

PEC

STEAM TURBINES BASIC INTRODUCTION FROM PROCESS ENG. PERSPECTIVE

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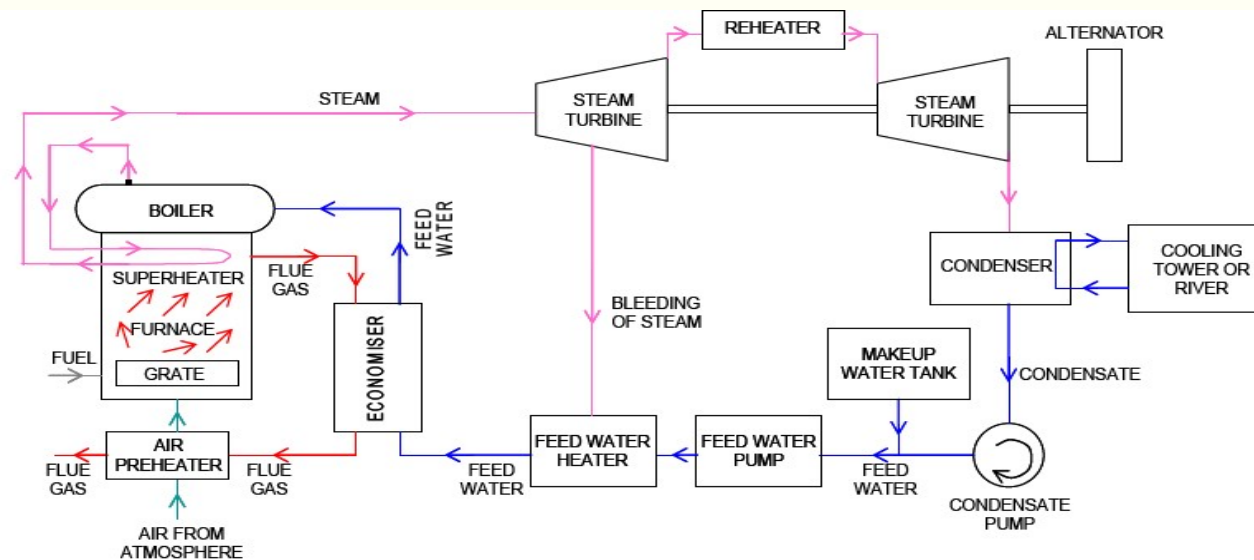
Agenda

- Definition.
- Principle of steam turbine.
- Classification.
- Types.
- Components.
- Losses.
- Popular Problems.
- Major Protection means.
- Techniques to improve Efficiency.
- Process Surveillance.
- Governing Standards.



What is the Turbine?

- Turbine is an engine that converts steam heat energy into mechanical energy (Work) where the steam is expanded in the turbine to generate the required work.
- The Power in a steam turbine is obtained by the rate of change in momentum of a high velocity jet of steam impinging on a curved blade which is free to rotate.



Principle of Steam Turbine

- The steam energy is converted mechanical work by expansion through the turbine.
- Expansion takes place through a series of fixed blades(nozzles) and moving blades.
- In each row fixed blade and moving blade are called stage.

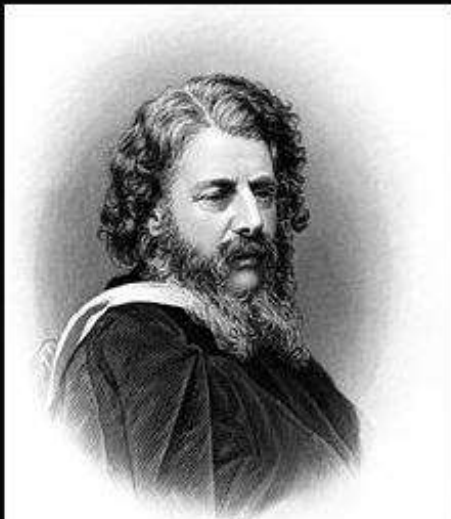


Principle of Steam Turbine

- Widely used in CHP(combined heat and power) applications.
- Capacities: 50 kW to hundreds of MWs.
- Thermodynamic cycle is the “**Rankine cycle**”.

*What is Rankine?
Or shall we say
Who is Rankine?*

William John Macquorn Rankine,
a Scottish polymath and Glasgow University professor.



05/Jul/1820 – 24/Dec/1872

52 Yrs. 5 Months 19 Days

W Macquorn Rankine

A hypothetical theory is necessary, as a preliminary step, to reduce the expression of the phenomena to simplicity and order before it is possible to make any progress in framing an abstractive theory.

(William John Macquorn Rankine)

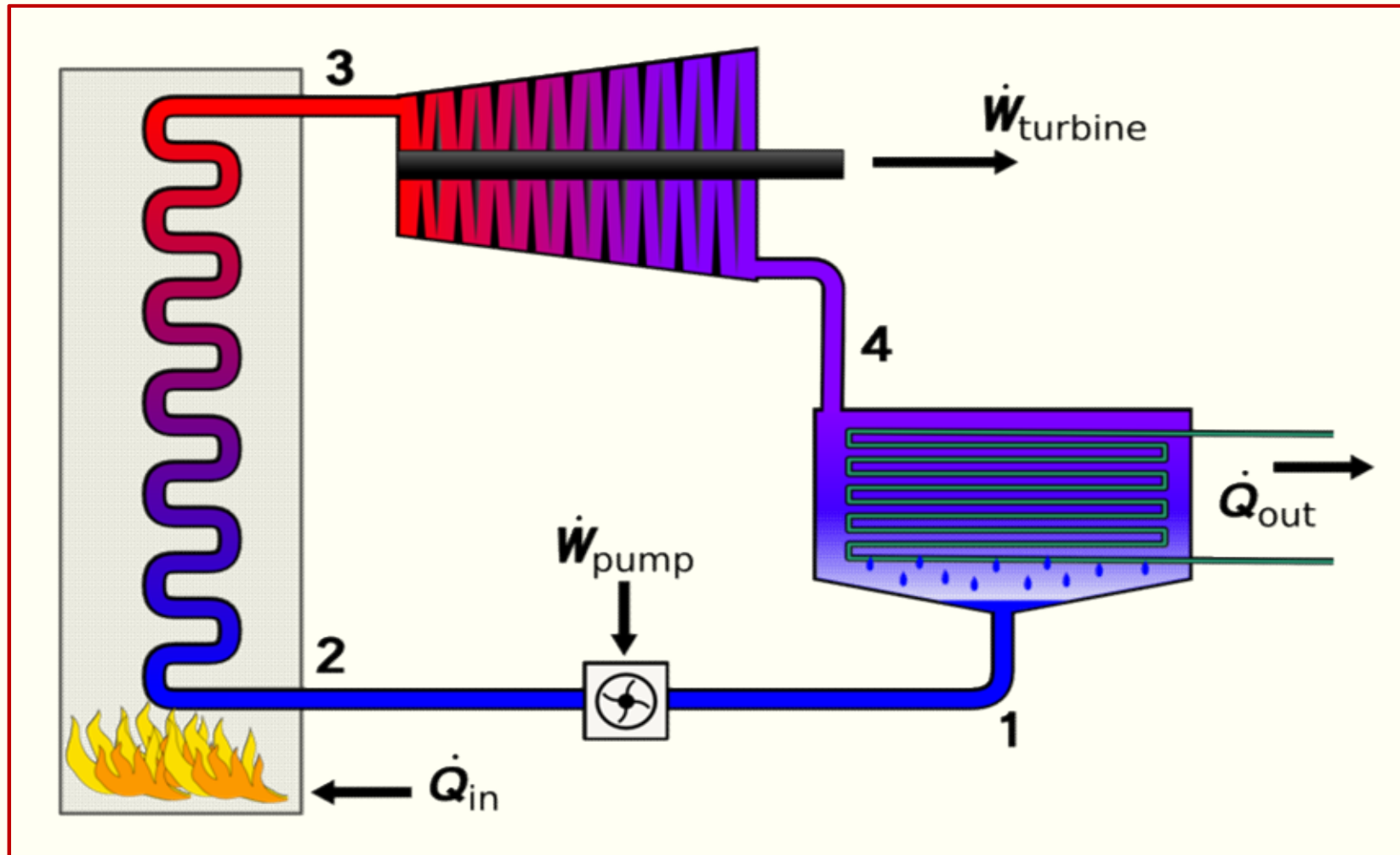
A Brilliant Mechanical Engineer

https://www.youtube.com/watch?v=vraxmgU9_3M

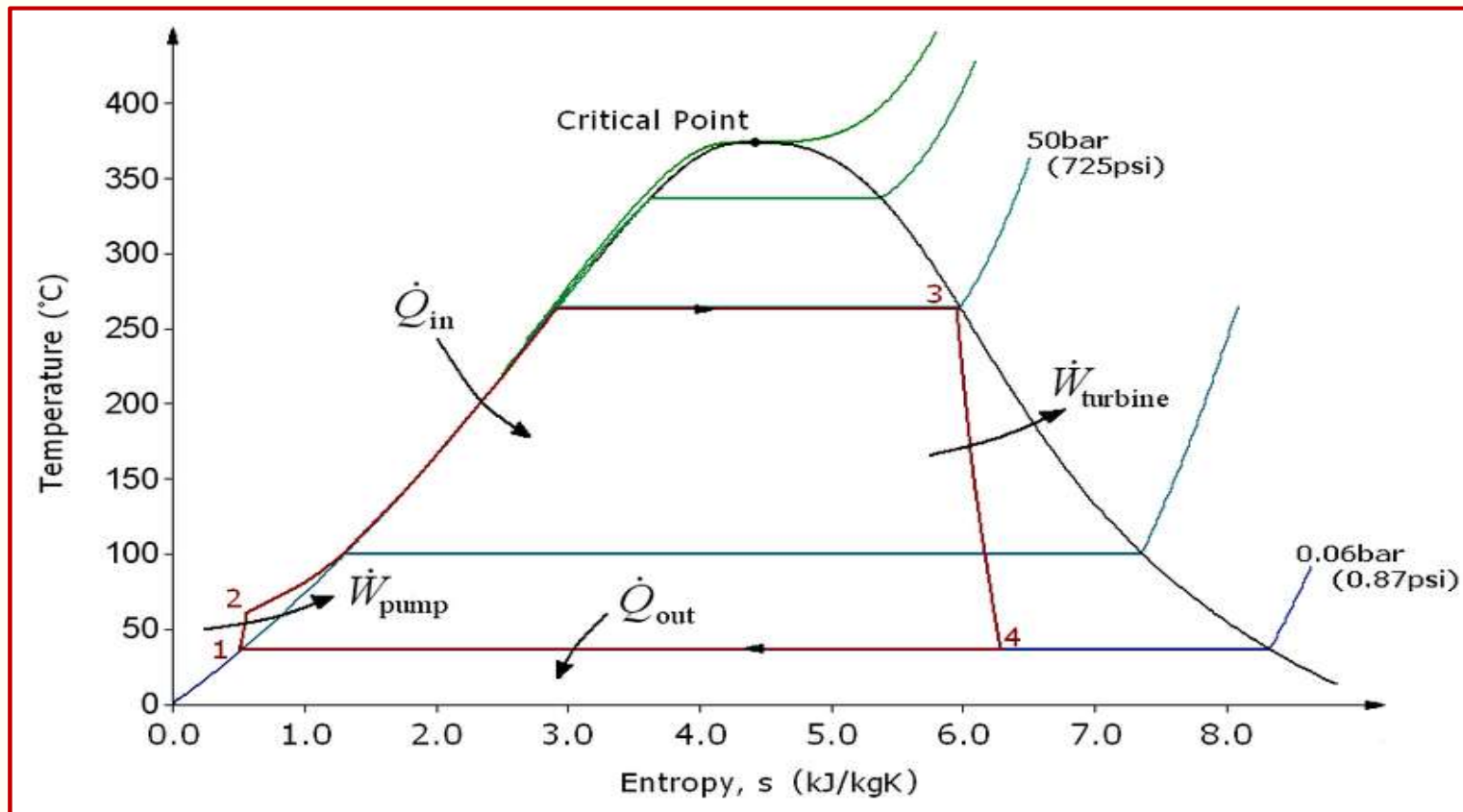
IZQuotes

Rankine Cycle

- Its name is derived from **William John Macquorn Rankine** who developed his publications over 1840's – 1860's, **he was only 20 years Old!!!**
- The Rankine cycle is an idealized thermodynamic cycle of a heat engine that converts heat into mechanical work while undergoing phase change.
- It is an idealized cycle in which friction losses in each of the four components are neglected.
- The heat is supplied externally to a closed loop, which usually uses water as the working fluid.



T-S Diagram



T-S Diagram

- **Process 1–2 Isentropic compression – Adiabatic Pumping:** The working fluid is pumped from low to high pressure. As the fluid is a liquid at this stage, the pump requires little input energy.
- **Process 2–3 Constant pressure heat addition in boiler – Isobaric Heat Supply:** The high-pressure liquid enters a boiler, where it is heated at constant pressure by an external heat source to become a dry saturated vapour. The input energy required can be easily calculated graphically, using an enthalpy–entropy chart (h–s chart, or Mollier diagram), or numerically, using steam tables.
- **Process 3–4 Isentropic expansion – Adiabatic Expansion:** The dry saturated vapour expands through a turbine, generating power. This decreases the temperature and pressure of the vapour, and some condensation may occur. The output in this process can be easily calculated using the chart or tables noted above.
- **Process 4–1 Constant pressure heat rejection in condenser – Isobaric Heat Rejection:** The wet vapour then enters a condenser, where it is condensed at a constant pressure to become a saturated liquid.

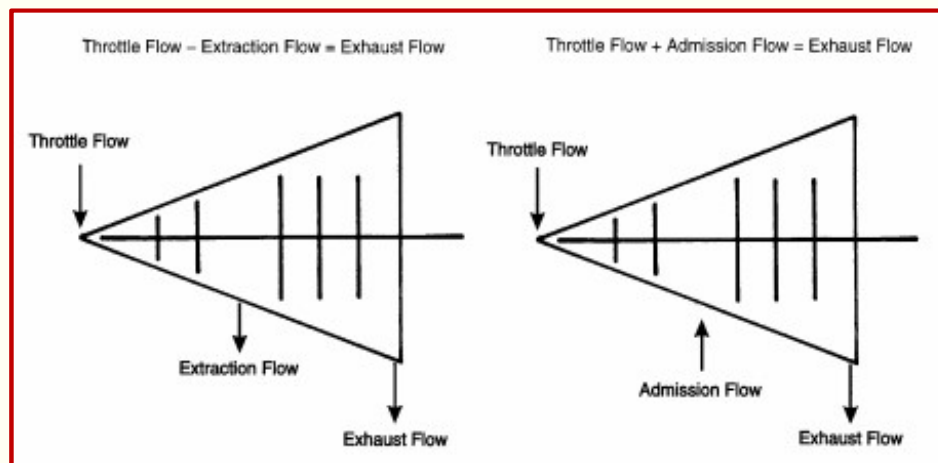
Classification of Steam Turbines

- According to the action of steam: Impulse / Reaction.
- According to the number of pressure stages: Single stage / Multistage.
- According to the type of steam flow: Axial / Radial.
- According to the number of shafts: Single Shaft / Multishaft.
- According to the method of governing:  Throttling / Nozzles / Bypass governing.
- According to the heat drop process: generators / one or more intermediate stage extraction / back pressure / topping.
- According to steam conditions: LP / MP / HP / Very HP / Supercritical Pressure.
- According to Exhaust conditions: Condensing Turbine / Backpressure Turbine / Extraction Turbine.
- According to speed: Fixed speed / Variable speed – Low Speed (≤ 3000 rpm) / High Speed (≥ 3000 rpm)

Types of Steam Turbine

Most common types:

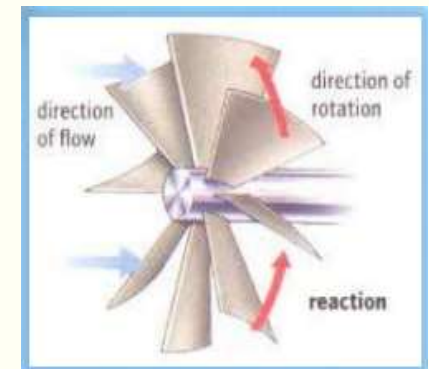
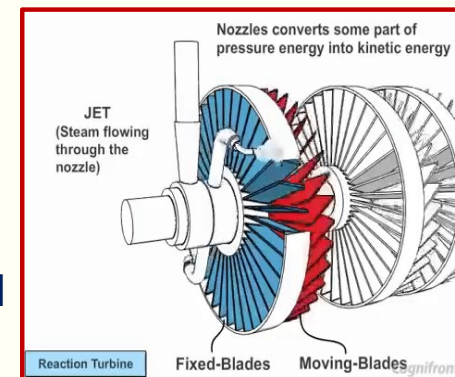
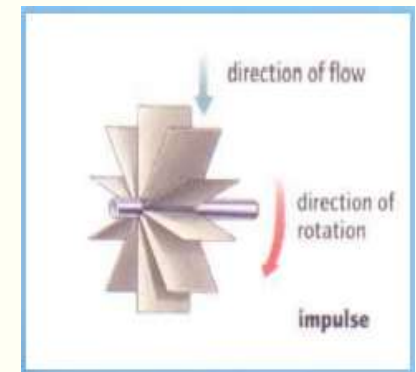
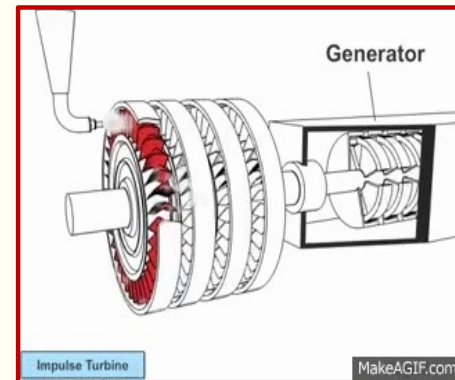
1. Condensing / Non-Condensing Steam turbines Back pressure steam turbine (exhaust steam at pressures below or above atmospheric pressure).
2. Extraction / Admission Steam turbines (Steam is extracted from, or admitted to, the turbine at some point between the inlet and exhaust).



Types of Steam Turbine

There are two main types:

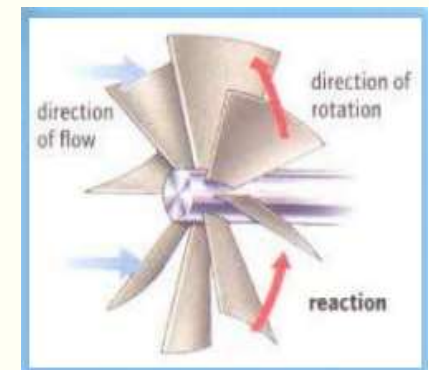
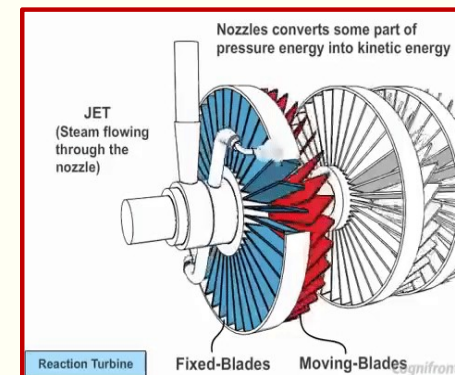
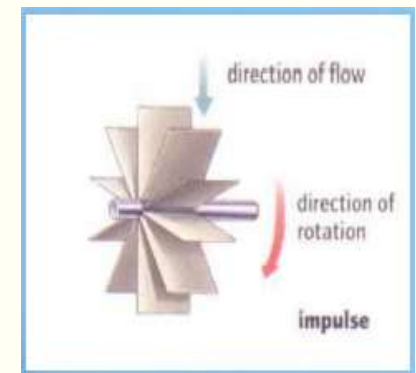
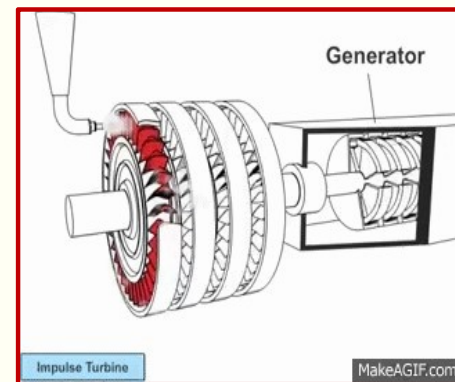
1. Impulse steam turbine: The basic idea of an impulse turbine is that a jet of steam from a fixed nozzle pushes against the rotor blades and impels them forward.
2. Reaction steam turbine: It utilizes a jet of steam that flows from a nozzle on the rotor (the moving blades) by fixed blades designed to expand the steam.



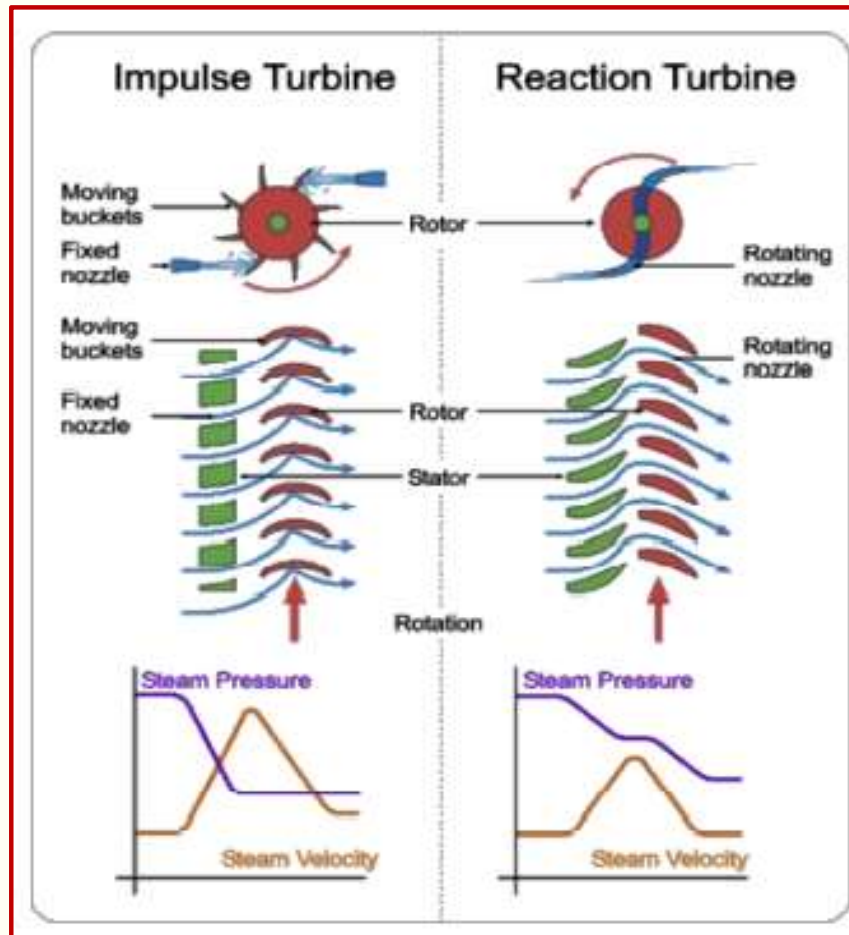
Types of Steam Turbine

The main difference between impulse and reaction turbine lies in the way in which steam is expanded while it moves through them such that:

- In the impulse type steam expands in the nozzle and its pressure doesn't change as it moves over the blades.
- In Reaction type the steam expands continuously as it passes over the blades and thus there is a gradual fall in pressure during expansion.

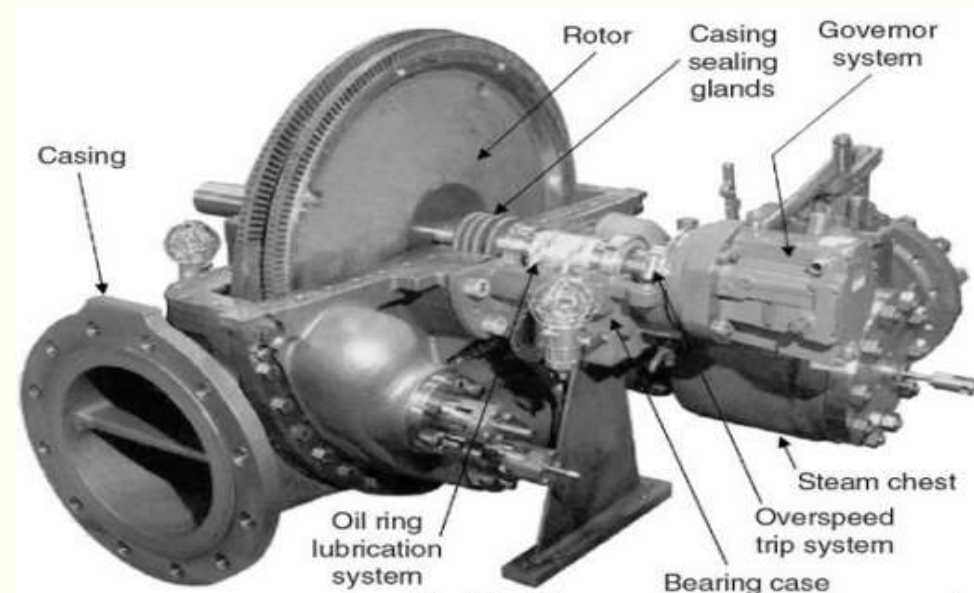
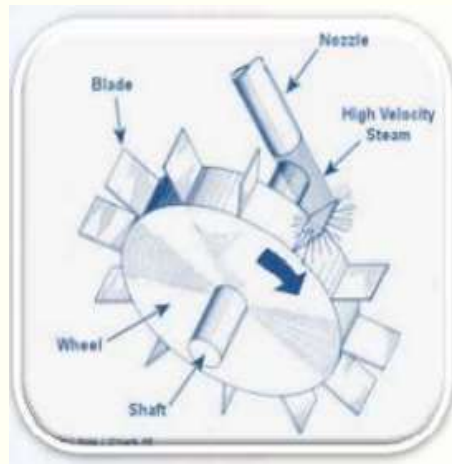


Types of Steam Turbine



Components of Steam Turbine

- Casing.
- Nozzles.
- Rotor.
- Blades.
- Governor.
- Servo Mechanism.
- Oil Pump.



Losses in Steam Turbine

- Residual velocity loss.
- Losses in regulating valves.
- Loss due to steam friction in nozzle.
- Loss due to leakage.
- Loss due to mechanical friction.
- Loss due to wetness of steam.
- Radiation loss.

Popular Problems of Steam Turbine

- Fatigue, Thermal / Corrosion (Pitting / Stress Corrosion Cracking – Steam quality & excessive process conditions).
- Vibration (loose parts / excessive process conditions – Overload).
- Misalignment (Vibration / poor maintenance workmanship).

Steam Turbine Protection Means

- Over speed trip.
- Master Trip.
- LP Trip.
- Low Lubricating Oil Pressure Trip.
- High Bearing Temp. Trip.
- High Vibration Trip.
- High Axial Disp. Trip.
- Relief Valve in Exhaust

Techniques to Improve Efficiency

- Various techniques are employed to maximize turbine efficiency, each designed to attack a specific loss mechanism.
- For example, the number of stages utilized can range from the fewest possible to develop the load reliably to the thermodynamically optimum selection.
- Spill bands can be utilized to minimize throttling losses.
- High efficiency nozzle/bucket profiles are available to reduce friction losses.
- Exhaust flow guides are available to reduce the pressure within the exhaust casing.
- The specific features employed on a given application are usually based on the trade-off between capital investment and the cost to produce steam over the life of the turbine –
SIMPLY, IT IS AN OPTIMIZATION APPROACH.

Process Surveillance – Why we should monitor closely?

- The key to plant safety and performance is the ability to accurately measure and track temperature, pressure, and flow.
- Information collected at specific measuring points can be used to:
 - Avoid Metallurgical Failures: Temperatures need to be maintained below components' melting points in order to avoid metallurgical failure. Too-high temperatures can also lead to creep deformation in the rotating blades.
 - Determine Efficiency and Performance: Calculate the efficiency of the turbine by knowing the inlet and exit temperatures, as well as the flow rate at the nozzle. When a turbine exhaust is used as heat input to a steam cycle, engineers can also estimate the performance of the heat recovery steam generator (HRSG) by using the temperature and flow measurement of the turbine exhaust.

Process Surveillance – Why we should monitor closely?

- Detect Inefficiencies — High exhaust temperatures and flow changes can be symptoms of an upset mode of turbine operation. If a flow measurement device picks up irregularities, the plant operator can perform a diagnostic to identify the underlying causes.
- Calculate Residual Life: Tracking temperatures over time allows To calculate how much life the component has left and to plan maintenance and replacements.

Process Surveillance – What & Where?

- Barometric pressure.
- Steam and steam condensate's flow rate, temperature, and pressure on:
 1. The cold reheat.
 2. The high pressure throttle.
 3. The hot reheat.
 4. Low pressure induction sections.
- Exhaust pressure.

API Standards

API 611 (ISO 10436) 4th Edition - General purpose steam turbines for refinery service (non-critical):

- General purpose turbines are horizontal or vertical turbines used to drive equipment that is usually spared, is relative small in size (power), or is in non-critical service.
- They are used where steam conditions will not exceed a pressure of 48 bar and a temperature of 400°C or where speed will not exceed 6000 rpm.

API Standards

API 612 (ISO 10437) 6th Edition - Special purpose steam turbine for refinery service (critical):

- The purchaser's approval is required for built-up rotors when blade tip velocities exceed 250 m/s at maximum continuous speed or when stage inlet steam temperatures exceed 440 °C.
- Over Speed shutdown system:
 - I. Electronic overspeed detection system.
 - II. Electro-hydraulic solenoid valves.
 - III. Emergency trip valve(s) / combined trip and throttle valve(s).

API Standards

- If specified a turbine with an exhaust pressure less than atmospheric pressure shall be provided with an exhaust vacuum breaker actuated by the shutdown system.
- Details of such a system shall be agreed by the purchaser and the turbine vendor.

