Skills Development Scotland

Graduate Apprenticeships

Framework document for

Engineering: Instrumentation, Measurement and Control at SCQF level 10

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Document control

Version history

Version	Revision(s)	Approved by	Date
1.0	Full template	SDS	18.04.17
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Terms and abbreviations

Term	Meaning
SDS	Skills Development Scotland
GA(s)	Graduate Apprenticeship(s) / Apprentice(s)
SCQF	Scottish Credit and Qualifications Framework
TEG	Technical Expert Group
QA	Quality Assurance
SIP	Skills Investment Plan
IMC	Engineering: Instrumentation, Measurement and Control
BEng	Bachelor of Engineering
UKSPEC	UK Standard for Engineering Professional Competence
IEng	Incorporated Engineer
CEng	Chartered Engineer

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Contents

1. Graduate Apprenticeships in Scotland

1.1 Purpose of the Graduate Apprenticeship framework document

The purpose of this document is to provide employers and learning providers with information required to deliver a Graduate Apprenticeship in **Engineering: Instrumentation, Measurement and Control**. The framework sets out the skills and learning outcomes identified through employer consultation that are required to support the development of this programme.

This framework document should be read in conjunction with the following publications:

1. Work-based Learning Principles
2. Product Specification at **SCQF level 10**
3. Quality Assurance Guidance

This documentation is available on the Skills Development Scotland (SDS) corporate website:

www.skillsdevelopmentscotland.co.uk

1.2 What are Graduate Apprenticeships?

Graduate Apprenticeships (GAs):

- are accredited work-based learning programmes that lead to degrees or degree-level, professionally recognised qualifications
- are part of the apprenticeship family, supporting the transition into employment by providing work-based learning pathways from Foundation and Modern Apprenticeships to Higher and Graduate Apprenticeships, at SCQF Levels 8 –11
- have been developed as part of the Scottish Government's approach to developing Scotland's young workforce and Skills Development Scotland's work-based learning strategy

1.3 Why do we need Graduate Apprenticeships in Scotland?

International experience demonstrates how degree-level apprenticeships can drive economic growth. We believe this approach can benefit the Scottish economy.

The range of approaches taken in countries including Switzerland and Germany to develop employer-led, work-based learning pathways to learning and employment provide the basis for how Scotland can use work-based learning to improve the operation of the labour market and to deliver economic growth[1]. Skills Development Scotland is now leveraging the development of Graduate Apprenticeships to support this change.

[1] **PWC (2015) Young Workforce' Index: How well are OECD economies developing the economic potential of their young people?**

1.4 Who develops Graduate Apprenticeships?

Graduate Apprenticeships are developed by Skills Development Scotland through consultation with employers, universities, professional bodies and qualification authorities in the form of Technical Expert Groups (TEGs). The TEGs act as advisory groups on behalf of the sector and are based on the current and future skills needs of industry. They advise on the topics and related outcomes that should be included in a framework.

More information about who was involved in the development of this framework can be found in **Appendix C**.

1.5 Who are Graduate Apprenticeships for?

Graduate Apprenticeships provide a new way into degree-level study for individuals who are either currently in employment or are entering into employment. GAs are available to employees aged 16 or over.

1.6 Who delivers Graduate Apprenticeships?

Graduate Apprenticeships are delivered by universities in partnership with employers and college learning providers. An up-to-date list of learning providers and the frameworks they offer can be found on **www.apprenticeships.scot**.

2. Delivery

As Graduate Apprentices are work-based degrees, the place of employment is the place of learning. The learning and skills development must be fully integrated into both the **delivery and assessment** of the degrees when part of a Graduate Apprenticeship. This integration can only be satisfactorily achieved by proper planning and design prior to delivery and not by add-on components or ad-hoc modifications.

The authenticity of the programme is shown in the way employers are involved in the design and delivery of the degrees and the way in which work-based learning is positioned as integral to both the learning and the assessment needed for successful completion of the programmes.

GA are designed as full-time programmes. They are not part-time or sandwich courses. Attendance at the place of learning will be agreed between the provider and the employer sending individuals on the programmes. Examples of how this might work are:

- by day release or
- by block release of three or four-week duration, three times per year
- through distance learning with an initial “boot camp or induction”

Fundamentally, most of an individual’s time should be spent in the workplace on directed study.

In designing the degrees to meet the work-based learning requirements of the GA, learning providers must ensure that they also meet the principles and criteria noted here:

Box 1. Principles and criteria

This GA is an **SCQF level 10** work-based degree. All proposed university degree programmes for this GA framework must:

- be **480 credits**
- be based on a partnership between employers and the learning provider
- evidence how the programmes exemplify the work-based learning requirements
- have clear goals and aspirations in support of equality and diversity with appropriate monitoring and other processes in place
- demonstrate how they will ensure that apprentices, upon graduation, will consistently achieve the necessary industry skills, knowledge and competence defined in **Appendix A**
- develop learning through reflection and review of work processes and experience
- meet the requirements to apply for professional body recognition

NB Delivery models based on sandwich years or industrial placement block release are not considered as work-based learning as part of this framework.

The successful delivery of Graduate Apprenticeships depends upon an effective partnership between the apprentice, the employer and the learning provider. This will involve additions to their normal responsibilities for employees, learning providers, and apprentices.

Delivery of the content of the GA will be agreed by the participating learning providers, which may involve delivery of specialist or employer-specific content. Employers should also be closely involved with all aspects of the programme, including the course specification, delivery, and assessment of practical activities.

The learning provider has responsibility for the quality assurance and enhancement of all elements of the programmes but they must adhere to the SDS specified documents referenced in **Section 1** and any additional guidance documentation provided as part of their competitive grant award. Practical activities must make use of the work environment and course content must take account of the technologies used in the apprentice's employment.

Apprentices must have individual learning and training plans. The learning provider and existing employer HR systems should be co-ordinated during the development of the individual learning and training plan to ensure that the required employer contextualisation is effective. Even within a specific employer, there may be apprentices who use differing technologies.

3. Roles and responsibilities

3.1 Role of the employer

Apprentices are employees and subject to the standard terms and conditions applying to all employees.

Employers participating in the Graduate Apprenticeship programme must:

- consider whether a candidate has a reasonable chance of achieving the selected programme during the selection process – this includes not only the course content but the acquisition of wider graduate attributes
- provide agreed information to support the candidate's application to the degree course
- provide apprentices with suitable opportunities for the type of experience in the workplace that will support their learning and skills acquisition
- provide each apprentice with a nominated mentor who must be readily accessible by the apprentice and to the learning provider
- liaise with the learning provider on the content and practical activities in the apprentice's individual learning and training plan
- provide information that will support the individual apprentice and their assessment

3.2 Role of the learning provider

Apprentices are both employed by the employer, as well as enrolled with the learning provider. As such they should have access to the same facilities as any other student.

GA course design and delivery must adhere to the principles detailed in preceding sections and in addition the learning provider must:

- adopt a flexible approach to considering the suitability of candidates by taking account of the portfolio of previous learning and experience an individual brings to the programme – this will include any relevant Foundation or Modern Apprenticeship undertaken – and support best practice in assessing individuals and in gathering evidence from employers where this is required
- liaise with the employer on the content and practical activities in the apprentice's individual learning plan

In addition, the learning provider should liaise with existing employer Training and Development and Quality Assurance (QA) systems to minimise double assessment. Development and meaningful implementation of individual learning plans is an essential component of the GA and assessments should take account of existing evidence wherever possible.

New evidence that directly relates to the workplace may be authenticated by employers or the individual's mentor.

There are a range of different delivery mechanisms, but the integration of knowledge within contextualised learning opportunities must be the overriding factor.

3.3 Content delivery and assessment

Content delivery and assessment responsibilities:

	Employer	***Learning Provider***	***Other***
Delivery of knowledge and understanding content	✓ Employer specific topics	✓ Generic and non-employer specific	✓ Private providers
Assessment of practical application	✓	✓	✓ Apprentice
Development of personal and business skills	✓ Specification, delivery, progress monitoring, assessment and mentoring	✓ Specification, delivery, progress monitoring and assessment	✓ May be a third party used for delivery, monitoring and assessment

4. Entry

4.1 Eligibility

- Graduate Apprenticeships are available to new and existing employees of participating employers.
- Candidates must be at least 16 years of age. However, the suitability of an individual for entry onto a GA will be decided by the employer and their learning provider partner.
- Candidates must be resident in Scotland at the start of the Graduate Apprenticeship. In addition to this, their employer's working premises must also be located in Scotland. When applying to become a Graduate Apprentice the individual will be required to satisfy the employer that they have the right to live and work in Scotland.
- Entry requirements are likely to vary across learning providers. For courses where there is a mandatory requirement for a specific subject, learning providers should consider ways they can provide support to individuals who don't hold a traditional qualification but have nevertheless shown aptitude and competence at the necessary level.

4.2 Recognition of prior learning

Candidates will undergo a selection process for a Graduate Apprenticeship, based on employer HR processes. The admissions departments need to take account of this and liaise with employers to provide advice and guidance on the prior learning and experience that will be accepted for entry onto the course.

A more flexible approach to entry requirements should be adopted by learning providers, and be done in consultation with employers. This should involve consideration of candidates on a case by case basis, who have completed relevant Foundation, Modern or Technical Apprenticeships as well as industry / vendor certifications.

Universities and other providers are asked to consider ways they can optimise the apprentice's prior learning within the programme to ensure there is no unnecessary repetition of learning.

5. Demand

Activity within the Engineering sector includes the manufacture of machinery, vehicles, transport equipment and electrical equipment. In addition, related research and development work, technical testing and analysis are included in this sector.

Employment [2]

In 2017, **employment in the sector was 168,600** accounting for six per cent of all employment in Scotland. Since the recession in 2008 employment in the sector has grown by less than one per cent, compared to a decline of one per cent growth all sectors. More recently (since 2015) employment has grown by two per cent compared to static employment nationally. This suggests **a large sector that is growing slightly faster than the average for all industries.**

Employment was highest in Aberdeen City and Shire (47,000). Glasgow (20,000) and Edinburgh, East and Midlothian (19,000) were the next largest regions, where employment in each was approximately two fifths of the employment in Aberdeen City and Shire. There were also concentrations of employment in Fife and West Lothian, where the absolute level of employment was lower but the sector accounts for an above average proportion of regional employment. In the regions mentioned the sector is an important source of jobs.

Looking forward, employment growth in the sector is forecast to slow and decline in the medium term. By 2020, employment in the sector will have declined by 800, a decrease of one per cent compared to no change across all industries. Over the longer term up to 2027, employment in the sector will be maintained at 2017 levels whilst nationally employment will grow by three per cent. Although there will be little expansion demand in the sector, the need to replace workers will generate demand. **Based on employment in 2017, 12 per cent of the workforce will need to be replaced by 2027. The sector's net requirement for**

[2] Oxford Economics Regional and Sectoral Forecast (2000-27)

workers up to 2027 will be 21,100. This is two per cent of the net requirement for workers across all industries.

The greatest proportion of the total net requirement for workers in the Engineering sector will be in Aberdeen City and Shire (29 per cent). Edinburgh, East and Midlothian will account for the next greatest proportion, 18 per cent.

Occupations [3]

In 2017, the majority (56 per cent) of the Engineering workforce were in higher level occupations. The proportion of the workforce in mid and low level occupations was lower, 25 per cent and 19 per cent respectively. By 2027 there will be a small change in the occupational structure of the workforce with two per cent more of the workforce being in higher level occupations and two per cent fewer in lower level occupations.

Engineering and Advance Manufacturing Sector Skills Investment Plan

The Engineering and Advance Manufacturing Sector Skills Investment Plan (developed in 2014) acknowledges apprenticeships as a principal pathway into the sector.

New Developments Influencing Demand for GAs in Engineering

In February 2016, the Scottish Government launched the Manufacturing Action Plan – a future manufacturing strategy for Scotland. An important pillar of this strategy is skills, including talent attraction and retention. As the strategy has been developed the delivery group has proposed the creation of a National Manufacturing Institute for Scotland (NMIS). Support for this was announced in the September 2017 Programme for Government, with a funding package expected in the autumn statement.

NMIS will consist of a ‘Factory of the Future’, a Skills Academy and regional/digital access points. It is expected that NMIS will attract inward investors creating many hundreds of highly skilled jobs in advanced manufacturing. Discussions with the trade body, Scottish Engineering, confirm that Graduate Apprenticeships in Engineering (Design and Manufacture, and Instrumentation, Measurement and Control) would be the ideal vehicle for businesses to gain the appropriate skills base needed to cope with the growth in advanced manufacturing.

[3] Oxford Economics Regional and Sectoral Forecast (2000-27)

6. The framework

6.1 Overview

The **Engineering: Instrumentation, Measurement and Control (IMC)** Graduate Apprenticeship is based on industry defined needs and has been developed in collaboration with employers and the education sector to allow knowledge, understanding, skills and competence to be developed with the necessary attributes industry expects from its graduates.

Within the **IMC** Graduate Apprenticeship, the degree content must be delivered per the principles and outcomes detailed in this framework.

The specific Graduate Apprenticeship included in this framework is:

- **Engineering: Instrumentation, Measurement and Control (IMC)**

The output of this framework will be a Graduate Apprenticeship at **SCQF level 10** entitled:

Graduate Apprenticeship in BEng (Hons) Engineering: Instrumentation, Measurement and Control

6.2 Purpose

The purpose of this programme is to develop comprehensive skills knowledge and understanding of classical and modern control theory, instrumentation, industrial automation, sensing and measurement systems for monitoring, control and safety applications.

The GA will provide apprentices with the ability to apply principles of modelling, classical and modern control concepts and controller design packages in various areas of industry.

Apprentices will develop an all-round knowledge of instrumentation and measurement systems including remote sensing, and their application, as well as current technological developments and applications to local, regional and global problems.

They gain highly developed practical skills to enable them to perform effectively in their roles. This covers the major aspects of industrial control systems engineering, ranging from classical linear control system design to non-linear, optimal and intelligent control systems, including distributed control systems, measurement systems and artificial intelligence, but is flexible to be adapted to a wide range of industries and application domains.

The range of technical, project, behavioural and transferable learning and skills outcomes specified for the GA degree programme are aimed at providing a flexible development programme applicable to a wide range of employers. Such skills and knowledge are applicable across a wide range of careers related to instrumentation and control engineering.

The **IMC** GA is designed to produce graduates with the following generic high-level skills and knowledge attributes:

Technical

- A thorough grounding in the principles, technology and practices of measurement, with an emphasis on the specification, installation, operation and asset lifecycle management of the common types of instrumentation used in industry.
- The ability to design, install, commission and maintain control and safety instrument systems including troubleshooting as part of a lifecycle maintenance programme including adherence to national and international standards.
- A familiarisation with the operation and use of a variety of process control and safety instrument systems.
- An understanding of modern signal transmission techniques and relevant standards.
- An understanding that good measurement is the basis for effective control and monitoring.
- The ability to specify and select a range of instrumentation, measurement and control systems suited for the specific application requirements.
- The ability to install, commission and maintain a wide range of instrumentation, measurement and control systems.
- The ability to design technical flow diagrams with computer-assisted engineering and design software for plant related process control, and instrumentation systems.
- The ability to analyse real time data and use computer modelling to improve the efficiency of production processes.

Project

- Understand how to manage projects (including preparing cost, manpower, material and duration estimates) for installing brand new or upgrading industrial instrumentation, measurement and control equipment efficiently, ethically and safely.
- Understand how and why to manage risk and change in a project (and operational environment).
- The ability to plan and manage inspection and maintenance schedules, including procurement provision.

Transferable

- Behave professionally and communicate effectively, including selling concepts, negotiating and closing proposals in meetings, writing reports and giving presentations to peers, managers, clients.
- The appropriate managerial, leadership and information technology skills.

Details of the high level learning and skills outcomes for these content areas are provided in **Appendix A** along with some examples of low level learning outcomes in **Appendix B**.

6.3 Occupational outcomes

An **Instrumentation, Measurement and Control** Engineer designs, installs, repairs, maintains and calibrates, industrial measuring and controlling instrumentation. This instrumentation makes sure that all machines in a plant are safe and running correctly. The operation and safety of the plant relies on these instruments and the Instrumentation and Control Engineer not only designs and implements instrumentation and control systems but also constantly monitors and calibrates these instruments. The role includes:

- Designing, operating and maintaining complex processing, chemical and manufacturing plants
- Developing advanced automation, measurement and control systems
- Environmental analysis and monitoring.

Experienced instrument technicians may advance to supervisory positions, be employed as engineering technicians, or move into company sales offices or training / education.

The **Engineering: Instrumentation, Measurement and Control** GA is aimed at employment in the following areas:

- Instrumentation and control engineer
- Instrumentation and measurement engineer
- Industrial engineer
- Process control engineer
- Commissioning engineer

6.4 Learning outcomes

Please refer to **Appendix A** for a full list of learning outcomes for the **Engineering: Instrumentation, Measurement and Control** GA.

6.5 Professional recognition

The primary focus of the **IMC** GA is on developing the knowledge, understanding and skills outcomes sought by employers. This GA framework can also support the achievement of professional recognition, as it includes the range of learning and skills outcomes outlined in UKSPEC to enable application for Incorporated Engineer (IEng) recognition (regardless of whether an individual university's degree has been accredited by a professional engineering body). A candidate on completion of a GA will also be on course to demonstrate the requirements for Chartered Engineer (CEng) in the future should they or their employer seek such recognition.

6.6 Related Scottish apprenticeship frameworks

The following Scottish Apprenticeship frameworks and qualifications are relevant pathways that may contribute toward progression into the Engineering GA. The apprenticeships are eligible for funding contributions from Skills Development Scotland, and provide employers with a range of alternative pathways at different levels of entry:

In school:

- Foundation Apprenticeship in Engineering (SCQF level 6)

FA Engineering SCQF L6

Post-school:

- Modern Apprenticeship in Engineering (SCQF level 6)

MA in Engineering SCQF L6

- Modern Apprenticeship in Industrial Applications (SCQF level 5)

MA in Industrial Applications SCQF L5

Appendix A. Learning and skills outcomes

Engineering: Instrumentation, Measurement and Control (SCQF level 10)

This section details the high level learning and skills outcomes for the GA in Engineering: Instrumentation, Measurement and Control that must be covered within the degree. Appendix B provides suggested low level outcomes that may be covered within each section.

This presents a broad set of employer defined outcomes against which universities can position their intended provision to meet the high-level learning outcomes and flavour the programme for their intended employer audience.

Please note: all students will be expected to undertake a significant engineering design or manufacturing project at the end their course. This project should draw together all main skills of the course and include a real world applied engineering project.

Topics and high-level learning and skills outcomes:

Learning and skills outcomes for Engineering: Instrumentation, Measurement and Control
1. IMC Engineering technology
1.1. Foundations
1.2. Industrial practice
1.3. Instrumentation
1.4. Industrial process control / automation
1.5. Safety
2. Behavioural and interpersonal
2.1. Communications
2.2. Personal attributes
2.3. Professional attributes
3. Engineering project and delivery management
3.1. Project management approaches and methodologies
3.2. Project planning
3.3. Project execution

Appendix B. Low-level outcomes examples

The next section provides examples of low level learning and skills outcomes which employers may expect individuals to cover in a Graduate Apprenticeship **Engineering: Instrumentation, Measurement and Control** degree.

The low-level learning and skills outcomes are not intended to be used as a pro-forma curriculum.

Each learning provider will have its own approach to delivering the degree and progression between stages. The low-level skills and derived learning outcomes that are detailed in the following sections will provide guidance to ensure that each degree covers the desired learning outcomes appropriately.

Table 1 Skills and knowledge coverage in IMC engineering technology

1. IMC Engineering technology
1.1. Foundations
1.2. Industrial practice
1.3. Instrumentation
1.4. Industrial process control / automation
1.5. Safety

1.1. Foundations

Mathematics

IMC1.1.a. Understand and apply differential and integral calculus and select and apply appropriate calculus techniques to solve engineering problems.

IMC1.1.b. Be able to perform fundamental mathematical operations such as differentiation and integration to solve differential equations, solve second order differential equations, Laplace transforms, Fourier series and transforms, and matrix algebra.

Physics

IMC1.1.c. Have an understanding of the physical principles behind a range of industry standard instruments.

IMC1.1.d. Understand and apply units and be able to demonstrate the ability to convert between different unit systems.

IMC1.1.e. <u>Pressure</u>: understand the differences between atmospheric, differential pressure and vacuum pressures and the different units used.

IMC1.1.f. Understand the different principles of measurement devices, including traditional (still used) and modern.

IMC1.1.g. Understand how differential pressure can be used to infer level and the constraints in such applications.

IMC1.1.h. Temperature: understand the units used and the principles used in the related measurement devices, both traditional (still used) and modern.

IMC1.1.i. Level: understand the physical principles used in the related level measurement devices, both traditional (still used) and modern.

IMC1.1.j. Flow: understand the principles of fluid dynamics including the concepts of flow regime (laminar, transient, turbulent); vortices; viscosity and momentum.

IMC1.1.k. Understand Bernoulli's theorem and be able to derive a flow formula and hence calculate a flow rate from this.

IMC1.1.l. Understand how fluid static and dynamic principles are used in liquid and gas flow measurement devices.

IMC1.1.m. Have a familiarity with the electromagnetic spectrum and its use in various measurement devices.

Chemistry

IMC1.1.n. Understand the Ideal Gas Law and its applications.

IMC1.1.o. Understand the different behaviours of solids, liquids and gases, and mixtures thereof, including phase transitions.

IMC1.1.p. Understand the principles of potentiometry/pH measurement; absorbance / concentration measurement, and conductivity measurements.

IMC1.1.q. Be familiar with a range of commonly used chemicals and their properties.

Electrical and Electronics

IMC1.1.r. Understand the principles of electronic and electrical theory applicable to I&C Engineering including:

- AC & DC voltage, current, power, phase & amplitude, resistance, capacitance, inductance, impedance, Ohms, Norton & Kirchhoff's laws.
- Basic analogue components and circuits; resistors, capacitors, inductors, transistors, diodes, LEDs, relays, amplifiers, etc.
- Magnetic and electro-magnetic fields, induced signal interference, reactive and apparent power, electrical motors.
- Basic digital counting principles such as binary, octal, etc.
- Digital circuitry, function blocks, registers, and how they are built up to form logic decisions as displayed in logic diagrams.
- Be able to read complex logic diagrams and drawings.
- Microprocessor fundamentals.
- Design and construction of simple electronic circuits

Process Engineering

IMC1.1.s. Have an appreciation of process engineering and process design.

IMC1.1.t. Understand the differences between continuous, batch and semi-batch processing.

IMC1.1.u. Be able to explain how different common unit operations work, and be able to select appropriate unit operations for a given process.

IMC1.1.v. Have an appreciation of the different requirements during start-up and shutdown of a plant as compared to during a production stage.

Information Technology

IMC1.1.w. Have a working knowledge of standard software packages (word processing, spreadsheets etc.)

1.2. **Industrial practice**

Site Working

IMC1.2.a. Be familiar with Site Safety Training, personal protective system (PPE), site orientation, risk assessment and the permit to work system.

Signal Transmission

IMC1.2.b. Understand the basic principles of signal transmission and different forms it can take; including signal conversion (I/P P/I, AD/DA etc.).

IMC1.2.c. Be familiar with common communication methods including radio, satellite, wireless, Ethernet etc. and transmission protocols.

Electrical Signals

IMC1.2.d. Understand cable design parameters, including materials to be used and why.

IMC1.2.e. Be able to undertake cabling design for power, analogue and digital signalling, including protection against interference, voltage drop constraints, signal distortion due to cable impedance, types of network cabling, cabling for hazardous areas and cable environmental challenges.

IMC1.2.f. Understand fibre optic cabling design and installation and how to apply these.

IMC1.2.g. Understand the methods of joining and terminating cables for application such as HART vs. foundation fieldbus.

IMC1.2.h. Be able to develop a cable schedule.

Pneumatic/Hydraulic

IMC1.2.i. Understand the design of instrument, process monitoring and hydraulic tubing; including the choice of material to be used for different applications with pressure, temperature, corrosion and safety factors to take into consideration.

IMC1.2.j. Understand how to safely cut, join and support high pressure tubing.

Electrical Equipment Certifications for Hazardous Areas

IMC1.2.k. Understand the theory of electrical equipment design for use in potentially explosive (dust and gas) atmospheres.

IMC1.2.l. Have an appreciation of the ATEX directive and certification related to the use of electrical and mechanical equipment in explosive atmospheres.

IMC1.2.m. Be able to specify equipment with suitable safety ratings for different environments.

IMC1.2.n. Understand intrinsic safety concepts including conducting the necessary calculations and designing IS loops.

IMC1.2.o. Be able to select, install and terminate such equipment.

Motor Controls

IMC1.2.p. Understand the range of Motor Control Centres (MCC's) and Intelligent Motor Control Centres (IMCC's) and how they control motors, whether they are direct on-line, start-delta or variable speed drives and how MCC's interface to process control and ESD/SIS systems.

Piping

IMC1.2.q. Be familiar with common pipe sizes and materials; connection methods; flange sizes; pressure ratings; and support systems.

Schematic Diagrams

IMC1.2.r. Be able to draw and read related complex schematic diagrams, including Pneumatic and Hydraulic control schematics, in the context of relevant industries and to relevant international standards.

IMC1.2.s. Have critical knowledge and understanding of Flowsheets, Process and Instrument Diagrams (P&IDs) and wiring loop Diagrams.

National and International standards

IMC1.2.t. Be aware of the range of relevant National and International standards for instrumentation & Controls including where they can be located, what they relate to and how these are interpreted and applied.

Computer Aided Design

IMC1.2.u. Be able to interpret standard drawings, use industry standard design, drafting and modelling software for the preparation of models, schematics and drawing, including the use of catalogues and libraries of standard components.

IMC1.2.v. Understand the selection, use, and advantages of, computer aided design in the design and operation of a process facility.

Ergonomics

IMC1.2.w. Have gained an appreciation of ergonomics in the design, installation, and upgrading of new and existing facilities, including control rooms, taking into consideration factors such as: access, safety, speed of interpretation and response to signals.

Process Simulators

IMC1.2.x. Have gained experience with process simulators. Process simulators are increasingly being built and programmed to emulate a complex process. In a laboratory or office environment, by interfacing to a copy of the process control system, a simulator is able to be used for training new operators, or for testing new control strategies for process optimisation without upsetting the real process with potentially significant cost implications.

1.3. **Instrumentation**

Measurement Systems

IMC1.3.a. Understand the structure/components of measuring systems; the advantages and disadvantages of on-line and off-line measurements, sampling; accuracy and precision; noise and noise reduction techniques; calibration and statistics.

IMC1.3.b. Have detailed understanding of the different measurement techniques that could be used to measure different types of process variables and be able to select and apply suitable measurement techniques from a variety of options.

IMC1.3.c. Be able to correctly design, install and commission instrument process sensing equipment. This includes locating instruments correctly in relation to the process and sensing points.

IMC1.3.d. Fully understand the implications of incorrect installation in respect of measurement uncertainty, ergonomics and environmental factors.

IMC1.3.e. Be able to critically analyse and interpret data and reach conclusions about process performance; trend analysis; and to aid fault finding.

IMC1.3.f. Be able to develop an instrument schedule.

Pressure, Temperature, Level and Flow sensor-transmitters

IMC1.3.g. Understand the principles of operation, design, construction and accuracy of a range of standard sensor-transmitters, including how they are connected to the process and the control and monitoring system.

IMC1.3.h. Understand the different communications methods available to connect transmitters (including HART, Foundation Fieldbus, Wireless) and their constraints.

IMC1.3.i. Be able to calibrate specialist instruments and complete calibration certificates in appropriate workshop environments using suitable test equipment. Where calibration facilities are not available for certain instruments, e.g. fiscal flow meters, understand how industry normally accommodates the calibration of such instruments.

Analysers

IMC1.3.j. Understand the range of industry standard off-line and on-line primary and range analysers currently available to meet various measurement needs.

IMC1.3.k. Be able to select and apply analysers with regards to: principles of operation, design and construction; power requirements, sampling methods, sample conditioning, accuracy, ease of installation, signal provision to monitoring system, alarm and executive actions available, maintenance requirements, environmental requirements, ergonomic requirements, spare parts requirements and cost effectiveness.

Other sensor-transmitters

IMC1.3.l. Understand the range of sensor transmitters used to monitor and measure parameters such as weight, speed, force etc. and how to apply them

Control valves, actuators and associated devices (positioners, etc.)

IMC1.3.m. Understand the different types of valves (including globe, ball, butterfly, gate etc.) that can be used and when to use them, including electric, pneumatic and hydraulic actuators.

IMC1.3.n. Understand the different applications of valves and associated valve flow characteristics obtainable by changing parameters such as the internal trim as well as performance inhibitors such as valve degradation, valve cavitation, erosion, velocity limits, pressure drop, accuracy, safety factors and the importance of positioners for repeatability.

IMC1.3.o. Understand important safety considerations such as fail open / fail closed, fail safe, acceptable leakage rates, pressure rating, valve and trim material requirements depending on the process to be controlled.

IMC1.3.p. Be able to calculate the flowrate through valves under different process conditions.

IMC1.3.q. Understand the design and operating principles of valve actuators and associated instruments and be able to select and size them accordingly.

IMC1.3.r. Understand the principles of operation of control valves.

Safety valves (including On/Off, Emergency Shutdown, Blowdown & Hydraulic Valves)

IMC1.3.s. Understand the design of safety valves and how to specify these in terms of types of trims, functionality, material of manufacture, safety integrity level, speed of response, flowrate through the valve, and acceptable leakage rates.

IMC1.3.t. Be able to design suitable control schematics for safety valves.

IMC1.3.u. Be able to dismantle a pneumatic valve and actuator to better understand its internal components. Be able to reassemble the valve and actuator and test its functionality.

1.4. **Industrial process control / automation**

Process Control

IMC1.4.a. Understand the differences between basic regulatory control, supervisory control, advanced control, and business-wide control.

IMC1.4.b. Have critical knowledge and understanding of the fundamental elements of linear (feedback) process control.

IMC1.4.c. Be able to apply control system design techniques for single-input single-output (SISO) and multiple-input multiple-output (MIMO) systems using classical control theory, state-space methods and computer-based (sampled-data) digital control systems.

IMC1.4.d. Understand the characteristics of enhanced control techniques other than feedback control including feedforward, cascade, selective, override, and ratio control, and when and how to apply these.

IMC1.4.e. Be able to tune a controller, including the application of a variety of tuning methods.

IMC1.4.f. Understand the different forms of PID controllers such as derivative on PV controllers; anti reset windup etc., and when to use them.

IMC1.4.g. Be able to apply classical control theory to practical control based real world problems.

Modelling

IMC1.4.h. Be able to develop transfer function models for a variety of processes, items of plant, instrumentation, etc., from first principles, using linear approximations and deviation variables.

IMC1.4.i. Be able to set up dynamic models of a system, simulate the dynamic models, analyse the performance of a system including the steady state and dynamic characteristics.

IMC1.4.j. Be able to use block diagram algebra to determine overall transfer functions, both open and closed loop, and hence establish responses of such to simple inputs (step, pulse and impulse, sinus, ramp etc.).

IMC1.4.k. Be able to recognise that many systems are inherently multivariable but that effective control can be realised by means of multiple SISO loops, and appreciate the use and limitations of RGA for assigning MVs to CVs.

IMC1.4.l. Understand the nature of interactions in MIMO systems, recognise the importance of diagonalisation as a design technique, and appreciate the functionality, use and limitations of cross compensators and decouplers.

Design of Plant-wide Control Systems

IMC1.4.m. Be able to perform plant-wide control design on a model process.

Supervisory Control Systems

IMC1.4.n. Supervisory Control and Data Acquisition Systems (SCADA): Understand the elements of a SCADA system, its functionality, speed of response, constraints, power requirements, how it interfaces to a process and other control systems.

IMC1.4.o. Be able to design a suitable SCADA system including interfaces, power and I/O requirements, SCADA location, cabling and cooling.

IMC1.4.p. Discrete Controllers: Understand the functionality, capability and constraints of discrete controllers in SISO applications.

IMC1.4.q. Be able to install discrete controllers in SISO applications.

IMC1.4.r. Programmable Logic Controllers (PLC's): Understand the key elements of a PLC, including its advantages and disadvantages, how it interfaces to the process, an operator and other systems. Understand the various methods used to program and display the logic within a PLC. Be able to program and commission a PLC.

IMC1.4.s. Condition Monitoring and Maintenance: Install condition monitoring systems to allow the real time monitoring of assets and facilitate a condition based maintenance approach.

IMC1.4.t. Distributed Control System (DCS): Understand the advantages and disadvantages of a DCS, particularly in relation to their role as the main control system for large process facilities.

IMC1.4.u. Understand how a DCS can interface to a control room, process facilities and other smaller process package controls (often PLC's). Understand how a DCS handles SISO and MIMO control signals, alarms, network communications, input & output (I/O) communications with process instrumentation via such communications as HART & Foundation Fieldbus. Understand data storage and reporting requirements.

IMC1.4.v. Telemetry: Understand the telemetry process by which measurements and other data are collected at remote or inaccessible points and transmitted to receiving equipment for monitoring.

IMC1.4.w. Be able to select and apply telemetry devices as part of control systems design and implementation.

Supervisory Control

IMC1.4.x. Be familiar with supervisory control, for control of many individual controllers or control loops, such as within a distributed control system including how to design and implement supervisory control.

IMC1.4.y. Understand the design of control system operator interfaces including: ergonomic aspects related to Control Panels, Human Machine Interfaces, Graphic Displays, Alarm Management, etc.

Advanced control

IMC1.4.z. Understand the principles of Advanced Process Control (APC) and how to apply the techniques and technologies for APC implemented within industrial process control systems.

Batch/sequence control

IMC1.4.aa. Be able to recognise the different needs of continuous, batch and semi-batch process control applications.

IMC1.4.bb. Understand the terminology of the international standard IEC61512 (also referred to as ISA-S88) Batch control - Part 1: Models and terminology, for defining reference models for batch control.

IMC1.4.cc. Understand how the recipe, physical and procedural models of batch control relate to each other.

IMC1.4.dd. Be able to specify the requirements for sequence control in the form of flow charts (subject to the constraints of process logic, plant status, timing requirements and abnormal condition handling).

IMC1.4.ee. Be able to translate sequential control specifications into sequential function charts with transitions and steps, the latter decomposed into actions.

IMC1.4.ff. Understand the logic of sequence progression and appreciate good practice with regard to sequence structure and parallelism.

IMC1.4.gg. Be familiar with design and operation aspects of start-up and shut-down.

Control System Security

IMC1.4.hh. Understand the potential cyber security threats to industrial control systems, the need to protect these and the potential impact on maintaining secure control of physical processes that relate to infrastructure including power, transport, water, gas and other systems.

IMC1.4.ii. Understand the need to carefully manage IT system patching and updates, including automatic updates that may cause systems to restart or shut down.

IMC1.4.jj. Be able to perform a risk assessment on a typical industrial control system assessing the range of potential threats, including malware, hacking, unauthorised access to systems etc.

IMC1.4.kk. Be aware of the role of the Centre for the Protection of National Infrastructure (CPNI) as it relates to instrumentation, measurement and control, associated plant and infrastructure.

Other Control Systems

IMC1.4.ll. Have gained an appreciation of non-linear systems, artificial intelligence and robotics and how to apply these in control systems.

1.5. **Safety**

General

IMC1.5.a. Understand the inherent nature of safety and loss prevention, and the principal hazard sources in chemical and related processes (including flammability, explosivity, toxicity and biological hazards).

IMC1.5.b. Understand the principles of risk assessment and of safety management, and be able to apply techniques for the assessment and abatement of process and product hazards.

IMC1.5.c. Understand methods of identifying process hazards (e.g. HAZOP) and be able to apply these.

IMC1.5.d. Be aware of specialist aspects of safety and environmental issues, such as noise, hazardous area classification, relief and blowdown, and fault tree analysis.

IMC1.5.e. Understand the role of functional safety and the functional safety lifecycle.

Safety Instrument Systems (SIS) and Emergency Shutdown (ESD) systems

IMC1.5.f. Have an appreciation of the roles of Safety Instrument Systems (SIS's), and the associated processes evolved as a result of past industrial accidents/incidents.

IMC1.5.g. Understand the functionality of SIS's, how they are designed and how they interface to other systems.

IMC1.5.h. Understand Safety Integrity levels (SIL's), how they are established and how process facilities can be designed to meet the SIL classifications.

IMC1.5.i. Understand how to apply the hazardous Area and Operability Process (HAZOP) and how it supplements the SIL process.

IMC1.5.j. Be able to undertake a practical HAZOP/SIL evaluation

Alarm Management

IMC1.5.k. Understand the need to evaluate and prioritise alarms to mitigate alarm flooding scenarios that may arise during the initial cause of major incidents, to identify the root cause and hence take the correct executive actions.

IMC1.5.l. Be aware of relevant national guidelines for alarm management and how to apply them.

IMC1.5.m. Understand alarm management processes and be able to supplement the HAZOP/SIL evaluation with an alarm prioritisation exercise.

Fire & Gas Detection Systems

IMC1.5.n. Be able to design and maintain Fire & Gas protection systems, including associated PLC's.

IMC1.5.o. Understand how F&G systems function, how they interface to larger control systems and what executive actions they take (through logic diagrams and/or cause & effects diagrams).

IMC1.5.p. Understand how fire and gas detectors, deluge and other fire suppressant systems function.

Table 2 Skills and knowledge coverage in behavioural and interpersonal

2. Behavioural and interpersonal
2.1. Communications
2.2. Personal attributes
2.3. Professional attributes

2.1. **Communications**

IMC2.1.a. Be able to make concise, engaging and well-structured verbal presentations, arguments and explanations of varying lengths, with and without the use of media, taking into account the audience viewpoint at all times.

IMC2.1.b. Competent in active listening appreciating others views and contributions.

IMC2.1.c. Able to give and receive feedback constructively applying appropriate techniques and incorporate it into his/her own development and life-long learning.

IMC2.1.d. Be able to effectively prepare and deliver presentations using relevant presentation media products such as PowerPoint, Prezi etc., and the use of appropriate visualisations and images.

IMC2.1.e. Be fluent in written communications and report writing, with the ability to articulate complex issues.

IMC2.1.f. Be competent at selling, questioning, negotiating and closing techniques in a range of interactions and engagements, both with internal and external stakeholders.

2.2. **Personal attributes**

IMC2.2.a. Be creative, self-motivated and self-aware and able to reflect on successes and failures in ways that strengthen their positive attitude and develop their self-reliance through an understanding of their own personal preferences, styles, strengths and weaknesses.

IMC2.2.b. Is able to identify the preferences, motivations, strengths and limitations of other people and apply these insights to work more effectively with and to motivate others.

IMC2.2.c. Be able to understand the outputs from and apply insights to using personal profiling information such as Myers Briggs Type Indicator, or Kirton Adaption/Innovation Indicator.

IMC2.2.d. Be able to put forward, demonstrate value and gain commitment to a moderately complex technology-oriented solution, demonstrating understanding of business need, using open questions and summarising skills and basic negotiating skills.

IMC2.2.e. Apply analytical and critical thinking skills to engineering problems and to systematically analyse and apply structured problem solving techniques to them.

IMC2.2.f. Be able to make a critical assessment of own performance; and develop strategies for personal improvement and professional development.

2.3. **Professional attributes**

IMC2.3.a. Able to deal with different, competing interests within and outside the organisation with excellent negotiation skills.

IMC2.3.b. Be able to conduct effective research, using literature and other media, into engineering and business related topics.

IMC2.3.c. Have gained and be able to demonstrate competence in gathering information from people using a variety of techniques including interviewing.

IMC2.3.d. Have gained an understanding of performance evaluation tools and be able to demonstrate competence in designing and applying performance evaluation tools (including 360-degree feedback).

IMC2.3.e. Have gained an understanding of the importance of learning strategies and techniques in own development and life-long learning and for corporate learning and development.

IMC2.3.f. Understand how teams work effectively to produce engineering technology solutions, and be able to work effectively with others including those of different disciples

IMC2.3.g. Practice good teamwork coordination, negotiation and interfacing skills, taking initiative and developing and applying leadership skills.

IMC2.3.h. Understand the need for high ethical and professional standards and understand how they are applied to issues facing engineers.

IMC2.3.i. Have knowledge of the local legislative framework and how it is applied to the management of safety, health and environment in practice and in the workplace, from the perspectives of all involved, including operators, designers, contractors, researchers, visitors and the public.

Table 3 Skills and knowledge coverage in engineering project and delivery management

3. Engineering project and delivery management
3.1. Project management methodologies
3.2. Project planning
3.3. Project execution

3.1. **Project management methodologies**

IMC3.1.a. Be able to follow a systematic methodology for initiating, planning, executing, controlling, and closing engineering projects.

IMC3.1.b. Understand what is meant by asset management and how to apply it.

3.2. **Project planning**

IMC3.2.a. Understand project planning for engineering projects, including planning and scheduling work, cost estimation, budget control, manpower estimations, material specifications, and bill of materials management.

IMC3.2.b. Be able to construct a project plan for a multi-threaded engineering project.

IMC3.2.c. Understand how to estimate the range of activities and produce overall estimates of costs/effort and allocating and managing appropriate contingency.

3.3. **Project execution**

IMC3.3.a. Be able to manage a project (typically less than six months, no inter-dependency with other projects and no strategic impact) to deliver the specified outputs on time, including identifying and resolving deviations and the management of problems and escalation processes

IMC3.3.b. Be able to apply industry standard processes, methods, techniques and tools to execute projects.

IMC3.3.c. Understand how to identify and manage deviations from the planned schedule of a project, reporting on progress and derivation of progress and the use of “S” Curves.

IMC3.3.d. Understand the importance of regular project reviews and the need to effectively manage the project review process, including planning and management

IMC3.3.e. Understand the issues of quality, cost and time concerned with project implementation, including contractual obligations and resource constraints.

Appendix C. Framework development summary

A GA framework sets out the required knowledge, skills and learning outcomes identified through employer and key partner consultation to support the delivery of a Graduate Apprenticeship programme. This is achieved through employer and key partner input to Technical Expert Groups (TEGs).

TEGs are short life working groups designed to act as an advisory group on behalf of the sector and contributes to the development and course design of a GA. TEGs are integral to the process of developing GAs that provide quality, consistency and relevance to industry.

Each TEG is made up of employers, professional or industry bodies, learning providers, and subject/technical experts from the related industry.

The following organisations were consulted in the development of this framework:

Engineering: Instrumentation, Measurement and Control (SCQF level 10)

Employers	Learning providers	Qualification and industry bodies
Howden Process Compressors	Forth Valley College	Institute of Instrumentation, Measurement and Control
Petroineos	Glasgow Caledonian University	SQA
FMC Technologies	Heriot-Watt University	
Wood Group	University of the West of Scotland	
SSE		
Scottish Water		

Skills
Development
Scotland

This framework is also available on the Skills Development Scotland corporate website:
www.skillsdevelopmentscotland.co.uk