Chapter 2.7: Cogeneration

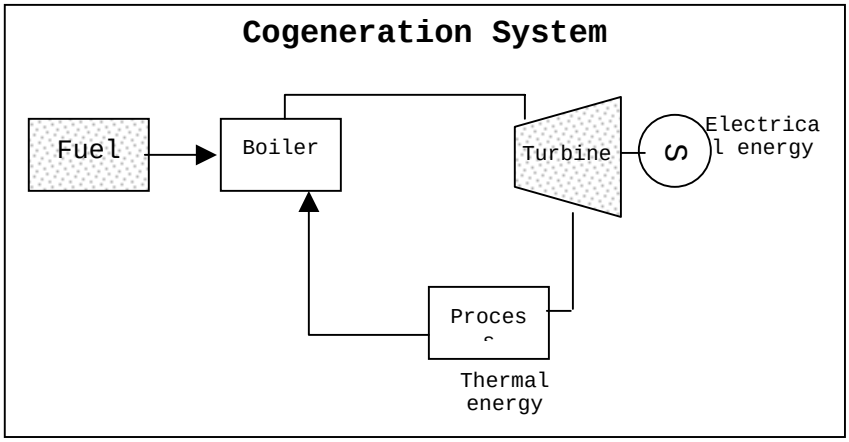
Part-I: Objective type questions and answers

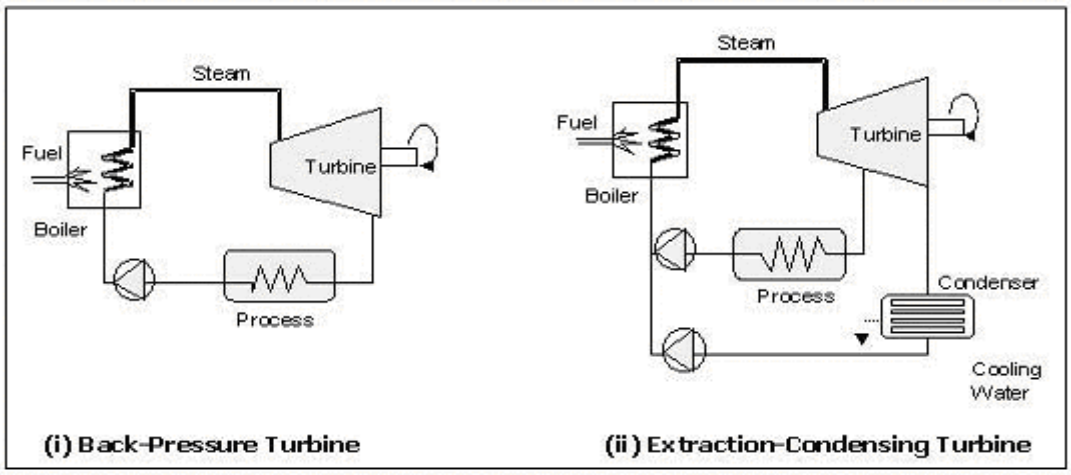
1.	In cogeneration, the system efficiencies can go up to ------ a) 70% b) 80% c) 90% d) 60%
2.	Cogeneration is the simultaneous generation of ----------. a) heat and power b) steam and condensate c) Mechanical Energy and power d) All the above
3.	In the context of cogeneration turbine, thermodynamic process taking place due to: a) contraction b) expansion c) condensation d) all the above
4.	Rankine cycle is related to a) boiler b) steam turbine c) condenser d) all the above
5.	Find the thermodynamic cycle not related to cogeneration. a) Brayton cycle b) Rankine cycle c) Otto cycle d) Bell-Coleman cycle
6.	In a combined cycle power plant consisting of gas turbine and waste heat boiler, the exhaust gas temperature is ____. a) around 150 °C b) around 500 °C c) around 300 °C d) around 400 °C
7.	Match the following: Cogeneration system / Over all efficiency (%) 1. Reciprocating engine – i) 70 – 85 2. Gas turbine – ii) 60 – 80 3. Extraction-condensing steam turbine – iii) 75-85 4. Back pressure steam turbine – iv) 84-92 1-iii; 2-i; 3-ii, 4-iv
8.	_____ type of steam turbines have high power to heat ratio a) back pressure turbine b) gas turbine c) extraction condensing turbine d) None of the above
9.	In a glass industry, exhaust gas from the glass melting furnace is used for power generation by installing steam boiler and turbine. Then the type of co-generation is called as: a) gas turbine b) diesel generator c) topping cycle d) bottom cycle

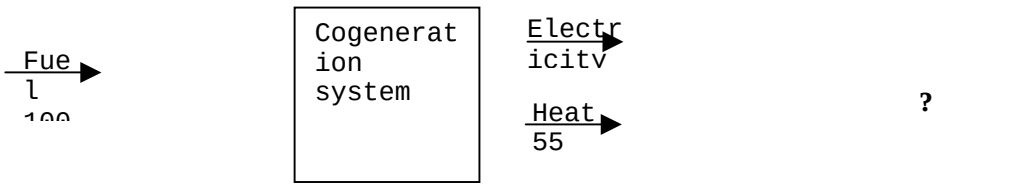
10.	The equipment having the highest efficiency in case of conventional power plant is --- a) boiler b) turbine c) generator d) cooling tower
11.	The overall efficiency of combined cycle cogeneration is of the order of: a) 69 – 83 b) 90 – 95 c) 70 – 90 d) 55 – 60
12.	The cogeneration system which has high overall system efficiency is ---- a) Gas turbine b) Reciprocating engine c) Back pressure steam turbine d) Combined cycle
13.	The statement "the overall thermal efficiency of an extraction condensing turbine in cogeneration system is lower than that of back pressure turbine system". State whether True / False?
14.	The ratio of actual work output of the turbine to the net energy input is termed as----- a) Overall efficiency b) Generator efficiency c) Turbine efficiency d) None of the above
15.	Heat to power ratio in a paper industry is in the range of ---------- a) 1.1 – 4.5 b) 1.5 – 2.5 c) 0.8 – 3.0 d) 1.5 – 2.5
16.	Heat to power ratio of combined cycle cogeneration is in the range of---------- a) 4.0 – 5.0 b) 1.0 – 1.7 c) 2.0 – 10 d) 1.0 – 5.0
17.	A gas turbines operates under exacting conditions of ____. a) low speed & low temperature b) low speed & high temperature c) high speed & low temperature d) high speed & high temperature
18.	Air compressor alone consumes about ------- of the energy generated in a gas turbine a) 20-30% b) 30-40% c) 40-50% d) 50-60%
19.	Which one of the following cannot be used as fuel for the gas turbine: a) naphtha b) LPG c) natural gas d) LSHS
20.	Cogeneration concept is not applicable to which type of industry? a) sugar b) paper & pulp c) refinery d) refractory

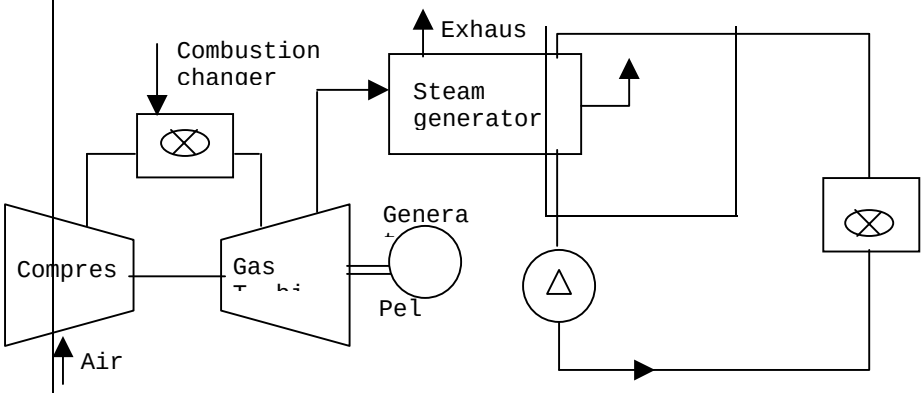
Part-II: Short type questions and answers

1.	What are the efficiency figures for a conventional power plant? How much of energy is lost in transmission and distribution of electricity The efficiency of conventional power plant is around 35%. Around 10-15% of losses are associated with the transmission and distribution of electricity in the electrical grid.

2.	What is cogeneration? Explain Briefly. Cogeneration is the sequential generation of two different forms of useful energy from a single primary energy source. The two different forms of energy are: - Electrical and thermal energy - Mechanical energy and thermal energy  In conventional power plant efficiency is only 35% and remaining 65% of energy is lost. In cogeneration system efficiency can go up to 90%. Cogeneration is also known as combined heat and power (CHP) and total energy system. Cogeneration offers energy savings ranging between 15-40%.
3.	Write the other known names of cogeneration? Cogeneration is also known as 'combined heat and power (CHP)' and 'total energy system'.
4.	What percentage of input energy escapes through exhaust of turbine steam or gas? When steam or gas expands through a turbine, nearly 60 to 70% of the input energy escapes with the exhaust steam or gas.
5.	Why cogeneration system efficiency will be higher? Cogeneration is the simultaneous generation of heat and power, both of which are used. Electricity generated by cogeneration plant is normally used locally and hence the transmission and distribution losses are negligible.
6.	Explain gas turbine cogeneration system? In the gas turbine energy input comes from the fuel that is injected into the combustion chamber. The gas/air mixture drives the turbine with high temperature waste gases existing to the atmosphere. If steam is generated using this waste heat for the process it is called a 'gas turbine cogeneration system'.
7.	Explain the term 'back pressure steam' in steam turbines. In the back pressure steam turbine, steam enters the turbine chamber at high pressure and expands to low or medium pressure. Enthalpy difference is used for generating power/work.

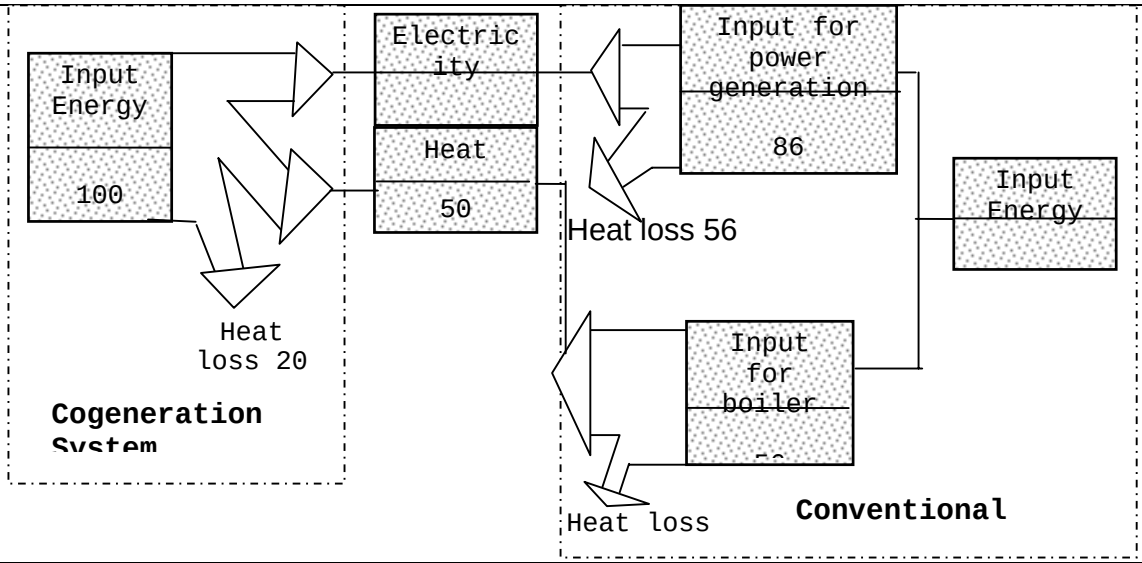
8.	Differentiate "Back Pressure Turbine" and "Extraction Condensing Turbine" through sketches?  **Schematic diagrams of steam turbine cogeneration systems**
9.	What is the main difference between "Topping Cycle" and "Bottoming Cycle"? A topping cycle plant generates electricity or mechanical power first whereas a bottoming cycle plant generates heat first.
10.	State the principle of Rankine Cycle cogeneration? The Rankine Cycle provides an ideal outlet for waste heat recovered from any process or generation situation. Instead of condensing the entire steam if the back pressure steam is utilised in the process, it is called a Rankine cycle cogeneration.
11.	What is heat to power ratio for a cogeneration application? Heat to power ratio is defined as the ratio of thermal energy to electricity required by the energy consuming facility. It can be expressed in different units such as Btu/kWh, kcal/kWh, lb./hr/kW, etc.
12.	Compare the "Overall cogeneration efficiencies of various configurations? ***Cogeneration System*** — ***Overall efficiency (percent)*** *Back-pressure steam turbine* — 84-92 *Extraction-condensing steam turbine* — 60-80 *Gas turbine* — 70-85 *Combined cycle* — 69-83 *Reciprocating engine* — 75-85

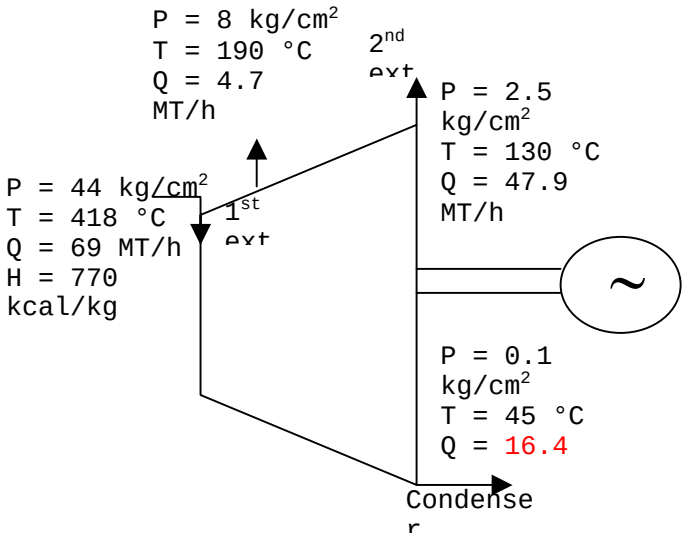
13.	List important technical parameters to be considered in a cogeneration system. a) Heat to power ratio b) Quality of thermal energy needed c) Load pattern d) Fuel available e) System reliability f) Dependent systems Vs independent system g) Retrofit Vs new installation h) Electricity buy back i) Local environment consideration
14.	What is heat-to-power ratio and state its importance? Heat to power ratio is defined as the ratio of thermal energy to electrical energy on the basis of same energy unit (kW) Heat to power ratio is one of the most important technical parameters influencing the selection and type of cogeneration system and should match with the cogeneration system which is planned to be installed.
15.	Evaluate efficiency of the following. Cogeneration  Efficiency of cogeneration system $\left(\frac{30+55}{100}\right)x100 = 85\%$
16.	Match the following. Cogeneration system — Heat to power ratio kW_{th}/KW_e a) Back pressure steam turbine — 1) 4.0 – 14.3 b) Extraction-condensing steam turbine — 2) 1.1 – 2.5 c) Gas turbine — 3) 1.0 – 1.7 d) Combined cycle — 4) 1.3 – 2.0 e) Reciprocating engine — 5) 2.0 – 10 (a) – (1) (b) – (5)

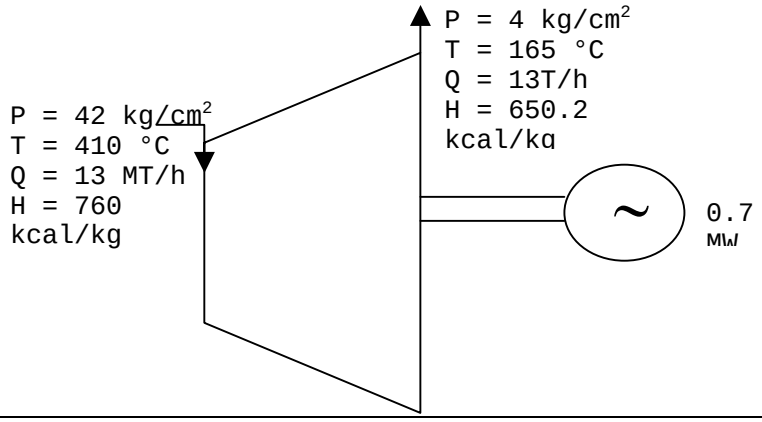
	(c) – (4) (d) – (3) (e) – (2)
17.	Advantages and disadvantages of diesel engine and waste heat recovery boiler and cooling water heat exchangers cogeneration. **Advantages** • Low civil construction cost due to block foundation and least number of auxiliaries • High power efficiency • Best suitability as stand by power source **Disadvantageous** • Low overall efficiency • Limited suitability for low quality fuels • Availability of low temperature steam • High maintenance prone
18.	In a power plant terminology, what do you mean by combined cycle operation? Combined cycle form a hybrid which includes Brayten cycle in the first portion and standard Rankine cycle following it is the combination.
19.	Draw a typical gas turbine based cogeneration system. Typical cycle is shown below. 
20.	Space heating and cooling application falls under cogeneration heat recovery – explain? One of the topping cycle cogeneration, where hot water from an engine jacket cooling system flowing to a heat recovery boiler, it is converted to process steam and hot water for space heating and cooling applications.

Part-III: Long type questions and answers

1.	Does Cogeneration make sense? If yes, explain briefly Cogeneration is an energy efficient technology. It has an advantage of reducing the primary energy use therefore reduces the energy cost; while providing the same quantity of two different required forms of energy.

	The following figure shows a comparison of energy balance for typical cogeneration system and conventional system power generation system.
	
	Conventional energy supply system requires about 40% more primary energy then cogeneration system to meet the same energy needs. The soundness of cogeneration system can be highlighted more by a practical example, given below. A plant needs a total energy of 11.7 MW of energy and 10.7 tph of steam at low pressure and 4.7 MW of electrical energy. The primary energy requirement for a conventional energy supply system is 21.7 MW. However, a cogeneration system can provide the same energy services by using 15.9 MW of primary energy.
2.	Where does cogeneration find its application? Where there is simultaneous need for heat and power (electrical and thermal (mechanical)), there is a potential for cogeneration. However, significant savings is energy costs can be achieved and cogeneration system can be more meaningful if the energy consuming facility has the following characteristics. 1) Reliable power requirement 2) Utilisation of higher thermal energy than electricity 3) Quite stable load patterns of thermal energy and electricity 4) Long operating hours 5) High price of grid electricity or inaccessibility to grid Thermal energy need of a facility may be for the following purposes. o Drying, preheating, process steam, o producing chilled water, o hot water generation, heating fluids etc. Some of the application areas where cogeneration has been successfully practised are listed below: ✓ Industrial cogeneration: Food processing, Pharmaceutical, Pulp and paper, Refinery, Fertilizers, Textile, Brewery and distillery, Steel, cement, Glass, Ceramic industry, etc. ✓ Residential / commercial / institutional cogeneration: Hospitals, Hotels and Commercial

	buildings There are typical clients of cogeneration, however the feasibility of cogeneration system is very much site specific and depends on many factors.
3.	Explain any four types of topping cycle cogeneration systems? The four types of topping cycle cogeneration systems are: (1) A gas turbine or diesel engine producing electrical or mechanical power followed by a heat recovery boiler to create steam to drive a secondary steam turbine. This is called a combined-cycle topping system. (2) The second type of system burns fuel (any type) to produce high-pressure steam that then passes through a steam turbine to produce power with the exhaust provides low-pressure process steam. This is a steam-turbine topping system. (3) A third type employs hot water from an engine jacket cooling system flowing to a heat recovery boiler, where it is converted to process steam and hot water for space heating. (4) The fourth type is a gas-turbine topping system. A natural gas turbine drives a generator. The exhaust gas goes to a heat recovery boiler that makes process steam and process heat.
4.	From the given diagram, evaluate (i) heat load on cooling tower (ii) power generation in MW. 
	Input heat to turbine (a) : 69,000 x 770 = 5,31,30,000 kWh Output heat at different streams 1st extraction (b) : 4700 x 672.6 = 31,61,220 Kcal/h 2nd extraction (c) : 47,900 x 650.2 = 3,11,44,580 Kcal/h Condenser heat load (d) : 16,400 x 571.6 = 93,74,240 Kcal (i) Heat load on cooling tower : 9374240 Kcal (ii) Heat equivalent to power generation: Input-Output : 5,31,30,000 – 4,36,80,040 : 9449960 Kcal/h Power generation : 9449960/860 : 10,988 kW : 10.99 MW

5.	From the given diagram, evaluate the cogeneration efficiency. 
	Input heat to turbine (a) : 13,000 x 760 = 98,80,000 Kcal/h Output heat as extraction : 13,000 x 650.2 = 84,52,600 Kcal/h Thermal efficiency : total useful heat/input heat : 8452600/9880000 = 0.855 = 85.5% Electrical efficiency (Ep) : Electrical energy produced/input heat : 602000/9880000 = 0.06 = 6% Overall cogeneration efficiency : Eth + Ep = 85.5 + 6 : 91.5%