conduct* and the *Overarching Code of Practice for the Performance of Engineering Work,* respectively.

Example of an ethical dilemma for Chemical Engineering professionals:

Suppose a Chemical Engineering professional is working on a project to develop a new petrochemical facility. The proposed facility promises substantial economic benefits for the company and local community, including job creation and increased revenue. However, the project also entails significant environmental impacts, such as air and water pollution, greenhouse gas emissions and habitat destruction. Here is how a Chemical Engineering professional might deal with the dilemma:

- **Comprehensive impact assessment**: Conduct a thorough environmental impact assessment (EIA) to quantify the potential environmental consequences of the project. This includes evaluating air and water quality, assessing ecological impacts, and estimating greenhouse gas emissions
- **Stakeholder engagement**: Engage with stakeholders, including local communities, environmental organisations, regulatory agencies and company leadership to gather diverse perspectives and concerns regarding the project's impacts.
- **Risk mitigation strategies**: Identify and implement measures to mitigate environmental risks and minimise negative impacts. This may involve incorporating pollution control technologies, adopting best practices in waste management and implementing energy-efficient processes.
- **Ethical Decision Making:** Apply ethical frameworks, such as utilitarianism or environmental ethics to weigh the potential benefits of the project against its environmental costs. Consider the long-term consequences and implications for future generations.
- **Transparency and accountability:** Maintain transparency throughout the decision-making process by providing accurate and objective information to stakeholders. Take responsibility for any adverse impacts and commit to continuous improvement and monitoring.
- **Alternative solutions:** Explore alternative approaches and technologies that offer a more sustainable balance between economic development and environmental protection. This may include renewable energy sources, green chemistry principles, or circular economy practices.

- **Professional integrity**: Uphold the ethical principles and standards of the chemical engineering profession, including integrity, honesty and professionalism. Advocate for environmentally responsible practices and strive to minimise harm to human health and the environment.

In summary, addressing ethical dilemmas requires a holistic approach that considers both economic and environmental factors. Chemical Engineering professionals must navigate these challenges with integrity, transparency and a commitment to sustainable development. Fraud and other unethical practices undermine the integrity of the Engineering Profession, compromise public safety and may result in legal penalties, loss of professional licences and damage to reputations. It is essential for engineers to adhere to ethical standards and regulatory requirements to maintain trust and credibility in their work.

It is imperative that Applicant Engineers familiarise themselves with ECSA's Rules of Conduct, a listing of ethics regarding integrity and competency. In addition, applicants should have knowledge of the ECSA Code of Conduct with an understanding of how it relates to their area of practice. Attention to the health and safety of persons and the areas of competency, truth, integrity and honest behaviour is of paramount importance.

4.1.9 Outcome 9: Exercise sound judgement by evaluating the outcomes, impacts and alternatives in the course of complex engineering activities. (Responsibility Level E)

Exercising engineering sound judgment involves making decisions and taking actions based on a combination of technical expertise, ethical considerations, practical experience and critical thinking skills. Engineers are expected to exercise sound judgement during engineering activities by considering several factors based on consequences they foresee and the regulatory requirements such as policies and standards.

Example of a Chemical Engineering professional exercising engineering sound judgement:

Scenario: A chemical engineering professional is tasked with designing a novel chemical process for a specialised application. However, there are no existing standards or codes specifically applicable to this unique process due to its innovative nature and lack of precedent in the industry.

Exercise of engineering sound judgement:

- **Risk assessment**: Conduct a comprehensive risk assessment, identifying potential hazards and evaluating the consequences of various process parameters and operating conditions.
- **Literature review:** Conduct an extensive literature review to gather insights from related fields and similar processes. Draw upon fundamental principles of Chemical Engineering and relevant scientific research to inform the design.
- **Expert consultation:** Engage with subject matter experts, both within and outside the organisation to seek guidance and validate assumptions. Collaborate with interdisciplinary teams to leverage diverse perspectives and expertise.
- **Experimental validation**: Design and conduct pilot-scale experiments to validate theoretical models and assess the feasibility and performance of the proposed process. Iteratively refine the design based on experimental data and observations.
- **Simulation and modelling**: Utilise process simulation software to model different scenarios and optimise process parameters. Perform sensitivity analyses to understand the impact of variations in inputs and identify potential bottlenecks or optimisation opportunities.
- **Prototyping and testing**: Build prototypes or small-scale prototypes to test the functionality and scalability of the proposed process. Conducts rigorous testing to evaluate performance under realistic conditions and identify potential areas for improvement.
- **Documentation and reporting**: Document the design process, assumptions, methodologies and results in detail. Prepare comprehensive reports outlining the rationale behind design decisions, potential risks and mitigation strategies.
- **Continuous Improvement**: Embrace a culture of continuous improvement and learning, seeking feedback from peers, stakeholders and end-users. Iteratively refine the design based on feedback and new insights gained throughout the development process.

In this example, Chemical Engineering professionals exercise sound engineering judgement by relying on fundamental principles, expert advice, experimentation and rigorous analysis to design a novel chemical process without specific standards or codes to guide them. Through a systematic and interdisciplinary approach, Chemical Engineers ensure the integrity, safety and effectiveness of the process while driving innovation in the field of Chemical Engineering.

Applicants are therefore expected to demonstrate this competency by evaluating a situation presented to them in the absence of full evidence. The requirement is that engineers thoroughly investigate, analyse and identify several factors and understand the risks associated with certain decisions.

4.1.10 Outcome 10: Be responsible for making decisions on part or all of complex engineering activities. (Responsibility Level E)

Having the contextual knowledge and operating on Level E of the Degree of Responsibility (DoR) affords applicants an opportunity to demonstrate how they were able to make decisions and take on responsibility for significant parts of one or more complex engineering activities. Seeking advice or guidance from the relevant superiors assists Applicants in making informed decisions and assuming responsibility for those decisions.

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." In the field of Chemical Engineering:

- all considered inter-related factors are indicative of professional responsibility accepted working on complex engineering activities
- engineers operate on tasks at all levels of engineering complexity within their education and experience (e.g., Process Safety Engineering)
- responsibility is the 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 important elements. The calculations, for example, fault levels, load calculations and losses, are done to ensure the correct material and components are used.

4.1.11 Outcome 11: Undertake sufficient professional development activities to maintain, extend competence and enhance the ability to adapt to emerging technologies and the ever-changing nature of work (Responsibility Level D)

Professional development is essential for engineers to continuously improve their skills, advance their careers, contribute to innovation and uphold the highest standards of professionalism and integrity in their practice. It is important for Applicants to draw up a continuous professional development (CPD) plan. If possible, a specific field of the sub-discipline is chosen, available developmental alternatives are established, a programme is drawn up (in consultation with employer if costs are involved) and options that are open to expand knowledge into additional fields are investigated.

Record-keeping must not be left to the employer or anybody else. Trainees must manage their own training independently by taking initiative and being in charge of experiential development towards the level of Professional Engineer.

The following list of formal learning activities is by no means extensive or comprehensive; it is simply a sample of useful courses:

- Project management
- Conditions of Contract / Value Engineering – New Engineering Contract (NEC), Joint Building Contract Committee (JBCC), etc.
- Microsoft Office tools (MS Excel, MS Word, MS PowerPoint, MS Teams, MS Access, MS Outlook, One Note, MS Project, MS Vision, OneDrive etc.)
- HAZOP study methods and techniques
- Layer of Protection Analysis (LOPA)
- Root Cause Analysis (RCA)
- Training in the use of simulation tools such as MS Excel, MATLAB, Aspen, SimSci, ChemCAD, AFT, Metsim
- Training in safety-related legislation such as the NEMA, OHS Act and the MHS Act
- Undertake initial professional Development (IPD) activities
- Value Engineering and other Value Improvement Practices (VIPs)

- Preparation of specifications
- Environmental aspects of projects
- Professional skills such as report writing and presentations
- Project and operational planning methods
- Standard Conditions of Contract (NEC3, FIDIC, PROCSA, GCC, etc.)
- Preparation of specifications
- Negotiation skills in Engineering
- Finance risk analysis
- Quality assurance systems
- Occupational health and safety
- Energy efficiency
- Maintenance engineering.

Training and courses that do not carry official CPD points, such as courses or training offered within the employer organisation or by other organisations, are also appropriate. For a list of recommended learning, refer to section **5.2** (Recommended learning)

4.2 Training for registration as a Professional Engineering Technologist

4.2.1 Outcome 1: Define, investigate and analyse broadly defined engineering problems (Responsibility Level E)

When individuals seek to register as Professional Chemical Engineering Technologists, one of the key competencies they need to demonstrate is the ability to define, investigate and analyse broadly defined engineering problems. This requirement means Applicants should be able to effectively identify and understand engineering problems and develop a clear understanding of what needs to be solved. To illustrate this, consider the following examples from specific industries:

Example from the petroleum industry in an oil refinery:

One of the engineering problems Chemical Engineering technologists might have to solve is optimising the refinery process to improve energy efficiency and reduce emissions. To define the engineering problem, Chemical Engineering technologists gather relevant information and consult with stakeholders, such as refinery operators and environmental experts. They then analyse the current process, identify potential areas for improvement and define the problem's specific goals and constraints. For example, they may aim to reduce energy consumption by 10% while adhering to strict environmental regulations. Next, they investigate the problem by collecting and organising data from various sources, which could involve analysing historical operational data, conducting experiments in the refinery and researching best practice and innovative technologies used in similar industries. They then evaluate the information gathered to understand the problem and potential solutions comprehensively.

Once the investigation is complete, they analyse the problem, using their technical knowledge and expertise to conceptualise potential solutions and make justified assumptions and limitations. For example, they might consider different process configurations, equipment modifications or alternative feedstocks. They then evaluate the potential impact of each solution on energy efficiency, emissions, cost and other relevant factors.

Through this process of defining, investigating and analysing the broadly defined engineering problem, Chemical Engineering Technologists are able to develop a well-informed and comprehensive understanding of the refinery's challenges, which would enable them to propose effective solutions and contribute to the optimisation of the refinery process.

Example in the pharmaceutical industry:

Chemical Engineering Technologists in the pharmaceutical industry may be tasked with defining, investigating and analysing a broadly defined engineering problem related to the production of a new drug. The need could be optimising the manufacturing process to increase yield, reduce costs or improve product quality.

To define the problem, Technologists work with engineers, scientists and other stakeholders to understand the objectives, constraints and desired outcomes. Applicants then gather information about the existing manufacturing process, identify potential bottlenecks or inefficiencies, and define the problem statement.

Next, Technologists investigate the problem by collecting and analysing relevant data from various sources. This step could involve conducting experiments, analysing production data, reviewing literature and consulting with other subject matter experts. Applicants then organise and evaluate the information to gain insights into the root causes of the problem and potential areas for improvement.

Finally, Technologists analyse the problem using their theoretical technical knowledge and expertise. Applicants/Candidates conceptualise potential solutions, make justified assumptions, consider any limitations or constraints and evaluate the results of their analysis. This step could involve using mathematical models, simulation software or other engineering tools to assess the feasibility and effectiveness of different approaches.

4.2.2 Outcome 2: Design or develop solutions to broadly defined engineering problems (Responsibility Levels C and D)

Designing or developing solutions to broadly defined engineering problems refers to the ability to come up with innovative and practical solutions to solve engineering problems. This step involves using appropriate theories and information technologies, considering the impacts and sustainability of the solution and considering stakeholders' views. Technologists should be able to systematically analyse designs, correlate them with requirements and consider the wide-ranging impacts and costs. Applicants/Candidates should also be able to create detailed specification requirements and design documentation that meets a client's satisfaction. The solutions should be based on accepted methods, techniques or procedures based on the theory of practice, and they should consider sustainability.

Example in the oil and gas industry:

A Chemical Engineering technologist may be tasked with designing a process to remove impurities from crude oil to meet environmental regulations and improve the quality of the final product. This task would involve analysing the problem, considering various factors such as the composition of the crude oil, the desired quality specifications and the environmental impact of different purification methods.

Technologists then use appropriate theory and information technologies to design a solution that addresses the problem effectively. Applicants/Candidates then consider the wide-ranging impacts of the alternative solutions, such as the energy consumption, waste generation and overall sustainability of the process. They also consider the views and requirements of stakeholders, such as regulatory bodies, clients and the community.

To ensure the solution's successful implementation, Technologists create detailed specification requirements and design documentation. This documentation outlines the technical specifications, operating parameters and any necessary safety measures. Technologists work closely with clients to ensure that the solution meets their satisfaction and aligns with their specific needs.

Throughout the design and development process, Technologists adhere to accepted Chemical Engineering methods, techniques and procedures. Applicants/Candidates also consider the solution's long-term sustainability, aiming to minimise environmental impact and maximise efficiency.

4.2.3 Outcome 3: Comprehend and apply knowledge that is embodied in established engineering practices that is specific to the jurisdiction in which the Engineering Technician practices. (Responsibility Level E)

Contextual knowledge refers to applying engineering procedures, processes, systems and methodologies specific to Chemical Engineering. This activity could involve understanding and utilising various Chemical Engineering calculations, such as mass and energy balances, process design, equipment sizing and optimisation techniques.

Having a working knowledge of areas of practice that interact with Chemical Engineering to underpin teamwork is important as Chemical Engineering technologists often work closely with other professionals, such as mechanical and electrical professionals, to design, operate and optimise chemical processes. Understanding the principles and practices of these related disciplines is essential for effective collaboration.

Demonstrating knowledge and application of engineering standards, codes of practice, legislation, regulations and finance in the Chemical Engineering practice area forms part of contextual knowledge. This activity could entail understanding and adhering to safety regulations, environmental regulations, building codes and industry-specific standards for equipment and processes. It also includes being aware of financial considerations, such as cost estimation, budgeting and project management.

Having technological knowledge that applies to Chemical Engineering is another aspect of contextual knowledge. This activity includes understanding the fundamental principles of Chemical Engineering unit operations, such as distillation, heat transfer, reaction kinetics and fluid dynamics to technology. It also involves staying up to date with technological advancements, such as process automation, renewable energy applications and sustainable manufacturing practices.

An industry example of contextual knowledge in Chemical Engineering could be the design and operation of a chemical plant. In this example, Chemical Engineering technologists would apply engineering procedures, processes and methodologies specific to chemical plant design, such as process flow diagrams, piping and instrumentation diagrams, and equipment selection. They would familiarise themselves with relevant engineering standards, codes of practice and regulations governing the construction and operation of chemical plants. Examples of such regulations include the National Building Regulations and Building Standards Act, 103 of 1977. This Act sets out the requirements for building design, construction and maintenance, including chemical plant facilities.

Additionally, Chemical Engineering technologist need to stay informed about emerging technologies and best practice in the industry to ensure the plant is efficient, safe and environmentally sustainable.

4.2.4 Outcome 4: Manage part or all of one or more broadly defined engineering activities (Responsibility Level D)

Engineering project management involves managing part or all of one or more broadly defined engineering activities. For this outcome, Chemical Engineering technologists should be responsible for planning, organising, leading and controlling engineering activities to achieve desired results. Applicants/Candidates are required to effectively manage and contribute to the successful completion of engineering activities in their practice area.

Example in a pharmaceutical company:

A pharmaceutical company is developing a new drug formulation, and a Chemical Engineering technologist is assigned to manage the engineering activities related to the production process.

In this scenario, the role of the engineering project manager would involve the following:

- **Managing self, people, work priorities, processes and resources:** Engineering technologists need to effectively manage their own time and prioritise tasks. Additionally, they would be responsible for coordinating and leading a team of engineers and technicians involved in the project. This task would require them to allocate resources efficiently and ensure everyone works towards the project goals.
- **Planning and organising broadly defined engineering activities:** This entails developing a detailed project plan, including timelines, milestones and deliverables. This plan outlines the engineering activities required to create and optimise the drug production process. Chemical Engineering technologists need to organise resources, such as equipment, materials and personnel, to ensure smooth execution of the plan.
- **Leading and controlling engineering activities:** As project managers, chemical engineering technologists lead and guide the team members. They monitor progress, identify potential issues or risks and take necessary actions to keep the project on track. This task may involve making decisions, resolving conflicts and adjusting the project plan.
- **Managing contracts and professional relationships:** This task involves managing contracts with suppliers, contractors and other project stakeholders. It includes negotiating terms, ensuring compliance and maintaining positive professional relationships to facilitate smooth project execution.

4.2.5 Outcome 5: Communicate clearly using multiple media and collaborate inclusively with a broad range of stakeholders in the course of engineering activities. (Responsibility Level C)

Chemical Engineering technologists are required to demonstrate professional communication. Professional communication means effectively communicating with a wide range of stakeholders in various media. For a person seeking to register as a Professional Chemical Engineering Technologist, communication involves the following:

- Writing clear and compelling documentation.
- Issuing instructions and guidance.
- Delivering oral presentations appropriate for the audience and purpose of the communication.

This communication may be in written form, such as technical reports, legal documents and editorial pieces, or oral, such as presentations.

An example of professional communication could be a technologist working on a project to develop a new chemical process. In this case, the Technologist must write clear and concise technical reports documenting any findings and recommendations. These reports need to be accurate, well-structured and error-free to ensure other professionals in the field can easily understand them.

Additionally, Chemical Engineering Technologists may need to issue instructions or guidance to a team involved in implementing the new process. In this situation, Technologists need to communicate clearly and concisely, taking into account the varying skill levels of the audience such as engineers, technicians, operators and artisans. Chemical Engineering technologists need to provide instructions that are easy to follow and understand, ensuring that everyone involved in the project can effectively carry out their tasks. It is often the case that Chemical Engineering Technologists work with maintenance personnel such as artisans or contractor staff, who must execute the detailed work. Hence, it is critical for Technologists to be able to issue clear instructions.

Furthermore, Chemical Engineering technologists may need to present their findings and progress to a diverse audience, including superiors, peers, clients and stakeholders. In these oral presentations, Chemical Engineering technologists must use appropriate structure, style, language, visual aids and supporting documents to convey their message effectively. They need to consider the technical aspects of the project, such as presenting information using drawings or flow diagrams. Chemical Engineering Technologists must also consider the impacts and implications of their work, ensuring that the audience can grasp the significance of the content being presented.

4.2.6 Outcome 6: Recognise the reasonably foreseeable economic, social, cultural, and environmental effects of broadly defined engineering activities seeking to achieve sustainability (Responsibility Level B)

The impact of engineering activities refers to the effects of engineering projects and processes on various aspects of society, the environment and the economy. It involves understanding and evaluating the potential consequences of these activities and taking measures to mitigate any adverse effects.

On the other hand, risk mitigation refers to identifying potential risks associated with engineering activities and implementing measures to minimise or eliminate those risks. This activity includes assessing the likelihood and severity of possible hazards, developing strategies to prevent or control them and implementing safety measures to protect people, property and the environment.

Example in the chemical manufacturing industry:

Implementing a chemical manufacturing project can impact the economy, society, culture and the environment. The task to evaluate the impacts and risks associated with the project could include assessing the impact on local communities, the availability of resources, the potential for pollution or waste generation and the project's long-term sustainability. Here are some examples of planning impacts and risk mitigation strategies associated with each:

Economic impacts

- **Impact:** Job creation and economic growth.
- **Risk mitigation:** Develop a comprehensive workforce development plan to ensure the availability of skilled labour. Collaborate with local institutions and provide training programs to enhance the local workforce's skills.
- **Impact:** Economic diversification.
- **Risk mitigation:** Engage with local government authorities to understand the local bylaws and regulations. Develop a long-term financial plan to ensure the project's sustainability and minimise financial risks.

Social impacts

- **Impact:** Community health and safety concerns.
- **Risk mitigation:** Conduct a thorough risk assessment and implement robust safety protocols and emergency response plans. Engage with local communities to address their concerns and provide regular updates on safety measures.
- **Impact:** Social disruption due to project construction.
- **Risk mitigation:** Develop a community engagement plan to communicate project timelines, potential disruptions and mitigation measures. Implement strategies to minimise noise, dust and traffic impacts during construction.

Cultural impacts

- **Impact:** Potential impact on cultural heritage sites or indigenous communities.
- **Risk mitigation:** Conduct a cultural heritage assessment to identify and protect any significant sites. Engage with indigenous communities and respect their cultural values and traditional knowledge. Develop a cultural heritage management plan to mitigate any potential impacts.
- **Impact**: Changes to the local community's way of life.
- **Risk mitigation:** Engage with local community leaders and stakeholders to understand their concerns and aspirations. Develop a community development plan that includes initiatives to support local businesses, education, healthcare and infrastructure development.

Environmental impacts

- **Impact:** Air and water pollution.
- **Risk mitigation:** Implement advanced pollution control technologies and monitoring systems. Develop a comprehensive waste management plan to minimise and properly dispose of hazardous waste. Comply with local environmental regulations and standards.
- **Impact:** Habitat destruction and biodiversity loss.
- **Risk mitigation:** Conduct an environmental impact assessment to identify sensitive habitats and species. Develop a biodiversity conservation plan that includes habitat restoration and protection measures. Implement sustainable practices such as energy and water conservation, waste reduction and recycling.

4.2.7 Outcome 7: Meet all legal and regulatory requirements and protect the health and safety of persons during all broadly defined engineering activities (Responsibility Level E)

When seeking to register as a professional Chemical Engineering technologist, one of the requirements is to demonstrate competence in addressing the statutory and regulatory requirements. Those seeking registration as Professional Chemical Engineering Technologists must demonstrate their commitment to meeting legal obligations, protecting the health and safety of individuals, and ensuring compliance with industry standards throughout the project life cycle.

Refer to the list at the beginning of section 4 of most common Acts and regulatory standards in the Chemical Engineering profession.

Example in the oil and gas industry:

A Chemical Engineering technologist may develop and operate chemical processes for refining petroleum. In this context, addressing statutory and regulatory requirements would involve:

- **Identifying applicable legal and regulatory requirements**: This could include understanding and complying with environmental regulations, safety standards and occupational health and safety laws specific to the oil and gas industry. One example is understanding the Occupational Health and Safety Act, 85 of 1993, which provides regulations and guidelines for ensuring the health and safety of workers.

- **Demonstrating awareness of health and safety regulations**: Applicants should provide examples of situations where Chemical Engineering technologists have demonstrated awareness regarding health and safety regulations. This could involve implementing safety protocols, conducting risk assessments and ensuring compliance with relevant safety standards. Examples could include:
  - implementing a safety management system to identify and mitigate drilling, production and oil transportation risks
  - regularly inspecting and maintaining equipment and infrastructure to ensure their safe operation
  - providing workers with appropriate personal protective equipment (PPE) and ensuring its proper use
  - conducting safety training programmes for employees to enhance their awareness and knowledge of safety procedures
  - establishing emergency response plans and conducting drills to prepare for potential accidents or incidents.

- **Ensuring the safety of all affected persons**: Applicants should show how they have prioritised the protection of individuals involved in the engineering activities. This could include using safe and sustainable materials, components, processes and systems to minimise risks to workers and the environment. Examples are listed below:
  - Conducting regular health and safety assessments to identify and address workplace hazards.
  - Providing training and education on occupational health and safety practices to employees.
  - Ensuring compliance with regulations related to noise exposure, hazardous substances and ergonomics.
  - Establishing incident reporting and investigation procedures to identify the root causes and prevent future occurrences.

- Implementing measures to prevent work-related injuries and illnesses, such as proper ergonomics, regular breaks and medical surveillance programmes.

- **Identifying risks and risk management strategies**: Applicants should demonstrate the ability to identify potential risks associated with Chemical Engineering activities and propose effective risk management strategies. This could involve implementing safety measures, conducting hazard analyses and developing emergency response plans. Examples could include the following:

  - **Hazard Analysis and Critical Control Points (HACCP):** Implementing an HACCP system to identify and control potential hazards in producing, handling and transporting oil and gas products. This involves thoroughly analysing the entire process, identifying critical control points and implementing measures to prevent or minimise risks.
  - **Process Safety Management (PSM):** Developing and implementing a comprehensive PSM programme to identify and manage risks associated with Chemical Engineering activities. This includes conducting hazard assessments, implementing safety procedures, training employees and regularly auditing and reviewing the programme's effectiveness.
  - **Emergency Response Planning:** Developing robust emergency response plans that outline procedures for responding to potential incidents such as spills, leaks, fires, or explosions. This includes establishing communication protocols, training employees on emergency response procedures, conducting drills and exercises, and coordinating with local emergency response agencies.
  - **Environmental Impact Assessments (EIAs):** Conducting thorough EIAs before initiating any new projects or operations to identify potential environmental risks and develop mitigation strategies. This includes assessing the impact on air quality, water resources, wildlife and local communities, and implementing measures to minimise negative effects.
  - **Waste Management:** Implementing proper waste management practices to handle and dispose of hazardous materials generated during oil and gas operations. This

includes segregating and storing waste properly, ensuring compliance with local regulations and utilising appropriate treatment and disposal methods.

4.2.8 Outcome 8: Conduct engineering activities ethically (Responsibility Level E)

Demonstrating the ethics of engineering means adhering to a set of ethical principles and standards in one's professional practice. This includes understanding and complying with the ECSA Code of Conduct for registered persons, identifying ethical problems and affected parties, and selecting the best solution to resolve these problems.

Another industry example of demonstrating the ethics of engineering for a Chemical Engineering technologist could be the public sector in water treatment plants.

In this scenario, Chemical Engineering technologists ensure safe and efficient water treatment for public consumption. They must comply with ethical standards and norms to protect public health and the environment. By demonstrating engineering ethics in the public sector, Chemical Engineering technologists ensure that their work aligns with professional standards, protects public interests and upholds the integrity of the engineering profession.

Chemical engineering technologists can demonstrate this competence by following these steps:

Identifying ethical problems and affected parties

Technologists may encounter ethical problems related to water quality, resource management or public safety. For example, they may discover that a certain chemical used in the water treatment process poses potential health risks to consumers. In such cases, the affected parties would include the public who consume the treated water.

Selecting the best solution

To resolve the ethical problem, chemical engineering technologists should consider various factors, including the potential risks, available alternatives and legal requirements. They may consult with other professionals, such as chemists, environmental engineers or public health experts, to determine the best course of action. In this example, the Technologist may propose alternative chemicals or treatment methods that are safer yet still effective in ensuring water quality.

Comprehension and application of professional ethics

Chemical Engineering technologists should act within their limits of competence and ensure that their decisions prioritise public health and safety. They should communicate any potential risks or concerns to relevant authorities and stakeholders, and work towards implementing the best solution while complying with regulatory requirements.

4.2.9 Outcome 9: Exercise sound judgement by evaluating the outcomes, impacts and alternatives in the course of broadly defined engineering activities. (Responsibility Level E)

Exercising sound engineering judgment means making informed decisions by carefully evaluating the outcomes, impacts and alternatives related to engineering activities. It involves considering factors such as environmental impacts, interrelationships with other disciplines, time constraints, cost limitations and other relevant constraints, even when faced with limited knowledge.

An example of exercising sound judgment for a Chemical Engineering technologist is working on a consulting project for a manufacturing company that wants to improve the efficiency of its chemical processes. Chemical Engineering Technologists are tasked with evaluating different options and proposing a final solution.

In exercising sound judgment, Chemical Engineering Technologists first gather relevant data and information about the existing processes, including their strengths, weaknesses and potential areas for improvement. They then consider the impacts and interrelationships with other disciplines, such as environmental and safety considerations, as well as any regulatory constraints.

In terms of material sustainability, Chemical Engineering technologists also consider the environmental impact of the materials used in the manufacturing processes. This task could involve evaluating the use of hazardous or toxic substances and exploring alternative, more environmentally friendly materials.

Chemical Engineering Technologists then assess the materials' life cycle, considering factors such as their extraction, production, use and disposal. This includes evaluating each stage's energy and resource requirements and the potential for recycling or reusing materials.

In addition, Chemical Engineering Technologists consider the availability and long-term sustainability of the materials. This step could involve assessing their source, whether they are renewable or finite resources and the potential for future scarcity or supply chain disruptions.

Based on these considerations, Chemical Engineering Technologists aim to propose solutions that minimise harmful or non-sustainable materials, promote the use of renewable or recyclable materials and optimise the overall sustainability of the manufacturing processes.

Applicants/Candidates could recommend process modifications, such as using alternative feedstocks, implementing recycling systems or suggesting adopting more sustainable technologies or practices.

Chemical Engineering Technologists also take a wide-ranging view of the solution, considering potential risks and their consequences. Applicants/Candidates assess the implications for stakeholders, such as employees, nearby communities and the environment. This assessment could involve evaluating the potential environmental impact of different process modifications or considering the safety implications for workers.

Additionally, Chemical Engineering Technologist consider the broader social and economic implications of their recommendations. Applicants/Candidates might assess the company's potential cost savings or efficiency gains, as well as any potential job impacts or community benefits.

Based on this evaluation, Chemical Engineering Technologists then develop a range of options and propose a final solution that balances all these considerations. They provide recommendations considering the technical feasibility, cost-effectiveness, sustainability and potential impacts on various stakeholders.

By exercising sound judgment in this way, Chemical Engineering Technologists ensure that their recommendations are well-informed, considerate of potential risks and impacts and aligned with the best interests of all affected parties.

4.2.10 Outcome 10: Be responsible for making decisions on part or all of broadly defined engineering activities. (Responsibility Level E)

Responsibility in decision-making refers to the ability to make informed and ethical decisions that significantly impact the field of Chemical Engineering. It involves considering various factors, such as safety, environmental impact, cost-effectiveness and regulatory compliance. A professional Chemical Engineering technologist's responsibility in decision-making also requires a comprehensive understanding of the field, adherence to ethical standards and a commitment to ensuring the safety, efficiency and sustainability of Chemical Engineering processes.

For example, in the oil and gas industry, Chemical Engineering technologists may be responsible for making decisions regarding the selection and use of chemicals in drilling and production processes. They would need to consider factors such as the potential environmental impact of the chemicals, their compatibility with other substances and their effectiveness in achieving desired outcomes. Chemical Engineering technologists must also ensure compliance with health and safety regulations and industry standards.

In this scenario, decision-making responsibility would involve conducting thorough research, analysing data and consulting with experts to make informed decisions about chemical selection and usage. The individual would need to consider the potential risks associated with different chemicals, evaluate their environmental impact and choose the most suitable options that align with industry best practices and sustainability goals.

Furthermore, responsibility in decision-making also includes understanding the consequences of those decisions and putting in place mitigations. If any issues or challenges arise due to the choices made, professional Chemical Engineering technologists should be prepared to address them and take corrective actions.

4.2.11 Outcome 11: Undertake sufficient professional development activities to maintain, extend competence and enhance the ability to adapt to emerging technologies and the ever-changing nature of work. (Responsibility Level D)

Professional development refers to the ongoing process of acquiring and enhancing the knowledge, skills and competencies necessary to excel in a particular profession. It involves activities and opportunities that help individuals stay up to date with the latest developments in their field, improve their expertise and advance their careers.

Addressing professional development means actively engaging in activities that contribute to growth and development as a Chemical Engineering Technologist. The development could include various forms of learning, such as attending workshops, conferences and seminars, pursuing higher education and participating in training programmes to stay informed about industry trends and advancements.

An example of demonstrating this outcome by a Chemical Engineering technologist in the oil and gas sector might be engaging in professional development by attending conferences on process optimisation, safety standards or emerging technologies in the industry. Chemical Engineering technologists could also enrol in specialised training programmes to enhance their knowledge of specific equipment or software used in their field. Additionally, they might pursue certifications or licences demonstrating expertise and commitment to professional development, such as becoming a certified safety professional or obtaining a licence to operate a specific equipment.

Another example driven by the advent of the Fourth Industrial Revolution (4IR) is the integration of advanced technologies, such as artificial intelligence, robotics and automation, into various industries. This rapid technological advancement necessitates that professionals continuously adapt and upskill in courses related to artificial intelligence to remain relevant and competitive in the job market.

By actively addressing professional development, individuals seeking to register as professional Chemical Engineering technologists demonstrate their commitment to staying current with industry advancements, expanding their skill sets and continuously improving their abilities. The professional development enhances their professional credibility and opens opportunities for career growth and advancement within the field. For a list of recommended learning, refer to section 5.2 (Recommended learning).

4.3 Training for registration as a Professional Engineering Technician

4.3.1 Outcome 1: Define, investigate and analyse well-defined engineering problems (Responsibility Level E)

When individuals seek to register as a Professional Chemical Engineering Technicians, one of the key competencies they need to demonstrate is the ability to define, investigate and analyse well-defined engineering problems. This requirement means the applicant should be able to effectively identify and understand engineering problems and develop a clear understanding of what needs to be solved. For Engineering Technicians to solve well-defined engineering problems, it is imperative to understand the nature of the engineering problem. Inability to understand the engineering problem could lead to incorrect design or incorrect development of solutions. Engineering problems should be thoroughly investigated through site visits, collecting technical information and checking engineering drawings. No investigation can be completed using desktop information only.

A practical problem for Applicant Engineering Technicians means the encountered problem cannot be solved by artisans because theoretical calculations and engineering decisions are necessary to substantiate the proposed solution:

- Further investigation to identify the nature of the problem is seldom necessary.
- The problem is easily recognised as part of the larger engineering task, project or operation.
- It is recognised that the problem occurred in the past or the possibility exists that it may have happened before – definitely not something new.
- Solving the problem does not require the development of a new solution – find out how it was solved before.

- Encompassed means encircled. The standards, codes and documented procedures must be obtained to solve the problem, and authorisation from the supervisor or mentor must be obtained to waive the stipulations.
- The responsibility lies with the Engineering Technician to check that the information received as part of the encountered problem is correct and added to as necessary to ensure the correct and complete execution of the work.
- The problem handled by Engineering Technician must be limited to well-known matters, preferably needing standardised solutions without possible complications.
- Practical solutions to problems include knowledge of the skills displayed by Specified Category Practitioners and Engineering Artisans without sacrificing theoretical engineering principles and/or cutting corners to satisfy the involved parties.
- Engineering technicians need guidance from Technologists or Engineers.

Example from the water treatment plant:

A Chemical Engineering technician may be responsible for defining, investigating and analysing a problem related to water quality or treatment processes. Applicants would collect data on the water source, such as its composition and contaminants, from the laboratory, and then investigate the problem by analysing the treatment processes, evaluating the efficiency of various treatment methods and identifying any potential issues or bottlenecks, such as comparing the design and current yield data. Technician then propose solutions to improve water quality or optimise the treatment process based on the analysis.

4.3.2 Outcome 2: Design or develop solutions to well-defined engineering problems (Responsibility Levels C and D)

Designing or developing solutions to well-defined engineering problems refers to the ability to come up with innovative and practical solutions to solve engineering problems.

Once the analysis of the engineering problem has been established, Applicants are expected either to design or to develop engineering solutions to resolve well-defined engineering problems. Well-defined engineering problems can be solved in standardised or prescribed ways. They are encompassed by standards, codes and documented procedures.

The solutions should be based on accepted methods, techniques or procedures based on the theory of practice and should consider sustainability.

In choosing the solution a design criteria matrix is required to justify the solution/design (e.g., life cycle cost, operability, maintainability etc)

Example in the Chemical Engineering industry:

In the Chemical Engineering industry, a professional Chemical Engineering technician may be tasked with designing a process to convert waste materials into valuable products. This task could solve well-defined engineering problems, such as finding ways to efficiently and economically convert biomass waste into biofuels. Technicians would need to consider various factors, such as the chemical reactions involved, the equipment required, the process's environmental impact and the solution's economic feasibility. Applicants would need to use appropriate theories and information technologies to design the process, ensure that it meets the client's requirements and document the specifications for implementation.

4.3.3 Outcome 3: Comprehend and apply knowledge that is embodied in established engineering practices that is specific to the jurisdiction in which the engineering technician practises. (Responsibility Level E)

Applying engineering procedures, processes, systems and methodologies specific to Chemical Engineering could involve understanding and utilising various Chemical Engineering calculations, such as mass and energy balances, process design, equipment sizing and optimisation techniques.

Applicant Chemical Engineering technicians are required to apply engineering knowledge acquired during the accredited undergraduate programmes to resolve well-defined engineering problems and subsequently to provide solutions to such problems. During training, Applicant Engineering Technicians are expected to be introduced to engineering standards, procedures, and the different systems used in the process of engineering problem-solving. It is imperative that Applicant Engineering Technicians are able to understand and demonstrate the application of acceptable engineering theory, engineering standards, engineering procedures, systems and governing laws in solving well-defined engineering problems.

Applicant Engineering Technicians must be able to base their decision on theory learnt at School.

Calculations confirming the correct application and use of equipment must be done on practical, well-defined activities. Reference must be made to the standards and procedures that were used and how calculations was derived from NDip theory.

In this scenario, Chemical Engineering technicians would be responsible for managing various aspects of the project, such as the following:

- **Planning:** Develop a detailed project plan that outlines the scope, objectives, timeline and resources required for the project, as well as identifying key milestones and deliverables.
- **Organising:** Allocating resources, including personnel, equipment and materials to ensure that the project tasks are executed as planned. This task involves coordinating with different teams and departments involved in the project.
- **Leading:** In this task, Technicians provide guidance and direction to the project team members, ensuring that they understand their roles and responsibilities. Technicians should motivate and inspire the team to work towards the project's objectives.
- **Controlling:** Monitoring the project's progress, tracking key performance indicators, and taking corrective actions if deviations from the plan occur. This task includes managing risks, resolving issues and ensuring the project stays on track.
- **Managing contracts and relationships:** Technicians should be able to establish and maintain professional and business relationships with contractors, suppliers and other stakeholders involved in the project. This task includes negotiating contracts, managing procurement processes and ensuring compliance with legal and regulatory requirements.

4.3.4 Outcome 4: Manage part or all of one or more well-defined engineering activities. (Responsibility Level D)

The areas in which Applicant Chemical Engineering Technicians work generally follow a conventional project or product-development life cycle model.

The key project management activities involve time, cost and quality. Applicant Engineering Technicians should be able to manage their engineering work activities and minimise project delays in operations and maintenance and capital projects.

Engineering project management involves managing part or all of one or more well defined engineering activities. For this outcome, Chemical Engineering technicians should be responsible for planning, organising, leading and controlling engineering activities to achieve desired results. Applicants are required to effectively manage and contribute to the successful completion of engineering activities in their practice area.

Applicant Engineering Technicians or persons wishing to register with ECSA as a Professional Engineering Technician must participate in and contribute to the work activities in a project life cycle. Applicant Engineering Technicians are not expected to change their places of employment to acquire all the skills in the project life cycle that are listed above.

4.3.5 Outcome 5: Communicate clearly using multiple mediums and collaborate inclusively with a broad range of stakeholders in the course of engineering activities. (Responsibility Level C)

A Chemical Engineering technician is required to demonstrate professional communication. Professional communication means effectively communicating with a wide range of stakeholders in various media.

This communication may be in written form, such as technical reports, legal documents and editorial pieces or oral, such as presentations.

While conducting engineering works, Applicant Engineering Technicians are expected to communicate with their team members, supervisors, clients and contractors effectively.

Professional communication is a vital skill for Applicant Engineering Technicians to possess since all their decisions are communicated to different parties. Professional communication is important in running effective meetings, working with people who are not technical, working with other cultures, issuing and receiving instructions, reporting on engineering works and sharing ideas.

Applicants must develop effective communication skills during training and be able to demonstrate such skills to be registered as Professional Engineering Technicians.

4.3.6 Outcome 6: Recognise the reasonably foreseeable economic, social, cultural and environmental effects of well-defined engineering activities seeking to achieve sustainability. (Responsibility Level B)

Well-defined engineering problems may have an impact on the social, environmental and cultural components. Applicants should be able to recognise and address the impact of their well-defined engineering activities. It involves understanding and evaluating the potential consequences of these activities and taking measures to mitigate any adverse effects.

Social effects encompass all issues that directly or indirectly affect people and their livelihoods. Engineering activities may affect people's way of life, their political system, their health and wellbeing and their personal and property rights. When doing a project, Chemical Engineering technicians must check how it benefits the community around job creation and skills development.

Environmental effects include the effects on people's environment (i.e., air and water quality, dust and exposure to noise, adequacy of sanitation) and the effects on large ecosystems. This might include disruption of ecosystems and fauna and flora in addition to increased land temperatures and damage to historical buildings.

Cultural effects include people's customary beliefs, religion, language and norms, for example, the ceremonies and customs of a particular group or society. This includes, for example, translating the standards that are from the Equipment Manufacturers into English as most products are from China or Japan for example.

4.3.7 Outcome 7: Meet all legal and regulatory requirements and protect the health and safety of persons during all well-defined engineering activities. (Responsibility Level E)

Applicants wishing to register with ECSA as Professional Engineering Technicians are expected to have a working knowledge of the related regulations and Acts and to be able to demonstrate how this legislation affects their well-defined engineering activities at Responsibility Level E (performing). Technicians, like engineers and technologists, are also required to comply with the regulations applicable to their respective industries in the performance of their duties. The compliance ensures that their engineering work is carried out legally and safely for the protection of the profession and their integrity. Refer to the list at the beginning of section 4 for the most common Acts and regulatory standards.

There may be other Acts not listed here, which may also be pertinent to an applicant's specific work environment such as, • work instructions, standards, and/or specifications of the enterprise. Applicants 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.

The onus is, once again, on Applicants and their Mentors/Supervisors to familiarise themselves with these practices in the South African industry.

4.3.8 Outcome 8: Conduct engineering activities ethically (Responsibility Level E)

Applicant Engineering Technicians should be able to identify ethical issues arising during engineering activities, identify affected parties and determine how such issues may affect them. The solution to an ethical problem must consider all affected parties.

Applicant Chemical Engineering Technicians must perform engineering work and make technical decisions while adhering to the *ECSA Code of Conduct* for registered persons. The following factors should be considered when performing engineering work:

- Make decisions within the limits of the practitioner's education, training and experience.
- Act with integrity and in accordance with the general norms of professional conduct.

- Strive to respect the interests of the public and health and safety and minimise environmental impact.
- If the scope of work falls outside the area of expertise of the Applicant Chemical Engineering Technicians, they should seek guidance from relevant parties.

An example of demonstrating engineering ethics in a company involving hazardous chemicals could involve the responsible handling and disposal of hazardous chemicals. Chemical Engineering Technicians are often involved in designing and operating processes that involve the use of dangerous substances. Ethical behaviour in this context would require Chemical Engineering technologists to prioritise the safety of workers, the public and the environment.

4.3.9 Outcome 9: Exercise sound judgement by evaluating the outcomes, impacts and alternatives in the course of well-defined engineering activities. (Responsibility Level E)

Exercising sound engineering judgment means making informed decisions by carefully evaluating the outcomes, impacts and alternatives related to engineering activities. It involves considering factors such as environmental impacts, interrelationships with other disciplines, time constraints, cost limitations and other relevant constraints, even when faced with limited knowledge.

Applicant Chemical Engineering Technicians should be able to make judgement on a sustainable solution after ensuring that all factors, including consideration of other disciplines, have been taken into consideration.

Applicant Chemical Engineering Technicians must familiarise themselves with organisational risk policies and standards.

Engineering activities classified as well-defined in which Engineering Technicians use standard procedures, codes of practice, specifications, etc., require judgement to be displayed to identify any activity falling outside the well-defined range (defined above) by:

- seeking advice when risk factors exceed his/her capability

- determining any consequences outside the immediate work contexts (e.g. long-term, not normally handled); and
- accounting for interested and affected parties with defined needs outside the well-defined parameters.

4.3.10 Outcome 10: Be responsible for making decisions on part or all of well-defined engineering activities. (Responsibility Level E)

Responsibility in decision-making refers to the ability to make informed and ethical decisions that significantly impact the field of Chemical Engineering. It involves considering various factors, such as safety, environmental impact, cost-effectiveness and regulatory compliance. Professional Chemical Engineering Technicians responsibility in decision-making also requires a comprehensive understanding of the field, adherence to ethical standards and a commitment to ensuring the safety, efficiency and sustainability of Chemical Engineering processes.

Chemical Engineering technicians must also ensure compliance with health and safety regulations and industry standards.

Responsible decision-making includes applying engineering knowledge acquired from accredited engineering programmes. It includes using relevant calculations to justify why certain solutions are chosen to solve well-defined engineering problems.

This is, in the first instance, continuous self-evaluation to ascertain that the task given is done correctly, on time and within budget. Continuous feedback to the task originator, instruction and corrective action, if necessary, form important elements.

4.3.11 Outcome 11: Undertake sufficient professional development activities to maintain, extend competence and enhance the ability to adapt to emerging technologies and the ever-changing nature of work. (Responsibility Level D)

Professional development refers to the ongoing process of acquiring and enhancing the knowledge, skills and competencies necessary to excel in a particular profession. It involves activities and opportunities that help individuals stay up to date with the latest developments in their field, improve their expertise and advance their careers.

Record-keeping must not be left to the employer or anybody else. Trainees must manage their own training independently by taking initiative and being in charge of experiential development towards the level of Professional Engineering Technician. Knowledge of the employer's policy and procedures on training is essential. For a list of recommended learning, refer to section 5.2 (Recommended learning)

5. FUNCTIONS PERFORMED

As previously discussed, Chemical Engineering is an essential discipline within the broader engineering family, pivotal in numerous sectors, industries and applications. Its primary objective is to convert raw materials into valuable products by utilising transformation processes, advanced technologies and systems to enable the development and optimisation of efficient and sustainable processes that drive innovation, enhance productivity and contribute to society's advancement.

As Chemical Engineering practitioners progress through their experiential careers, they must become cognisant of the different levels or degrees of responsibility and the corresponding activities and duties in preparation for registration in the various professional engineering categories.

5.1 Degrees of responsibilities

Progression throughout the various experiences presented in document **R-04-T&M-Guide-PC** and below in Table 2 refers to the gradual increase in the DoR that Applicant Engineering Professionals are required to undergo during professional training or experience. Considering the nature of the work, specific examples and outcomes appropriate to training in Chemical Engineering are presented in Table 2 below:

Table 2: Progression to gather experience at appropriate levels of responsibility suitable for the registration category desired by prospective applicants

Degree of Responsibility	Nature of work	Activities/duties to gain experience
A: Being exposed	Shadows experienced practitioners, attending meetings, and familiarizing themselves with the overall operations of the industry or company to understand how their role fits into the larger business context and observe the tasks and responsibilities of senior or more experienced colleagues.	• Undergo induction. • Observe processes and work of competent practitioners. • Understand the business environment and the dynamics that shape the businesses and the industries in which they operate. • Understand the business model, key conversion processes, and the critical outcomes. • Understand the value added by Chemical Engineering Practitioners and other professionals in the business.
B: Assisting	Work in specific processes under close supervision.	• Develop insight and understanding of the different processes and systems in transforming inputs into goods and services. • Develop an appreciation of the numerous resources at the disposal of Chemical Engineering practitioners. • Obtain experience in the day-to-day operations of the business to gain insight and understanding of the different processes and systems involved in transforming inputs into goods and services, with specific emphasis on productivity and quality measurements. **Example:** • A Chemical Engineering professional being exposed to the electricity industry would observe the processes involved in producing electricity from different sources such as coal, gas, hydro, nuclear and renewables. They would learn about the business model of electricity production and understand the role of Chemical Engineering in optimising the production processes for plants related to electricity production.
C: Participating	Work under the limited direction, guidance, or	• Gain first-hand experience of a broad range of Chemical Engineering activities (e.g., process

Degree of Responsibility	Nature of work	Activities/duties to gain experience
	supervision of another professional or senior staff member.	design and re-engineering, planning and control, work study, value engineering, materials and information management, people management skills, logistics, specialists' inputs, tools and equipment, and quality assurance). **Example:** • In the electricity industry, a chemical engineering professional may be involved in the planning and controlling of production processes for electricity generation. They would work alongside senior staff members to optimise the efficiency and quality of processes such as coal combustion, gas turbine operation, hydroelectric power generation or nuclear power plant operation. They would also analyse the performance of various components and systems, such as boilers, turbines and heat exchangers to identify if the plant is operating according to the design performance parameters and report these parameters to seniors. • In manufacturing, a Chemical Engineering professional may optimise the chemical reactions and processes involved in producing iron and steel, ferroalloys or aluminium products. They would work under the guidance of senior staff members to refine the ironmaking process, operate steelmaking furnaces and ensure proper casting and solidification of steel to achieve desired properties. • In the chemical industry, a Chemical Engineering professional may participate in activities such as selecting appropriate raw materials, designing reactors and separation units and optimising process conditions to maximise efficiency and product quality. They would work under the limited direction of a senior staff member to analyse reaction kinetics, design reactors and optimise reaction conditions to achieve desired product yields and selectivity. They would also

Degree of Responsibility	Nature of work	Activities/duties to gain experience
		gain experience in various separation processes, such as distillation, extraction, crystallization and membrane filtration to separate desired products from reaction mixtures. In addition, they would gain experience in various activities such as process design, planning, control, work study, materials management and quality assurance. They would also learn about the problems and limitations associated with specific philosophies, methods and techniques, with emphasis on cost/effort and relative benefit. • In the food and beverage industry, a chemical engineering professional may be involved in the design and optimisation of processes for converting raw materials into food products. They would work under the limited direction of a senior staff member to develop processes for mixing, blending, heating, cooling, drying and packaging food products. They would also gain experience in optimizing fermentation conditions to produce fermented food and beverages, such as beer, wine, yogurt and cheese, while ensuring product consistency and quality. Additionally, they would focus on developing processes to ensure food safety.
D: Contributing	Work independently but requires detailed approval of work outputs from a supervisor or senior staff member.	• Be involved in activities such as the planning of production, the control of quality and costs of process study and work study, good material handling and workplace layout, activity-based costing, benchmarking, business cases, process re-engineering, maintenance practice and procedures, and project management and system specification. The collective work of such activities is vital in the economical use of people, materials and machines. • Give specific attention to human aspects concerning communication, interpersonal relationships and teamwork, training, cost

Degree of Responsibility	Nature of work	Activities/duties to gain experience
		analysis, budget control and profit accountability. These should proceed in parallel, applying Chemical Engineering techniques and employing computers in problem-solving. **Example:** • In the manufacturing industry, a Chemical Engineering professional in the contributing phase may work independently on projects related to iron and steel production. They would optimise chemical reactions, design process equipment and ensure efficient operation. However, they would still require detailed approval from a supervisor or senior staff member for their work outputs, such as process flow diagrams, equipment specifications and optimisation parameters. .
E: Performing	Works in a team without supervision, recommends work outputs, and is responsible but not necessarily accountable.	• Sign off and approve the engineering work of other junior engineering staff. • Take a leadership role to develop and apply skills in management areas such as labour relations, management accounting, business law and general business management. • Write scoping of work or projects, as well as corresponding contracts. • Lead a team in the chemical industry to select appropriate raw materials, design reactors and separation units and optimise process conditions to maximise efficiency and product quality. • Recommend instruments and control systems to monitor and control process variables in chemical processes. • Analyse reaction kinetics, design reactors and optimise reaction conditions to achieve desired product yields and selectivity. • Lead the development and implementation of separation processes, such as distillation, extraction, crystallization and membrane filtration.

Degree of Responsibility	Nature of work	Activities/duties to gain experience
		Example: Chemical Engineering professionals working in the professional services industry may be responsible for managing an engineering project, such as constructing a chemical plant, to demonstrate the responsibility level of performing. They would be responsible for managing the entire project life cycle or parts thereof, including initiation, planning, execution, monitoring and control, and closure. Typical tasks of responsibility may be overseeing the entire project, including budget and cost management, bill of materials, quality control and risk management. They may coordinate with various stakeholders, such as contractors, suppliers and clients to ensure the project is executed smoothly and meets all regulatory requirements. Project managers would also be responsible for managing the project team, assigning tasks, ensuring timely completion of deliverables and managing changes to the scope or the project requirements. They evaluate the economic evaluation of each solution, technology or equipment, analysing costs and making decisions based on financial considerations, risk, technical, social and sustainability factors.

5.2 Recommended learning

As specified in outcome 11 for each of the registration categories, engineering professionals would need to demonstrate continued professional development. In addition, keeping up with technological advancements, especially in the advent of the 4IR which drives the integration of digital technologies into various industries, necessitates the inclusion of these additional skills in the guideline:

- **Data analytics and machine learning:** Understanding how to analyse and interpret large datasets using statistical techniques and machine learning algorithms can help optimise processes and improve decision-making.
- **Process automation and control:** Learning about advanced control systems, real-time optimisation and industrial automation technologies can enhance efficiency and productivity in chemical processes.
- **Internet of Things (IoT) and Industrial Internet of Things (IIoT):** Acquiring knowledge about IoT and IIoT technologies can enable the integration of sensors, devices and data networks to improve monitoring, control and maintenance of chemical processes.
- **Cybersecurity:** With the increased connectivity of industrial systems, understanding cybersecurity principles and practices is crucial to protect sensitive data and prevent cyber-attacks.
- **Digital twin:** Familiarity with the concept of digital twin, which involves creating a virtual replica of a physical process or system, can help optimise operations, troubleshoot issues and predict performance.
- **Augmented reality (AR) and virtual reality (VR):** Being proficient in AR and VR technologies can facilitate training, visualisation and remote collaboration in chemical engineering projects.
- **Advanced materials and nanotechnology:** Keeping up with advancements in materials science and nanotechnology can open up new possibilities for designing and developing innovative chemical processes and products.
- **Sustainable and green technologies:** Gaining knowledge about sustainable and environmentally friendly technologies can help address the growing concerns of climate change and promote sustainable practices in the chemical industry.
- **Innovation and entrepreneurship:** Developing skills in innovation, creativity and entrepreneurship can enable chemical engineering technologists to identify new opportunities, drive technological advancements and contribute to the growth of the industry.

- **Ethical and social implications:** Understanding the ethical and social implications of emerging technologies can help chemical engineering technologists make informed decisions and ensure responsible and sustainable practices in their work.

Some large companies offer significant training opportunities, particularly companies that are specialists in their field. In companies where such opportunities are few, Candidates are advised to consider joining the relevant VA, or other relevant sub-discipline specific VAs

REVISION HISTORY

Revision number	Revision date	Revision details	Approved by
Rev 0 Draft A	11 May 2024	The DSTG have been merged into one Discipline Specific Training Guide for Registration as a Professional Engineer, Technologist and Technician in Mechanical Engineering and to ensure that the DSTG clearly detail how each outcome can be achieved.	RDDR BU
Rev 0 Draft B	30 May 2024	The review has included an introduction section. The document further indicates the type of engineering work that the different categories should undertake. Section 4. Developing Competency: Document (R-08-PE/PT/PN) Under Training for Registration as a Professional Engineer, Professional Engineering Technologist and Professional Engineering Technician has been revised to ensure that each training element is aligned to each outcome, *4.1.1 Investigation & Analysis* The content under this section is aligned with Outcome 1 *4.1.2 Engineering Design & Development of solution* The content under this section is aligned with Outcome 2 *4.1.3 Contextual Knowledge* The content under this section is aligned with Outcome 3 *4.1.4 Engineering Project Management* The content under this section is aligned with Outcome 4 *4.1.5 Professional Communication*	Working group

Revision number	Revision date	Revision details	Approved by
		The content under this section is aligned with Outcome 5 *4.1.6 Impact of Engineering Activities & Risk Mitigation* The content under this section is aligned with Outcome 6 *4.1.7 Statutory & Regulatory Requirements* The content under this section is aligned with Outcome 7 *4.1.8 Ethics of Engineering* The content under this section is aligned with Outcome 8 *4.1.9 Exercising sound judgment* The content under this section is aligned with Outcome 9 *4.1.10 Responsibility in Decision-making* The content under this section is aligned with Outcome 10 *4.1.11 Professional Development* The content under this section is aligned with Outcome 11	
Rev 0 Draft C	06 Jun 2024	Document revised with WG	RI BU, and WG
Rev 0 Draft D	07 Jun 204	Document submitted to the IEA Task Team for alignment to the IEA changes	IEA Review Task Team
Rev 0 Draft E	13 Jun 2024	Reviewed and checked	Executive: RPSC
Rev 0	25 Jun 2024	Approval	RPSC
Rev 0	25 Jun 2024	Added Appendix and changed Header and cover page	RPSC

The Discipline-specific Training Guide for

Registration as a Professional Engineer, Technologist, or Technician in Chemical Engineering

Revision 0 dated 25 June 2024 and consisting of 78 pages reviewed for adequacy by the Business Unit Assistant Manager and is approved by the Executive: Regulatory Instruments and International Relations (**ERSIR**).

.... 9/12/2024 ....

Business Unit Manager | Date

.... 2024/12/09 ....

Executive: ERSIR | Date

This definitive version of this policy is available on our website

APPENDIX A: TRAINING ELEMENTS

Synopsis: Applicants should achieve specific competencies at the prescribed level during their 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.

11. Become conversant with your employer's training and development programme and develop your own lifelong development programme within this framework.

Complex, Broadly-defined and Well-defined engineering work is usually characterised by the application of engineering 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 Engineering Technologist	**Explanation and Responsibility Level**
1. Purpose This standard defines the competence required for registration as a **Professional Engineer, Technologist and Technician**. Definitions of terms having particular meaning within this standard is given in text in relevant section.	DSTGs give context to the purpose of the Competency Standards. The **Engineer, Technologist and Technician** operate within the 12 disciplines ECSA recognises. Each discipline can be further divided into sub-disciplines and finally into specific workplaces as given in section 4 of the specific DSTG. <u>DSTGs 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)</u>. **NOTE:** The training period must be used to develop the trainee's competence towards achieving the standards below at a Responsibility Level E, i.e., Performing. (Refer to the specific DSTG)
2. Demonstration of competence Competence must be demonstrated within Complex, broadly defined and Well-defined *engineering activities,* defined below, by integrated performance of the outcomes defined at the level defined for each outcome. Required contexts and functions may be specified in the applicable DSTG.	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) Activities can be in-house or contracted out; evidence of integrated performance can be submitted irrespective of the situation.
Level Descriptor: Complex engineering activities (**CEA**), Broadly-defined engineering activities (**BDEA**), and Well-defined engineering activities (**WDEA**) 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, and has interfaces with other parties and disciplines. c) Involves a variety of resources, including people, money, equipment, materials and technologies. d) Requires resolution of occasional problems arising from interactions between wide-ranging or conflicting technical, engineering or other issues. e) Are constrained by available technology, time, finance, infrastructure, resources, facilities, standards and codes and applicable laws. f) Have significant risks and consequences in the practice area and in related areas.	**Level Descriptor: CEA, *BDEA and WDEA*** in the various disciplines are characterised by several or all of the following: 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 **CEA, *BDEA and WDEA*** activities and problems. **CEA, *BDEA and WDEA*** activities in the sub-discipline needs 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. 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 broadly defined 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 design; planning; investigation and problem resolution; improvement of materials, components, systems or processes; manufacture or	**Activities** include but are not limited to design; planning; investigation and problem resolution; improvement of materials, components, systems or processes; engineering operations; maintenance;

construction; engineering operations; maintenance; project management; research; development and commercialisation.	project management. For **Engineers, Technologists and Technicians**, research, development and commercialisation happen more frequently in some disciplines but 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, broadly defined and Well-defined,* engineering problems	**Responsibility Level E** Analysis of an engineering problem means the 'separation into parts possibly with comment and judgement'. Complex, *Broadly, Well-defined* means: 'not minute or detailed' and 'not kept within narrow limits'.
Complex, Broadly-defined and Well-defined engineering problems have the following characteristics. a) They require coherent and detailed engineering knowledge, underpinning the technology area; and one or more of the following: b) Are ill-posed, under- or over-specified, require identification and interpretation into the technology area. c) Encompass systems within complex engineering systems; 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	a) Coherent and detailed engineering knowledge for **Engineer, Technologist and Technician** 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) It is recognised that the problem can be classified as 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) 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.	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 **Engineer, Technologist and Technician** 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 **Engineer, Technologist and Technician** may be solved by alternatives that are unaffordable, detrimental to the environment, socially unacceptable, not maintainable, not sustainable, etc; the **Engineer, Technologist and Technician** 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) **The Engineer, Technologist and Technician** 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 broadly defined problems typified by the following performances is expected: 1.1 Performed or contributed to defining engineering problems leading to an agreed definition of the problems to be solved. 1.2 Performed or contributed to investigating engineering problems including collecting, organising and evaluating information.	To perform an engineering task an **Engineer, Technologist and Technician** will typically receive an instruction from a senior person (customer) to do a specific task, and must: 1.1 Ensure 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 Ensure the engineering problem and related information are segregated from the bulk of the information, investigated and evaluated. 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.

1.3 Performed or contributed to analysis of engineering problems using conceptualisation, justified assumptions, limitations and evaluation of results.	
3. Outcomes to be satisfied:	**Explanation and Responsibility Level**
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 section 4 of the specific DSTG.
Outcome 2: Design or develop solutions to **Complex, Broadly-defined and Well-defined** engineering problems	**Responsibility Levels 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 broadly defined problem, typified by the following performances is expected: 2.1 Designed or developed solutions to **Complex, Broadly-defined and Well-defined** engineering problems.	After the task received is fully understood and interpreted, a solution to the problem posed can be developed (designed). To synthesise a solution is 'the combination of separate parts, elements, substances, etc. into a whole or into a system' by the following: 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

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 of detailed specification requirements and design documentation for implementation to the satisfaction of the client.	requirements set out by the instruction received, and the theoretical calculations to support each alternative must be done and submitted as an attachment. 2.2 The **Engineer, Technologist and Technician** will in some cases be unable 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, Broadly-defined and Well-defined*** *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. **The Engineer, Technologist and Technician** must seek approval for any deviation from these established methods but must also initiate and/or participate in the development and revision of 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 **Engineer, Technologist and Technician** practices is given in section 4 of the specific DSTG.
Assessment criteria: This outcome is normally demonstrated in the course of design, investigation or operations.	Design work for **Engineer, Technologist and Technician** is based on B Eng, BTech, N Dip, theory and is mostly the utilisation and configuration of manufactured components and selected materials and associated

3.1 Apply engineering principles, practices, technologies, including the application of, B Eng, BTech or B Eng (Tech) and N Dip, theory in the practice area. 3.2 Indicate working knowledge of areas of practice that interact with practice area to underpin teamwork. 3.3 Apply related knowledge of finance, statutory, safety and management.	novel eininneering., **Engineer, Technologist and Technician** develop and apply codes and procedures in their design work. Investigation would be on broadly defined incidents and condition monitoring, and operations mostly on developing and improving engineering systems and operations. 3.1 Calculations at B Eng, BTech or B Eng (Tech) and/or NDip, theoretical level confirming the correct application and utilisation of equipment, materials and systems listed in section 4 of the specific DSTG must be done on broadly defined activities. 3.2 The understanding of **complex, broadly defined, well defined,** 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	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, **Engineer, Technologist and Technician** 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 **Engineer, Technologist and Technician** must be aware of and decide on the relevant requirements applicable to each specific

administration, quality management, risk management, maintenance management, regulation, project and construction management.	project that he/she is 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, Broadly-defined and Well-defined*** engineering activities.	**Responsibility Level D** Manage means 'control'.
Assessment criteria: The Candidate is expected to display personal and work process management abilities: 4.1 Managed self, people, work priorities, processes and resources in broadly defined engineering work. 4.2 Role in planning, organising, leading and controlling broadly defined engineering activities evident. 4.3 Knowledge of conditions and operation of contractors and the ability.	In Engineering operations **Engineer, Technologist and Technician** are typically 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 broadly defined engineering work. 4.3 Depending on the project, **Engineer, Technologist and Technician** 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/her broadly defined engineering activities.	**Responsibility Level C**
Assessment criteria: Demonstrates effective communication by:	Refer to Range Statement for Outcome 4 and 5 below.

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	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 ***Complex, Broadly-defined and Well-defined*** *engineering* involves: a) Planning ***Complex, Broadly-defined and Well-defined*** activities b) Organising ***Complex, Broadly-defined and Well-defined*** activities c) Leading ***Complex, Broadly-defined and Well-defined*** activities d) Controlling ***Complex, Broadly-defined and Well-defined*** 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' **The Engineer, Technologist and Technician** 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 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 on cost control, etc.
Group C: Impacts of Engineering Activity	**Explanation and Responsibility Level**
Outcome 6:	**Responsibility level B**

Recognise the foreseeable social, cultural and environmental effects of ***Complex, Broadly-defined and Well-defined*** engineering activities generally	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 wildlife, 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/her broadly defined 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 safe 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, Technologist and Technician** 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 the following:	
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. It is identified and studied by the **Engineer, Technologist and Technician** 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 confirms or checks that the instructions are in line with regulations. The **Engineer, Technologist and Technician** is responsible to see that this is done, and if not, establish which regulations apply, and ensure that they are adhered to. Usually, the people working on site are strictly controlled.W.r.t. health and safety, but the **Engineer, Technologist and Technician** checks that this is done, but 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, Technologist and Technician** 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, Technologist and Technician** or other professional specialists must be consulted. It is the responsibility of the **Engineer, Technologist and Technician** 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, Technologist and Technician**.

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: 8.1 Conversance and operation in compliance with ECSA's Rules of Conduct for registered persons confirmed 8.2 How ethical problems and affected parties were identified, and the best solution to resolve the problem selected.	Systematic means 'methodical; based on a system'. 8.1 ECSA's Code of Conduct, as per ECSA's website, is known and adhered to. 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, Broadly-defined and Well-defined*** 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.	9.1 The extent of a project given to a junior **Engineer, Technologist and Technician** is characterised by the several broadly defined 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 Factors taken into consideration given, bearing in mind, risk, consequences in technology application and affected parties.	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 broadly defined where the **Engineer, Technologist and Technician** 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 broadly defined range, as defined above: a) Getting the work done in spite of numerous risk factors needs good judgement and substantiated decision-making. b) Consequences are 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, Broadly-defined and Well-defined*** 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.	10.1 All interrelated factors taken considered are indicative of professional responsibility accepted working on broadly defined activities.

10.3 Academic knowledge of at least B Eng, BTech N Dip, level combined with past experience used in formulating decisions.	10.2 The **Engineer, Technologist and Technician** does not operate on tasks at a higher level than, complex, broadly defined, well defined and consults 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 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, forms 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, Broadly-defined and Well-defined*** engineering activity.	The responsibility is mostly allocated within a team environment with an increasing designation as experience is gathered.
Note 1: Demonstrating responsibility is 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 regarding 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 **Engineer, Technologist and Technician** engineering**.**

Range Statement: Professional development involves: a) planning own professional development strategy b) selecting appropriate professional development activities c) recording professional development strategy and activities, while displaying independent learning ability.	a) In most places of work training is seldom organised by a training department. It is up to the **Engineer, Technologist and Technician** to manage his/her own experiential development. **Engineer, Technologist and Technician** frequently end up in a 'dead-end street' being left behind doing repetitive work. If self-development is not driven by him/herself, 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 **Engineer, Technologist and Technician** is vital to his/her success

APPENDIX B: TRAINING ELEMENTS

1	**Introduction**
1.1	*Induction programme* (typically 1–5 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 Practical Aspects of Engineering* (typically 6–12 months) *and covers how things are:* (Responsibility Levels A–B)
Experience in one or more of these sectors but not all:	
1.2.1.	Manufacturing
1.2.2	Construction
1.2.3	Erection
1.2.4	Field installation
1.2.5	Testing
1.2.6	Commissioning
1.2.7	Operation
1.2.8	Maintenance
1.2.9	Fault location
1.2.10	Problem investigation
2	**Design or develop solution**
2.1	*Experience in design and application of design knowledge (Typically 12–18 months) Focus is on planning, design and application* (Responsibility Levels C–D)
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)
Working in one or more of these sectors but not all:	
3.1.1.	Design or develop solution
3.1.2	Manufacture
3.1.3	Construction
3.1.4	Erection
3.1.5	Installation
3.1.6	Commissioning
3.1.7	Maintenance
3.1.8	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)
4.1.1	Risk assessments
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