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Compression Processes - Gullfaks Village

Note Title 06.02.2013

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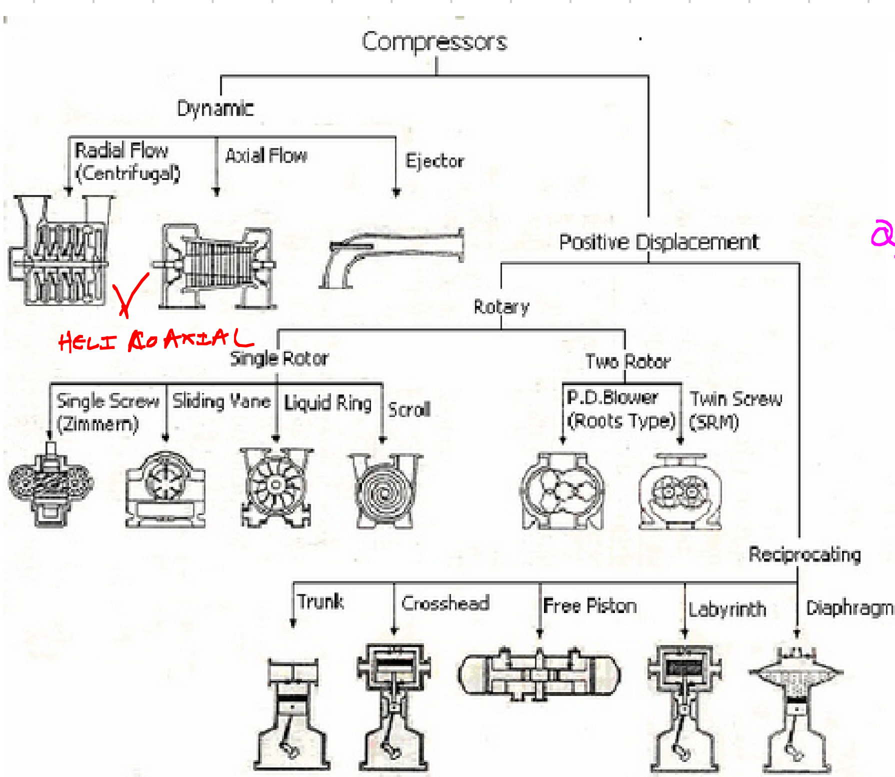
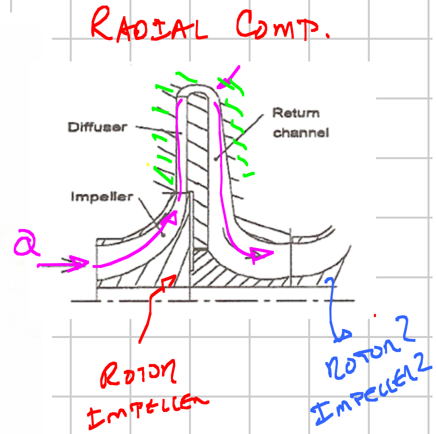
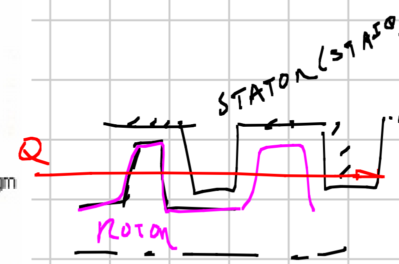
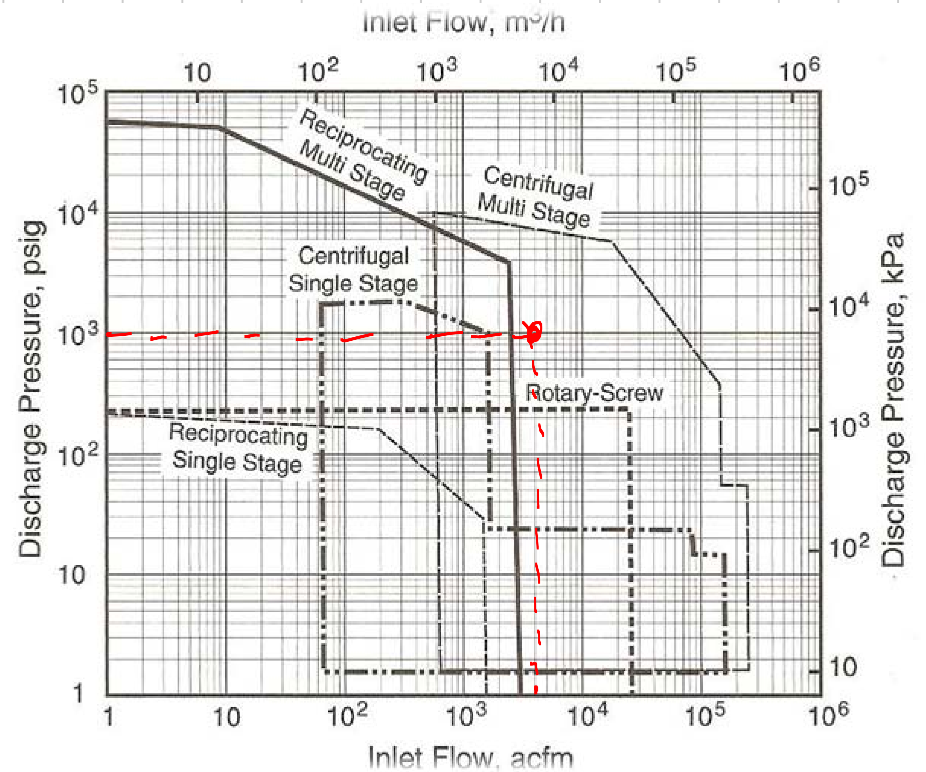


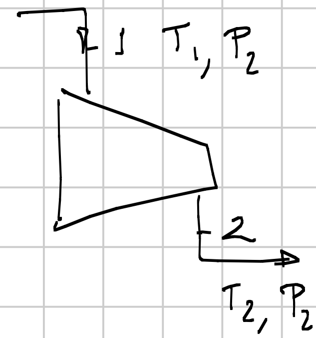




COMPRESSOR PROBLEM AREAS

- SELECTION OF COMPRESSOR TYPE:
  - Axial or centrifugal compressor
  - Horizontally- / vertically-split casing
- CALCULATION OF:
  - Shaft power
  - Number of stages
  - Discharge (exit) temperature
  - Speed
  - Number of compressors
- SELECTION OF:
  - Driver
  - Anti surge system
  - Gearbox
  - Lay-out of package





$T_{sc} = 288.15\ K$

$P_{sc} \approx 1.013\ bar$

$$\dot{m} = \rho_{sc} Q_{sc} = \rho_{Act} Q_{Act}$$

$$\hookrightarrow Q_{AC} = Q_{sc} \frac{\rho_{sc}}{\rho_{AC}} = Q_{sc} \frac{P_{sc}}{z_{sc} T_{sc}} \times \frac{T_{AC} z_{AC}}{P_{AC}}$$

$z_{sc} \approx 1$

$$\rho_{AC} = \frac{P_{AC}}{R Z_{AC} T_{AC}}$$

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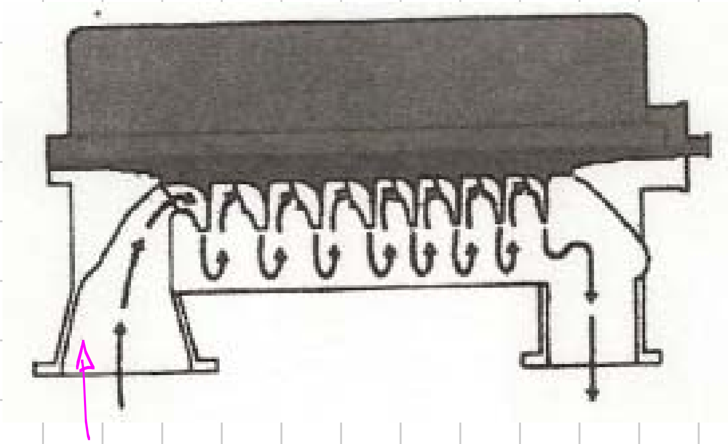
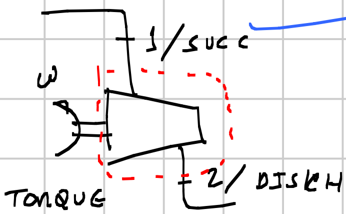


EVERY ROTOR/IMPELLER CORRESPONDS TO 1 COMPRESSION STAGE

COMPRESSION PROCESS: (THERMODYNAMICS)



$$\dot{W} - \dot{Q} = \frac{dE}{dt} = \dot{m}\left[\left(h_2 + \frac{1}{2}V_2^2 + z_2\right) - \left(h_1 + \frac{1}{2}V_1^2 + z_1\right)\right]$$

ENERGY

$$\dot{W} = \dot{m}\,(h_2 - h_1) = \dot{m}\,\Delta h$$

$\dot{W}$ → [JOULE/s]; $\dot{m}$ → kg/s; h → ENTALPY [JOULE/kg]

⟹ THIS IS THE THEORETICAL POWER NEEDED TO COMPRESS THE GAS FROM ① TO ②

⟹ SPECIFIC WORK ⟹ $w_s = \Delta h = h_2 - h_1$

h → ENTALPY ⟹ FOR IDEAL GAS:

$$h = C_p T$$

h → [J/kg]; C_p → SPECIFIC HEAT [J/kg-K]; T → TEMP. [K]

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• Compression Process

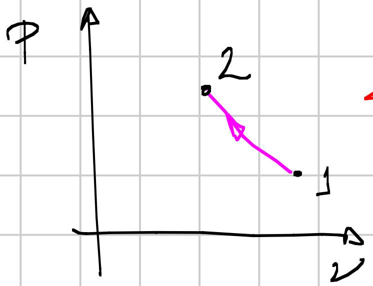
↳ Isentropic → Adiabatic & Reversible

Ideal ←

$Pv^k = Ctte$

↳ Polytropic

⋮

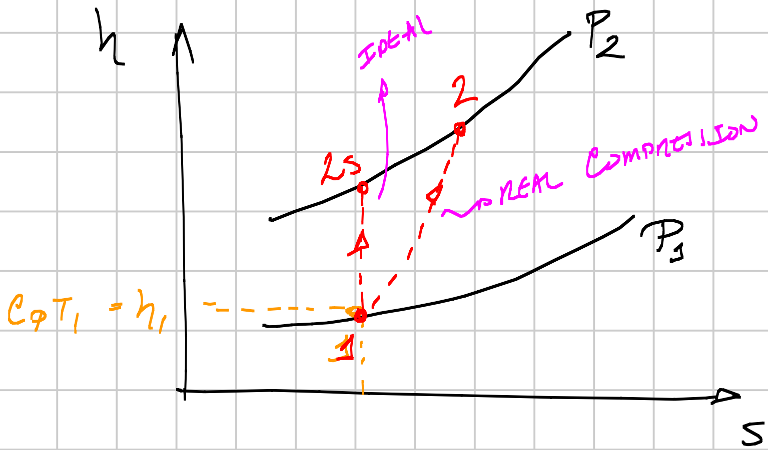


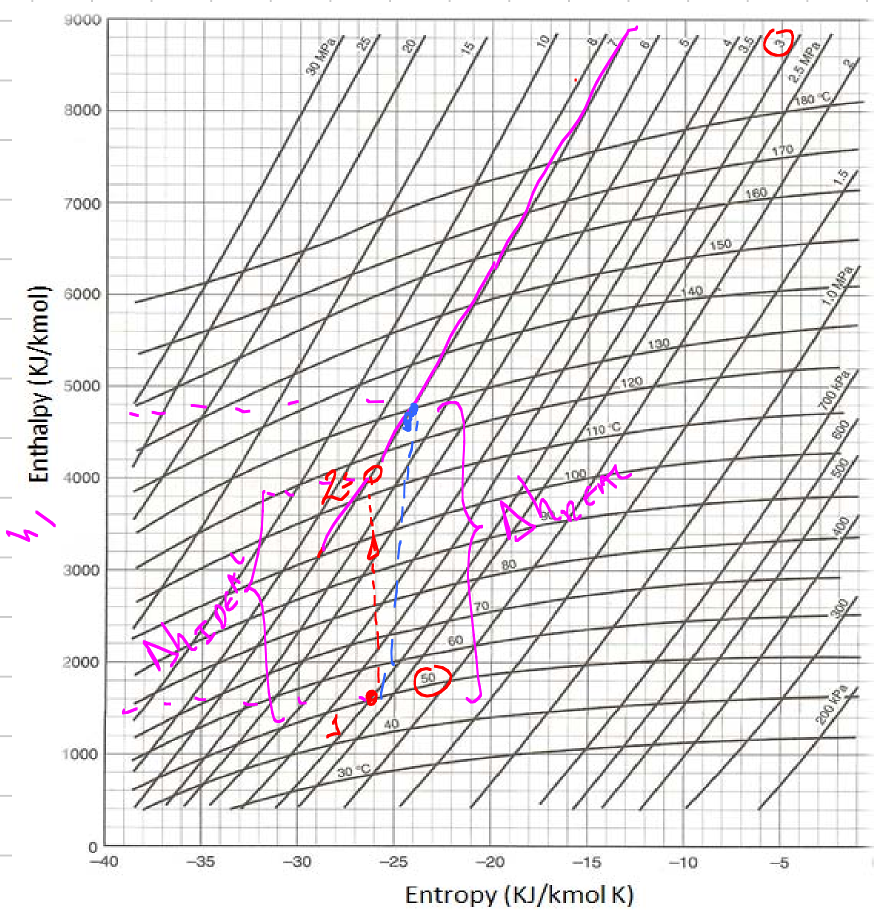
$K = \frac{C_p}{C_v}$ ... Adiabatic exponent

Natural Gas

$K = 1.3 - 0.31(SG - 0.5)$

$SG = \frac{MM_{gas}}{28.97 = MM_{Air}}$





$T_1 = 50°C$

$P_1 = 3\ MPa$

$T_2 = 130°C$

$P_2 = 7\ MPa$

$T_{2s} = 115°C$

THE ADIABATIC OR ISOENTROPIC EFFICIENCY:

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$$\eta_{\text{ADIABATIC or ISOENTROPIC}} = \left[\frac{\frac{T_{2s}}{T_1} - 1}{\frac{T_2}{T_1} - 1}\right] = \frac{\left(\frac{115}{50} - 1\right)}{\left(\frac{130}{50} - 1\right)} = 0.81$$

BUT IN COMPRESSOR ... WE PREFFER TO USE THE POLYTROPIC EFFICIENCY

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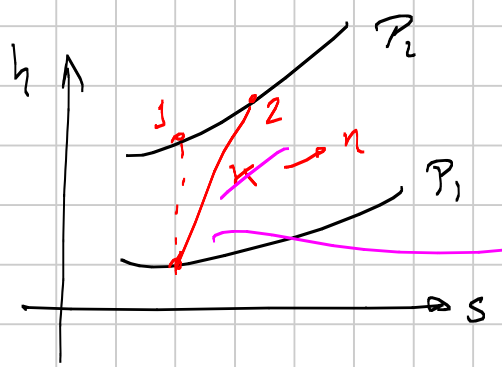
POLYTROPIC EFFICIENCY:



PRESSURE

$$P v^{n} = \text{Cte}$$

n → POLYTROPIC EXPONENT

POLYTROPIC PROCESS
↳ BEST REPRESENT REAL COMPRESSION PROCESS!

$$\eta_p = \frac{\ln\left(\frac{P_2}{P_1}\right)}{\ln\left(\frac{T_2}{T_1}\right)}$$

$$\frac{n-1}{n} = \frac{k-1}{k\,\eta_p}$$

FOR EXAMPLE ⇒ $\eta_p = 82\%$, $k = 1.4$ → $n = \dfrac{1}{1 - \dfrac{k-1}{k\,\eta_p}} \approx 1.6$

POLYTROPIC ENTALPHY HEAD:

SPECIFIC WORK → $\Delta h_p = T_1 \, Z_{AV} \, R \, \dfrac{n}{n-1}\left[\left(\dfrac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$

r_P

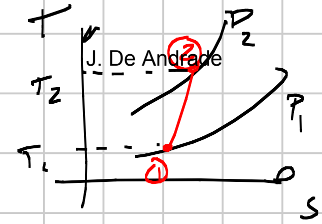
Z_{AV} → AVERAGE = $\dfrac{Z_{SUC} + Z_{DISC}}{2}$

POLYTROPIC HEAD:

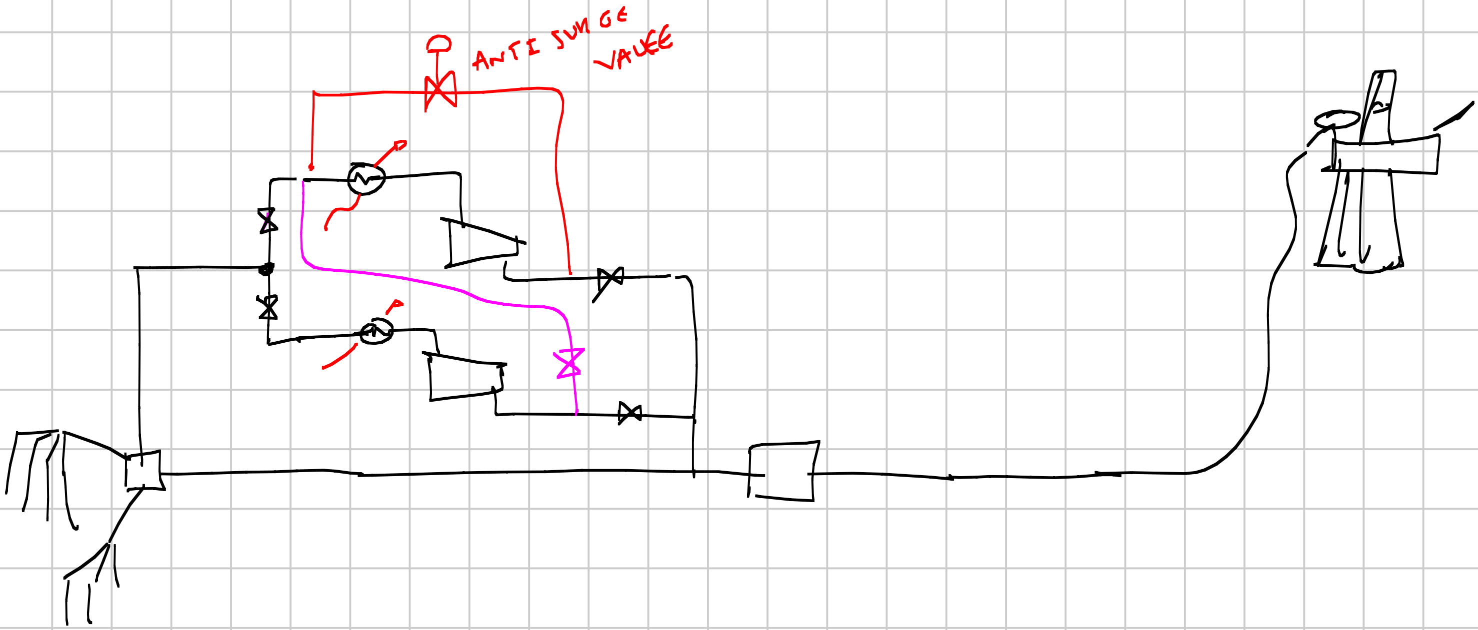
$$H_p = \frac{\Delta h_p}{g} \quad \left[\frac{kJ}{kg}\right], \; g \to 9.81 \to \left[\frac{m}{s^2}\right] \quad \Big\} \; [m]$$

DISCHARGE TEMP:

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$

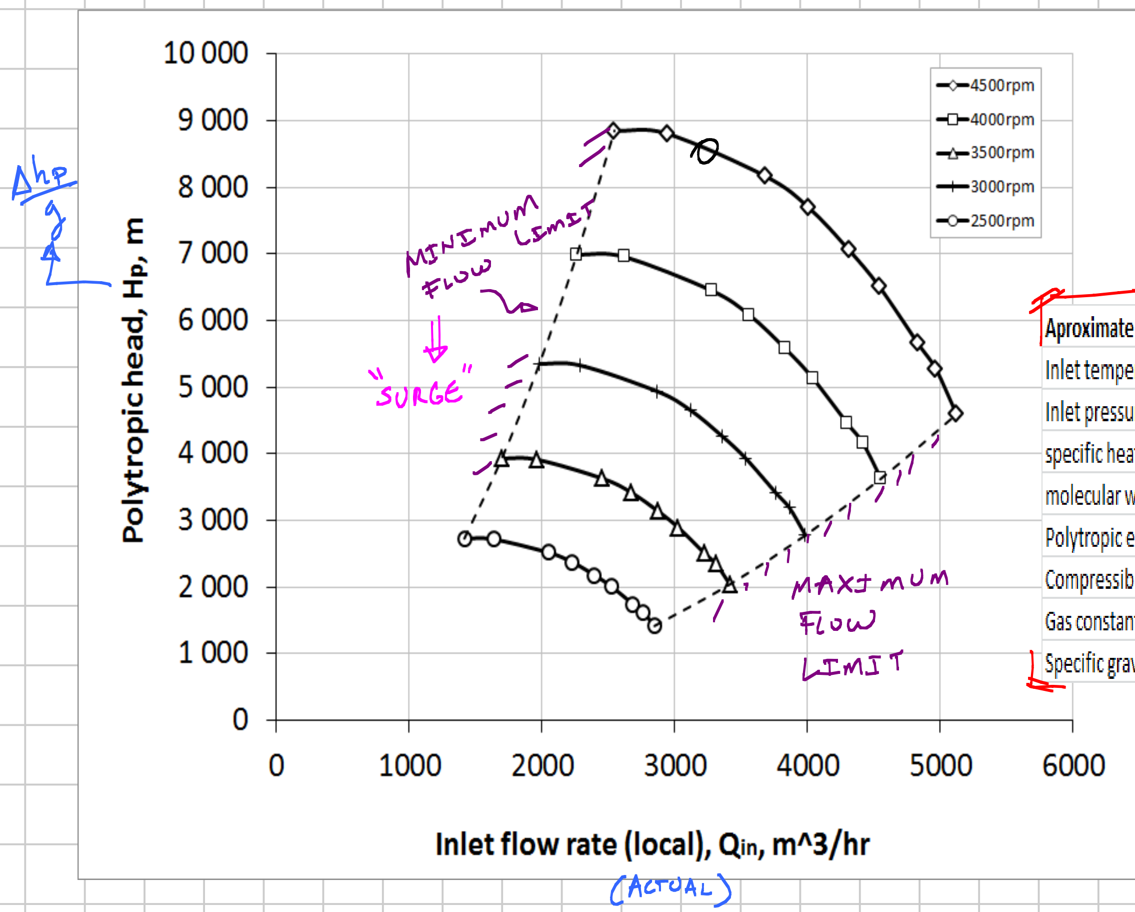


↳ YOU CONTROL WITH SUCTION COOLER



COMPRESSOR MAP

⇒ THE COMPRESSOR TEST IS CONTROLLED FOR CONSTANT CONDITIONS



Aproximate test conditions		
Inlet temperature, Tin	335.45	K
Inlet pressure, Pin	37.3	bar
specific heats ratio, k	1.43	-
molecular weight, MM	19.11	kg/kmol
Polytropic efficiency, np	0.85	-
Compressibility factor, Z	0.91	-
Gas constant, R	435.06	J/kg.K
Specific gravity, SG	0.66	-

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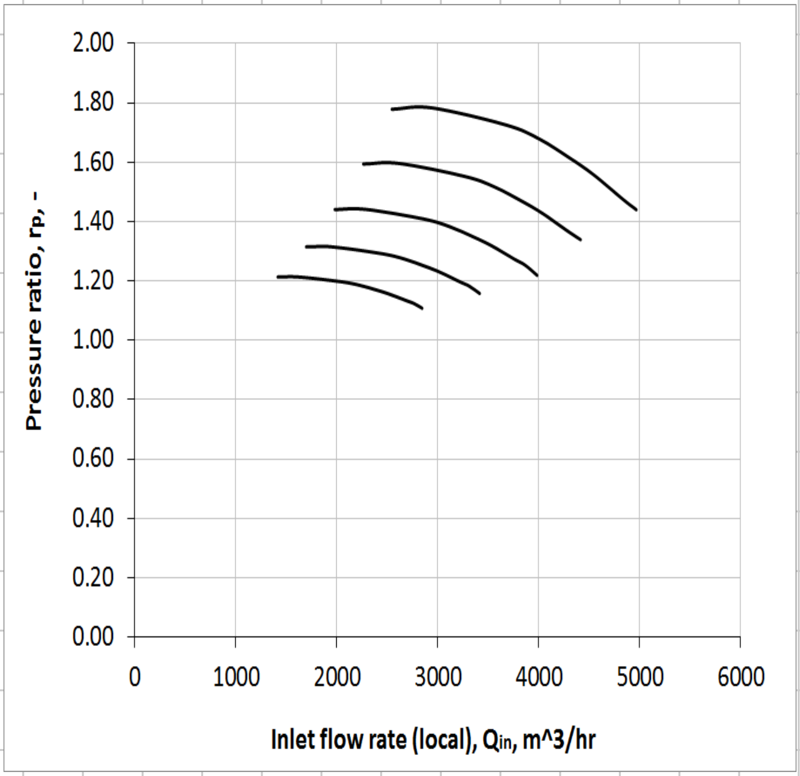
BY USING THE

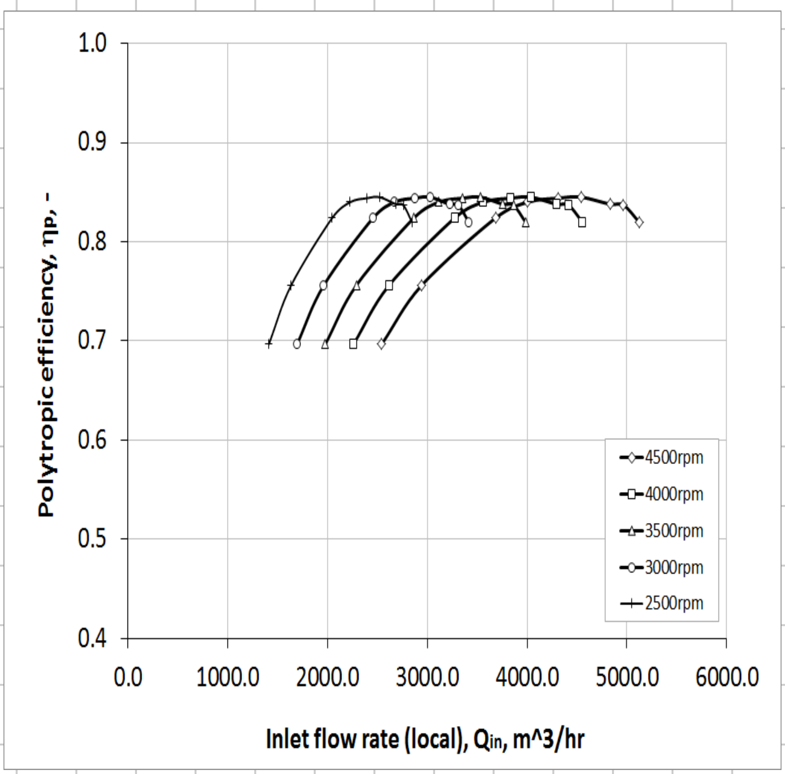
$$\Delta h_p = T_1 \, Z_{AV} \, R \, \frac{n}{n-1} \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

($\frac{P_2}{P_1} \rightarrow r_p$)

→ YOU CAN GET r_p VS. Q → PLOT



THE COMPRESSOR PERFORMANCE CURVES WILL CHAGE DEPENDING ON ACTUAL SUCTION CONDITIONS



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Power Consumption:

$$\text{Power} = \frac{\rho_{AC}\, g\, Q_{AC}\, H_p}{\eta_p \cdot \eta_m}$$

$\dot{m}$ (= $\rho_{AC} Q_{AC}$)

g → gravity

η_p → polytropic efficiency

η_m → 1

FOR GULLFAKS DRY GAS COMPRESSION STATION:

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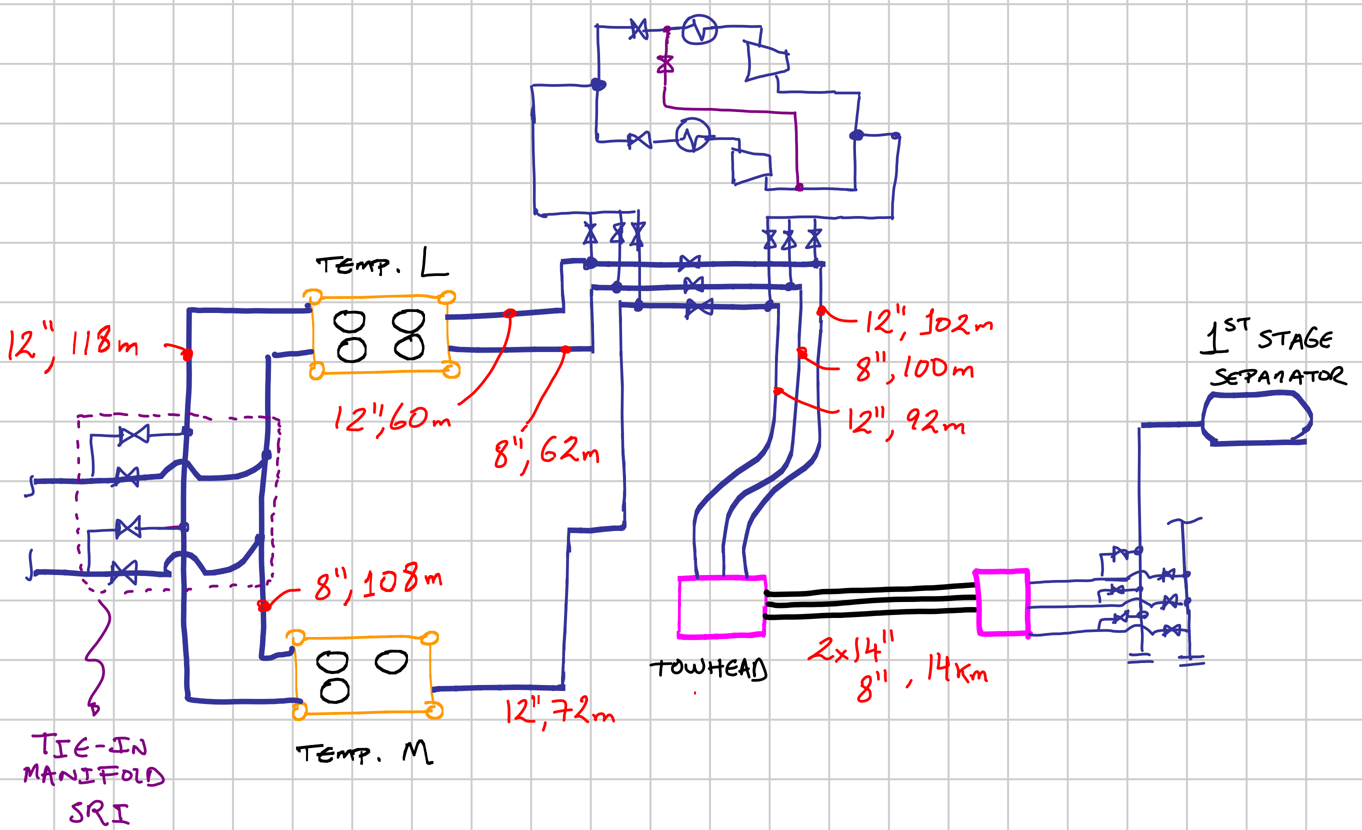

THE CONSTRAINS RELATED TO COMPRESSOR:

- COMPRESSOR SPEED → $N = 2000$ to 4500 rpm (MANUFACTURER RECOMMENDATION)
- DISCHARGE TEMPERATURE → $T_D < 110\,°C$ (LIMIT RELATED TO PIPELINE BUCKLING)
- POWER → MAX. 5MW IS AVAILABLE (MOTOR)
- MAXIMUM ΔP COMPRESSOR → $\Delta P_{MAX} = 32$ bar (MECHANICAL LIMIT)

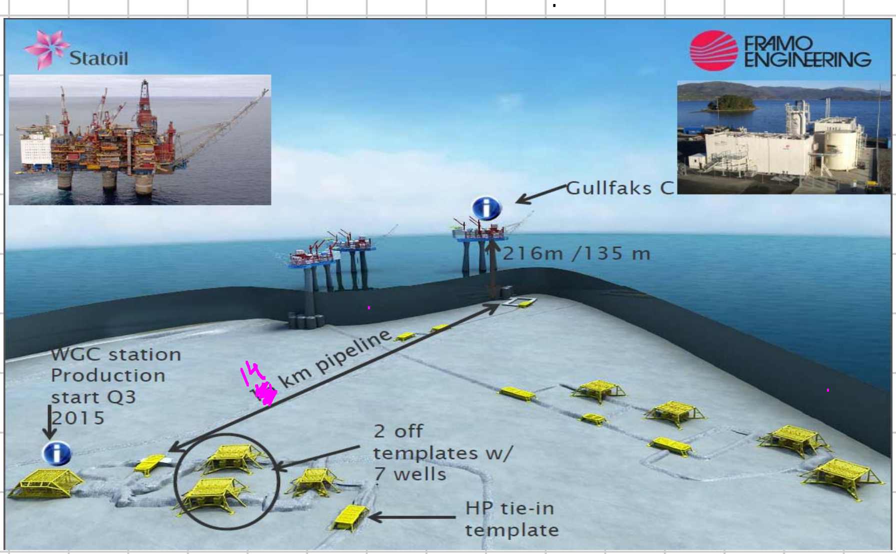

Figure 2 Subsea Multiphase Compressor – WGC4000 FRAMO

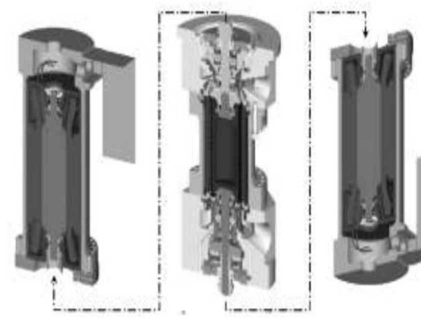

Figure 3 Cross Section of Left; upper motor, Center; hydraulic section, Right; lower motor