CH2356 Energy Engineering

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Thermal Power Plants

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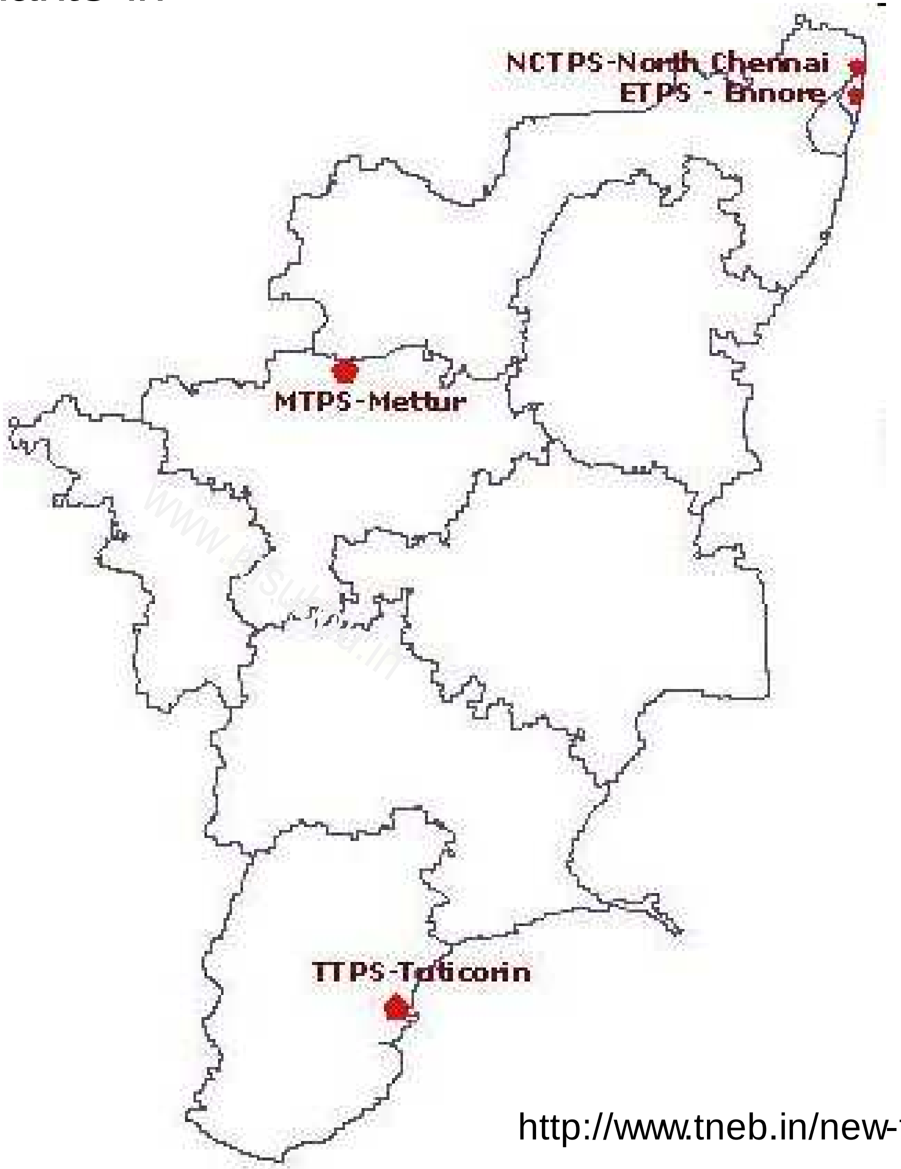
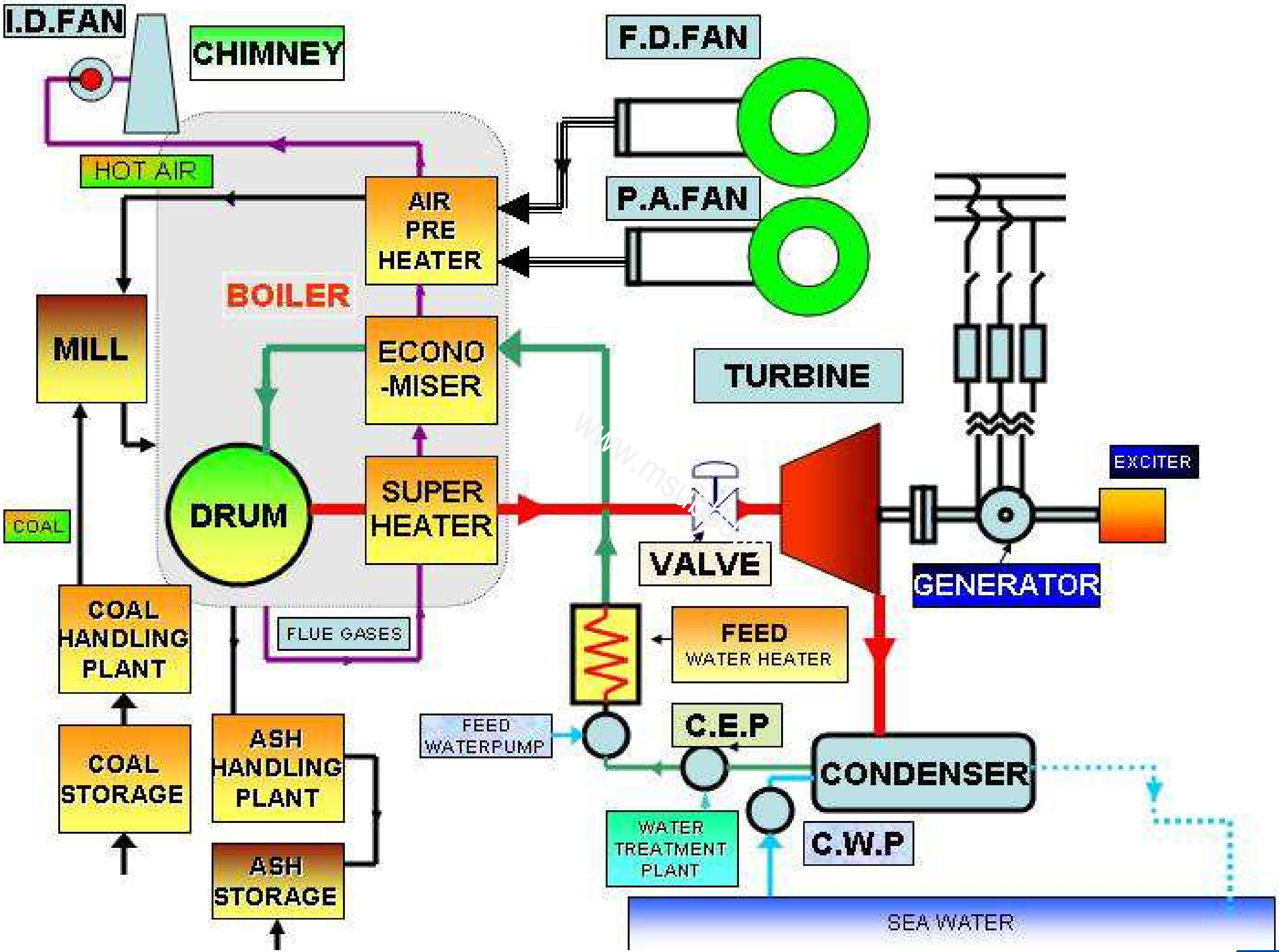
Tuticorin Thermal Power Plant

Coal based thermal power plants in Tamil Nadu (Jan 2011)



http://www.tneb.in/new-thermal.php


I.D.FAN
CHIMNEY
F.D.FAN
HOT AIR
AIR PRE HEATER
P.A.FAN
BOILER
MILL
ECONO -MISER
TURBINE
DRUM
SUPER HEATER
EXCITER
COAL
VALVE
GENERATOR
COAL HANDLING PLANT
FLUE GASES
FEED WATER HEATER
FEED WATERPUMP
C.E.P
CONDENSER
ASH HANDLING PLANT
COAL STORAGE
WATER TREATMENT PLANT
C.W.P
ASH STORAGE
SEA WATER

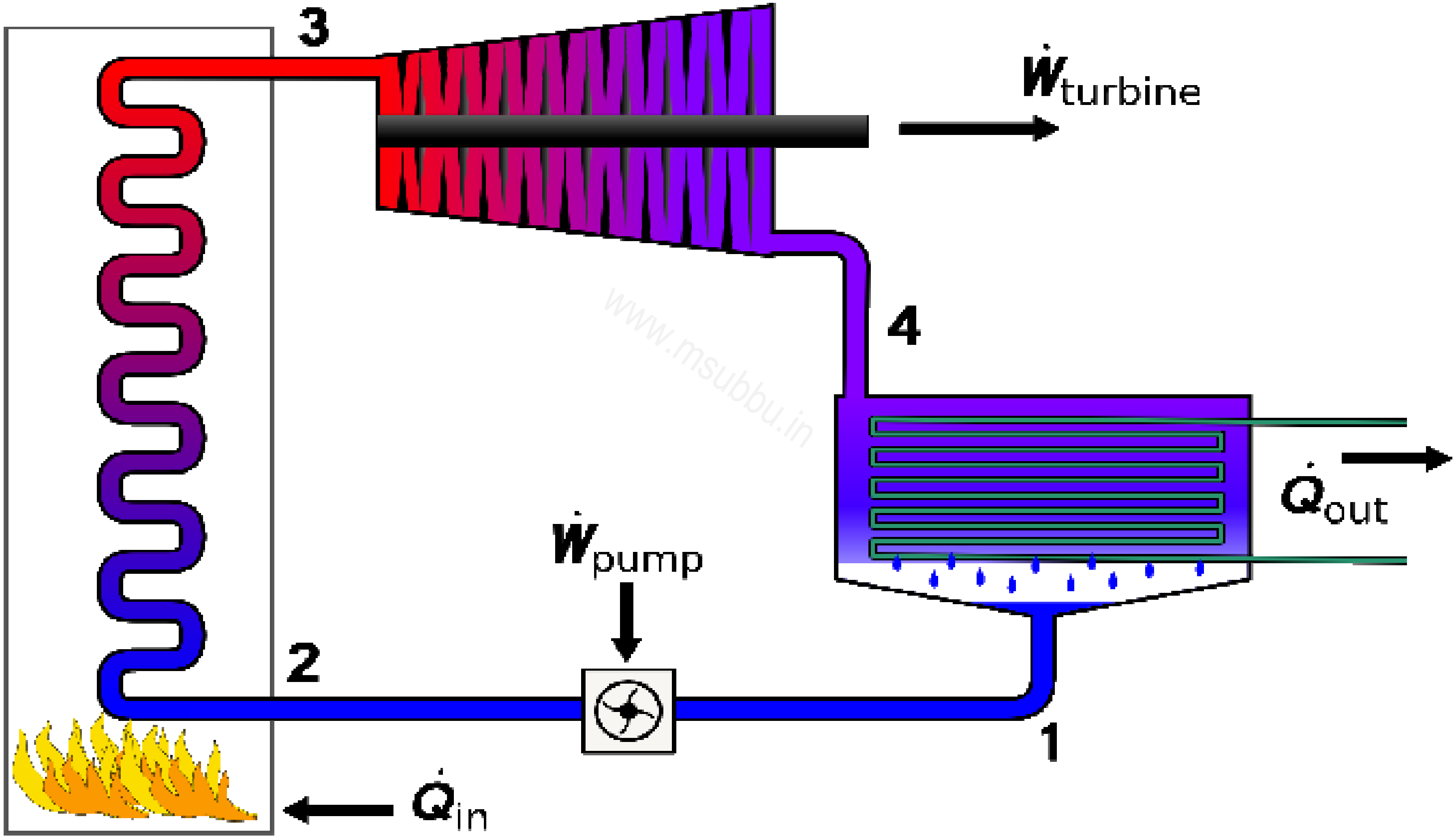
Power Plant Operation

- Coal comes by rail as crushed to <10-cm size and washed. This coal is further reduced to <1mm by the pulverizer in modern coal power plants. Gas-fired plants usually receive the natural gas through the pipeline at about 1-4 MPa.

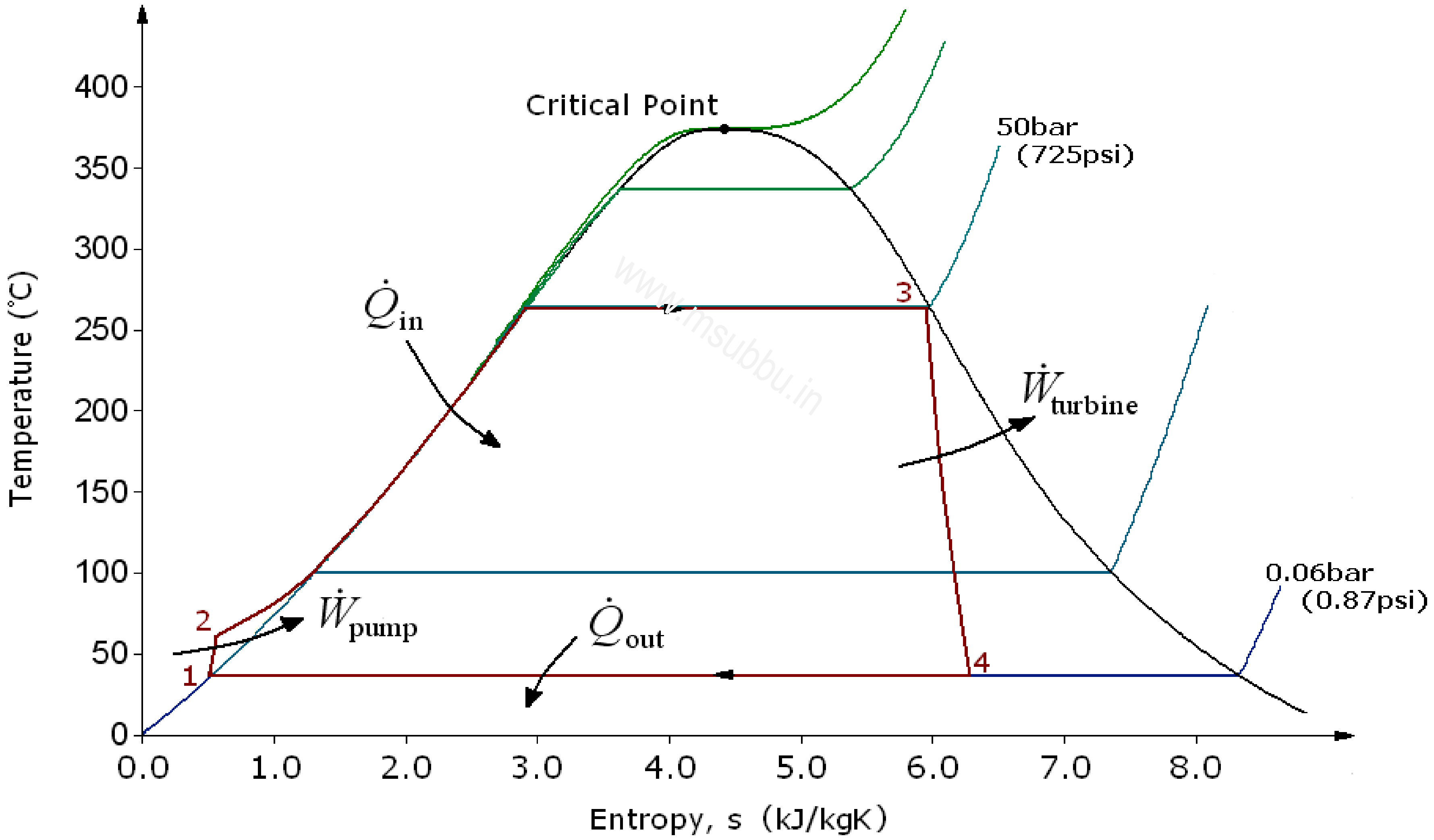
- For complete combustion, air in excess of the stoichiometric ratio is required. Pulverised coal requires 15-20% excess air; oil and gas requires 5-10% excess air.

- The fly ash needs to be captured and removed from stack gases.

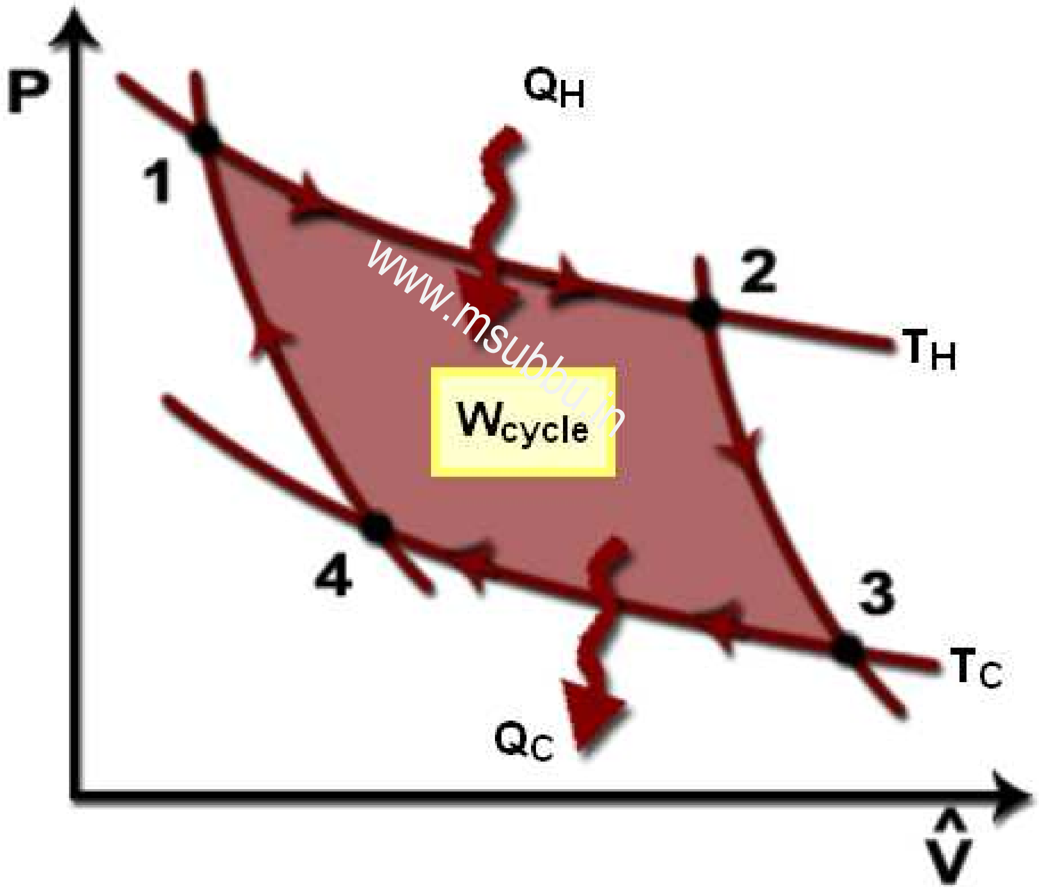
Rankine cycle layout



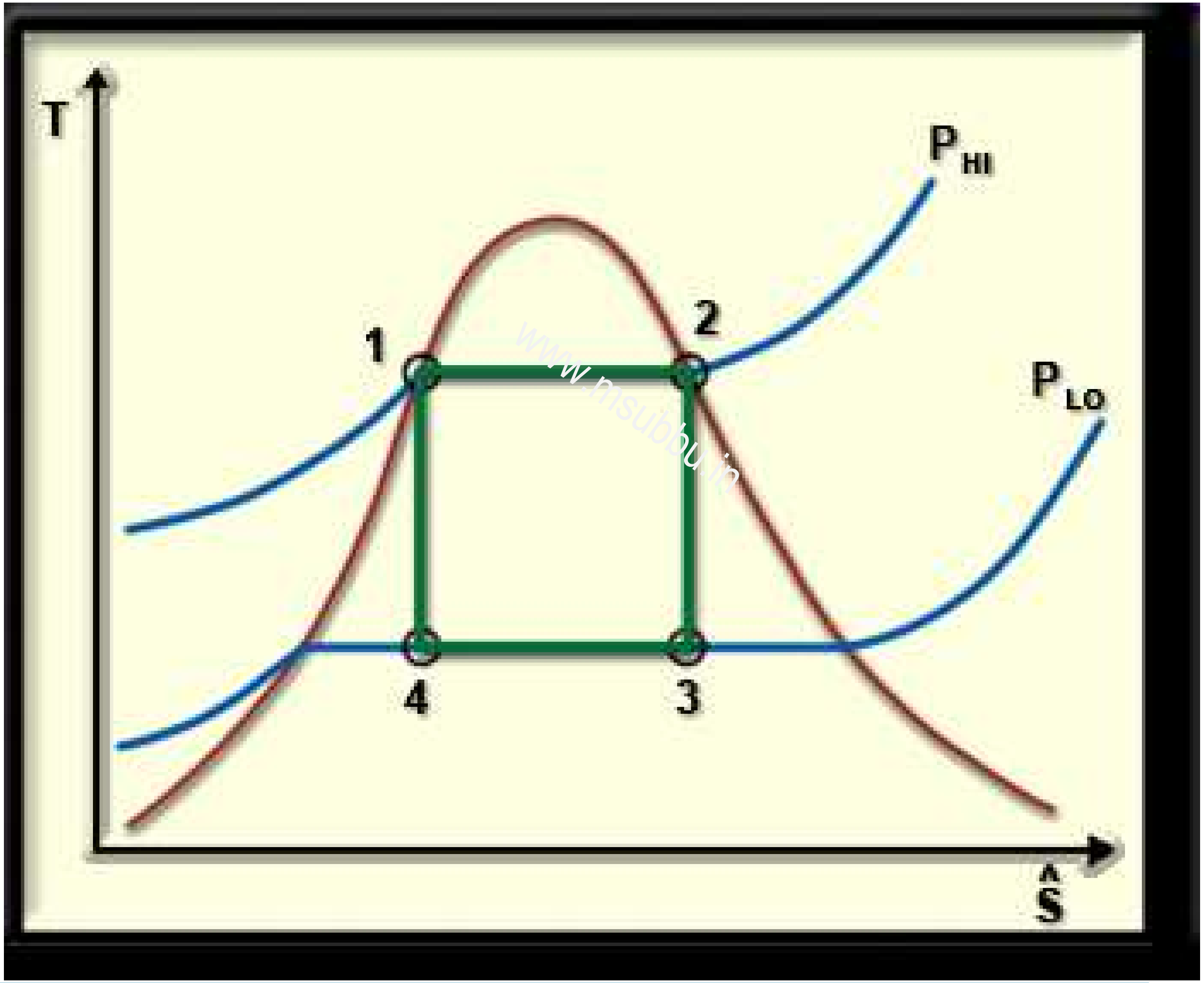
Rankine cycle

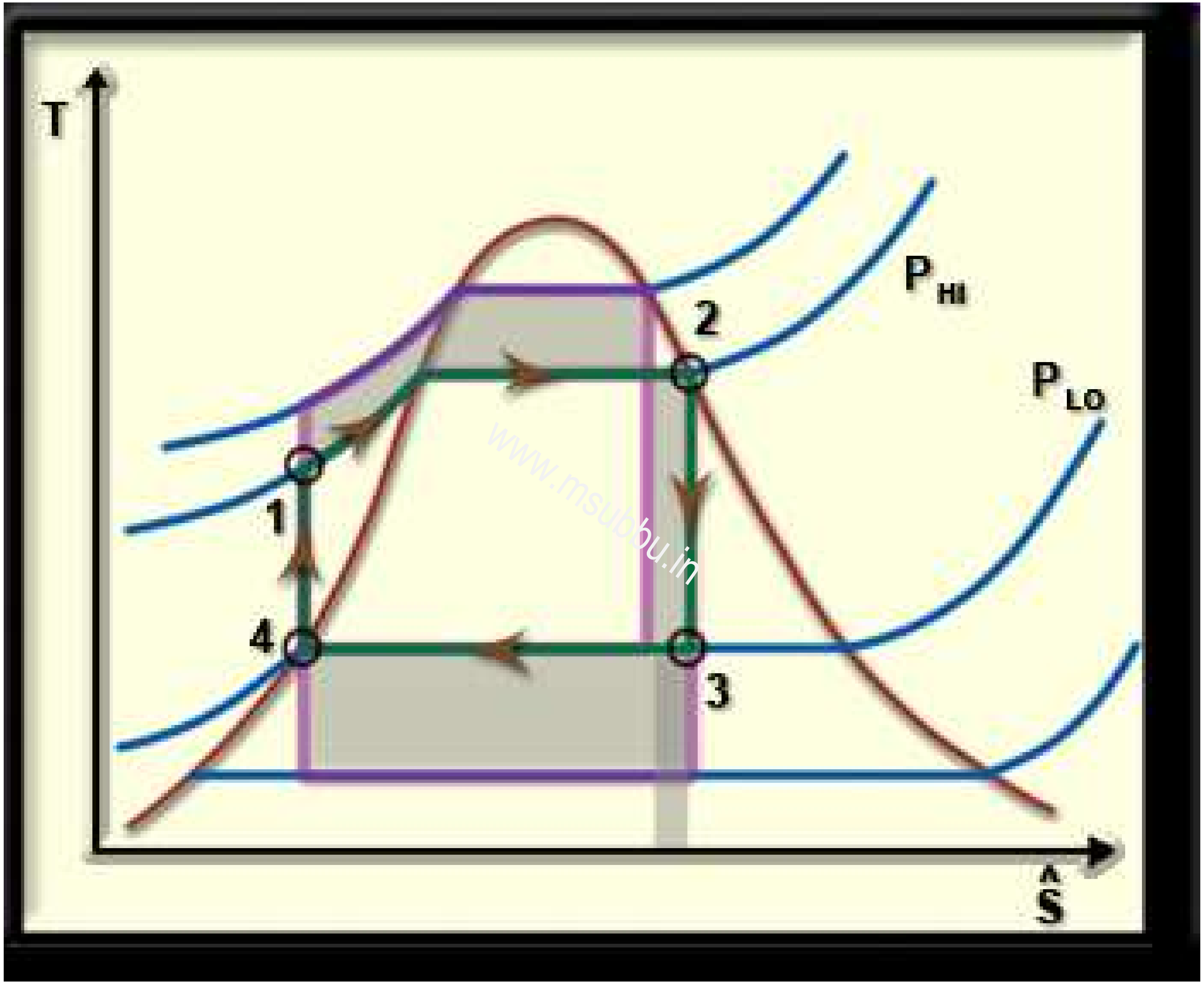


Carnot Cycle

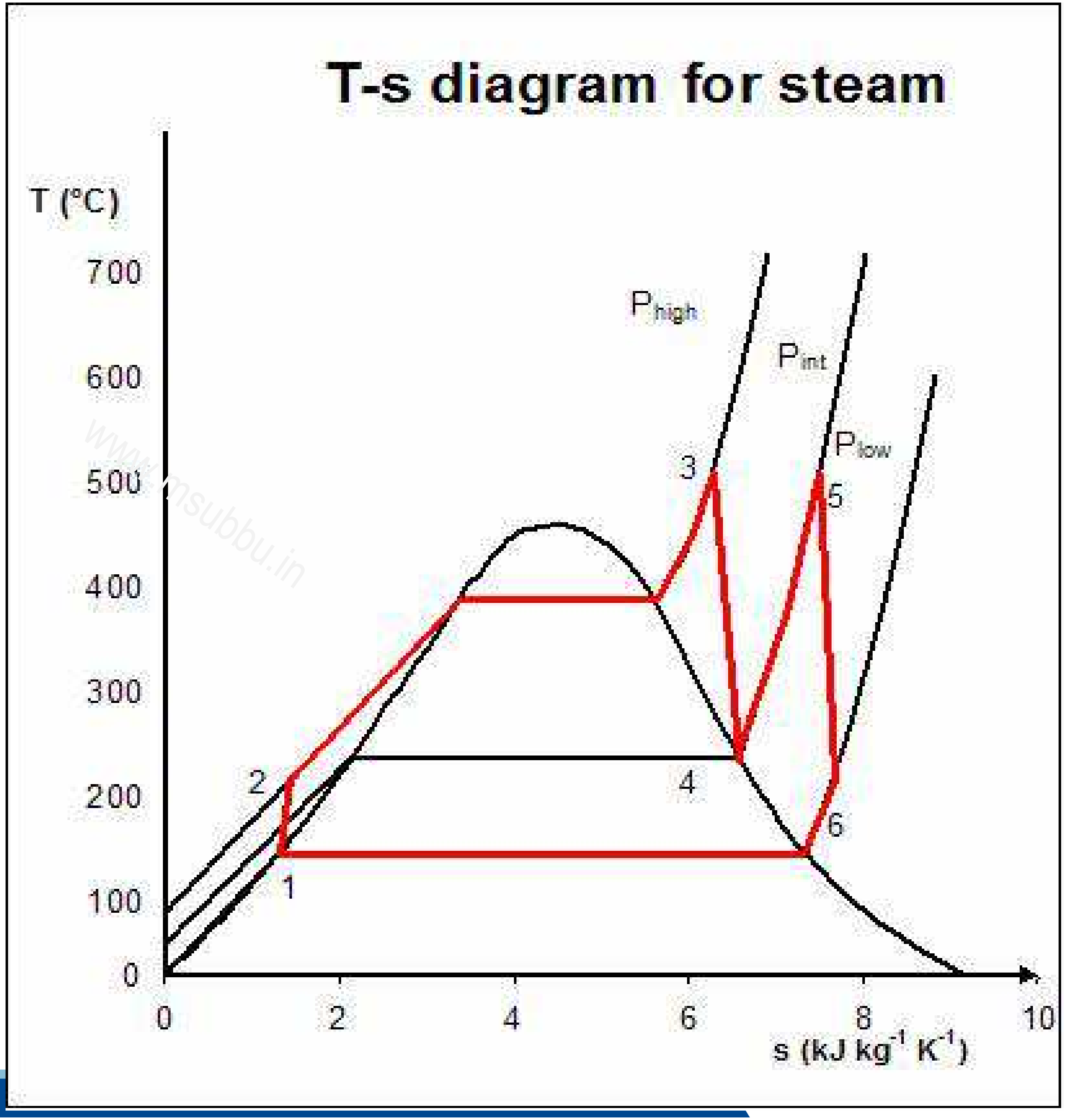


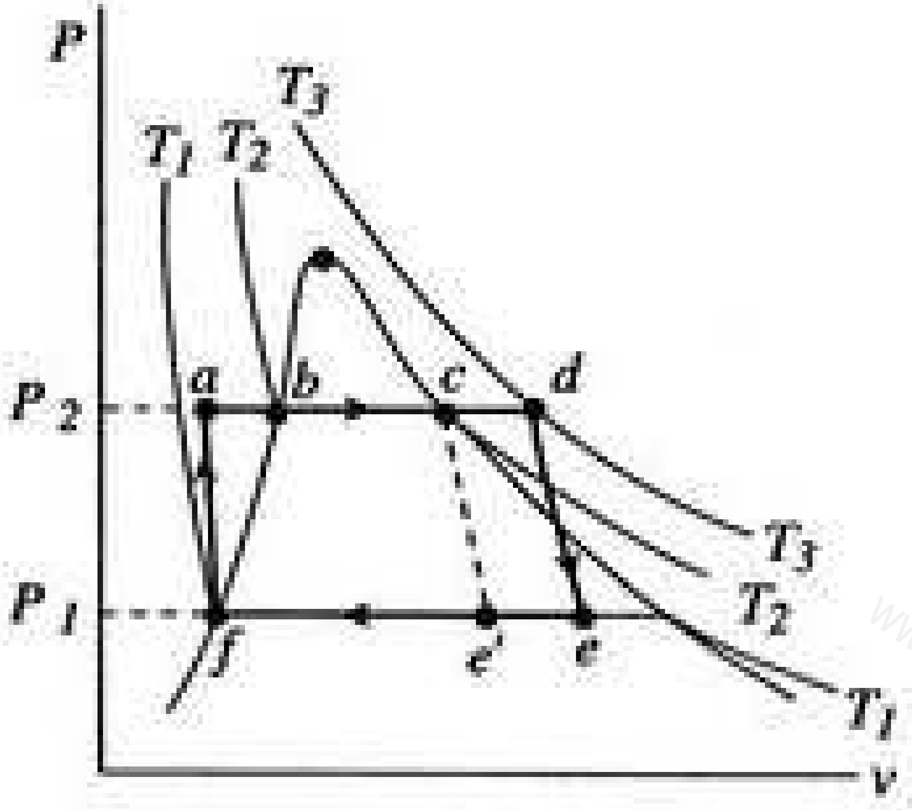
Carnot Cycle

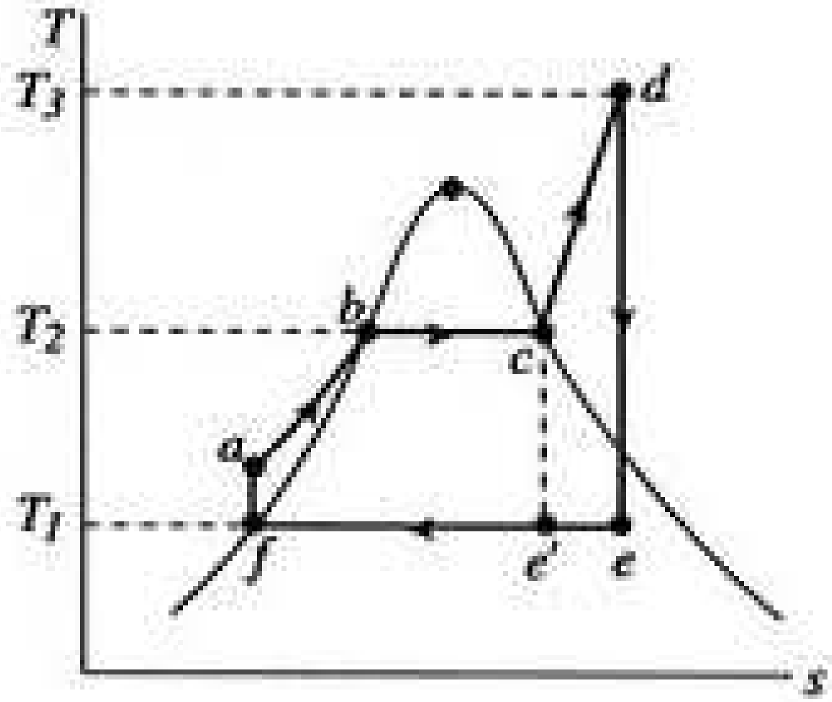


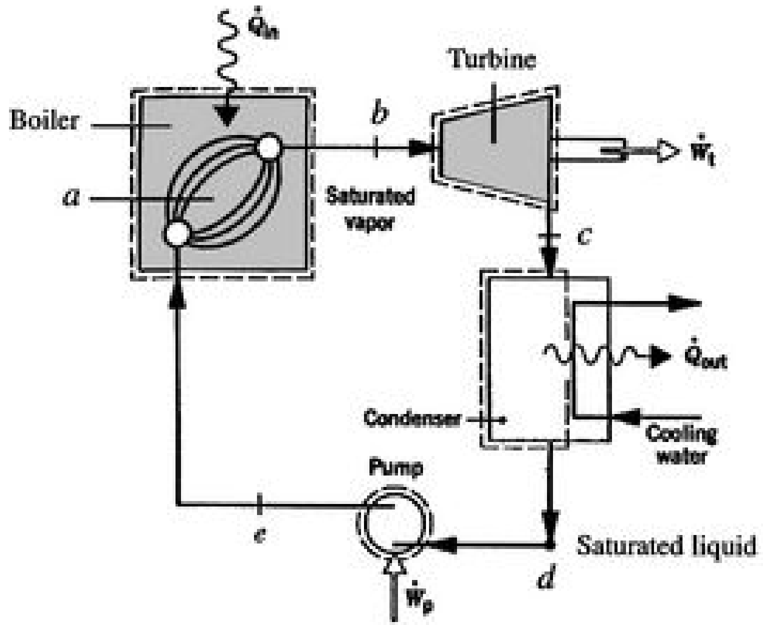

T
P HI
P LO
2
1
4
3
Ŝ

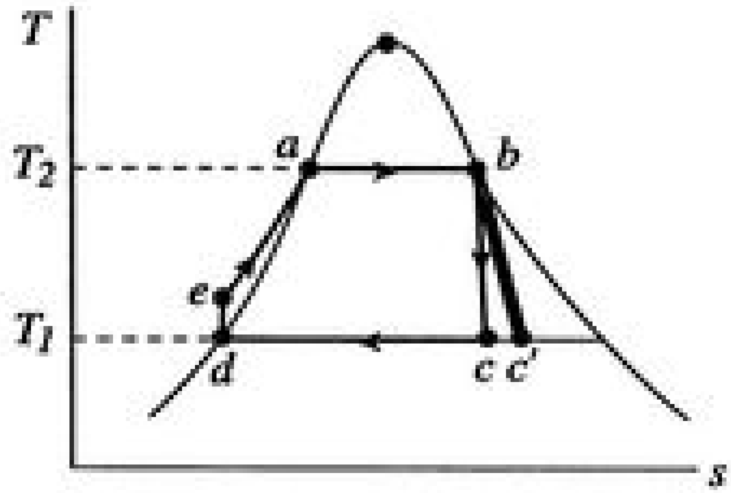
Rankine cycle with reheat

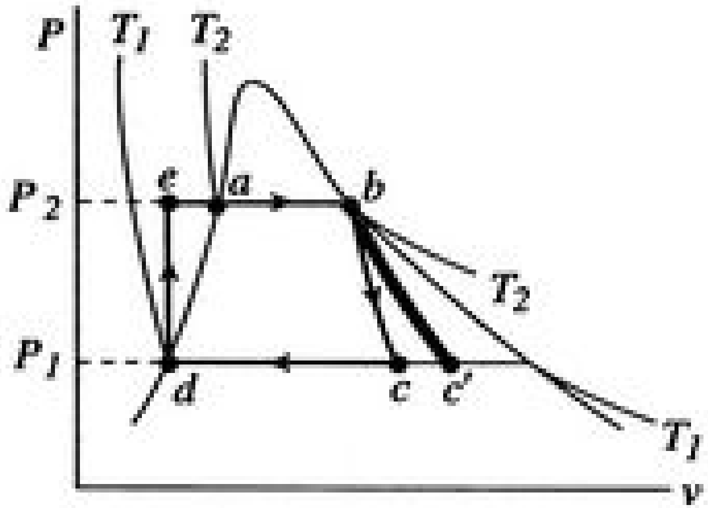


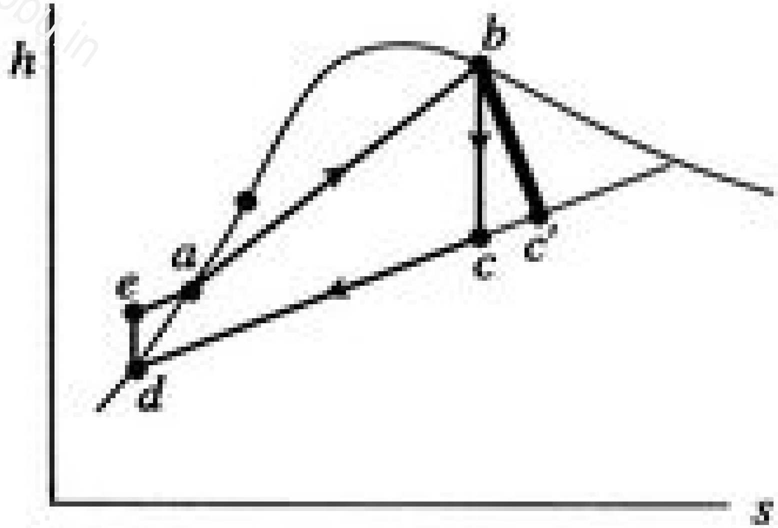

P
T3
T1 T2
P 2
a b c d
P 1
f e' e
T3
T2
T1
v


T
T3
d
T2
b
c
a
T1
f e' e
s

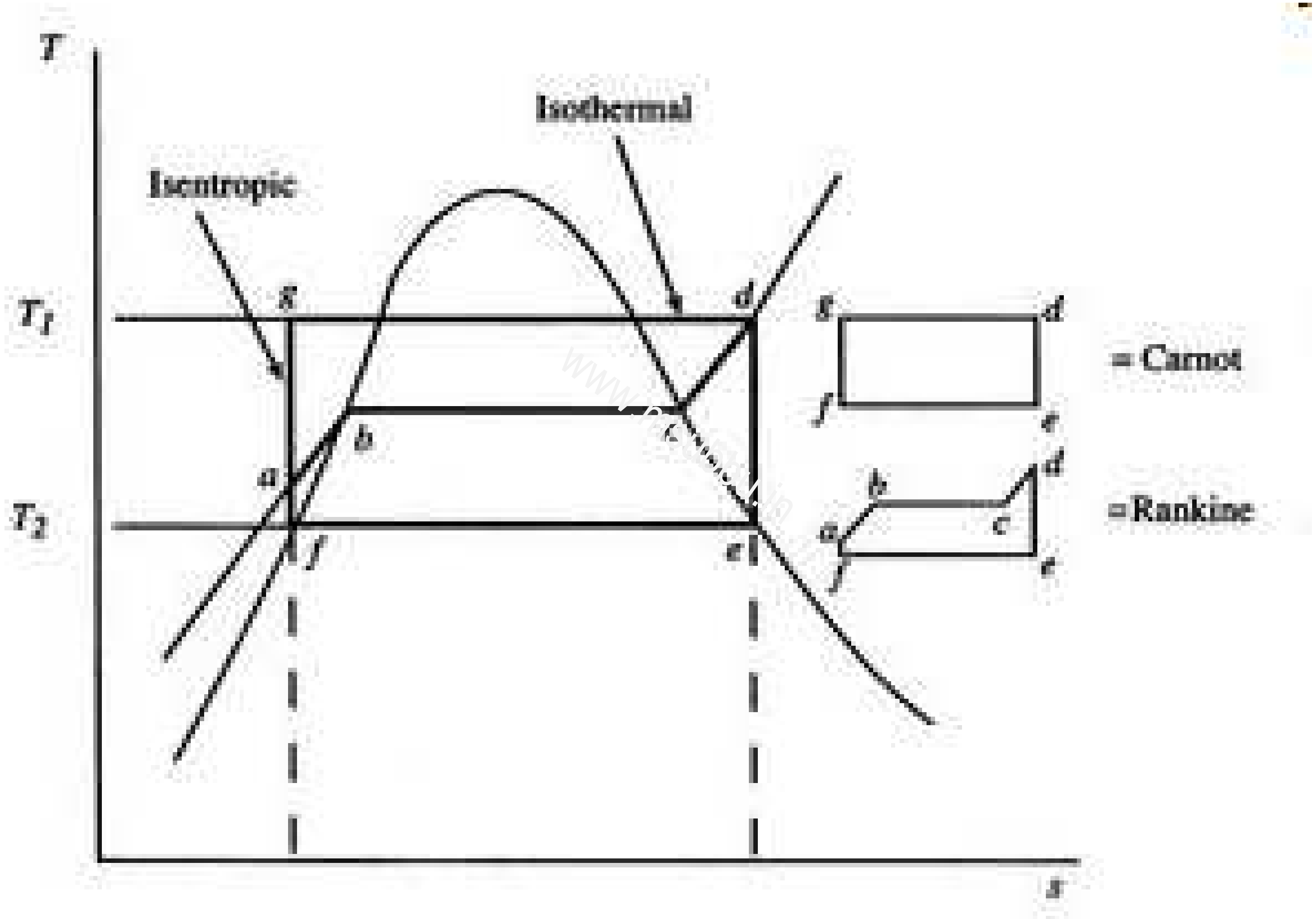

$\dot{Q}_{in}$
Boiler
a
b
Turbine
$\dot{W}_t$
Saturated vapor
c
$\dot{Q}_{out}$
Condenser
Cooling water
Pump
e
Saturated liquid
d
$\dot{W}_p$

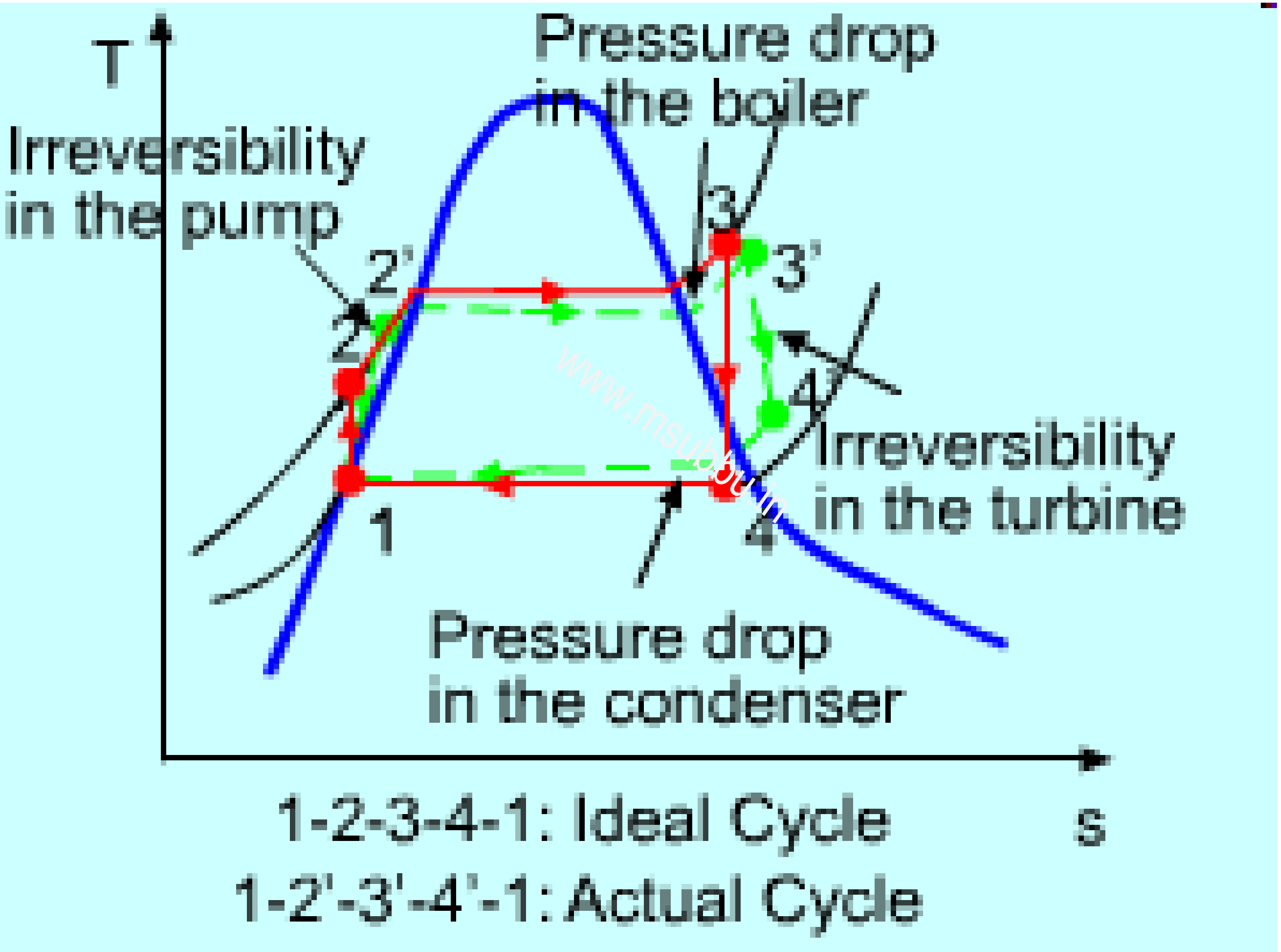

T
T_2
T_1
a
b
e
d
c
c'
s

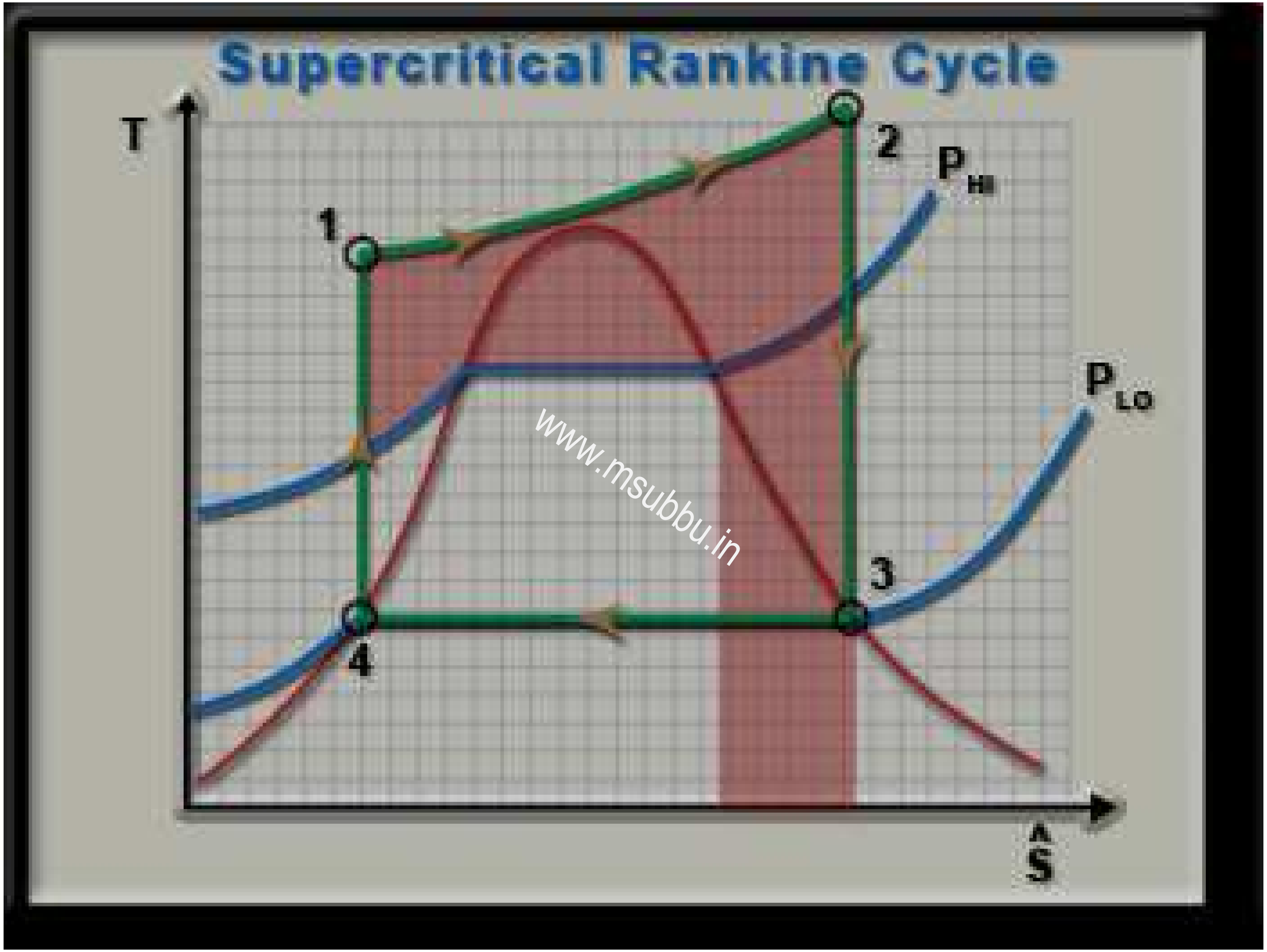

P
T_1
T_2
P_2
P_1
e
a
b
d
c
c'
T_2
T_1
v


h
b
a
e
d
c
c'
s

Comparison of Carnot cycle and Rankine Cycle




T
Irreversibility in the pump
Pressure drop in the boiler
2'
2
3
3'
4'
1
4
Irreversibility in the turbine
Pressure drop in the condenser
s
1-2-3-4-1: Ideal Cycle
1-2'-3'-4'-1: Actual Cycle


Supercritical Rankine Cycle
T
1
2
P HI
P LO
3
4
Ŝ

Power plant operation

- Rankine cycle with reheat – to reduce the formation of water droplets in turbine, and to increase the efficiency of the cycle.
- In order to maximize the efficiency of a steam power plant it is desirable to operate as high a temperature as possible in the super-heater. However, above about 650^{o}C various forms of metal fatigue become significant due to very high temperatures and pressures that the walls of the boiler tubes have to withstand.
- A typical 500 MW coal-fired plant consumes around 250 tonnes of coal an hour.

Efficiency of Thermal Power Plant

- The efficiency of a Rankine cycle is usually limited by the working fluid. Without the pressure reaching super critical levels for the working fluid, the temperature range the cycle can operate over is quite small: turbine entry temperatures are typically 565°C (the creep limit of stainless steel) and condenser temperatures are around 30°C. This gives a theoretical Carnot efficiency of about 63% compared with an actual efficiency of 42% for a modern coal-fired power station.

- The power output or capacity of an electric plant can be expressed in units of megawatts electric (MWe).

Fluidized Bed Combustion

- Fluidized bed combustion (FBC) reduces emissions of SO_2 and NO_2 by controlling combustion parameters and by injecting a sorbent (such as crushed limestone) into the combustion chamber along with the coal.

- Coal mixed with the limestone is fluidized on jets of air in the combustion chamber. Sulphur released from the coal as SO_2 is captured by the sorbent in the bed to form a solid calcium compound that is removed with the ash. The resultant waste is a dry, benign solid that can be disposed of easily or used in agricultural and construction applications. More than 90 per cent of the SO_2 can be captured this way.

Fluidized Bed Combustion (contd.)

- At combustion temperatures of 1,400 to 1,600° F, the fluidized mixing of the fuel and sorbent enhanced both combustion and sulphur capture. The operating temperature range is about half that of a conventional pulverized coal boiler and below the temperature at which thermal NOx is formed. In fact, fluidized bed NOx emissions are ab out 70 to 80 percent lower than those for conventional pulverized coal boilers.

- Thus, fluidized bed combustors substantially reduce both SO2, NOx emissions. Also, fluidized bed combustion has the capability of using high ash coal, whereas conventional pulverized coal units must limit ash content in the coal to relatively low levels.

Supercritical Technology

- "Supercritical" is a thermodynamic expression describing the state of a substance where there is no clear distinction between the liquid and the gaseous phase (i.e. they are a homogenous fluid). Water reaches this state at a pressure above 221 bar

- Up to an operating pressure of around 190 bar in the evaporator part of the boiler, the cycle is sub-critical. This means, that there is a non-homogeneous mixture of water and steam in the evaporator part of the boiler. In this case a drum-type boiler is used because the steam needs to be separated from water in the drum of the boiler before it is superheated and led into the turbine.

- Above an operating pressure of 221 bar in the evaporator part of the boiler, the cycle is supercritical. The cycle medium is a single phase fluid with homogeneous properties and there is no need to separate steam from water in a drum. Once-through boilers are therefore used in supercritical cycles.

Supercritical Technology (contd.)

- Supercritical cycle units offer a number of advantages. The most obvious advantage is higher efficiency, and therefore, saving of fuel resources. The improvement in efficiency varies from 1.3% to 3.6% depending upon the steam parameters.

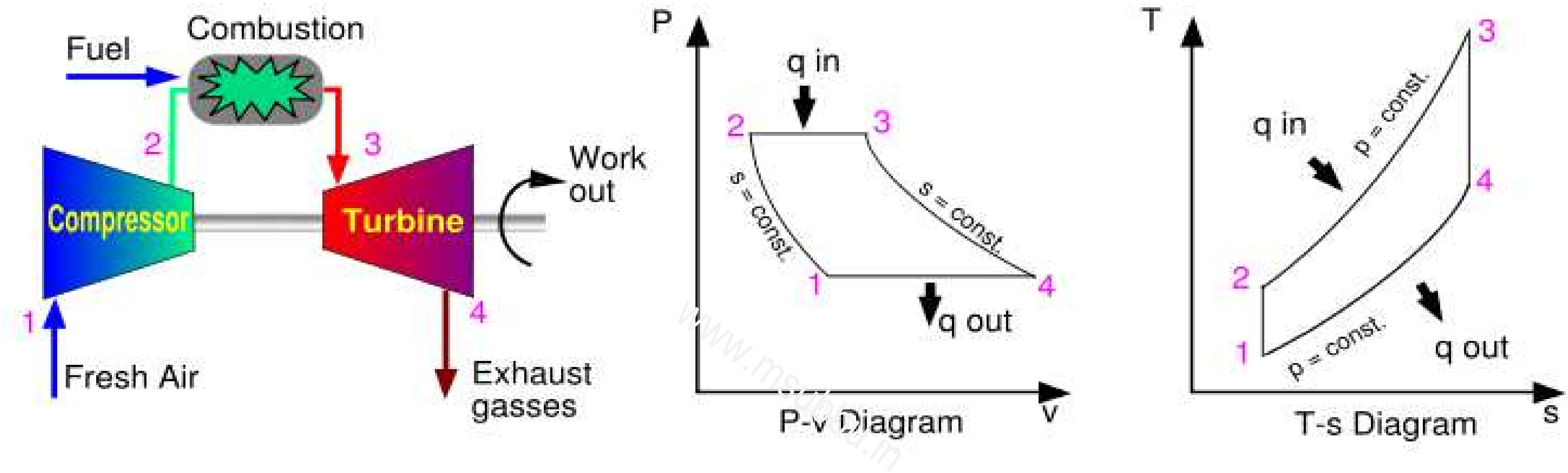
  e.g. Capital cost for a supercritical power station shall be about 2% higher than that of sub-critical power plant but at the same time the plant efficiency shall improve from 38.64% to 39.6%.

Recent Coal based power plants

- All the recently commissioned coal-fired power plants of high efficiency use pulverised coal combustion (PCC) with supercritical (strictly, beyond the critical point of water, 22.1 MPa, 374°C) steam turbine cycles.

- Among supercritical plants, those using the highest steam temperatures (around 580°C and above) can be referred to as ultra-supercritical, although that borderline is rather arbitrary.

Gas Turbines



Brayton Cycle

- Brayton cycle is also called as Joule cycle.
- Air enters the compressor at atmospheric pressure and is compressed to around 10-20 bar. It is then mixed with fuel in the combustion chamber, producing hot combustion gases that do work on the turbine. The exhaust gases are vented to the atmosphere.

Gas turbines

- In a gas turbine, the gaseous products of combustion are typically around 1300^{o}C. The turbine blades are covered by a ceramic coating of low thermal conductivity.

- Gas turbines for electricity generation originally evolved from ***jet turbine engines.***

- Since the working fluid does not change phase, a condenser is not involved in the process, so the overall size and cost of a gas turbine plant is less than that of an equivalent steam plant.

- Gas turbines operate in a ***Brayton*** (or ***Joule***) cycle. It is an open cycle but is equivalent to a closed cycle in the sense that the atmosphere acts as a heat exchanger that cools the air entering the combustion chamber.

Gas turbines (contd.)

- Gas turbines are relatively low capital cost devices that can be started up quickly and are employed for satisfying sudden changes in electricity demand.

- Efficiencies of simple gas turbines are up to around 40%.

Combined Cycle Gas Turbine (CCGT)

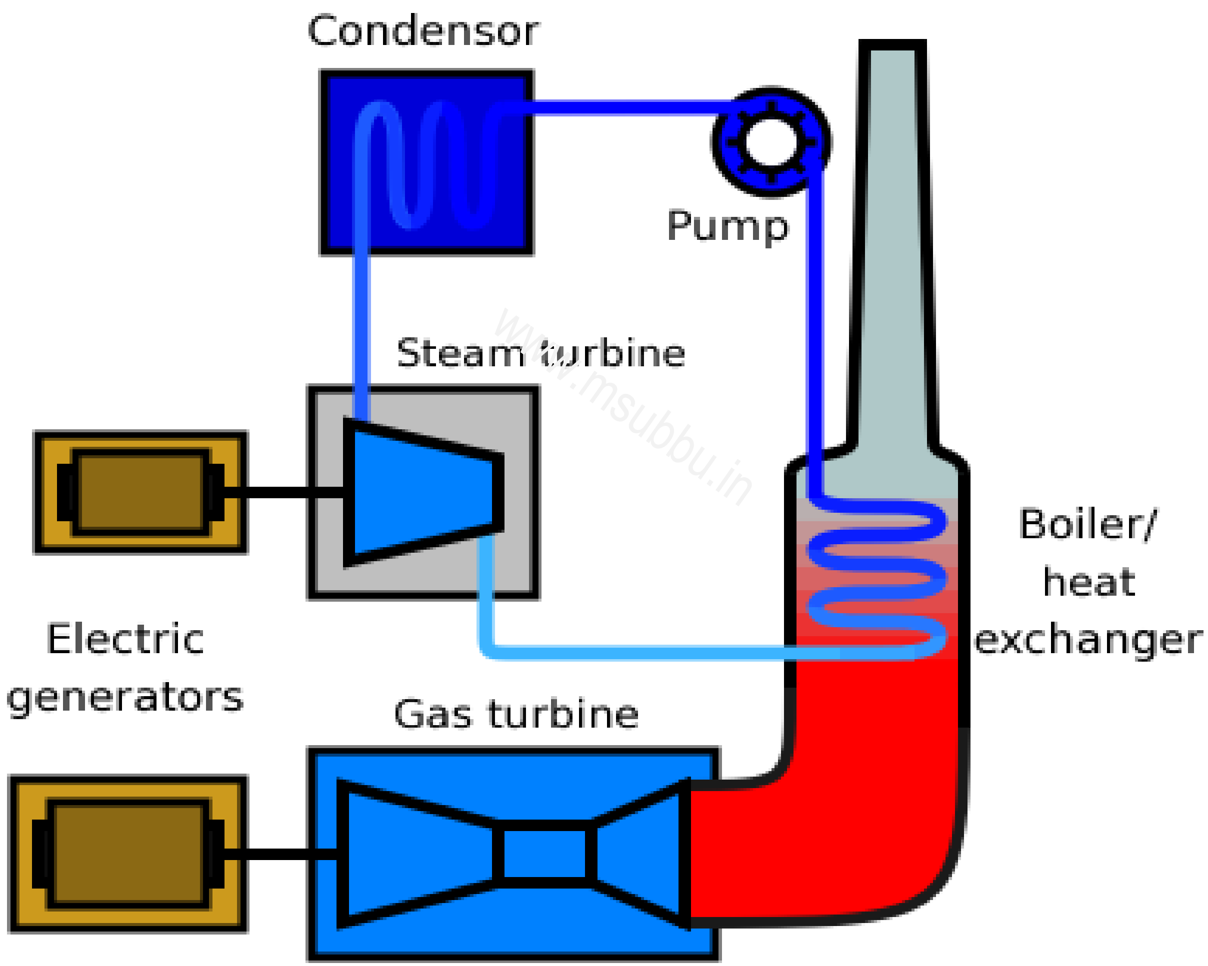
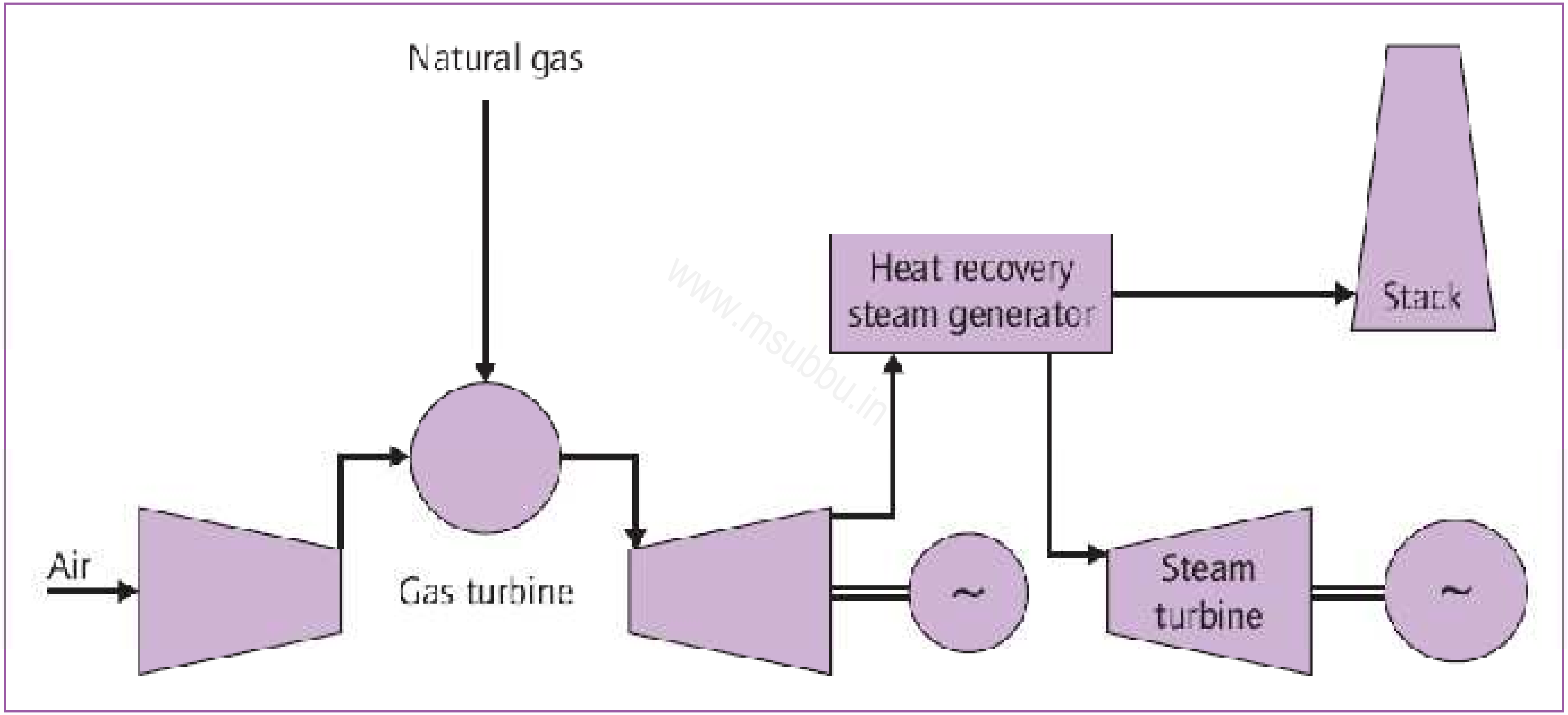


Figure 2 • Natural gas-fired combined cycle (NGCC)



CCGT

- The overall efficiency of a gas turbine can be increased by feeding the heat of the exhaust gases into a steam power plant. The combination of Brayton cycle and a Rankine cycle is called a ***combined cycle gas turbine*** (CCGT).

- The net effect is equivalent to that of a single cycle operating between the upper temperature of a Brayton cycle and the lower temperature of a Rankine cycle. Efficiencies of up to 60% are typical in CCGT plants.

NTPC

- With 15 coal based power stations, NTPC is the largest thermal power generating company in the country. The company has a coal based installed capacity of 24,885 MW. The total installed capacity of the company is 31134 MW with 15 coal based and 7 gas based stations, located across the country.

- Units sizes: 200 MW, 500 MW

- NTPC has been operating its plants at high efficiency levels. Although the company has 18.79% of the total national capacity it contributes 28.60% of total power generation due to its focus on high efficiency.

Thermal Power Plants – status in India

- Current installed capacity of Thermal Power (as of 12/2008) is **93.4 GW** which is 64.7% of total installed capacity.
- Current installed base of Coal Based Thermal Power is **77.5 GW** which comes to 53.3% of total installed base.
- Current installed base of Gas Based Thermal Power is **14.7 GW** which is 10.5% of total installed base.
- Current installed base of Oil Based Thermal Power is **1.2 GW** which is 0.9% of total installed base.

Thermal Power Plants – status in India

- Current installed capacity of Thermal Power (as of 30/11/2010) is **108.4 GW** which is 64.6% of total installed capacity.

- Current installed base of Coal Based Thermal Power is **89.8 GW** which comes to 53.3% of total installed base.

- Current installed base of Gas Based Thermal Power is **17.4 GW** which is 10.5% of total installed base.

- Current installed base of Oil Based Thermal Power is **1.2 GW** which is 0.9% of total installed base.