Presentation on Compressors

What is Compressor

……...a device used for pumping compressible fluids i.e,

air, gas & steam

What is the basic difference between Compressor & Blower

… acc. to API pressure rise above 0.35 bar is compressor and below is blower

Compressor Classification

a) By principle of operation

b) By construction type

c) By staging

d) By service duty

e) Lubricated/ non lubricated

Classification

Operation Principle

Positive Displacement/ Dynamic or Turbo

Staging

Single / Multi stage

Service

Critical service or non critical duty

Lubricated / Non Lube

Positive Displacement

(Increase press. by reducing volume)

Types are -

- **Reciprocating**
- **Rotary - Screw, Vane , Liquid Ring & Lobe**
- **Diaphragm**

Dynamic or Turbo Compressors

(By imparting K.E. to air/gas and then converting it into pressure)

Types are -

- **Centrifugal or Radial Compressors**
- **Axial Flow Compressors**

Classification by staging of compressors

Single Stage (compression of gas in one stage)

Multi-stage (compression of gas in more then one stage)

Classification by Duty

Critical Duty : Whereby stoppage of compressor will lead to interruption in the process and heavy loss in terms of production and would need elaborate start-up cycle including, re-heating recharging the catalyst etc.

Utility Duty: Is basically for those applications where in even if the compressor is shut the plant operation will not be terminated

Lubricated or Non Lube Compressors

Lubricated Compressors : Where the gas is mixed with lubricant

Non Lubricated Compressors: Where process gas or air remains uncontaminated by the the lubricant during the compression process

Basic Terminology for Compressors-

Flow rate: m3/hr , cfm (1cfm = 0.5886 m3/hr)

Pressure ratio: ratio of absolute discharge press. / absolute inlet pressure

Absolute press = gauge pressure + atmospheric pressure

Atmospheric pressure= pressure exerted by atmosphere

At sea level atms press. = 1.033 kg/cm2 A = 1.013 barA = 14.696 pisA = 760 mmHg= 1atms

1 kg/cm2=14.22 psi , 1 Mpa (mega pascal) = 10.1 bar

0 deg.cel. = 273 deg. K

Parameters for selection of compressor-

Application:

Gas handled:

Gas analysis:

Flow rate:

Suction Pressure :

Suction Temperature:

Mol wt. of Gas:

Z (Compressibility) & Cp/Cv:

Discharge Pressure:

Drive System:

Basic Terminology for Compressors-

NTP Conditions and STP conditions

NTP conditions (Nm3/hr)

At sea level (1.033 kg/cm2A, 273 deg. , 0% r.h.)

STP conditions (sm3/hr or scfm)

At sea level (1.033 kg/cm2A, 288 deg. , 0% r.h.)

Reciprocating Compressors-

Selection:

- Flow rate till 10000m3/hr

- Pressure till 3500 bar, Power till 7000 kW

Basic Design : As per API- 618

Construction:

-Vertical

-Horizontal

-Horizontal Balanced Opposed (mostly used now)

Suitable :

for variable pressure ratio and constant capacity at given speed

Reciprocating Compressors-

Drive System:

-Belt or Direct Driven

Drivers:

-Induction & Syn. Motors , also single bearing motors with rigid coupling

-Diesel or Gas Engines

Capacity Control:

-Suction Valve un-loaders (thru stepped control)

-Recycling or spill back

-VFD

Main Components: Cylinders, valves, piston, rings, cross head, connecting rod, crank-shaft

Reciprocating Compressors-

Advantages:

- simple & open in construction

- site repairs possible

-do not require specialist at site

-not effected by changes in ambient conditions

-no adverse effect due to changes in the gas mol. Wt.

-single and multistage with inter-cooling

-achieve very high pressure ratios

-low & medium speed machines (250 - 1200 rpm), low noise level

-cooling of cylinder jackets & inter-cooling keeps temp. down and saves power

-non lubricated cylinders by using special piston/ rider rings

Reciprocating Compressors-

Disdvantages:

-Maintenance prone mainly valves, piston/rider rings

-Large bulky foundation

-Long installation time

-In fact large compressors are assembled at site

-Hooking up of auxiliaries such lube oil console, tempered c/w console for cyl. Jacket cooling, mounting of pulsation separators etc.

-Pulsating flow requires costly piping and flow analysis

-Step-less capacity regulation not possible

-Loss in capacity with operation

-Standby machines required

Reciprocating Compressors-

Main Applications:

-In general engg.industries as plant & instrument air compressors till about 250 kW. Electric motor drive (where compressed air is used as energy source)

-Pneumatic conveying

-Fuel Gas Boosters to Gas Turbines (Acc. API-618 with electric motor driver till 2000 kW

-Gas booster, gas lift and gas re-injection compressors with gas engine drive in natural gas fields and pipeline transmission

-CNG compressors for filling (gas engine as well as motor driven)

Reciprocating Compressors-

Main Applications:

-Refineries : Recycle , Make Up Compressors till 6000 kW with low speed syn. Motors & also for feed gas, off gas & recycle gas compressors for H2 plants

-LNG Re-gassification terminals: Boil off gas compressors for very low temp. -160 deg.cel.

-Cryogenic plants for oxygen and nitrogen: As nitrogen & o gas boosters (mainly in steel, copper, plants

-PSA based N2 & oxygen plants: (paper, refinery, petrochemicals etc.)

Reciprocating Compressors-

Major manufacturers (World wide)

Process applications acc. API-618 , till 6000 kW

- **Peter Brotherhood, U.K.**
- **Nouvo Pignone (G.E.), Florence, Italy**
- **Thomassen, Rheden, Netherlands**
- **Dresser Rand, Painted Post, USA**
- **Neuman Essar, Germany**
- **Mitsui Engg & Shipbulding, Japan**
- **Kobe Steel, Japan**

Reciprocating Compressors-

Major manufacturers (India)

Process applications acc. API-618 , till 600 kW

- Dresser Rand, Naroda.

Plant & Instrument Air (till 350 KW)

- Atlas Copco, Nasik (formarly CP India)

-Ingersoll Rand, Naroda

-K.G. Khosla Compressors

Rotary Screw Compressors-

Selection:

- Flow rate till 40000m3/hr

- Pressure till 45 bar, Power till 3000 kW

Basic Design : As per API- 619

Service:

-Air

-Some Process Gases

-Lubricated & Non Lube version

Rotary Screw Compressors-

Drive System:

-Belt or Direct Driven

Drivers:

-Induction Motors

-Diesel Engines

Capacity Control:

-Suction Valve throttling (stepless control)

-Recycling or spill back

-VFD

Main Components: Screw elements, timing gears, lube oil & oil separator system, bearings

Rotary Screw Compressors-

Advantages:

- fewer components

- compact design, very good for portable applications

-package skid mounted concept

-quick site installation & no heavy foundation

-not effected by changes in ambient conditions

-no adverse effect due to changes in the gas mol. Wt. , infact good examples with dirty gases like in soda ash , coke oven plants

-non lube design possible

-streamlined flow

Rotary Screw Compressors-

Disdvantages:

-Not very reliable. Mainly anti-friction bearings used and these have limited life

-Close tolerances between screw elements

-Site repairs not possible

-Higher power consumption in lube design and also due to leakage between rotors.

-Process gas / air mixed with lube oil hence very effeicient oil separator is required which requires frequent maintenance

-Multi-staging not very easy

-High speed and high noise level

Rotary Screw Compressors-

Main Applications:

-In general engg. industries as plant & instrument air compressors till about 250 kW. Electric motor drive (where compressed air is used as enrgy source)

-Textile mills for air jet looms (Oil free screws)

-Pneumatic conveying

-Fuel Gas Boosters to Gas Turbines (Acc. API-619 with electric motor driver till 2000 kW

-Portable compressors for construction

Rotary Screw Compressors-

Major manufacturers (India)

Oil Injected

- **Atlas Copco, Pune**
- **Elgi Equipments, Coimbatore**
- **KG Khosla**
- **Ingersoll Rand**

Oil Free

- **Atlas Copco**

Rotary Screw Compressors-

Major manufacturers (World Wide)

Process Applications & Oil Free Duty

MAN Turbo, Germany

Arzerner, Germany

Kobe Steel, Japan,

Atlas Copco (air only), Sweden

Mycom , Belgium & Japan

RKR Verdichtertechnik, Germany (low press. Oil free)

Dynamic or Turbo Compressors-

- Centrifugal or Radial Flow Compressors

-Axial Flow Compressors

Selection:

Radial Compressors

- Centrifugal Compressors Flow rate: 2000 to 4,50,000 m3/hr

- Pressure ratio till 60, Power till 50,000 kW

Basic Design : As per API- 617 or API-672

These are horizontal split casing or barrel type for high press. appl

Single shaft single stage/Multistage, multi-casing compressors

Multi shaft integrally geared single or multi stage compressors

Dynamic or Turbo Compressors-

Selection:

Axial Flow Compressors

(air flows along the axial shaft of compressor from one set of air foil axial blades to another)

- Flow Rates : 1,50,000 to 12,00,000 m3/hr

- Pressure ratio till 12, Power till 90000 kW

Basic Design : As per API- 617

Single shaft construction

Highest Efficiency

More popular with steam turbine drive

Dynamic or Turbo Compressors -

Drive System:

-Directly coupled with driver or through gear box

Drivers:

-Induction & Syn. Motors

-Steam or Gas Turbine

-Combination drive train with induction motor generator and turbine

Capacity Control:

-Variable Inlet guide vanes/ VDV or combination of both

-Recycling

-Speed Variation

-Combination of IGV and speed control

Dynamic or Turbo Compressors -

Main Components of Centrifugal Compressor are:

Inlet Guide Vane , Impeller & rotor, diffuser (vaned or vane-less) ,volute casing ,sealing system

Main Components of Axial Compressor are:

Inlet Guide Vane , Inlet nozzle ring, set of rotating vanes, stationary blades that acts a diffusers

Dynamic or Turbo Compressors -

Advantages: Centrifugals

- reliable and suitable for uninterrupted operation without standby

- no wearing parts, compact design, easy installation

-consistent performance

-can handle very large flow rates

-high polytropic efficiency

-single and multistage with inter-cooling

-variable capacity at constant speed

-can handle most of the process gases besides air

-non lubricated / oil free compression

-flexibility in driver selection

Dynamic or Turbo Compressors -

Advantages:

Axial Compressors

- Highest efficiency

- no wearing parts

-consistent performance

-can handle very large flow rates

-compact design (high speed)

-variable capacity at constant speed

-non lubricated / oil free compression

Dynamic or Turbo Compressors -

Disdvantages: Centrifugal/ Axial

-Sensitive to changing ambient conditions

-Special protection system against surge

-Change in gas mol. wt. limits the operation

-Special arrangement to ensure no liquid carry over from process

-Elaborate filtration system required for the air

-High noise level.

-Special care to be taken for the variation in frequency

-Any dirt build/ polymer build up alter the performance adversely

-Due to high speed vibration monitoring system to be installed

-High initial cost

Dynamic or Turbo Compressors -

Main Applications:

-Standard Centrifugal Compressors

General Engg & other industries such as Glass, Automobiles,

Electronics, Synthetic Fibers, Textiles, plant & instrument air compressors for steel plants, refinery, power plants etc.

Normally with flow rates starting higher then 2000 m3/hr till 15000 m3/hr as single or multiple units

Dynamic or Turbo Compressors -

Process Applications of Centrifugal Compressors

Steel Plant-

Blast Furnace Blowers

(20000 to 8,00,000 m3/hr, press till 4.5 bar)

Type: Centrifugal multistage without inter cooling, Axials

Drive System: Motor, Steam Turbine thru gear box

Two or three units continuos operation

This application is characterized by rapid fluctuations in pressure and flow

Dynamic or Turbo Compressors -

Process Applications of Centrifugal Compressors

Steel Plant-

Coke Oven Exhausters and boosters

Motor & Steam Turbine Drive

Combination drive

Cryogenic Oxygen Plant (Air Separation Units)

Feed Air, Air Booster , N2 & O2 Boosters

(Rating 1000 kW till 20,000 kW)

Dynamic or Turbo Compressors -

Process Applications of Centrifugal Compressors

Ammonia/ Urea Plants-

Main Air Blower (10000 to 70000 m3/hr @ 25 to 39 bar)

Centrifugal Compressors (single shaft multicasing or multishaft)

Ratings 2000 KW till 16000 KW

Drive: Motor, Steam Turbine, Gas Turbine

Natural Gas Compressor:

(single shaft design nat. gas booster)

(10000 to 50000 nm3/hr Pin =13/ P out =45 bar)

Dynamic or Turbo Compressors -

Process Applications of Centrifugal Compressors

Ammonia/ Urea Plants-

Syn Gas Compressor

Largest & most complex compressor in Ammonia Plant

(two process gases are compressed in multi-casing compresors

Typ. Parameters: syn gas 200000 nm3/hr 22/213 bar +

Recycle compressor 600000 nm3/hr 190/225 bar)

Power ratting till 30 MW

Driver: Motor / Steam Turbine

Dynamic or Turbo Compressors -

Process Applications of Centrifugal Compressors

Ammonia/ Urea Plants-

Ammonia Refrigration Gas Compressor

Typ. Parameters: 40000 nm3/hr , 5.2 / 21 bar)

Power ratting till 6000 KW

Driver: Motor / Steam Turbine

Urea Synthesis

CO2 Gas Compressor 30000 nm3/hr , 1.5 / 200 bar)

Power Rating: till about 7000 KW

Dynamic or Turbo Compressors -

Process Applications of Centrifugal Compressors

Process Parameters of compressors at Typical Industries

Syn Gas Compressor : **syn gas 79000 nm3/hr, 25 / 230 bar**

recycle gas 360000 nm3/hr , 217 / 242 bar

Speed 15000 rpm

3 casing compressor

Main Air Blower : **26050 nm3/hr , 1.01/ 34.5 bar, 8800 rpm**

2 casing compressor

Ammonia ref. Comp : **31790 nm3/hr , 2.6 / 18.6 bar, 9500 rpm,**

single casing machine

Dynamic or Turbo Compressors -

Process Applications of Centrifugal Compressors

Refinery

-Main Air Blower FCCU (centrifugal or axial motor, steam turb)

40000 nm3/hr till 1,20,000 nm3/hr @ 3.5 bar, till 12 MW

Drive: Motor, Steam Turbine, Power recovery train – Typical Industries

-Wet gas compressor (Motor Drive) till 3 MW

-Hydrocracker - Recycle Gas Compressor - Steam Turbine Driven till 4.5 MW (H2 +HC mol wt. 8 450000 nm3/hr 150 / 200 bar)

-Hydrotreater/ DHDS -Recycle Compressors- Steam Turbine Drive

SRU- Clause Air Compressors - 35000 nm3/hr , 2.2 bar

Motor Drive or Steam Turbine Drive

Dynamic or Turbo Compressors -

Process Applications of Centrifugal Compressors

Chemicals

-Sulphuric Acid Plant ,Air Blower till 300000 nm3/hr and 8000 kW Motor ,or steam turbine or motor generator + turbine

-Caustic soda plant Chlorine gas compressor till 1500 kW with freon intercoolers

-Soda Ash (CO_2 compressors)

Oil & Gas

Pipeline compressors with Gas Turbine Drive

Gas lift and Reinjection compressors with Gas Turbine drive

Dynamic or Turbo Compressors -

Process Applications of Centrifugal Compressors

Copper Smelters

-Convertor Blowers

Till 4500 kW for supply cold air blast into convertor

(60000 nm3/hr @ 3 bar)

-SO2 Blowers till 4000 kW

Petrochemicals

PA, MA, Plant

Process Air Compressor with steam turbine & combination drive train

till 3500 kW, Flow Rates till 70000 nm3/hr @ 2.0 bar

Dynamic or Turbo Compressors -

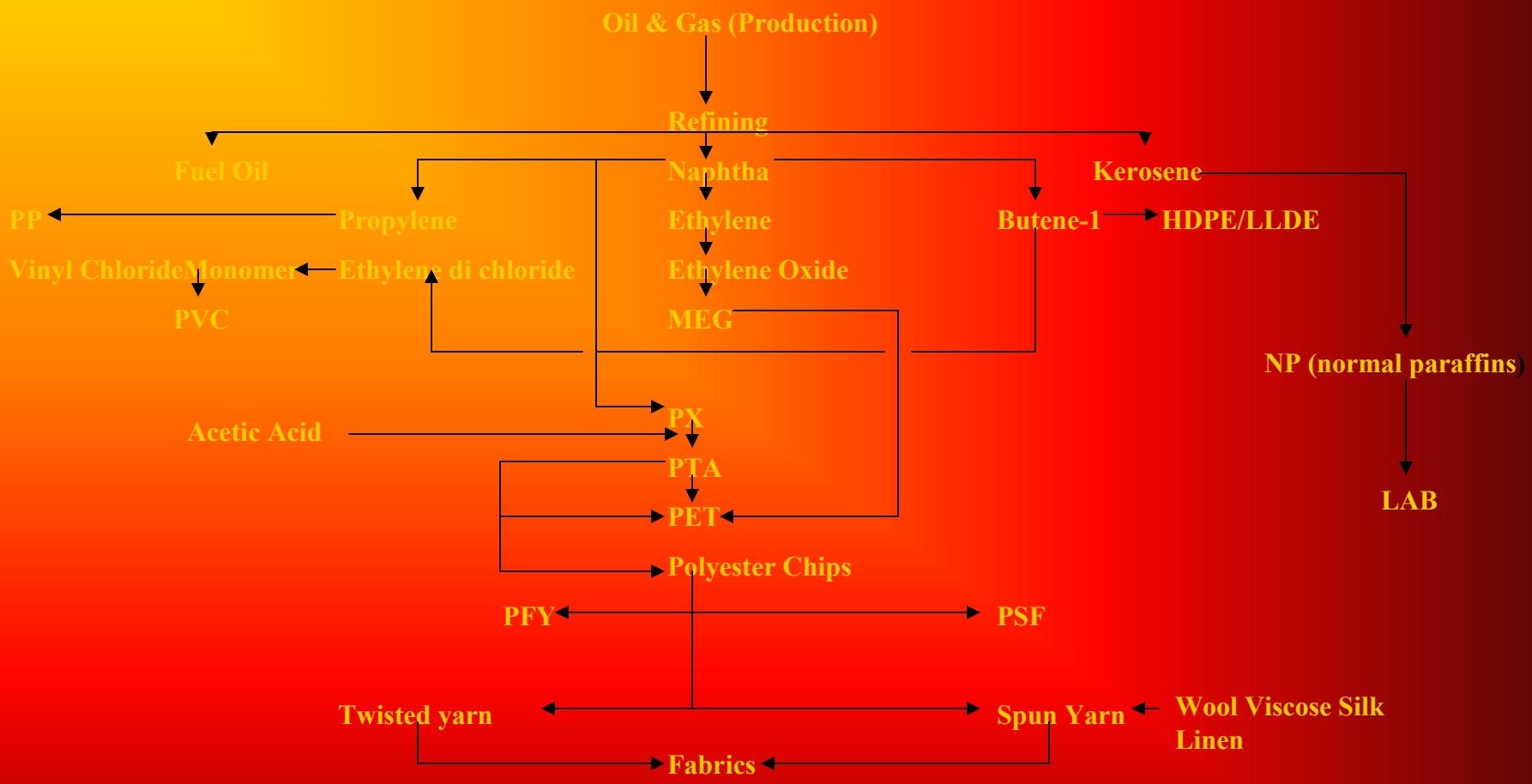
Process Applications of Centrifugal Compressors

Power Generation

-Fuel gas compressors to Gas Turbine

-IGCC units gassifier syn gas booster

Product Flow Chart - Oil Production to Fabric



Dynamic or Turbo Compressors

Major manufacturers (World wide)

Process applications acc. API-617 & API-672

- MAN Turbo,Germany U.K.

-Siemens,Germany (formerly Demag)

-Novuo Pignone, Italy -Elliot, USA

-Dresser Rand, France

-Ebara, Japan , -MHI, Japan ,-Kobe Steel, IHI & KHI Japan

-AG KK&K, Germany

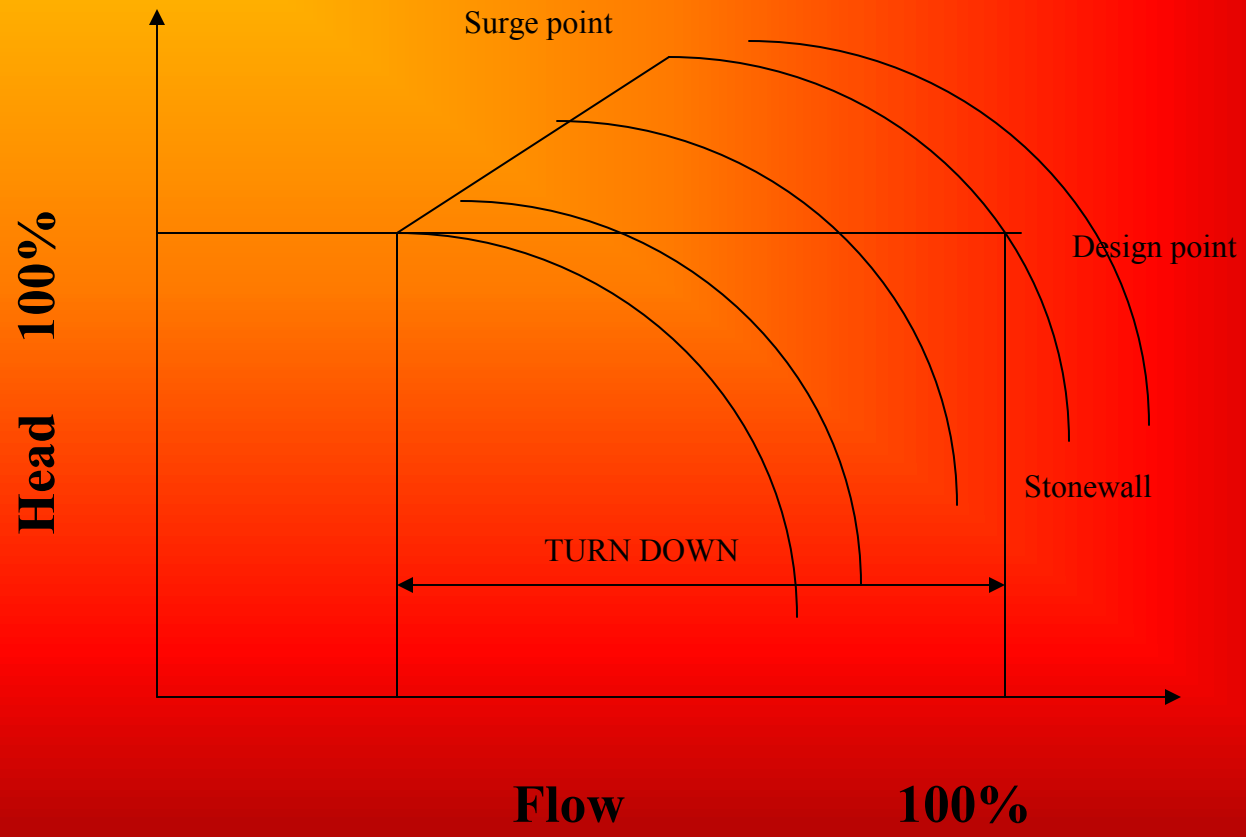
-Atlas Copco ,USA & Germany

-BHEL, India

Dynamic or Turbo Compressors -

Animated Presentation -CD of integrally geared compressor

Dynamic or Turbo Compressors -



Dynamic or Turbo Compressors -

Basic relationships

Head = n / n-1 * ZR Tin *((P2/P1)$^{n-1/n}$ -1)

R = Ru (847.5) / Mol. Wt. of gas

Polytropic efficiency = n-1/n / k-1/k

where k = Cp/Cv

n/n-1 = ln P2/P1 / ln T/T1 (T= deg. K)

Gas Power= m*H/ 102 * poly eff