



TES SYSTEMS AND CHP SYSTEMS

CEM REFRESHER TRAINING

KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP

FOR ENERGY MANAGEMENT AND EFFICIENCY PROFESSIONALS





PRIME MOVERS FOR COGENERATION

FOR ENERGY PROFESSIONALS

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ENERGY SPECIALIST CURRICULUM



WHAT SHOULD YOU LEARN



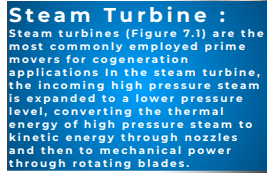
Prime Movers for Cogeneration

Relative Merits of Cogeneration Systems

Calculating Basic Fuel Equation for CHP Systems

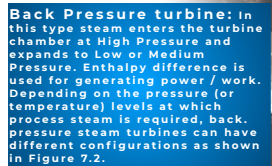
CHP Technologies





Steam Turbine :

Steam turbines (Figure 7.1) are the most commonly employed prime movers for cogeneration applications in the steam turbine, the incoming high pressure steam is expanded to a lower pressure level, converting the thermal energy of high pressure steam to kinetic energy through nozzles and then to mechanical power through rotating blades.



In extraction and double extraction back pressure turbines, some amount of steam is extracted from the turbine after being expanded to a certain pressure level. The extracted steam meets the heat demands at pressure levels higher than the exhaust pressure of the steam turbine.

The efficiency of a back pressure steam turbine cogeneration system is the highest. In cases where 100 per cent back pressure exhaust steam is used, the only inefficiencies are gear drive and electric generator losses, and the inefficiency of steam generation. Therefore, with an efficient boiler, the overall thermal efficiency of the system could reach as much as 90 per cent.



The fuel is burnt in a pressurized combustion chamber using combustion air supplied by a compressor that is integral with the gas turbine. In conventional Gas turbine (Figure 7.11), gases enter the turbine at temperatures between 1000 to 1500°C and leave at 400 to 500°C. The very hot pressurized gases are used to turn a series of turbine blades, and the shaft on which they are mounted, to produce mechanical energy. Residual energy in the form of a high flow of hot exhaust gases can be used to meet, wholly or partly, the thermal (steam) demand of the site. Waste gases are exhausted through a stack at 150 to 200°C. Gas turbine particularly suitable for high-grade heat supply.

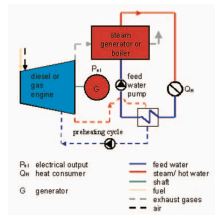
The available mechanical energy can be applied in the following ways:

- ☒ to produce electricity with a generator (most applications);

To drive pumps, compressors, blowers, etc.

A gas turbine operates under exacting conditions of high speed and high temperature. The hot gases supplied to it are free of any particles of dust or grit which would erode the blades and must contain not more than minimal amounts of contaminants, which would cause corrosion under operating conditions. High premium fuels are therefore most often used, particularly natural gas. Distillate oils such as gas oil are also suitable, and sets capable of using both are often installed to take advantage of cheaper interruptible gas tariffs. LPGs and Naphtha are also suitable, LPG being a possible fuel in either gaseous or liquid form.

RECIPROCATING ENGINE SYSTEMS



This system provides process heat or steam from engine exhaust. The engine jacket cooling water heat exchanger and lube oil cooler may also be used to provide hot water or hot air. There are, however, limited applications for this.

As these engines can use only fuels like HSD, distillate, residual oils, natural gas, LPG etc. and as they are not economically better than steam/gas turbine, their use is not widespread for co-generation. One more reason for this is the engine maintenance requirement.

RELATIVE MERITS OF COGENERATION SYSTEMS

Variant	Advantages	Disadvantages
Back pressure	<ul style="list-style-type: none"> High fuel efficiency rating 	<ul style="list-style-type: none"> Little flexibility in design and operation
Steam turbine & fuel firing in boiler	<ul style="list-style-type: none"> Simple plant Well-suited to low quality fuels 	<ul style="list-style-type: none"> More capital investment Low fuel efficiency rating High cooling water demand More impact on environment High civil const. cost due to complicated foundations
Gas turbine with waste heat recovery boiler	<ul style="list-style-type: none"> Good fuel efficiency Simple plant Low civil const. Cost Less delivery period Less impact on environment High flexibility in operation 	<ul style="list-style-type: none"> Moderate part load efficiency Limited suitability for low quality fuels
Combined gas & steam turbine with waste heat recovery boiler	<ul style="list-style-type: none"> Optimum fuel efficiency rating Low relative capital cost Less operation period Quick start up & stoppage Less impact on environment High flexibility in operation 	<ul style="list-style-type: none"> Average to moderate part-load efficiency Limited suitability for low quality fuels
Diesel Engine & waste heat recovery Boiler & cooling water heat exchanger	<ul style="list-style-type: none"> Low civil const. Cost due to block foundations & least no. of auxiliaries High Power efficiency Better suitability as stand by power source 	<ul style="list-style-type: none"> Low overall efficiency Limited suitability for low quality fuels Availability of low temperature steam Highly maintenance prone.

COMBINED HEAT AND POWER

☑ Also known as:

- Combined heat and power (CHP)
- Cogeneration
- Combined cooling, heating and power (CCHP)
- Building cooling, heating and power (BCHP)

☑ Definition:

- Simultaneous production and use of useful mechanical and useful thermal energy
- Mechanical energy is frequently used to turn a generator producing electrical energy
- Thermal energy can be used to generate cooling (i.e., absorption chiller)

WHY COGENERATION?

✓ CHP has the opportunity to:

- ➔ Improve system efficiency (as compared to typical power generation without useful heat recovery)
- ➔ Reduce total operating costs (compared to purchasing or generating electricity and heat energy in separate systems)
- ➔ Improve system reliability and availability (when CHP is used as a primary and the utility systems are used as a back-up source)

TYPES OF CYCLES

✓ Three primary types of cycles:

- ➔ Topping cycle
- ➔ Bottoming cycle
- ➔ Combined cycle (which is usually a dual topping cycle)

✓ Why is the type of cycle important?

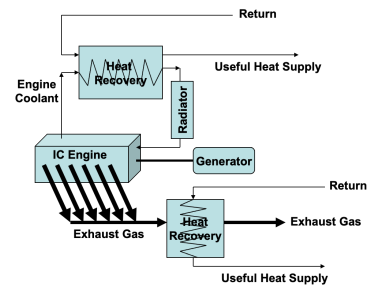
- ➔ Regulations apply differently based on type of cycle
- ➔ Bottoming cycle
- ➔ More on this when we get to qualified facilities

TOPPING CYCLE

✓ Primary energy first produces mechanical energy and residual thermal energy is recovered and used

- ➔ Example 1: High-pressure boiler steam is used to power a turbine. The resulting shaft power turns a motor or generator. In addition, steam out of the turbine provides useful heat energy to a process.
- ➔ Example 2: Diesel engine turns a generator producing electric power. Waste heat recovery is applied to the exhaust gas and engine coolant producing useful hot water.

TOPPING CYCLE EXAMPLE 1



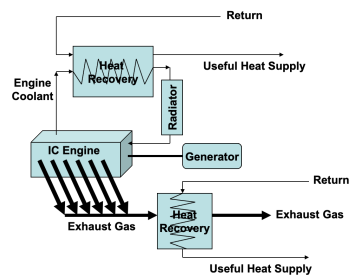
TOPPING CYCLE

✓ Steam enters a back pressure turbine with an enthalpy of 2800 kJ/kg, and exits the turbine with an enthalpy of 2600 kJ/kg. Assume no heat loss in the turbine. If the back pressure steam turbine drives a 95% efficient electric generator, how many kW will be produced? Steam flow rate is 10,000 kg/h.

$$\text{kW}_{\text{prod}} = \frac{10,000 \text{ kg}}{\text{h}} \left| \frac{(2800 - 2600) \text{ kJ}}{\text{kg}} \right| \frac{1 \text{ kWh}}{3600 \text{ kJ}} \left| \frac{0.95}{1} \right|$$

$$= 527.8 \text{ kW}$$

TOPPING CYCLE EXAMPLE 2

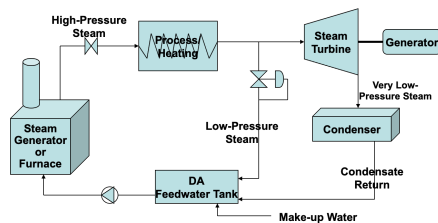


BOTTOMING CYCLE

✓ Primary energy first satisfies a thermal demand, such as a furnace, and residual thermal energy is recovered and used to produce useful mechanical or electrical power.

⇒ Example: A large combustion process, such as a heat treating furnace, where the exhaust is used in a waste heat boiler to develop steam that is used to power a turbine. The resulting shaft power turns a motor or generator.

BOTTOMING CYCLE EXAMPLE

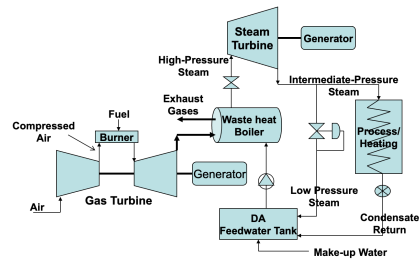


COMBINED CYCLE

✓ Cycle produces useful mechanical energy at two different stages within the process. Residual thermal energy is utilized at least once in the process.

⇒ Example: A combustion (gas) turbine creates shaft power, which powers a generator (a topping cycle). The exhaust gas (perhaps with supplemental firing) is used in a waste heat recovery boiler to develop steam, which is used to power a steam turbine. The shaft power from the turbine is used to power a motor or generator (normally a topping cycle but used here as a bottoming cycle). In addition, steam out of the turbine, either as extraction or back-pressure steam, provides useful heat energy to a process. (the useful thermal energy makes this CHP).

COMBINED CYCLE EXAMPLE



CHP TECHNOLOGIES

Technology	Advantages	Limitations
Steam Turbines	Long life Can burn solid fuels	Low electric generating efficiency
Combustion Turbines	High-temperature heat out High efficiency in larger systems Intermediate sizes available	Smaller systems have low electric generating efficiency
Internal Combustion Engines	High efficiency in smaller sizes Small and intermediate sizes available	Low temperature heat recovery
Microturbines	Small and intermediate sizes available	Expensive Reliability needs improvement
Fuel Cells	Small and intermediate sizes available Lowest emissions	Very expensive Not (really) commercially available

BEYOND
SMART CITIES

THANK YOU

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