Professional Engineering Exam

Thermal and Fluids Systems Engineering

Study Guide

Saudi Council of Engineers (SCE)
Education and Training Evaluation Commission (ETEC)
National Center for Assessment (NCA)

www.etec.gov.sa

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1. Aim

The objective of this Instruction Manual is to provide guidelines for the NCA proposed Professional Engineers Exam. These guidelines cover the eligibility conditions, the grading and passing conditions, the structure of the exam and the distribution of exam questions among various areas. In essence, this Instruction Manual represents a "bridge" between the developed exam standards and the actual phrased questions. It is designed to help item writers prepare questions in the Thermal and Fluids Systems Engineering Discipline paper.

2. Exam Structure

2.1 Exam Type

The exam is initially paper-based with questions being a combination of multiple-choice questions (MCQ) and essays.

2.2 Exam Organization

The exam will be conducted in two sessions during one day. The duration of the first session is 2.5 hours while the second section is 4 hours long. There is one-hour break between the two sessions.

2.2.1. Session #1

The first session is the common part to be taken by all the examinees from all disciplines. This part includes seven topics: (Ethics – Professionalism - Laws for Professional Practice, Professional Laws and Regulation - Environment and Natural Resources - Engineering Management - Engineering Economics - Heath, Safety & Security (HSS)).

The total duration of this session is 2.5 hours and the total number of questions is 30 MCQ and 2 essays.

2.2.2. Session #2

The second session is the Discipline Part. The following engineering disciplines are considered:

Code	Discipline
STE	Structural Engineering
GTE	Geotechnical Engineering
TRE	Transportation Engineering
WREE	Water Resources and Environmental Engineering
PE	Power Engineering
HVAC	Heating, Ventilation, and Air Conditioning (HVAC) and Refrigeration Engineering
TFSE	Thermal and Fluids Systems Engineering
CHE	Chemical Engineering
FPE	Fire Protection Engineering
ARCH	Architecture

The total duration of this session is 4 hours and the total number of questions is 30 MCQs and 7 essays. The examinee must answer all the MCQs and 3 essays out of 7.

2.3 Eligibility for the Exam

As per Saudi Council of Engineers Requirements.

2.4 Grades

Each part (common part and discipline part) carries a total grade of 100. The MCQs carry a grade of 60% while the essays carry a grade of 40%. Each MCQ has 4 choices for the answer. There is no negative marking for wrong answers.

2.5 Passing Rules

- The eligible candidate must take in his/her first sitting the two exam parts (common part and discipline part).
- In order to pass the exam, the candidate must obtain a grade of 60% or above in each part of the exam.
- If the candidate fails both parts of the exam (by receiving in each part a grade less than 60%), he/she can take the two parts of the exam but only when one full year has passed.
- If the candidate fails only one part of the exam (common part or discipline part), he/she must repeat only the part he/she failed, but he/she must pass this part within one year.
- If a year passed and the candidate did not succeed in passing the part he/she failed, then he/she has to take both parts of the exam.

2.6 Exam Rules

- No printed or electronic material is allowed during the exam. All necessary reference materials will be provided by NCA
- Calculators approved by NCA are allowed.
- Comprehensive exam rules will be provided by the examination authority, NCA, in a separate manual.

3. Table of Specifications for NCA Professional Engineering Exam: Thermal and Fluids Systems Engineering

Major Area	Multiple Choice Questions (MCQs)		Number of Essay Questions	Engineering Standard
	%	Number of Questions		
T1. Fluid Systems Analysis, Design and Operation	26.7	8	1	TFSE-T1
T2. Analysis and Design of Heat Transfer Equipment	20.0	6	1	TFSE-T2
T3. Combustion and Emission	6.7	2	-	TFSE-T3
T4. Rotating Equipment	10.0	3	-	TFSE-T4
T5. Steam Power Plants	13.3	4	1	TFSE-T5
T6. Gas turbines and Combined Cycles	10.0	3	1	TFSE-T6
T7. Internal Combustion Engines	6.7	2	-	TFSE-T7
T8. Desalination Systems	-	-	1	TFSE-T8
T9. Energy Efficiency	-	-	1	TFSE-T9
T10. Renewable Energy	-	-	1	TFSE-T10
T11. Hazards Prevention and Control	3.3	1	-	TFSE-T11
T12. Codes and Standards	3.3	1	-	TFSE-T12
Total	100%	30	Choose 3 out of 7	

4. Standards For Thermal and Fluids Systems Engineering

The Engineering Standards for the Thermal and Fluids Systems specialization, which is a part of the Mechanical Engineering Discipline, is structured around twelve applied topics:

T1. Fluid Systems Analysis, Design and Operation

T2. Analysis and Design of Heat Transfer Equipment

T3. Combustion and Emission

T4. Rotating Equipment

T5. Steam Power Plants

T6. Gas Turbines and Combined Cycles

T7. Internal Combustion Engines

T8. Desalination Systems

T9. Energy Efficiency

T10. Renewable Energy

T11. Hazards and Safety Control

T12. Codes and Standards

Mechanical engineers who work in in thermal fluids systems fields practice the above applied topics during their engineering career. Each of these topics has a number of indicators that ensure that the engineer has the necessary experiences to work in thermal fluids systems area.

Mechanical Engineers working in thermal fluids systems field are expected to possess and demonstrate command of the following Thermal Fluids Systems Engineering skills:

T1. Fluid Systems Analysis, Design and Operation

Mechanical engineers who work in Thermal Fluids Systems Area should have strong background in fluid mechanics, recognize and understand operation and theories of different types of fluid equipment, and have the capability to analyze the performance of fluid equipment, operate different fluid systems and design piping systems. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T1-1 Recognize different types of pumps and fans, their characteristics and corresponding applications.

TFSE-T1-2 Understand pump characteristic curves and understand how to use them to select the appropriate pumps for intended service.

TFSE-T1-3 Estimate pump power and efficiency, use pump specific speed to select pump type, and apply similarity laws for pumps and fans.

TFSE-T1-4 Know the necessary precautions to avoid cavitation in pumps.

TFSE-T1-5 Apply proper methods to test pumps and fans.

TFSE-T1-6 Recognize different types of pressure vessels, their characteristics and the corresponding applications.

TFSE-T1-7 Estimate pressure distributions and the corresponding resultant forces on internal surfaces of tanks holding fuel, water or other liquids.

TFSE-T1-8 Estimate forces resulting from liquids at rest on surfaces of tanks and on gates.

TFSE-T1-9 Select materials used in storage tanks' design according to codes and standards.

TFSE-T1-10 Perform pressure testing of new and repaired/retrofitted vessels.

TFSE-T1-11 Recognize protection procedures of high-pressure storage tanks.

TFSE-T1-12 Understand how to apply codes used for storage tank design and testing.

TFSE-T1-13 Recognize different types of valves, their characteristics and their use.

TFSE-T1-14 Select the size of valves appropriate for different applications.

TFSE-T1-15 Select appropriate actuators for different applications.

TFSE-T1-16 Recognize different types of compressible flow regimes including subsonic, sonic and supersonic flows.

TFSE-T1-17 Recognize different types of nozzles and diffusers used in different compressible flow regimes.

TFSE-T1-18 Determine exit conditions of nozzles and diffusers in compressible flow regimes.

TFSE-T1-19 Recognize different types of temperature sensors, pressure gages, velocity sensors, and flowmeters used in industrial applications.

TFSE-T1-20 Select appropriate sensors for different measurement applications.

TFSE-T1-21 Calibrate measurement equipment including temperature sensors, pressure gages, velocity and flow meters.

TFSE-T1-22 Recognize piping standards, fittings and symbols.

TFSE-T1-23 Estimate stresses in pipes, select pipe material and gage, and select and design piping support systems according to codes.

TFSE-T1-24 Estimate major and minor pressure losses in pipes and pipe fittings and accessories and create piping system curve.

TFSE-T1-25 Estimate energy required and cost to operate a piping system.

TFSE-T1-26 Optimize piping system diameter to minimize its yearly total cost.

TFSE-T1-27 Recognize how to avoid water hammer in pipelines.

TFSE-T1-28 Demonstrate ability to select and rate fans.

TFSE-T1-29 Recognize the standards of compressed gas piping.

TFSE-T1-30 Recognize different methods to control flow in pipelines.

TFSE-T1-31 Recognize different pipeline protection methods.

T2. Analysis and Design of Heat Transfer Equipment

Mechanical engineers who work in Thermal Fluids Systems area should have strong background in heat transfer, thermodynamics, should recognize and understand operation theories of different types of heat transfer equipment, and should have the capability to analyze the performance of heat transfer equipment, operate different types of heat transfer equipment and design heat exchangers, evaporator and boiler sections. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T2-1 Determine overall heat transfer coefficients and heat transfer rates for different conduction, convection and radiation configurations.

TFSE-T2-2 Recognize different types of thermal insulation and select appropriate thermal insulation for different applications.

TFSE-T2-3 Determine required or optimum insulation thickness and estimate payback period for thermal insulation.

TFSE-T2-4 Recognize different types of heat exchangers, and feed water heaters and select appropriate heat exchangers for different applications according to codes.

TFSE-T2-5 Estimate heat transfer rate for existing heat exchangers under design and off design conditions.

TFSE-T2-6 Design heat exchangers and feed water heaters for required heat transfer loads and perform part load analysis for heat exchangers and feed water heaters.

TFSE-T2-7 Carry out experiments to test heat exchangers performance and set up plans for preventive maintenance.

TFSE-T2-8 Implement effective methods to avoid or reduce fouling and scale building on heat exchangers surfaces.

TFSE-T2-9 Recognize different types of boilers and their characteristics.

TFSE-T2-10 Recognize the functions of components of water tube boilers, methods to separate vapor in the steam drum and different burner types used in boilers.

TFSE-T2-11 Understand water cycle inside water tube boiler. Recognize critical heat flux CHF in boilers and how to avoid it.

TFSE-T2-12 Understand water level control system and its function in a boiler.

TFSE-T2-13 Conduct heat and mass balance for boiler and its different sections and components and analyze boiler performance relative to its working conditions.

TFSE-T2-14 Determine fuel consumption, boiler efficiency and the energy cost to operate boilers.

TFSE-T2-15 Recognize the methods for boilers testing according to codes.

TFSE-T2-16 Recognize causes of corrosion and scale build up in boilers tubes and implement protection procedures against them.

TFSE-T2-17 Estimate gas emissions from boilers and check them with environmental codes.

TFSE-T2-18 Recognize different types of condensers used in power and desalination applications and their components and characteristics.

TFSE-T2-19 Analyze condenser operation and performance relative to its working conditions.

TFSE-T2-20 Design a condenser for a required heat transfer load.

TFSE-T2-21 Recognize different types of cooling towers, their components and their characteristics.

TFSE-T2-22 Conduct heat and mass balance for cooling towers and analyze cooling tower performance relative to its working conditions.

TFSE-T2-23 Estimate water consumption and blow down of a cooling tower.

TFSE-T2-24 Recognize different methods of waste heat recovery.

TFSE-T2-25 Recognize different air preheater types of boilers and their function.

TFSE-T2-26 Recognize different types of Heat Recovery Steam Generator, HRSG, and their components.

TFSE-T2-27 Conduct heat and mass balance for waste heat recovery systems.

TFSE-T2-28 Design different sections of HRSG and air preheaters.

TFSE-T2-29 Understand the concept of thermal energy storage and recognize different materials used in thermal energy storage.

TFSE-T2-30 Analyze and design ice storage system used in air conditioning and gas turbine inlet cooling.

TFSE-T2-31 Analyze and design thermal energy storage systems used for solar energy applications.

T3. Combustion and Emission

Mechanical engineers who work in Thermal Fluids Systems area should have strong background in fuel combustion, recognize different types of fuels and understand how to determine fuel heating values, understand operation theories of different types of combustors, and should have the capability to analyze emissions of combustion. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T3-1 Recognize different fuel types used in steam and gas turbine power plants and their characteristics.

TFSE-T3-2 Recognize different types of heating values of fuels and procedures to estimate them.

TFSE-T3-3 Balance ideal and real combustion equations and carry out analysis for flue gases.

TFSE-T3-4 Determine minimum allowable flue gas temperature, to avoid corrosion in boiler sections, and its relationship with dew point of the flue gas.

TFSE-T3-5 Recognize the impact of flue gas components on global warming.

TFSE-T3-6 Recognize different types of boiler burners and gas turbine combustors.

TFSE-T3-7 Carry out heat and mass balance for combustion and estimate temperature at combustor exit.

TFSE-T3-8 Estimate emissions from combustion systems and gas turbine combustors and recognize methods to control emissions.

T4. Rotating Equipment

Mechanical engineers who work in Thermal Fluids Systems area should recognize different types of rotating equipment including turbines and compressors, understand design theories, recognize operation procedures, and have the capability to analyze their performance. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T4-1 Recognize different types of steam and gas turbines, their characteristics and their components.

TFSE-T4-2 Identify the functions of different components and auxiliary systems of gas and steam turbines.

TFSE-T4-3 Recognize how pressure, velocity and temperature change along gas and steam turbine sections.

TFSE-T4-4 Evaluate work output and efficiency of gas and steam turbines and compare them to design and commissioning conditions.

TFSE-T4-5 Recognize proper techniques used for turbines load and speed control.

TFSE-T4-6 Recognize procedures for commissioning of steam and gas turbines.

TFSE-T4-7 Interpret data collected from measurements along the turbine including vibration and estimate its real performance.

TFSE-T4-8 Prepare maintenance plans based on analysis of vibration measurement and data collected from measurement along the turbine and prepare the budget needed for the maintenance.

TFSE-T4-9 Recognize different types of compressors used in gas turbines, their characteristics and their components.

TFSE-T4-10 Identify the functions of different components and auxiliary systems of compressors.

TFSE-T4-11 Estimate work input and efficiency of compressors.

TFSE-T4-12 Recognize techniques used for compressor capacity control.

TFSE-T4-13 Interpret data collected from measurements along the compressor including vibration and estimate its real performance.

TFSE-T4-14 Set up maintenance plans based on analysis of vibration measurement and data collected from measurement along the compressor and prepare the budget needed for the maintenance.

T5. Steam Power Plants

Thermal Fluids Systems Engineers should understand the operation of the steam power plant, its principles, and recognize function of its components. Also, they should be able to analyze and recognize procedures to modify its performance for different configurations under full and part load conditions, estimate emissions, interpret measurement data collected from the power plant to estimate its real performance, and plan maintenance based on the analysis of measurements collected. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T5-1 Identify different cycles and configurations of steam power plants including reheat, regeneration and super critical cycles.

TFSE-T5-2 Assess steam power plant performance relative to its working cycle and operating conditions.

TFSE-T5-3 Recognize, understand and apply various techniques to improve steam power plant efficiency and reduce energy conversion cost.

TFSE-T5-4 Analyze steam cycles used for power generation and heating. Estimate specific steam consumption SSC, specific fuel consumption SFC, overall thermal efficiency, and heat rate HR.

TFSE-T5-5 Estimate performance at full and part load conditions and compare them to design and commissioning performances.

TFSE-T5-6 Recognize different power plant load curves. Estimate plant capacity, use, load and diversity factors.

TFSE-T5-7 Estimate emissions from steam power plant (SOX, NOX, CO, unburnt fuel). Recognize techniques to reduce emissions from steam power plants.

TFSE-T5-8 Interpret data collected from measurements along the steam power plant and estimate its real performance.

TFSE-T5-9 Set up maintenance plans based on analysis of data collected from measurement along the steam power plant, and prepare the budget needed for the maintenance.

T6. Gas Turbines and Combined Cycles

Thermal Fluids Systems Engineers should understand the operation of gas turbine and combined cycle plants, analyze and understand methods to modify their performance for different configurations under full and part load conditions, estimate emissions, interpret measurement data collected from the power plant to estimate its real performance, plan maintenance based on the analysis of measurements collected. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T6-1 Recognize different cycles and configurations of gas turbines including single and double shafts turbines, single compressor, multi-compressors with intercooling, reheating and regeneration.

TFSE-T6-2 Analyze gas turbine plant performance relative to its working cycle and operating conditions. Estimate specific fuel consumption SFC, overall thermal efficiency, and heat rate HR. Estimate performance at full and part load conditions.

TFSE-T6-3 Recognize, understand and apply various techniques to improve gas turbine plant performance to increase its efficiency and reduce energy conversion cost.

TFSE-T6-4 Recognize different techniques of gas turbine inlet cooling and their functions and analyze gas turbine cycles with inlet cooling.

TFSE-T6-5 Analyze a combined cycle power plant performance relative to its working conditions.

TFSE-T6-6 Estimate emissions of gas turbine and combined cycles (SOX, NOX, CO, unburnt fuel). Recognize techniques to reduce emissions of gas turbines.

TFSE-T6-7 Interpret data collected from measurements along the gas turbine and estimate its real performance.

TFSE-T6-8 Set up maintenance plans based on analysis of data collected from measurement along the gas turbines, and prepare the budget needed for the maintenance.

T7. Internal Combustion Engines

Thermal Fluids Systems Engineers should understand the operation principles of internal combustion engines, analyze their performance under full and part load conditions, and estimate their emissions. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T7-1 Analyze actual cycles of diesel and gasoline engines. Assess various techniques to improve internal combustion engines performance.

TFSE-T7-2 Estimate work output, efficiency, and fuel consumption of internal combustion engines.

TFSE-T7-3 Conduct tests to measure the performance of internal combustion engines.

T8. Desalination Systems

Thermal Fluids Systems Engineers should recognize different desalination techniques, understand the operation principles of desalination systems, analyze their performance, and recognize their operation procedures. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T8-1 Recognize different techniques of desalination.

TFSE-T8-2 Recognize operation theory of MSF system and recognize different types of MSF systems and their characteristics.

TFSE-T8-3 Carry out mass and energy analysis of MSF systems, estimate performance parameters of MSF systems and estimate energy consumption of MSF systems.

TFSE-T8-4 Estimate cost of water produced by MSF system.

TFSE-T8-5 Recognize the commission procedures of MSF systems.

TFSE-T8-6 Interpret data collected from measurements along the MSF system and estimate its real performance.

TFSE-T8-7 Set up maintenance plans based on the analysis of data collected from measurements along the MSF system and prepare the budget needed for the maintenance.

TFSE-T8-8 Recognize operation theory of MED system and recognize different types of MED systems and their characteristics.

TFSE-T8-9 Carry out mass and energy analysis of MED systems, estimate performance parameters of MED systems and estimate energy consumption of MED systems.

TFSE-T8-10 Recognize different types of MED evaporators and their components.

TFSE-T8-11 Analyze evaporator operation and performance relative to its working conditions.

TFSE-T8-12 Estimate temperature losses along MED evaporators.

TFSE-T8-13 Design an evaporator for a required heat transfer load.

TFSE-T8-14 Estimate cost of water production of MED system.

TFSE-T8-15 Recognize the commission procedure of MED.

TFSE-T8-16 Interpret data collected from measurements along the MED system and estimate its real performance.

TFSE-T8-17 Set up maintenance plans based on analysis of data collected from measurement along the MED system and prepare the budget needed for the maintenance.

TFSE-T8-18 Recognize operation theory of RO system, recognize different types of RO systems and recognize different methods of energy recovery in RO systems.

TFSE-T8-19 Carry out mass and energy analysis of RO systems, estimate performance parameters of RO systems and estimate energy consumption of RO systems.

TFSE-T8-20 Estimate cost of water produced by RO system.

TFSE-T8-21 Interpret data collected from measurements along the RO system and estimate its real performance.

TFSE-T8-22 Set up maintenance plans, including required budget, based on analysis of data collected from measurement along the RO system.

T9. Energy Efficiency

Thermal Fluids Systems Engineers should recognize how to carry out energy auditing for commercial and industrial buildings, introduce different techniques to increase energy efficiency, be familiar with energy efficiency codes and establish procedures for energy efficiency measurement. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T9-1 Recognize the terminology used in energy efficiency.

TFSE-T9-2 Carry out effective energy audits for buildings and industrial installations.

TFSE-T9-3 Carry out detailed energy use and services analysis in buildings and industrial installations.

TFSE-T9-4 Recognize energy efficiency codes, standards and labels used in Saudi Arabia.

TFSE-T9-5 Introduce solutions to improve the energy efficiency in buildings, industrial installations and transportation sector.

TFSE-T9-6 Carry out engineering, economic and feasibility studies for solutions proposed to improve the energy efficiency in buildings, industrial installations and transportation sector.

TFSE-T9-7 Estimate payback period for proposed solutions to improve the energy efficiency in buildings, industrial installations and transportation sector.

TFSE-T9-8 Select, install and utilize appropriate equipment to measure energy consumption and efficiency in buildings, industrial installations and transportation sector.

TFSE-T9-9 Recognize impacts of energy efficiency measures on the environmental aspects.

T10. Renewable Energy

Thermal Fluids Systems Engineers should recognize different sources of renewable energy and how to convert them to useful forms, carry out analysis of solar and wind energy systems, and recognize different methods for energy storage. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T10-1 Recognize available types of renewable energy resources in Saudi Arabia, and techniques to convert them to useful forms of energy.

TFSE-T10-2 Conduct preliminary calculations to judge the viability of each type of renewable energy in Saudi Arabia.

TFSE-T10-3 Recognize availability of solar energy in Saudi Arabia and estimate the solar irradiance on tilted surfaces.

TFSE-T10-4 Utilize appropriate instruments to measure solar radiation.

TFSE-T10-5 Apply thermal radiation knowledge to estimate heat transfer from opaque, reflective and transparent surfaces.

TFSE-T10-6 Recognize solar energy conversion and utilization systems.

TFSE-T10-7 Recognize different types of solar collectors and their applications.

TFSE-T10-8 Design different types of solar collectors for heating and power generation.

TFSE-T10-9 Analyze performance of different types of solar collectors.

TFSE-T10-10 Recognize different types of solar power plants.

TFSE-T10-11 Analyze performance of different types of solar power plants.

TFSE-T10-12 Recognize different material used in thermal solar energy storage.

TFSE-T10-13 Analyze and design thermal energy storage system for heating and power generation.

TFSE-T10-14 Recognize regions in Saudi Arabia where the wind energy is available and collect the data of the wind velocity and direction needed to design and select appropriate wind turbines.

TFSE-T10-15 Utilize appropriate instruments to measure wind velocity and direction.

TFSE-T10-16 Recognize wind turbines different types and their characteristics.

TFSE-T10-17 Assess performance of different types of wind turbines based on wind speed and height of turbines and estimate power output and efficiency.

TFSE-T10-18 Recognize the aerodynamics of wind turbines

TFSE-T10-19 Select appropriate wind turbines types and size, and design wind turbine farms.

TFSE-T10-20 Carry out economic analysis of wind energy systems and calculate payback period.

T11. Hazards Prevention and Control

Thermal Fluids Systems Engineers should recognize different sources of hazards, assess the risk and recognize Saudi standards related to safety and apply safety plans to eliminate risk in the workplace. The following indicators are addressed in the Exam Questions related to this Topic:

TFSE-T11-1 Identify the different types of hazards and assess risks in work area.

TFSE-T11-2 Define the five (5) major categories of hazard control measures.

TFSE-T11-3 Determine requirements of safety in work areas according to Saudi standards.

TFSE-T11-4 Set up safety plans to control hazard and risk in work areas according to Saudi regulations.

TFSE-T11-5 Implement safety plans to eliminate and reduce risk in work areas.

TFSE-T11-6 Review and modify safety plans and investigate their effectiveness.

TFSE-T11-7 Advertise awareness of safety procedures and importance in the work areas.

T12. Codes and Standards (ASME, ASHRAE, Saudi Building Code, ARAMCO, SASO)

Thermal Fluids Systems Engineers should recognize different codes and standards related to design, operation, testing and commissioning of thermal fluids systems. The following indicators are addressed in the Exam Questions related to this Topic:

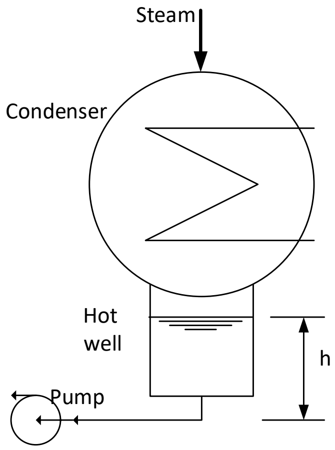
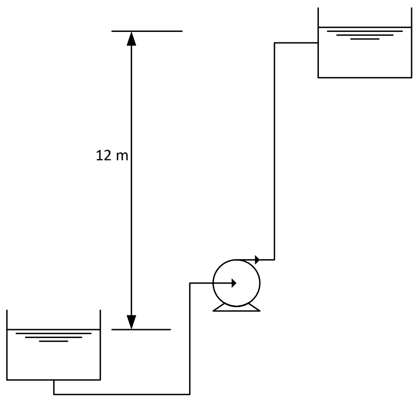
TFSE-T12-1 Recognize and implement the codes and standards used to design piping systems and implement them.

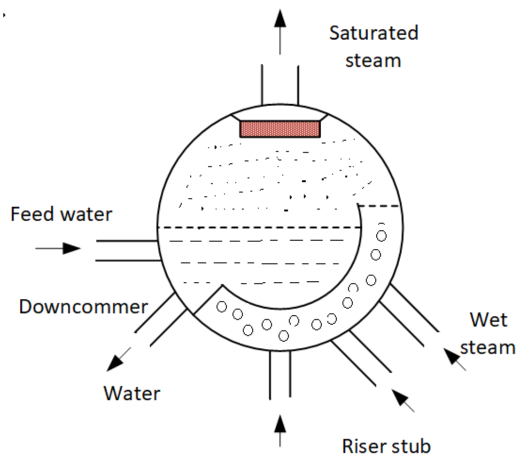
TFSE-T12-2 Recognize and implement the codes and standards of energy efficiency of different equipment and processes.

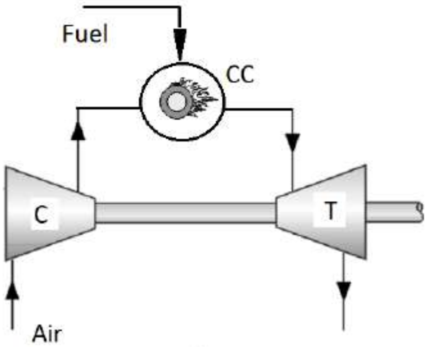
TFSE-T12-3 Recognize the codes and standards used to design and operate boilers and heat exchangers.

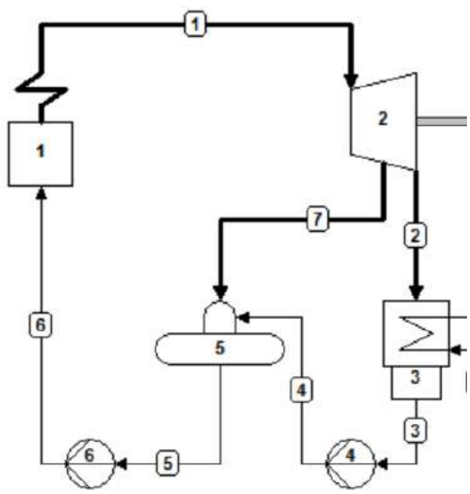
TFSE-T12-4 Recognize and implement the codes and standards used to design and operate pressure vessels.

5. Sample Questions

Q. No.	Major Area	Indicator Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min)	Supplied Reference
1	**T1. Fluid Systems Analysis, Design and Operation**	TFSE-T1-4	Estimate the height of water in the condenser hot well to avoid cavitation in the condensate pump if its NPSHR =1 m and condensation temperature is 40 °C.  A) h=0.24 m B) h=0.759 m C) h=1.0 m D) h=1.76 m	C	4	None
2	**T1. Fluid Systems Analysis, Design and Operation**	TFSE-T1-13	For the shown piping-pump system, at least you need to install .... A) one global valve B) one check valve C) one gate valve D) one relief valve  	B	3	None

Q. No.	Major Area	Indicator Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min)	Supplied Reference
3	**T2. Analysis and Design of Heat Transfer Equipment**	TFSE-T2-5	When a new heat exchanger of surface area A=10 m^2 was examined it transferred 20 kW of heat for a temperature difference LMTD=10 °C. After a year of operation, the heat transfer falls to 19.25 kW for a temperature difference LMTD = 10 °C. Estimate the fouling resistance built during this year. A) 0.000195 m^2 °C /W B) 0.005195 m^2 °C /W C) 0.005 m^2 °C /W D) 0.133 m^2 °C /W	A	3-4	None
4	**T2. Analysis and Design of Heat Transfer Equipment**	TFSE-T2-13	For the shown steam drum of a water tube boiler, consider the following information: The boiler pressure is 100 bar, steam outlet rate is 10 kg/s, and the dryness fraction at Riser Stub is 0.1. Assume the feed water is saturated. Determine the flow rate in the Downcomer. A) 1 kg/s B) 10 kg/s C) 100 kg/s D) 200 kg/s  	C	3-4	None
5	**T1. Fluid Systems Analysis, Design and Operation**	TFSE-T1-3	Using variable speed motor is an efficient energy method. A centrifugal pump runs at 1500 rpm and consumes 100 kW. Determine the suitable speed of the pump to reduce the flow rate to 80%. A) 300 rpm	C	4	None

Q. No.	Major Area	Indicator Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min)	Supplied Reference
			B) 1000 rpm C) 1200 rpm D) 1800 rpm			
6	**T6. Gas Turbine and Combined Cycles**	TFSE-T6-2	During a test of a gas turbine, the following information were found: Compressor work = 50 MW Turbine work = 75 MW Fuel consumption = 2 kg/s LHV of fuel = 40 MJ/kg Determine the heat rate HR of the gas turbine unit. A) HR=11.52 kJ/kW hr B) HR=3840 kJ/kW hr C) HR=1152.0 kJ/kW hr D) HR=11520 kJ/kW hr 	D	3-4	None
7	**T2. Analysis and Design of Heat Transfer Equipment**	TFSE-T2-2	A plastic material of thermal conductivity of k=0.12 W/m K is used as an electric insulator of an electric cable. The cable diameter is 8 mm. The convection heat transfer coefficient from cable surface is $h=20\ W/m^2 K$. Estimate the insulator thickness δ required to dissipate the maximum heat from the cable. A) δ = 0.0 mm B) δ = 1.0 mm C) δ = 2.0 mm D) δ = 3.0 mm	C	4	None

<table>
<tr><th>Q. No.</th><th>Major Area</th><th>Indicator Code</th><th>Question Statement (Answer's Choices)</th><th>Key Answer</th><th>Expected Time (min)</th><th>Supplied Reference</th></tr>
<tr><td>8</td><td>T5. Steam Power Plants</td><td>TFSE-T5-4</td><td>The data in table below were obtained during a test for the steam power plant shown below
<table>
<tr><th>Point</th><th>P, bar</th><th>h, kJ/kg</th><th>Point</th><th>P, bar</th><th>h, kJ/kg</th></tr>
<tr><td>1</td><td>100</td><td>3096</td><td>5</td><td>9</td><td>?</td></tr>
<tr><td>2</td><td>0.1</td><td>2066</td><td>6</td><td>100</td><td>?</td></tr>
<tr><td>3</td><td>0.1</td><td>191.8</td><td>7</td><td>9</td><td>2640</td></tr>
<tr><td>4</td><td>9</td><td>192.7</td><td></td><td></td><td></td></tr>
</table>

The percentage of bleed steam at 7 required for the open feed water heater is:
A) 22.5%
B) 33.3%
C) 40.5%
D) 46.5%</td><td>A</td><td>4</td><td>Steam table</td></tr>
<tr><td>9</td><td>T6. Gas Turbine and Combined Cycles</td><td>TFSE-T6-5</td><td>Consider a combined power plant that consists of a gas turbine unit and a steam power unit. The thermal efficiencies of the gas turbine and the steam power units are 30% and 35% respectively. Estimate the thermal efficiency of the combined power plant.
A) 10.5%
B) 54.5%
C) 65%
D) 75.5%</td><td>B</td><td>5</td><td></td></tr>
</table>

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<tr><th>Q. No.</th><th>Major Area</th><th>Indicator Code</th><th>Question Statement (Answer's Choices)</th><th>Key Answer</th><th>Expected Time (min)</th><th>Supplied Reference</th></tr>
<tr><td>10</td><td>T11. Hazard Prevention and Control</td><td>TFSE-T11-3</td><td>ASTM C1055 is the standard guide for heated system surface conditions that produce contact burn injuries. This guide recommends that surface temperatures remain at or below 140°F/60°C.
A thermal storage metallic tank has outer surface temperature of 200 °C without thermal insulation. It is required to insulate the tank to reach safe temperature. Available insulation is mineral fiber of thermal conductivity k=0.044 W/mK. The ambient temperature is 40 °C and the convective heat transfer coefficient at tank surface is 10 W/m^2K. Estimate minimum insulation thickness to reach safe surface temperature.
A) L=11 mm
B) L=21 mm
C) L=31 mm
D) L=41 mm</td><td>C</td><td>4</td><td></td></tr>
<tr><td>Essay 1</td><td>T6. Gas Turbine and Combined Cycles</td><td>TFSE-T6-1
TFSE-T6-2</td><td>A company ordered a gas turbine unit of the following specifications:
<table>
<tr><td>Power rated at ISO conditions</td><td>80 MW</td></tr>
<tr><td>HR at ISO conditions</td><td>11161 kJ/kW hr</td></tr>
<tr><td>Pressure ratio</td><td>10</td></tr>
<tr><td>TIT</td><td>1200 K</td></tr>
<tr><td>Efficiency at ISO conditions</td><td>32.25%</td></tr>
<tr><td>Compressor adiabatic efficiency η_c</td><td>85%</td></tr>
<tr><td>Turbine adiabatic efficiency η_t</td><td>90%</td></tr>
<tr><td>Turbine-generator mechanical/electrical efficiency η_m</td><td>90%</td></tr>
</table>
The unit will operate in a hot region from 25 to 50 °C and ambient atmospheric pressure of 96 kPa. You asked to investigate the performance of this unit in the temperature range of 25-50 °C. Estimate the unit output power, efficiency and heat rate in the above range.
You can use the following information:
For air: C_P =1.005 kJ/kg K, k=1.4
For flue gas: C_p=1.1 J/kg K, k=1.4
ISO conditions: P=1.013 bar, T=15 °C
Use ideal gas equation</td><td></td><td>40</td><td></td></tr>
</table>

Q. No.	Major Area	Indicator Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min)	Supplied Reference
Essay 2	**T9. Energy Efficiency** **T3. Combustion and Emission**	TFSE-T9-5 TFSE-T9-6 TFSE-T3-8	The heating load for an air conditioning system of a building needs 2000 m^3/day of hot water at 50 ^oC for 100 days per year. The return cold water is 30 ^oC. There are three options for heating: a. Using electric heater b. Using natural gas fired heater of η_g = 80% efficiency c. Using a heat pump of COP_h=3.5 This information is available: Electricity cost = SR 0.18/kWh Natural gas cost = 12 Saudi Riyal per Million Metric British Thermal Unit 1 Btu =1.055 kJ Compare energy cost for three options. Discuss using these options on emissions from combustion in natural gas heater and boiler of the power station which supply the electricity.		30-40	

6. Solutions of Sample Questions

Multiple Choice Questions (MCQs)

Question # 1

Indicator TFSE-T1-4 Know the necessary precautions to avoid cavitation in pumps.

Example TFSE-T1-4

Solution TFSE-T1-4

From steam table at T_c = 40 °C:

P_c= 7.385 kPa, ρ_f = 992.06 kg/m^3

To avoid cavitation:

NPSHA = NPSHR = 1m (1)

NPSHA=$h_a + h_s - h_f - h_v$

Where h_a is abs pressure head in the condenser

h_s is the static head above the pump

h_f is the pressure losses from hot well to pump

h_v is vapor pressure at operating temperature

For current case, the absolute pressure inside the condenser = vapor pressure inside the condenser, or:

$h_a = h_v$

neglect losses from hot well to the pump. Then,

NPSHA = h_s (2)

From eqs 1 and 2:

h_s =1 m

then the required static head in the hot well is 1 m.

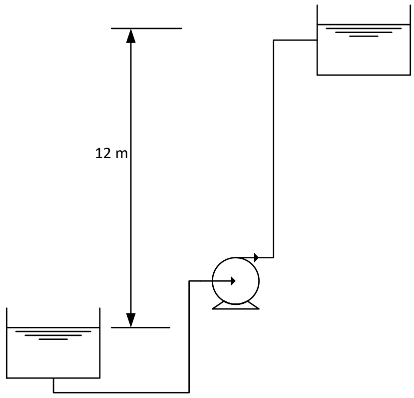
Answer is: (C)

Question # 2

Indicator TFSE-T1-13 Recognize different types of valves, their characteristics and their use.

Example TFSE-T1-13

For the sown piping-pump system, at least you need to install ....



A) one global valve
B) one check valve
C) one gate valve
D) one relief valve

Solution TFSE-T1-13

We need at least one check valve to prevent flow from upper tank upon the pump shut down

The answer is: (B)

Question # 3

Indicator TFSE-T2-5 Estimate heat transfer rate for existing heat exchangers under design and off design conditions.

Example TFSE-T2-5

When a new heat exchanger of surface area A=10 m^2 was examined it transferred 20 kW of heat for a temperature difference LMTD=10 °C. After a year of operation, the heat transfer falls to 19.25 kW for a temperature difference LMTD = 10 °C. Estimate the fouling resistance built during this year.

A) 0.000195 m^2 °C /W
B) 0.005195 m^2 °C /W
C) 0.005 m^2 °C /W
D) 0.133 m^2 °C /W

Solution TFSE-T2-5

Before using the heat exchanger:

$Q_n = U_n A \Delta T$

U_n=20000/(10*10) = 200 W/m^2 °C

R_n = 1/U = 0.005 m^2 °C /W

After one year in operation:

$Q_o = U_n A \Delta T$

U_o=19250/(10*10) = 192.5 W/m^2 °C

R_o = 1/U = 0.005195 m^2 °C /W

$R_{fouling}$ = Ro – Rn = 0.000195 m^2 °C /W

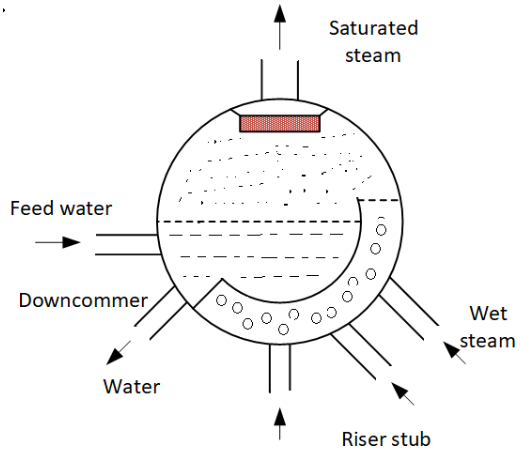
The answer is: (A)

Question # 4

Indicator TFSE-T2-5 Estimate heat transfer rate for existing heat exchangers under design and off design conditions.

Example TFSE-T2-5

For the shown steam drum of a water tube boiler, consider the following information: The boiler pressure is 100 bar, steam outlet rate is 10 kg/s, and the dryness fraction at Riser Stub is 0.1. Assume the feed water is saturated. Determine the flow rate in the Downcomer.1 kg/s



A) 10 kg/s
B) 100 kg/s
C) 200 kg/s

Solution TFSE-T2-5

Steam flow rate at steam outlet is dry saturated: m_S = 10 kg/s

The feed water flow rate to the steam drum = Steam flow rate at steam outlet = m_S = 10 kg/s

To ensure mass balance of the steam drum:

The flow rate exits from downcomer of the steam drum which is saturated water

= the flow rate inlet at Riser stub to the steam drum which is a wet steam of = m_r

In the steam drum, wet steam is separated to saturated vapor which exits from steam outlet and saturated liquid mixed with water feed and exits through downcomer.

Then: $m_S = x * m_r$ [where dryness fraction (x) = 0.1]

Hence: $m_r = 10/0.1 = 100$ kg/s

The answer is: (C)

Question # 5

Indicator TFSE-T1-3 Estimate pump efficiency, use of pump specific speed to select pump type and apply similarity laws for pumps and fans.

Example TFSE-T1-3

Using variable speed motor is an efficient energy method. A centrifugal pump runs at 1500 rpm and consumes 100 kW. Determine the suitable speed of the pump to reduce the flow rate to 80%.

A) 300 rpm
B) 1000 rpm
C) 1200 rpm
D) 1800 rpm

Solution TFSE-T1-3

The similarity laws give

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^3 \left(\frac{N_1}{N_2}\right)$$

For same pump D1=D2

Then N2 =N1 *Q2/Q1 = 1500*0.8 = 1200 rpm

The answer is : (C)

Question # 6

Indicator TFSE-T6-2 Analyze gas turbine plant performance relative to its working cycle and operating conditions. Estimate specific fuel consumption SFC, overall thermal efficiency, and heat rate HR. Estimate performance at full and part load conditions.

Example TFSE-T6-2

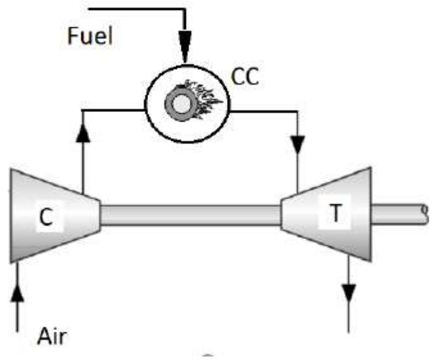
During a test of a gas turbine, the following information were found:

Compressor work = 50 MW

Turbine work = 75 MW

Fuel consumption = 2 kg/s

LHV of fuel = 40 MJ/kg



Determine the heat rate HR of the gas turbine unit.

A) HR=11.52 kJ/kW hr
B) HR=3840 kJ/kW hr
C) HR=1152.0 kJ/kW hr
D) HR=11520 kJ/kW hr

Solution TFSE-T6-2

$W_{net} = W_t - W_c$ = 75-50 = 25 MW = 25000 kW
$Q_a = m_f$ * LHV =2*40000 = 80000 kW
HR = Q_a / W_{net} = 80000*3600/25000 = 11520 kJ/kW hr

The answer is : (D)

Question # 7

Indicator TFSE-T2-2 Recognize different types of thermal insulation and select appropriate thermal insulation for different applications.

Example TFSE-T2-2

A plastic material of thermal conductivity of k=0.12 W/m K is used as an electric insulator of an electric cable. The cable diameter is 8 mm. The convection heat transfer coefficient from cable surface is h=20 W/m^2 K. Estimate the insulator thickness δ required to dissipate the maximum heat from the cable.

A) δ= 0.0 mm
B) δ= 1.0 mm
C) δ= 2.0 mm
D) δ= 3.0 mm

Solution TFSE-T2-2

k = 0.12 W/m K

h=20 W/m^2 K

The critical radius of insulation: $r_{cr} = k/h = 0.006$ m

The cable radius r = 0.004 mm

$r < r_{cr}$

This means using this insulation will increase heat transfer from the cable which reaches the peak when the outer radius of the insulation = r_{cr} = 0.006 m

i.e. the insulation thickness to maximize heat transfer from the cable is δ = 2.0 mm

The answer is : (C)

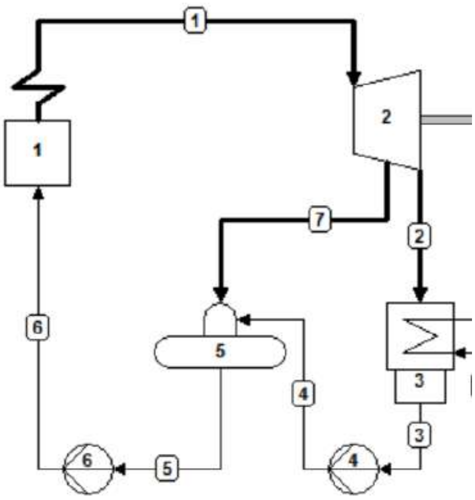
Question # 8

Indicator TFSE-T5-4 Analyze steam cycles used for power generation and heating. Estimate specific steam consumption SSC, specific fuel consumption SFC, overall thermal efficiency, and heat rate HR.

Example TFSE-T5-4

The data in table below were obtained during a test for the steam power plant shown below

Point	P, bar	h, kJ/kg	Point	P, bar	h, kJ/kg
1	100	3096	5	9	?
2	0.1	2066	6	100	?
3	0.1	191.8	7	9	2640
4	9	192.7			



The percentage of bleed steam at 7 required for the open feed water heater is:

A) 22.5%
B) 33.3%
C) 40.5%
D) 46.5%

Solution TFSE-T5-4

For open feed water heater: the water exits at 1 should be saturated water at 9 bar or subcooled, i.e.

$T_5 \leq$ Tsat at P=9 bar

Then $h_5 = h_f$ at P=9 bar

= 742.56 kJ/g

The heat balance of the open feed water heater leads to:

$m_7 h_7 + m_4 h_4 = m_5 h_5$ (1)

The mass balance of the open feed water heater leads to:

$m_4 + m_7 = m_5$ (2)

substitute from (2) into (1):

$m h_7 + (1-m) h_4 = h_5$ (3)

where is bleed ratio $m = m_7 / m_5$

The percentage of bleed steam at 7 = m *100 = 22.5%

The answer is : (A)

Question # 9

Indicator TFSE-T6-5 Analyze a combined cycle power plant performance relative to its working conditions.

Example TFSE-T6-5

Consider a combined power plant that consists of a gas turbine unit and a steam power unit. The thermal efficiencies of the gas turbine and the steam power units are 30% and 35% respectively. Estimate the thermal efficiency of the combined power plant.

A) 10.5%
B) 54.5%
C) 65%
D) 75.5%

Solution TFSE-T6-5

$\eta_g = 0.3 = W_g/Q_a$

$\eta_s = 0.35 = Ws/(Q_a - W_g)$

$\eta_{comined} = (W_g + W_s)/Q_a = W_g/Q_a + Ws/Q_a = W_g/Q_a + Ws/(Q_a - Wg) *(Q_a - Wg)/Q_a$

$= \eta_g + \eta_s (1 - \eta_g) = \eta_g + \eta_s - \eta_g \eta_s$

$= 54.5\%$

The answer is : (B)

Question # 10

Indicator TFSE-T11-3 Determine requirements of safety in work areas according to Saudi standards.

Example TFSE-T11-3

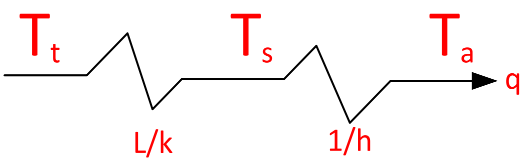
ASTM C1055 is the standard guide for heated system surface conditions that produce contact burn injuries. This guide recommends that surface temperatures remain at or below 140°F/60°C.

A thermal storage metallic tank has outer surface temperature of 200 °C without thermal insulation. It is required to insulate the tank to reach safe temperature. Available insulation is mineral fiber of thermal conductivity k=0.044 W/mK. The ambient temperature is 40 °C and the convective heat transfer coefficient at tank surface is 10 W/m^2K. Estimate minimum insulation thickness to reach safe surface temperature.

A) L=11 mm
B) L=21 mm
C) L=31 mm
D) L=41 mm

Solution TFSE-T11-3

To reach safe temperature at insulation surface, you should reduce it to T_s= 60 °C



T_t=200 °C
T_a=40 °C
h=10 W/m^2K
k=0.044 W/mK
Heat transfer through insulation layer : q=(Tt-Ts)*k/L
Heat transfer by convection at outer surface of insulation: q=(Ts-Ta)*h
q=200 W/m^2
L=0.0308 m

The answer is : (C)

Essay Question #1

Indicator TFSE-T6-1 Recognize different cycles and configurations of gas turbines including single and double shafts turbines, single compressor, multi-compressors with intercooling, reheating and regeneration.

Indicator TFSE-T6-2 Analyze gas turbine plant performance relative to its working cycle and operating conditions. Estimate specific fuel consumption SFC, overall thermal efficiency, and heat rate HR. Estimate performance at full and part load conditions.

A company ordered a gas turbine unit of the following specifications:

Power rated at ISO conditions	80 MW
HR at ISO conditions	11161 kJ/kW hr
Pressure ratio	10
TIT	1200 K
Efficiency at ISO conditions	32.25%
Compressor adiabatic efficiency η_c	85%
Turbine adiabatic efficiency η_t	90%
Turbine-generator mechanical/electrical efficiency η_m	90%

The unit will operate in a hot region from 25 to 50 ºC and ambient atmospheric pressure of 96 kPa. You asked to investigate the performance of this unit in the temperature range of 25-50 ºC. Estimate the unit output power, efficiency and heat rate in the above range.

You can use the following information:

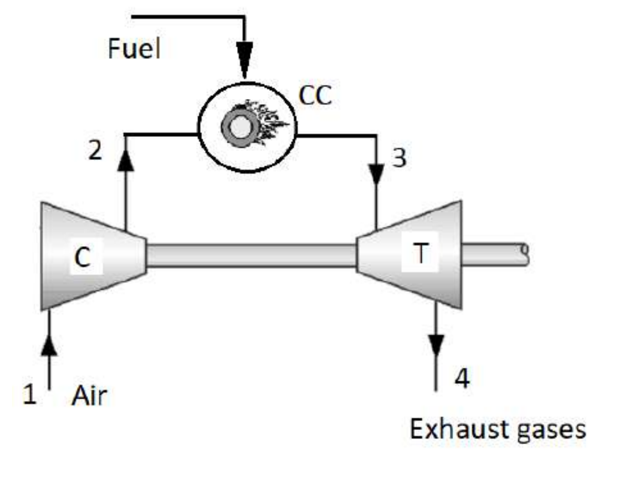
For air: C_P =1.005 kJ/kg K, k=1.4

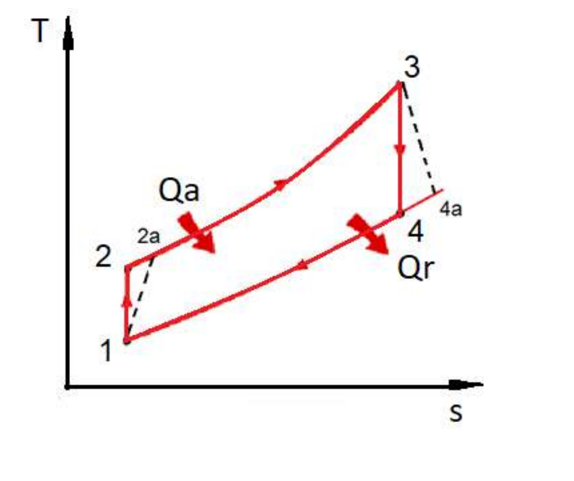
For flue gas: C_p=1.1 J/kg K, k=1.4

ISO conditions: P=1.013 bar, T=15 ºC

Use ideal gas equation

Solution





The above figures represent flow and T-s diagrams for the gas turbine unit.

The gas turbine is a constant volume device. The data at ISO conditions will be used to determine air volume flow rate at compressor inlet.

For ISO conditions: P_1=1.013 bar, T_1=15 ºC

T_1=15+273 P_1=101.3 kPa

For isentropic compression in compressor: $T_2=T1*r_p^{(k-1)/k} = 556$ K

For adiabatic compression $\eta_c=(T_2-T_1)/(T_{2a}-T_1) = 0.85$
T2a=603.3 K

TIT=T3=1200 K

For isentropic expansion in turbine: $T_4=T_3/r_p^{(k-1)/k} = 621.5$ K

For adiabatic expansion $\eta_t=(T_3-T_{4a})/(T_3-T_4) = 0.9$ T_{4a}=679.4 K

Compressor work: $W_c= C_{pa}\,(T_{2a}-T_1) = 316.9$ kJ/kg

Turbine Work: $W_t=Cpg\,(T_3-T_{4a}) = 572.7$ kJ/kg

Cycle work: $W_{cycle} = W_t-W_c = 255.8$ kJ/kg

Net work: $W_{net} = W_{cycle} * \eta_m = 230.2$ kJ/kg

Air flow rate: $m_{iso} = W_{iso}/W_{net} = 80000/W_{net} = 347.6$ kg/s

$\rho_1=P_1/R\,T_1 = 101.3/(0.287*288) = 1.226$

$V_{iso} = m_{iso}/\rho_1 = 283.6\ m^3/s$ This flow rate is constant for any compressor inlet conditions

For inlet conditions: P_1=96 kPa, T_1=25 ºC

T_1=25+273 = 298 K P_1=96 kPa

ρ_1=P1/R T1

air mass flow rate: $m = V_{iso} * \rho_1$

For isentropic compression in compressor: $T_2=T_1*r_p^{(k-1)/k}$

For adiabatic compression $\eta_c=(T_2-T_1)/(T_{2a}-T_1)=0.85$

$TIT=T_3=1200$ K

For isentropic expansion in turbine: $T_4=T_3/r_p^{(k-1)/k}$

For adiabatic expansion $\eta_t=(T_3-T_{4a})/(T_3-T_4)=0.9$

Compressor work: $W_c= C_{pa}$ (T2a-T1)

Turbine Work: $W_t=C_{pg}(T_3-T_{4a})$

Cycle work: $W_{cycle} = W_t-W_c$

Net work: $W_{net} = W_{cycle} * \eta_m$

Unit output power $W= m\, W_{net}$

Heat added $Q_a = m\, C_{pg}(T_3-T_{2a})$

Unit efficiency $\eta = W/ Q_a$

$HR = Q_a *3600/W$

These data are listed in the table below.

This procedure is repeated for 30, 40 and 50 °C and the results are listed below

T1	T2	T2a	T3	T4	T4a	ρ_1	m	W_c	W_t	W_{cycle}	W_{net}	W	η	HR
K	K	K	K	K	K	kg/m³	kg/s	kJ/kg	kJ/kg	kJ/kg	kJ/kg	MW	%	kJ/kW hr
298	575.3	624.3	1200	621.5	679.4	1.122	318.3	327.9	572.7	244.8	220.3	70.1	31.8	11319
303	585	634.8	1200	621.5	679.4	1.104	313.1	333.4	572.7	239.3	215.3	67.4	31.5	11403
313	604.3	655.7	1200	621.5	679.4	1.069	303.1	344.4	572.7	228.2	205.4	62.2	31.08	11584
323	623.6	676.77	1200	621.5	679.4	1.036	293.7	355.4	572.7	217.2	195.5	57.4	30.5	11783

Essay Question #2

TFSE-T9-5 Introduce solutions to improve the energy efficiency in buildings, industrial installations and transportation sector.

TFSE-T9-6 Carry out engineering, economic and feasibility studies for solutions proposed to improve the energy efficiency in buildings, industrial installations and transportation sector.

TFSE-T3-8 Estimate emissions from combustion systems and gas turbine combustors and recognize methods to control emissions.

The heating load for an air conditioning system of a building needs 2000 m^3/day of hot water at 50 °C for 100 days per year. The return cold water is 30 °C. There are three options for heating:

a. Using electric heater

b. Using natural gas fired heater of η_g = 80% efficiency

c. Using a heat pump of COP_h=3.5

This information is available:

Electricity cost = SR 0.18/kWh

Natural gas cost = 12 Saudi Riyal per Million Metric British Thermal Unit

1 Btu =1.055 kJ

Compare energy cost for three options. Discuss using these option on emissions from combustion in natural gas heater and boiler of the power station which supply the electricity.

Solution:

Water density ρ = 1000 kg/m^3

The water mass flow rate is

m = 2000*ρ/(24*3600) =	23.14814815	kg/s
The heating capacity of the heater		
$Q = m\ Cp\ (T_h - T_c)$ =	1937.96	kW
For Electric Heating option		
E_e =Energy/100 day = Q*24*100	4651111.1	kW.hr/year
Electric energy cost = E_e *0.18	837200	SR/year

For Natural Gas Heating Option:

Heat input to gas heater in Btu		
$Q_g = Q/(1.055\ \eta_g)$	2296.16	Btu/s
E_g =Energy/100 day =		
Q_g*3600*24*100 =	19838862559	Btu/100 day
E_g in million Btu/100day= = Eg/1000000	19838.86	million Btu/100 day
Cost of Natural gas = E_g*cost of natural gas =	238066.35	SR/year

For Heat pump

Work of the heat pump = W= Q/COPh =	553.70	kW
E_p = Elec Energy consumed by heat pump/100 day = W*24*100 =	1328888.89	kW hr/year
Cost of Heat pump elec energy = E_p *0.18 =	239200.0	SR/year

As shown from above calculations:

The cost of using electricity in heating is the highest

The costs of using heat pump or natural gas are closed.

For Emissions:

Assume the efficiency of the power station is η_{ps}= 30%, the amount of the fuel needed in the power station and natural gas heater is proportional to heat added in the boiler of power

station and gas heater:

For electric heating the heat needed in the boiler $Q_{be} = Q/\eta_{ps}$ = 6460 kW

For natural gas heating the heat needed in heater $Q_g = Q/\eta_{ps}$ = 2422 kW

For heat pump heating the heat needed in the boiler $Q_{bhp} = W/\eta_{ps}$ = 1845 kW

The fuel needed in the power station to supply heat pump power is the lowest.

Then, the emission will be the lowest for using the heat pump in heating.

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