Higher National unit specification

General information

Unit title: Marine Engineering: Heat Engine Principles (SCQF level 8)

Unit code: HJ4A 35

Superclass: XQ

Publication date: June 2017

Source: Scottish Qualifications Authority

Version: 02

Unit purpose

This unit is designed to enable learners to develop their knowledge and understanding in applying the principles of heat engines to the solution of problems within Marine Engineering systems.

This unit is designed for use in the training of Merchant Navy Engineering Officers.

Outcomes

On successful completion of the unit the learner will be able to:

1 Apply the fundamental properties of thermodynamics to a process.
2 Evaluate and apply heat engine cycles to marine engines.
3 Calculate heat transfer through complex systems.
4 Calculate the properties of constituent parts during combustion of marine fuels.

Credit points and level

1 Higher National unit credit at SCQF level 8: (8 SCQF credit points at SCQF level 8)

Recommended entry to the unit

It would be an advantage if learners had a knowledge and understanding of thermodynamics. This can be evidenced by possession of the following units: *Marine Engineering: Auxiliary Systems*, or the new HNC Thermodynamics unit. Learners should also have a minimum of Mathematics at SCQF level 7, this may be evidence by the unit *Engineering Mathematics 2* (H7K1 34).

Higher National unit specification: General information (cont)

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Core Skills

Achievement of this unit gives automatic certification of the following Core Skills component:

Complete Core Skill None

Core Skill component Using Number at SCQF level 6

There are also opportunities to develop aspects of Core Skills which are highlighted in the support notes of this unit specification.

Context for delivery

If this unit is delivered as part of a Group Award, it is recommended that it should be taught and assessed within the subject area of the Group Award to which it contributes.

The Assessment Support Pack (ASP) for this unit provides assessment and marking guidelines that exemplify the national standard for achievement. It is a valid, reliable and practicable assessment. Centres wishing to develop their own assessments should refer to the ASP to ensure a comparable standard. A list of existing ASPs is available to download from SQA's website **(http://www.sqa.org.uk/sqa/46233.2769.html)**.

Equality and inclusion

This unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence.

Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**.

Higher National unit specification: Statement of standards

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Acceptable performance in this unit will be the satisfactory achievement of the standards set out in this part of the unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Where evidence for Outcomes is assessed on a sample basis, the whole of the content listed in the Knowledge and/or Skills section must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Apply the fundamental properties of thermodynamics to a process.

Knowledge and/or Skills

- Relationship between p, V and T for polytropic and adiabatic processes
- Work transfer for reversible processes
- Heat transfer for reversible processes
- Specific heat at constant pressure and constant volume
- Change of entropy of a perfect gas
- P–V and T–S diagrams
- Avogadro's Law
- Universal Gas Constant

Outcome 2

Evaluate and apply marine heat engine cycles.

Knowledge and/or Skills

- Second law of thermodynamics
- Comparison of the Carnot cycle with ideal heat engines, its thermal efficiency and the application of Carnot’s principle to the second law of thermodynamics
- Comparison of the Carnot cycle with ideal heat engine cycles
- Ideal engine cycles described using P-V and T-S diagrams and practical counterparts applied to Marine engines
- Thermal efficiency, indicated and brake mean effective pressure, work done and air standard efficiency of Ideal cycles
- Thermal efficiency, work and heat transfer of Gas Turbines

Higher National unit specification: Statement of standards (cont)

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Outcome 3

Calculate heat transfer through complex systems.

Knowledge and/or Skills

- Fourier's Law for conductive heat transfer
- Heat transfer through thick cylinders, single and double lagged pipes, spheres and hemispherical ends of cylinders
- Heat transfer through boundary layers
- Overall heat transfer coefficient 'U' for composite flat plates and composite lagged pipes, using thermal conductivity and surface heat transfer coefficient
- Stefan Boltzmann constant
- 'Black body' radiation and 'emissivity factor'

Outcome 4

Calculate the properties of constituent parts during combustion of marine fuels.

Knowledge and/or Skills

- Combustion of fuel by mass and volume
- Stoichiometric, insufficient, and actual air supply and the proportional gravimetric constituents of a fuel from flue gas analysis
- Higher and Lower Calorific Values of fuels and the heat energy released by the various constituents
- Dalton's laws to stoichiometric and other mixtures of gaseous fuels and air
- 'Dew point' of water vapour from flue gas analysis
- Heat carried away in flue gases and heat transfer from gas to water heat exchangers

Evidence Requirements for this unit

Written and or/oral evidence should be generated through assessment in supervised conditions. Assessment should be conducted under closed-book conditions and as such learners should not be allowed to bring any textbooks, handouts or notes to the assessment. Learners will be permitted to use scientific calculators. The assessment for all four Outcomes can be combined together into one assessment which learners should sit at one single assessment event lasting no more than two and a half hours.

The Evidence Requirements state that learners must ensure answers are derived 'from the application of the formulae and correct application of the principles of the calculation'. This allows for acknowledgement of the correct working and application of formulae, even where the learners' final answer may be inaccurate.

The statement allows for the eventuality where a single error at one stage in an extended calculation sequence has a cumulative effect on the final answer, even though working/formulae are otherwise correctly applied. Acknowledgement of the correct working should be given in such cases.

Where calculations are performed the learner must:

- apply appropriate formulae
- apply the principles of the calculation
- show all working through a calculation
- provide reasonable answers to the questions asked. The answer should derive from the application of the formula and correct application of the principles of the calculation.

Outcome 1

Evidence for the Knowledge and/or Skills items in Outcome 1 should be provided on a sample basis. Written and/or oral evidence based on a sample of **four from eight** Knowledge and/or Skills items should be provided in any assessment of this Outcome.

In order to ensure that learners will not be able to foresee what items they will be questioned on, a different sample of four out of eight Knowledge and/or Skills items are required each time the unit is assessed.

Where sampling takes place, a learner's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing the learner is able to:

- apply the relationship between P, V and T for polytropic and adiabatic processes.
- calculate work transfer for reversible processes, this should include:
  - Constant volume process
  - Constant pressure process
  - Isothermal process
  - Isentropic or Adiabatic process
  - Polytropic process.
  - calculate the heat transfer for the above reversible processes.
  - apply the relationship between specific heat at constant pressure and constant volume.
  - solve problems relating to change of entropy for reversible processes.
  - evaluate processes using P-V and T-S diagram.
  - solve problems relating to Avogadro's Law.
  - solve problems relating to the universal gas constant.

Outcome 2

Evidence for the Knowledge and/or Skills items in Outcome 2 will be provided on a sample basis. The evidence may be presented in responses to specific questions. Each learner will need to demonstrate that they can correctly answer questions based on a sample of the knowledge and skills items listed in the Outcome. In any assessment of this Outcome, **three out of six** Knowledge and/or Skills items should be sampled.

Higher National unit specification: Statement of standards (cont)

Unit title: Marine Engineering: Heat Engine Principles (SCQF level 8)

In order to ensure that learners will not be able to foresee what items they will be questioned on, a different sample of three from five Knowledge and/or Skills items are required each time the unit is assessed. Learners must provide a satisfactory response to all items.

Where sampling takes place, a learner's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing the learner is able to:

— apply the second law of thermodynamics to Heat Engines.
— explain the Carnot cycle with the aid of a P-V diagram.
— analyse ideal Heat Engine cycles by comparing with the Carnot cycle.
— describe ideal and practical Heat Engine cycles using P-V and T-S diagrams.
— evaluate ideal Heat Engine cycles by solving problems relating to thermal efficiency and work done.
— calculate thermal efficiency, work and heat transfer for Gas Turbine cycles.

Outcome 3

Evidence for the Knowledge and/or Skills items in Outcome 3 will be provided on a sample basis. The evidence may be presented in responses to specific questions. Each learner will need to demonstrate that they can correctly answer questions based on a sample of the knowledge and skills items listed in the Outcome. In any assessment of this Outcome, **three out of six** Knowledge and/or Skills items should be sampled.

In order to ensure that learners will not be able to foresee what items they will be questioned on, a different sample of three from six Knowledge and/or Skills items are required each time the unit is assessed. Learners must provide a satisfactory response to all items.

Where sampling takes place, a learner's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing the learner is able to:

- apply Fourier's Law for conductive heat transfer.
- calculate heat transfer through complex systems.
- calculate heat transfer through boundary layers.
- calculate the overall heat transfer coefficient 'U' for composite flat plates and composite lagged pipes using thermal conductivity and surface heat transfer coefficient.
- use the Stefan Boltzmann constant to calculate heat transfer by radiation.
- use the 'emissivity factor' to calculate the heat radiated from a simple system.

Where calculations are performed the learner must:

- apply appropriate formulae.
- apply the principles of the calculation.
- show all working through a calculation.
- provide reasonable answers to the questions asked. The answer should derive from the application of the formula and correct application of the principles of the calculation.

Higher National unit specification: statement of standards (cont)

Unit title: Marine Engineering: Heat Engine Principles (SCQF level 8)

Outcome 4

Evidence for the Knowledge and/or Skills items in Outcome 4 will be provided on a sample basis. The evidence may be presented in responses to specific questions. Each learner will need to demonstrate that they can correctly answer questions based on a sample of the knowledge and skills items listed in the Outcome. In any assessment of this Outcome, **five out of ten** Knowledge and/or Skills items should be sampled.

In order to ensure that learners will not be able to foresee what items they will be questioned on, a different sample of five from ten Knowledge and/or Skills items are required each time the unit is assessed. Learners must provide a satisfactory response to all items.

Where sampling takes place, a learner's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing the learner is able to:

- calculate and analyse the combustion of fuel by mass and volume.
- calculate the stoichiometric and actual air requirements.
- calculate air supply and the proportional gravimetric constituents of a fuel from flue gas analysis.
- calculate mass and volumes of exhaust products resulting from insufficient air supply.
- calculate the approximate Higher and Lower Calorific Values from the heat energy released by the various constituents of fuels.
- apply Dalton's laws to stoichiometric and other mixtures of gaseous fuels and air.
- calculate the 'dew point' of water vapour from flue gas analysis.
- calculate the heat carried away in flue gases and heat transfer from gas to water heat exchangers.

Higher National unit Support Notes

Unit title: Marine Engineering: Heat Engine Principles (SCQF level 8)

Unit Support Notes are offered as guidance and are not mandatory.

While the exact time allocated to this unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this unit

This unit has been written in order to allow learners to develop skills, knowledge and understanding of the principles of marine heat engines in the following areas:-

1 Apply the fundamental properties of thermodynamics to a process.
2 Evaluate and apply marine heat engine cycles.
3 Calculate heat transfer through complex systems.
4 Calculate the properties of constituent parts during combustion of marine fuels

There are recommendations as to how much time should be spent on each Outcome. This has been done to help lecturers decide what depth of treatment should be given to the topics attached to each of the Outcomes. Whilst it is not mandatory for centres to use this list of topics it is strongly recommended that they do so to ensure continuity of teaching and learning.

A list of topics is given below. Lecturers are advised to study this list of so that they can get a clear indication of the standard of achievement expected of learners in this unit.

1 Apply the fundamental properties of thermodynamics to a process. (8 hours)

In this section it is expected that questions set should relate to real life examples, using marine terminology, as found aboard ship. Topics will include:

- Differing pressures, volumes and temperatures in marine engine cylinders
- Differing pressures, volumes and temperatures in air receivers
- Flue gases in closed vessels
- Gas flow through nozzles

2 Evaluate and apply marine heat engine cycles. (8 hours)

In this section it is expected that:

- Calculation questions set should relate to the ideal cycles
- Descriptive answers should explain how real cycles differ from ideal ones
- Practical cycles should relate to those found on Marine plant.

Higher National unit Support Notes (cont)

Unit title: Marine Engineering: Heat Engine Principles (SCQF level 8)

3 Calculate heat transfer through complex systems. (12 hours)

In this section it is expected that questions set should relate to real life examples, using marine terminology, as found aboard ship. Topics will include:

- Complex systems including thick cylinders, single and double lagged pipes, spheres and hemispherical ends of cylinders.
- Radiation problems should be for simple systems such as flat plates.

4 Calculate the properties of constituent parts during combustion of marine fuels (12 hours)

In this section it is expected that questions set should relate to real life examples, using marine terminology, as found onboard ship. The fuels chosen for analysis should be common fuels used for Marine plant and relate to current legislation. Topics will include:

- Boilers
- Internal combustion engines
- Gas turbines
- Heavy Fuel Oil
- Marine Diesel
- Gaseous fuels

Guidance on approaches to delivery of this unit

This unit should be delivered by a combination of whole class teaching, tutorial work and practical laboratory work where appropriate. The latter is seen as particularly important as it provides learners with an opportunity to relate theoretical knowledge to a practical mechanical context. The unit has been designed to incorporate sufficient time to allow lecturers to teach all the core thermodynamic principles in the unit.

As this unit provides core thermodynamic principles that underpin much of the studies in other areas of the HND Marine Engineering award, it is recommended that the unit be delivered towards the start of the award.

Where this unit is incorporated into other Group Awards it is recommended that it be delivered in the context of the specific occupational area(s) that the award is designed to cover.

The unit has been written such that there is sufficient time built in to allow learners to practise what they have learnt through appropriate formative assessments.

Higher National unit Support Notes (cont)

Unit title: Marine Engineering: Heat Engine Principles (SCQF level 8)

Guidance on approaches to assessment of this unit

Evidence can be generated using different types of assessment. The following are suggestions only. There may be other methods that would be more suitable to learners.

Centres are reminded that prior verification of centre-devised assessments would help to ensure that the national standard is being met. Where learners experience a range of assessment methods, this helps them to develop different skills that should be transferable to work or further and higher education.

The assessment for all four Outcomes could be combined together into one assessment paper which learners should sit at one single assessment event lasting no more than two and a half hours. Assessment should be closed-book conducted under controlled supervised conditions.

. Where sampling is used an alternative sample should be used when reassessing learners. Assessment should take place under invigilated conditions and follow the assessment centres examination policy

Questions used to elicit learner evidence should take the form of an appropriate balance of short answer, restricted response and structured questions.

Opportunities for e-assessment

E-assessment may be appropriate for some assessments in this unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all learner evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. The most up-to-date guidance on the use of e-assessment to support SQA's qualifications is available at **www.sqa.org.uk/e-assessment**.

Opportunities for developing Core and other essential skills

In all Outcomes each of the assessments requires the learner to be able to solve problems involving thermodynamics. This will give the learner the opportunity to develop the component 'Using Number' of the Core Skill *Numeracy* at SCQF level 5 and 6. The specific Core Skill elements that the learner will have to complete are 'Work confidently to solve a numerical problem' SCQF level 5 and 'Carry out a number of sustained, complex calculations' SCQF level 6

The assessment of this unit may also contribute towards the component 'Written Communication (writing)' of the Core Skill Communication at SCQF level 6. Learners may have to structure their responses, which could include varying structure and presenting essential information in a logical manner. The specific Core Skill elements that learners may have to complete are 'Present all essential ideas/information and supporting detail in a logical and effective order' and 'Vary sentence structure, paragraphing, and vocabulary to suit the purpose and target audience'.

Higher National unit Support Notes (cont)

Unit title: Marine Engineering: Heat Engine Principles (SCQF level 8)

In all Outcomes learners have an opportunity to apply graphical skills when interpreting and presenting information. This will give the learner the opportunity to develop the component 'Using graphical information' of the Core Skill *Numeracy* at SCQF level 6. In the drawing of P-V and T-S diagrams and flue gas analysis learners will develop the specific Core Skill elements 'Extract, analyse, and interpret graphical information' and 'Select an appropriate form of complex table, chart, diagram, or qualitative form and communicate complex information in that form'.

There may also be opportunities to gather evidence towards Core Skills in Problem Solving at SCQF level 6, and Information and Communication Technology (ICT) at SCQF level 4.

The Critical Thinking Core Skill component at SCQF level 6 may be developed in all four Outcomes while learners apply thermodynamics theory to solve engineering problems.

Learners will be able to consider any harmful effects that marine engineering operations may have upon the environment and be given the opportunity to mitigate them, for example fuel oil selection, pollution control and ballast water management. Consideration can also be given to sustainability in the selection and recycling of materials used in the workplace such as insulation material and machinery components.

This unit has the Using Number component of Numeracy embedded in it. This means that when learners achieve the unit, their Core Skills profile will also be updated to show they have achieved Using Number at SCQF level 6.

History of changes to unit

Version	Description of change	Date
02	Core Skills component Using Number at SCQF level 6 embedded.	01/06/17

General information for learners

Unit title: Marine Engineering: Heat Engine Principles (SCQF level 8)

This section will help you decide whether this is the unit for you by explaining what the unit is about, what you should know or be able to do before you start, what you will need to do during the unit and opportunities for further learning and employment.

This unit has been designed to allow you to further develop knowledge, skills and understanding in Heat Engine principles and concepts.

This unit will also provide you with an opportunity to study the theoretical and practical operating cycles for different types of Heat Engines.

This unit will also allow you the opportunity to develop the necessary knowledge and skills to evaluate heat transfer to surroundings through complex walls.

You will also learn to evaluate Heat Engines by analysing the products of combustion and to produce an associated heat balance.

It is good to gain sound theoretical knowledge and understanding but it is also important that you are able to set your theoretical knowledge within a practical marine engineering context. Thus, it is likely during the unit you will be provided with the opportunity to relate theory to practice by doing practical experiments.

The formal assessment for this unit will normally consist of a single assessment paper lasting no more than two and a half hours. The assessment will be conducted under closed-book conditions in which you will not be allowed to take notes or textbooks into the assessment. However, you will be allowed to use a scientific calculator. You will sit this assessment paper at the end of the unit.

This unit will consist of four Outcomes that you will study:

1 Apply the fundamental properties of thermodynamics to a process.
2 Evaluate and apply marine heat engine cycles.
3 Calculate heat transfer through complex systems.
4 Calculate the properties of constituent parts during combustion of marine fuels.

There are opportunities in this unit to develop a component of the Core Skill Numeracy at SCQF level 6 as you will perform calculations, manage formulae and equations. You will also be able to develop a component of the Core Skill of Problem Solving at SCQF level 6 in the interpretation of the problems you solve in this unit. Finally, you will have the opportunity to develop a component of the Core Skill of Communication at SCQF level 6.

This unit has the Using Number component of Numeracy embedded in it. This means that when you achieve the unit, your Core Skills profile will also be updated to show you have achieved Using Number at SCQF level 6.