Higher National Unit specification: general information

Unit title: Marine Engineering: Advanced Marine Thermodynamic Principles

Unit code: H0EC 35

Superclass: XQ

Publication date: January 2012

Source: Scottish Qualifications Authority

Version: 01

Unit purpose

This Unit is designed to enable candidates to further develop the knowledge and understanding required to apply the basic principles of heat engines to the solution of problems within Marine Engineering systems. The Unit will also provide the candidate with a base from which future advanced work in Marine Engineering may be undertaken.

On completion of the Unit the candidate should be able to:

1 Analyse the use of multistage reciprocating air compressors.
2 Apply the concept of reverse heat engine to refrigeration and recognise the properties of common refrigerants.
3 Determine the efficiency of steam plant and power from a velocity and a pressure compound steam turbine.

Recommended prior knowledge and skills

It would be an advantage if candidates had a knowledge and understanding of thermodynamics. This can be evidenced by possession of the following HNC Units: Marine Engineering: Introduction to Marine Heat Engine Principles and Marine Engineering: Auxiliary Thermodynamic Principles. The candidates should also have a minimum of a level 6 mathematics or equivalent.

Credit points and level

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

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

General information (cont)

Core Skills

There are opportunities to develop the Core Skill of *Numeracy* and the Core Skills component Critical Thinking in this Unit, although there is no automatic certification of Core Skills or Core Skills components.

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.

Higher National Unit specification: statement of standards

Unit title: Marine Engineering: Advanced Marine Thermodynamic Principles

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The sections of the Unit stating the Outcomes, Knowledge and/or Skills, and Evidence Requirements are mandatory.

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. Candidates 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

Discuss and evaluate the use of multistage reciprocating air compressors**.**

Knowledge and/or Skills

- Use p-V diagrams to describe ideal and actual cycles for multistage compression.
- Analyse the effect of intercooling between stages by calculating heat transfer during compression and cooling.
- Evaluate the work transfer for ideal and actual cycles including clearance for multistage compression.
- Calculate isothermal efficiency.
- Calculates indicated and input power requirements.

Evidence Requirements

Evidence for the Knowledge and/or Skills items in Outcome 1 could be provided on a sample basis. The evidence may be presented in responses to specific questions. Each candidate will need to demonstrate that they can answer correctly questions based on a sample of the knowledge and skills items listed in the Outcome. In any assessment of this Outcome, **two out of five** Knowledge and/or Skills items should be sampled.

In order to ensure that candidates will not be able to foresee what items they will be questioned on, a different sample of two out of five Knowledge and/or Skills items are required each time the Unit is assessed. Candidates must provide a satisfactory response to all items.

Higher National Unit specification: statement of standards (cont)

Unit title: Marine Engineering: Advanced Marine Thermodynamic Principles

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

- Use p-V diagrams to describe and evaluate the operation of intercooled, multistage compressors
- Calculate heat transfer during compression and cooling and evaluate the effect of intercooling
- Calculate the work transfer for multistage compression cycles including clearance volume
- Calculate the isothermal efficiency
- Solve problems relating to work and power of intercooled, multistage compressors

Where calculations are performed the candidate 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

Evidence should be generated through assessment in supervised conditions. Assessment should be conducted under closed-book conditions and as such candidates should not be allowed to bring any textbooks, handouts or notes to the assessment. Candidates will be permitted to use scientific calculators during the assessment.

The Evidence Requirements state that candidates 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 candidates' 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.

Higher National Unit specification: statement of standards (cont)

Unit title: Marine Engineering: Advanced Marine Thermodynamic Principles

Outcome 2

Apply the concept of reverse heat engine to refrigeration and recognise the properties of common refrigerants.

Knowledge and/or Skills

- Evaluate the concept of entropy to refrigeration using tables and formulae.
- Analyse vapour compression cycles and reversed Carnot cycle using p-H and T-S diagrams.
- Analyse the effects of superheating and undercooling and describe the effects using p-H and T-S diagrams.
- Evaluate COP of actual plant and compare to COP of reversed Carnot cycle.
- Describe the use of intermediate cooling and evaluate the application of intermediate cooling by flash chamber.

Evidence Requirements

Candidates will need to provide evidence to demonstrate their Knowledge and/or Skills by showing that they can:

Evidence for the Knowledge and/or Skills items in Outcome 2 could be provided on a sample basis. The evidence may be presented in responses to specific questions. Each candidate 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, **two out of five** Knowledge and/or Skills items should be sampled.

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

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

- Evaluate refrigeration cycles, employing the concept of entropy, using formulae and tables of common refrigerants used in the marine industry
- Use p-H, T-S diagrams to describe vapour compression refrigeration cycles including undercooling and superheating
- Calculate the effects of undercooling and superheating on a vapour compression refrigeration cycle
- Calculate COP of an actual vapour compression cycle and compare to the COP of the reverse Carnot cycle
- Describe intermediate cooling and calculate the effect of applying intermediate cooling by flash chamber

Where calculations are performed the candidate 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

Evidence should be generated through assessment in supervised conditions. Assessment should be conducted under closed-book conditions and as such candidates should not be allowed to bring any textbooks, handouts or notes to the assessment. Candidates will be permitted to use scientific calculators during the assessment.

The Evidence Requirements state that candidates 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 candidates' 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.

Higher National Unit specification: statement of standards (cont)

Unit title: Marine Engineering: Advanced Marine Thermodynamic Principles

Outcome 3

Determine the efficiency of steam plant and power from a velocity and a pressure compound steam turbine.

Knowledge and/or Skills

- Analyse the heat energy distribution in a boiler and compile a heat balance account.
- Use H-S and T-S charts to analyse the basic Carnot and Rankine cycles including improvements from superheating, reheating and feedheating.
- Evaluate thermal efficiency of the above cycles.
- Apply steady flow energy equation to steam nozzles to calculate throat and exit velocities.
- Explain reasons for change of nozzle form and convergent and convergent/divergent sections.
- Construct blade velocity diagrams for impulse and reaction turbines.
- Calculate kinetic and leaving losses.
- Calculate stage power, stage efficiency and stage axial thrust for a velocity and a pressure compounded turbine.
- Calculate the number of stages from given steam conditions for a reaction turbine.

Evidence Requirements

Candidates will need to provide evidence to demonstrate their Knowledge and/or Skills by showing that they can:

Evidence for the Knowledge and/or Skills items in Outcome 3 could be provided on a sample basis. The evidence may be presented in responses to specific questions. Each candidate 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, **four out of nine** Knowledge and/or Skills items should be sampled.

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

Higher National Unit specification: statement of standards (cont)

Unit title: Marine Engineering: Advanced Marine Thermodynamic Principles

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

- Calculate the heat energy distribution in a boiler and compile a heat balance account
- Demonstrate the use of H-S and T-S charts and tables to evaluate basic cycles including superheating, reheating, feedheating
- Evaluate the thermal efficiency of basic steam cycles
- Calculate throat and exit velocities of steam nozzles by applying the steady flow energy equation
- Explain nozzle form and reasons for change of section
- Evaluate impulse and reaction turbines by constructing blade velocity diagrams
- Calculate kinetic and leaving losses for turbines
- Calculate stage power, stage efficiency and stage axial thrust for a velocity and a pressure compounded turbine
- Calculate the number of stages from given steam conditions for a reaction turbine

Where calculations are performed the candidate 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

Evidence should be generated through assessment in supervised conditions. Assessment should be conducted under closed-book conditions and as such candidates should not be allowed to bring any textbooks, handouts or notes to the assessment. Candidates will be permitted to use scientific calculators during the assessment.

The Evidence Requirements state that candidates 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 candidates' 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.

Higher National Unit specification: support notes

Unit title: Marine Engineering: Advanced Marine Thermodynamic Principles

This part of the Unit specification is offered as guidance. The support notes 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 candidates to develop skills, knowledge and understanding of the principles of Marine Heat Engines in the following areas:

1 Analyse the use of multistage reciprocating air compressors.
2 Apply the concept of reverse heat engine to refrigeration and recognise the properties of common refrigerants.
3 Determine the efficiency of steam plant and power from a velocity and a pressure compound steam turbine.

In designing this Unit, the Unit writer has identified the range of topics expected to be covered by lecturers. The writer has also given 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 candidates in this Unit.

1 Analyse the use of multistage reciprocating air compressors. (8 hours)

In this section it is expected that questions set should relate to real life examples, using marine terminology, as found aboard ship. The compressors considered should be of no more than three stages and may use water or air cooled intercoolers. The effects of excessive clearance volume, changes in ambient temperature and pressure, fouling of intercoolers should also be considered.

2 Apply the concept of reverse heat engine to refrigeration and recognise the properties of common refrigerants. (8 hours)

In this section it is expected that questions set should relate to a vapour compression refrigeration plant including superheating, undercooling and intercooling using the concept of entropy. pH and TS diagrams should be used to show the condition of the plant at the main points of the cycle. Thermodynamic property tables should be used to determine the condition of the refrigerants; some interpolation should be included but must not be excessive.

3 Determine the efficiency of steam plant and power from a velocity and a pressure compound steam turbine. (24 hours)

In this section it is expected that questions set should relate to real life examples, using marine terminology, as found aboard ship and should involve the use of thermodynamic property tables and charts to determine the properties of water and steam in the wet, saturated and superheated states. Questions on boiler heat balance and steam cycles should reflect practical operations. Questions relating to turbines should include velocity and pressure compounding.

Guidance on the 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 candidates 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 this 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 candidates to practise what they have learnt through appropriate formative assessments.

Guidance on the assessment of this Unit

The assessment for all four Outcomes should be combined together into one assessment paper which candidates should sit at one single assessment event lasting no more than two hours. Assessment should be conducted under controlled, supervised conditions. Assessment should be conducted under closed-book conditions and as such candidates should not be allowed to bring any textbooks, handouts or notes to the assessment. Candidates will be permitted to use scientific calculators during the assessment.

A different sample of the knowledge and/or skills should be chosen when reassessing candidates.

Assessment Guidelines

Outcome 1

The assessment of this Outcome could be combined together with that for Outcomes 2 and 3 to form a single assessment paper, details of which are given under the Evidence Requirements for Outcome 3.

Outcome 2

The assessment of this Outcome could be combined together with that for Outcomes 1 and 3 to form a single assessment paper, details of which are given under the Evidence Requirements for Outcome 3.

Outcome 3

The assessment of this Outcome should be combined together with that for Outcomes 1, 2 and 3 to form a single assessment paper. This single assessment paper should be taken at a single assessment event lasting two hours and carried out under supervised, controlled conditions.

Assessment should be conducted under closed-book conditions and as such candidates should not be allowed to bring any textbooks, handouts or notes to the assessment. Candidates will be permitted to use scientific calculators during the assessment.

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

Online and Distance Learning

This Unit may be delivered by open learning, however centres would need to put measures in place to ensure that assessments are completed under controlled conditions.

Opportunities for developing Core Skills

Throughout this Unit candidates are required to perform calculations, manage formulae and equations that provide the opportunity to develop the Core Skill of *Numeracy* at SCQF level 6. In Outcome 2 and 3 candidates will also be required to interpret complex tabulated and graphical information again providing the opportunity to develop the specific Core Skill elements of 'Extract, analyse and interpret graphical information' and 'Work confidently with numerical or statistical methods'

The presentation of problems in assessments which candidates require to interpret and work through will also develop the Critical Thinking component of *Problem Solving*, at SCQF level 6. This will allow candidates to develop the specific Core Skill elements 'Assess the relevance of these factors to the situation or issue' and 'Develop and justify an approach to deal with the situation or issue'.

Higher National Unit specification: support notes (cont)

Unit title: Marine Engineering: Advanced Marine Thermodynamic Principles

In the answering of assessment work candidates may have the opportunity to develop Written Communication of the Core Skill *Communication* at SCQF level 6. The specific Core Skill elements that the candidate may have to complete are 'Use conventions which are effective in achieving the purpose of the piece and adapted as necessary for the target audience'.

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**

History of changes to Unit

Version	Description of change	Date

General information for candidates

Unit title: Marine Engineering: Advanced Marine Thermodynamic Principles

This Unit has been designed to allow you to further develop knowledge, skills and understanding in Marine Thermodynamic principles and concepts.

This Unit will also provide you with an opportunity to study the theoretical and practical operating cycles for multistage air compressors and refrigeration plants.

You will also learn to evaluate steam plant by analysing the boiler, turbine and steam cycle.

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 Mechanical 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 may consist of a single assessment paper lasting no more than two hours. The assessment will be conducted under closed-book conditions in which you will not be allowed to take notes, textbooks, etc 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 three Outcomes that you will study:

1 Analyse the use of multistage reciprocating air compressors.
2 Apply the concept of reverse heat engine to refrigeration and recognise the properties of common refrigerants.
3 Determine the efficiency of steam plant and power from a velocity and a pressure compound steam turbine.

Throughout this Unit you are required to perform calculations, manage formulae and equations which will give you the opportunity to develop a component of the Core Skill of *Numeracy* at SCQF level 6. You will also solve problems in assessments which will give you the opportunity to develop the Critical Thinking component of *Problem Solving*, at SCQF level 6. In addition in the answering of assessment work you may have the opportunity to develop a component of *Communication* at SCQF level 6.