GTEN Spring Technical Course
May 26, 2025 Halifax NS, Canada

Gas Compression in Pipelines and Offshore Platforms

Rainer Kurz

RKSBenergy, LLC

45 min

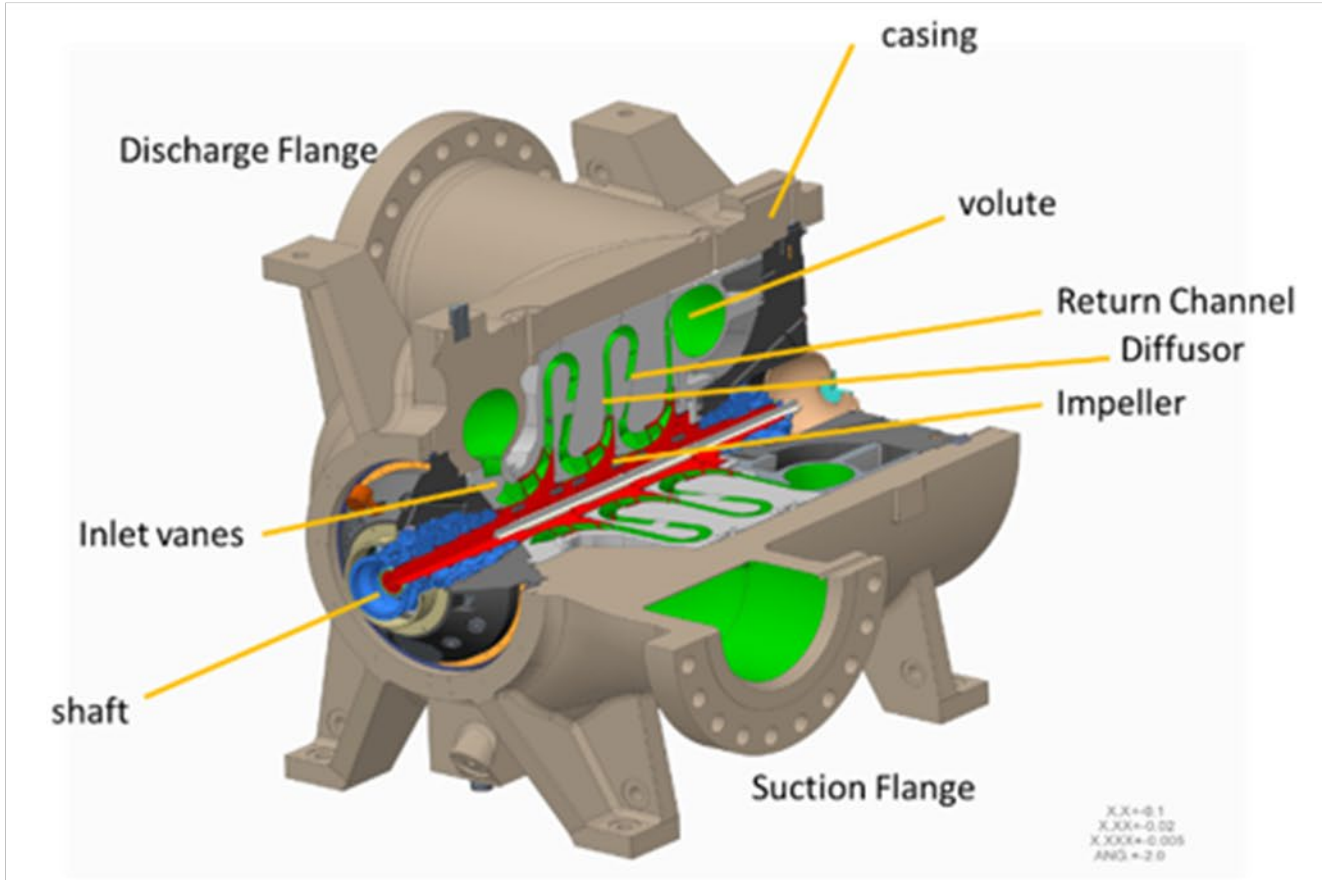
Overview

- Compressors
- Aero and Thermodynamics
- Drivers
- Control, Surge , Stall
- Rotordynamics
- Applications
- Summary

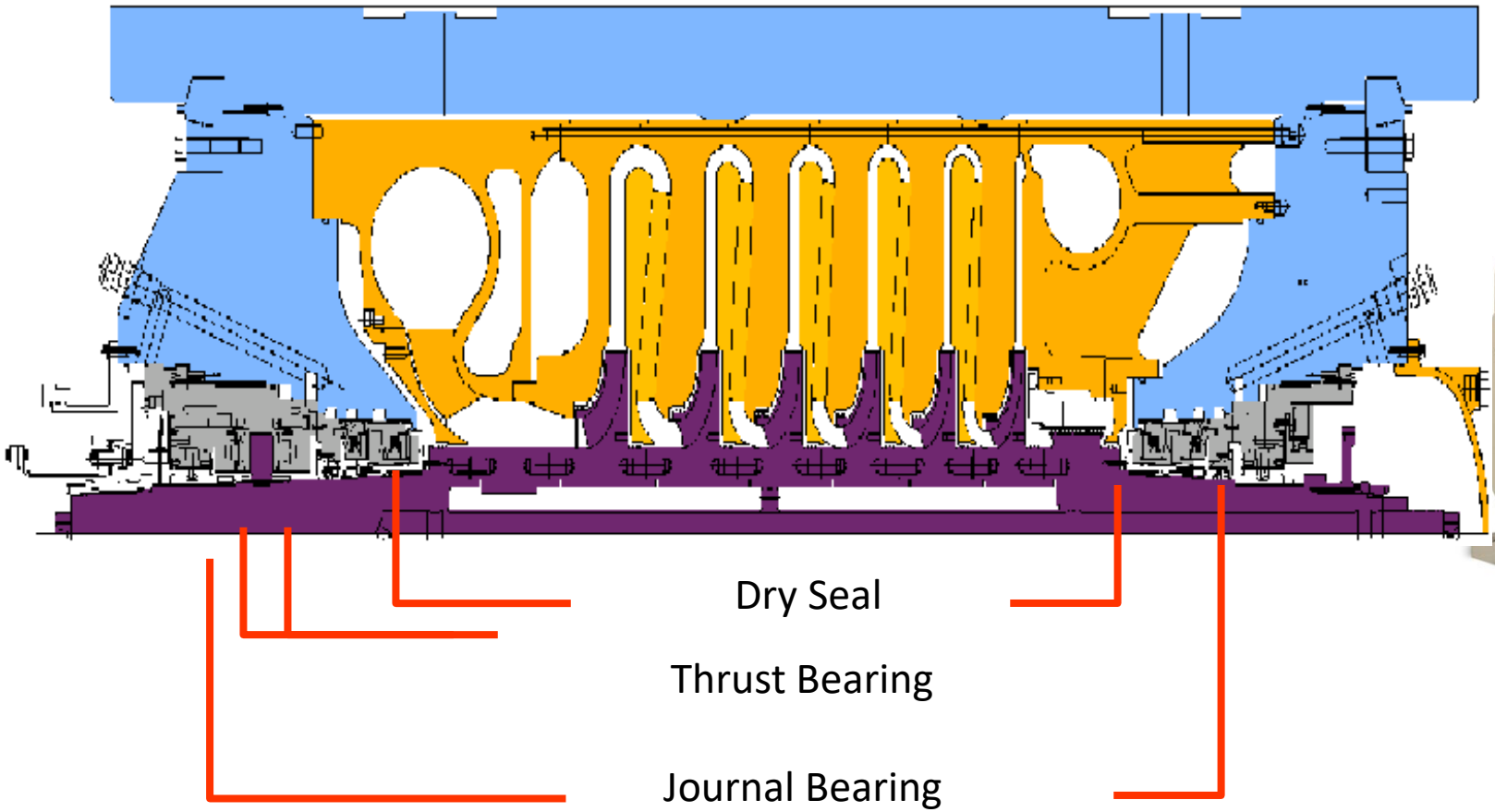
Compressors

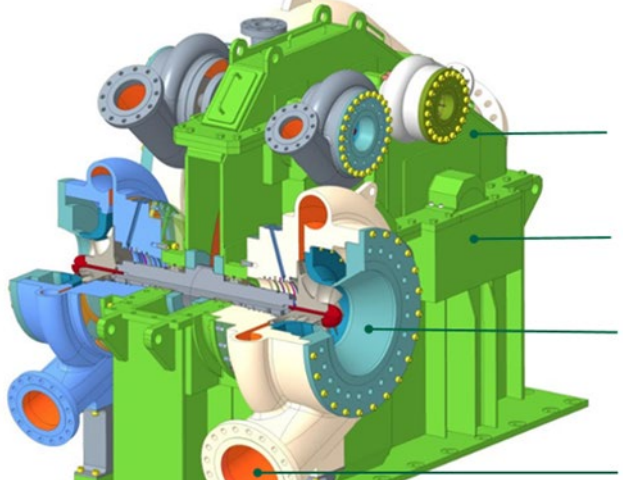
Components

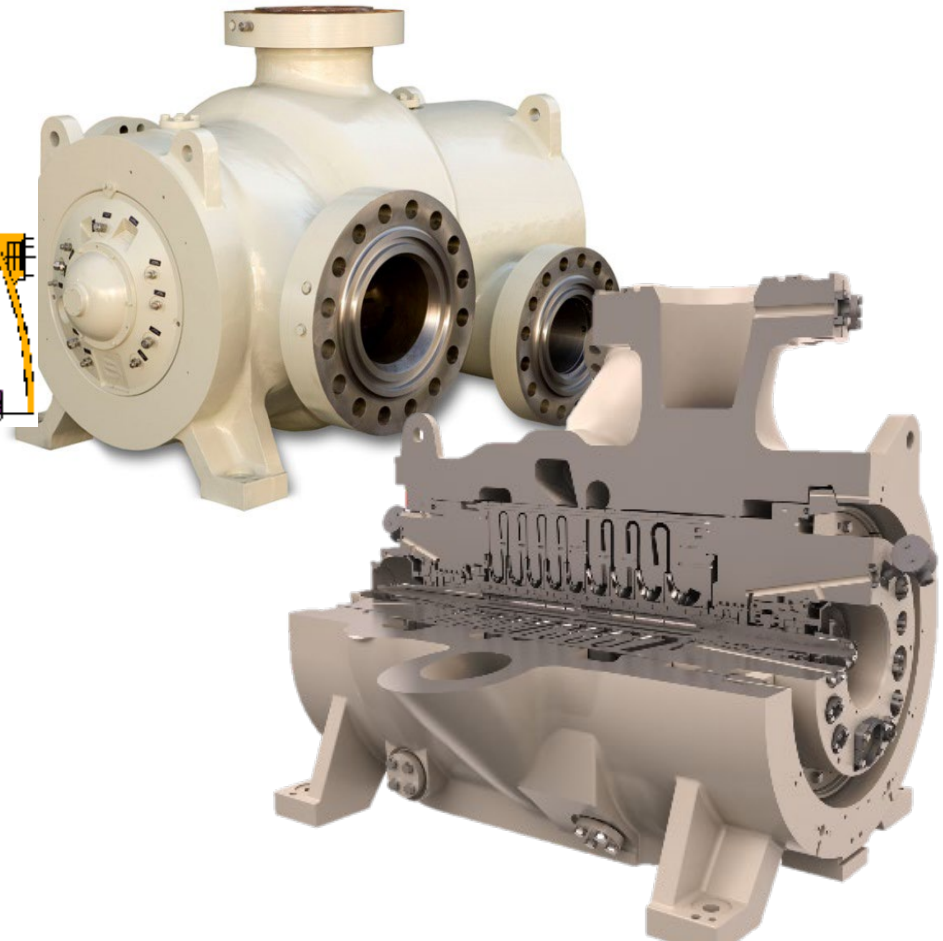
- Suction flange
- Inlet guide vanes
- Impeller
- Diffuser
- Return vane
- Volute
- Discharge flange



Centrifugal Compressor

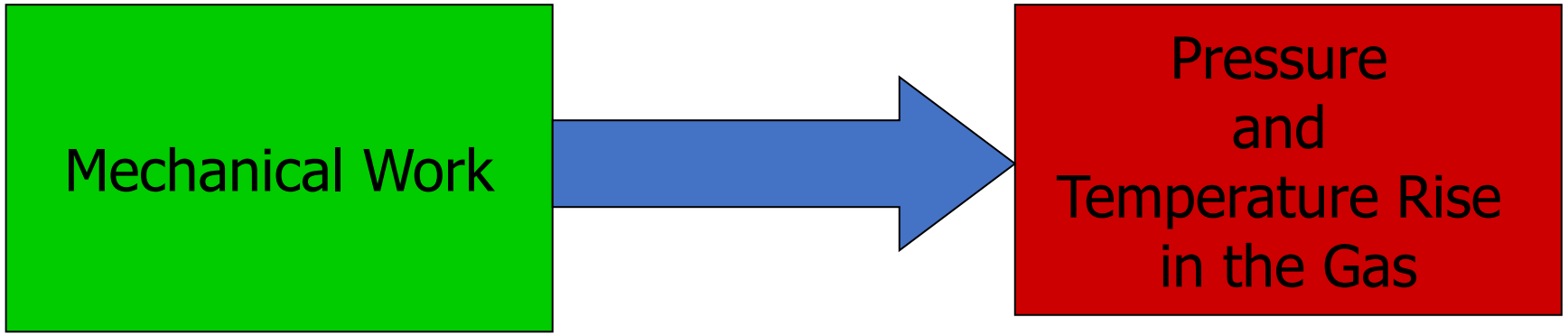






Aero and Thermodynamics

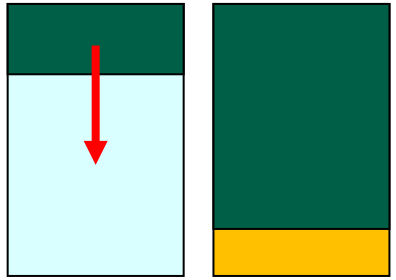
Head, Work and Energy



- The Compressor uses mechanical energy (‘Work’) to increase the energy of the Gas (‘Enthalpy Difference’). This energy increase is often referred to as actual head.
- The increase in energy of the gas shows as increase in pressure and temperature.
- Power is Mass Flow times Work.
- There will be losses

Gas Laws

- The relationship of pressure, temperature and density
- Same principle for centrifugal and reciprocating compressors:

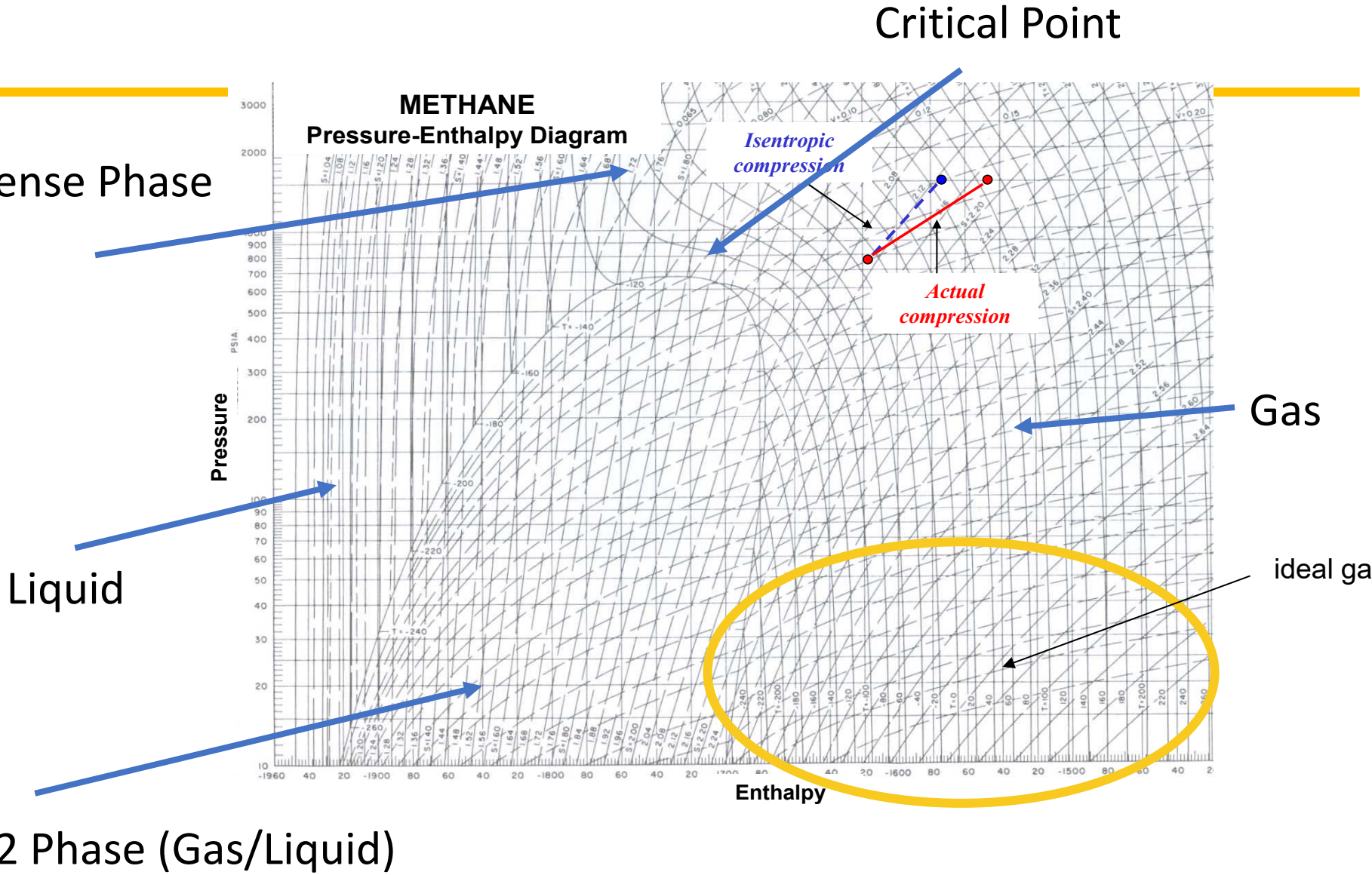


- When gas is compressed, both its density and its temperature increase (unless heat is exchanged with the environment)
- Adiabatic : No heat exchange with the environment

GAS BEHAVIOR: NG,CO2 AND H2 AND ALL THAT

These are just gases

- Except supercritical CO_2 is a bit special, but this may not be relevant
- Except H_2 is very light

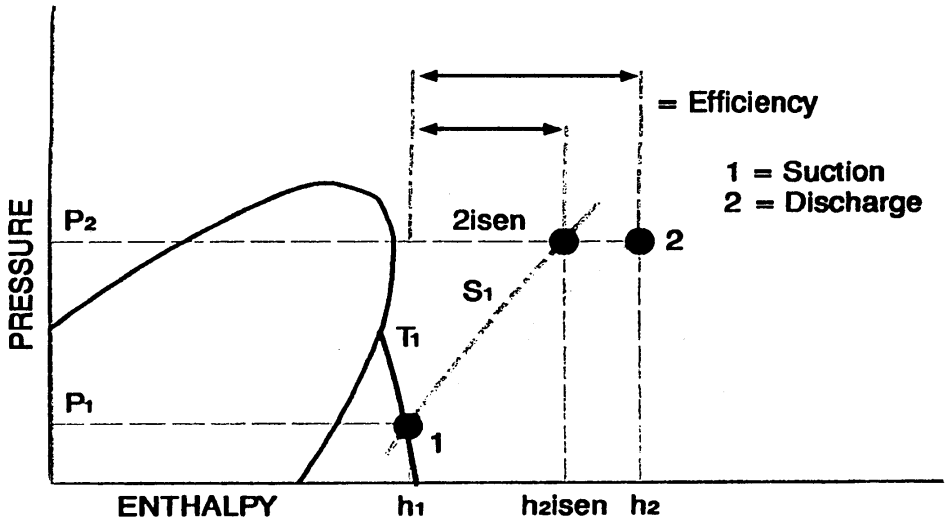


Isentropic and Polytropic Efficiency

$$\eta_s = \frac{H_s}{H}$$

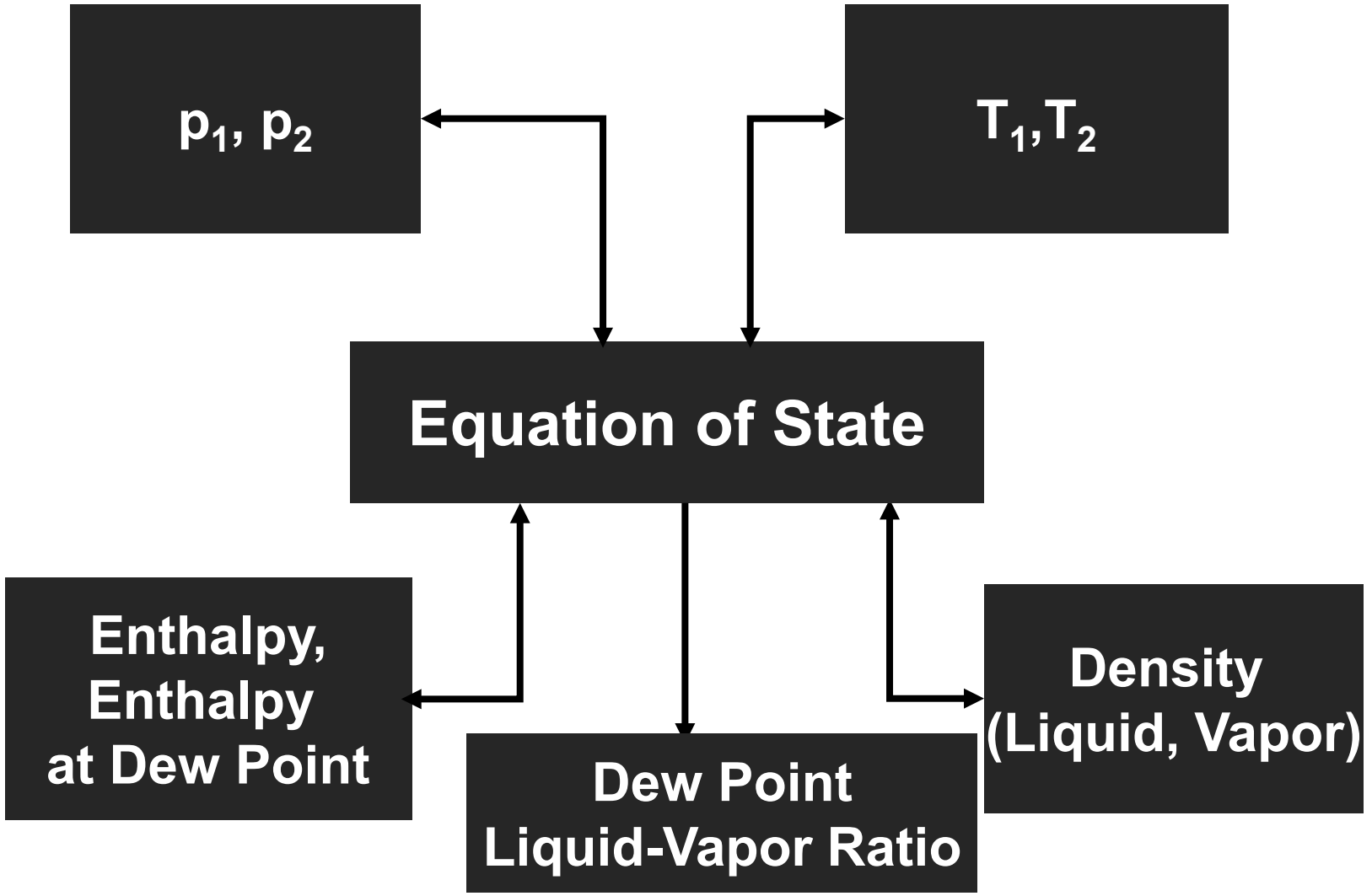
$$\eta_p = \frac{H_p}{H}$$

$$H = \frac{H_s}{\eta_s} = \frac{H_p}{\eta_p}$$



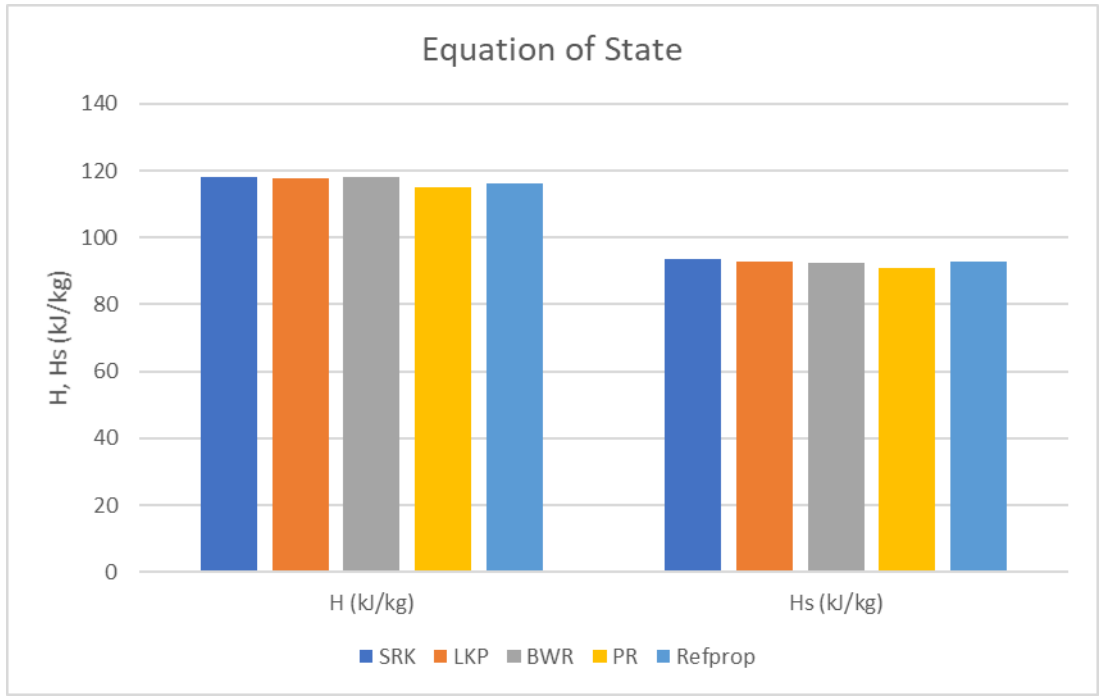
$$\text{Efficiency} = \frac{\text{Enthalpy(2isen) - Enthalpy(1)}}{\text{Enthalpy(2) - Enthalpy(1)}}$$

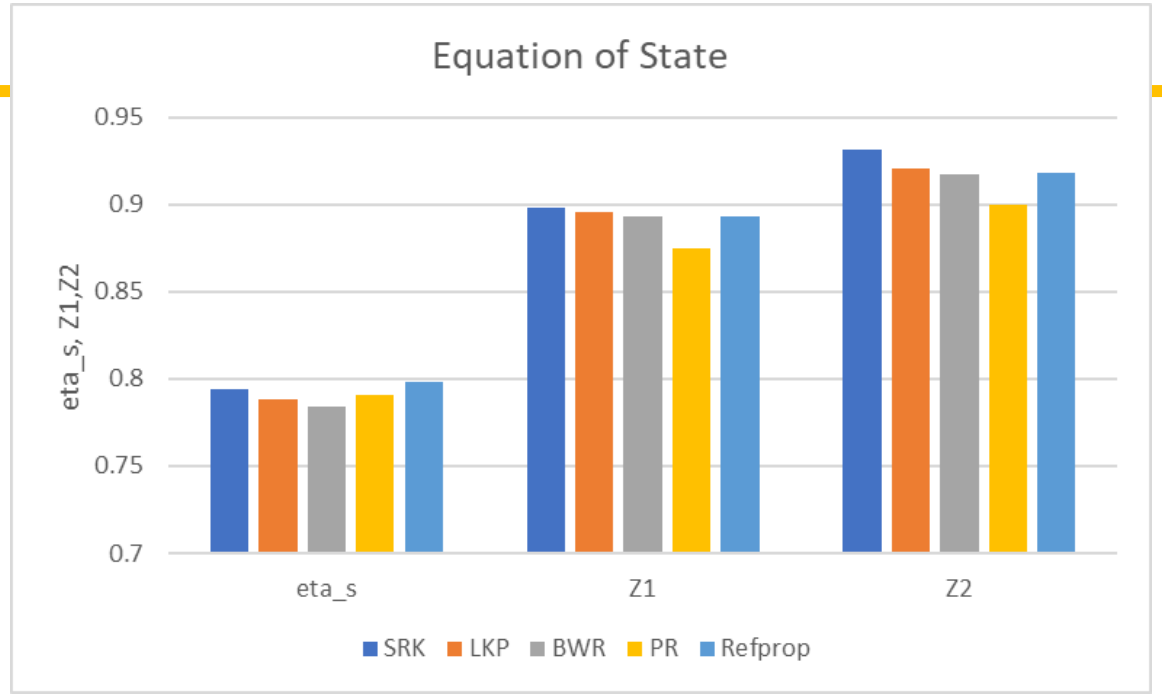
How Equations of State Are Used



Equations of State

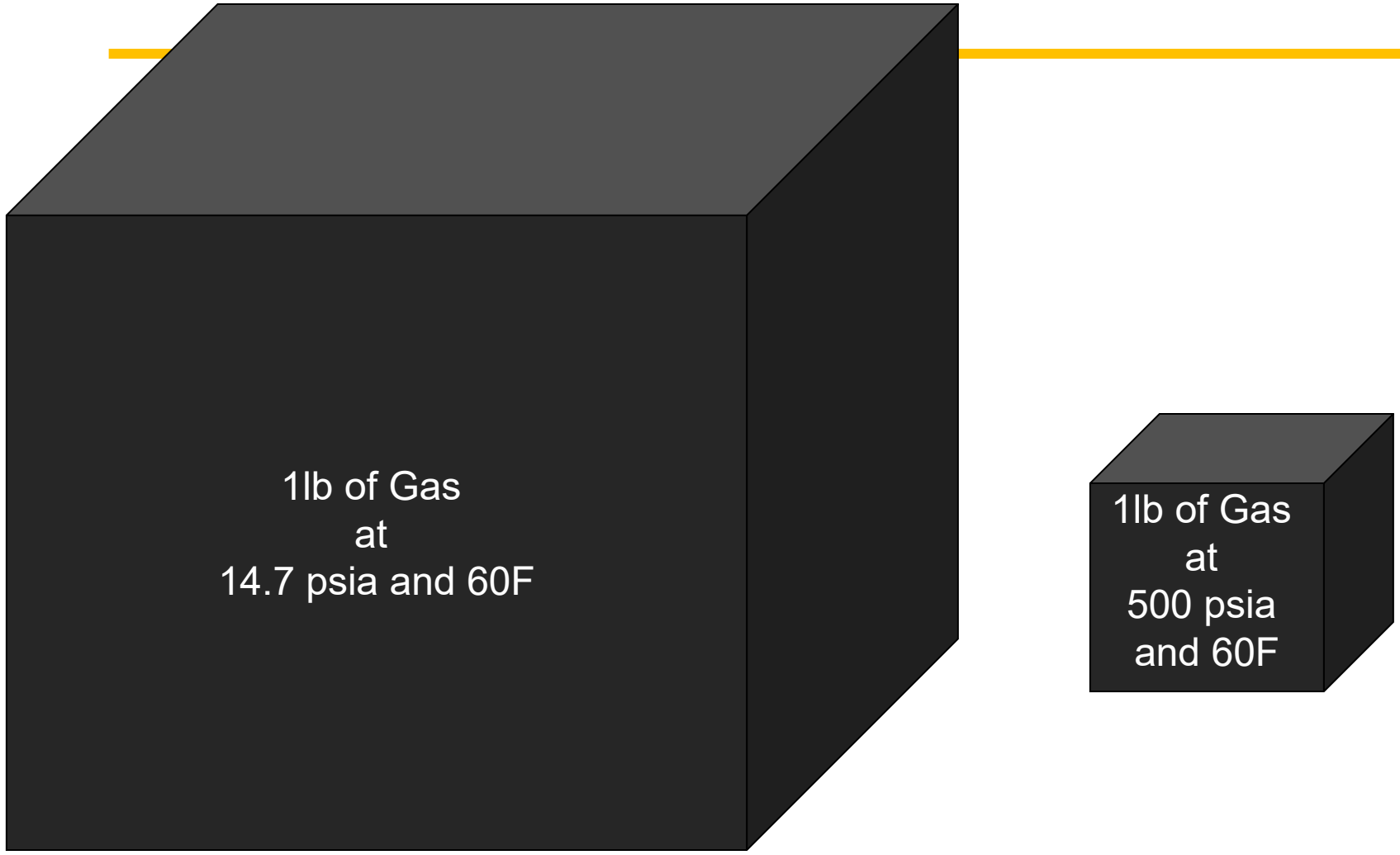
SRK, LKP, BWR, PR, Refprop





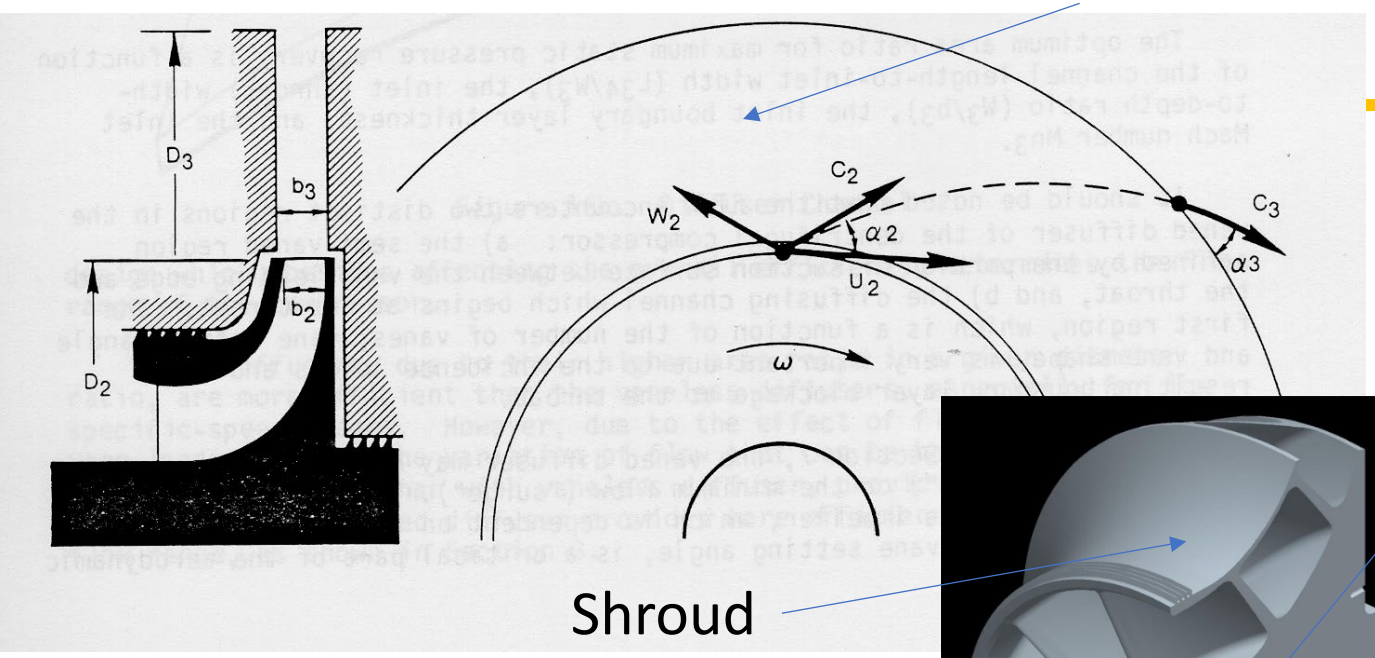
All calculations based on the following data:
Gas: 90%CH4, 5% C2H6, 2% C3H8,2% N2, 1% CO2
p_1= 50 bara p_2= 100 bara
T_1=20° C T_2=82° C

ACFM and SCFM



Compressor Stage

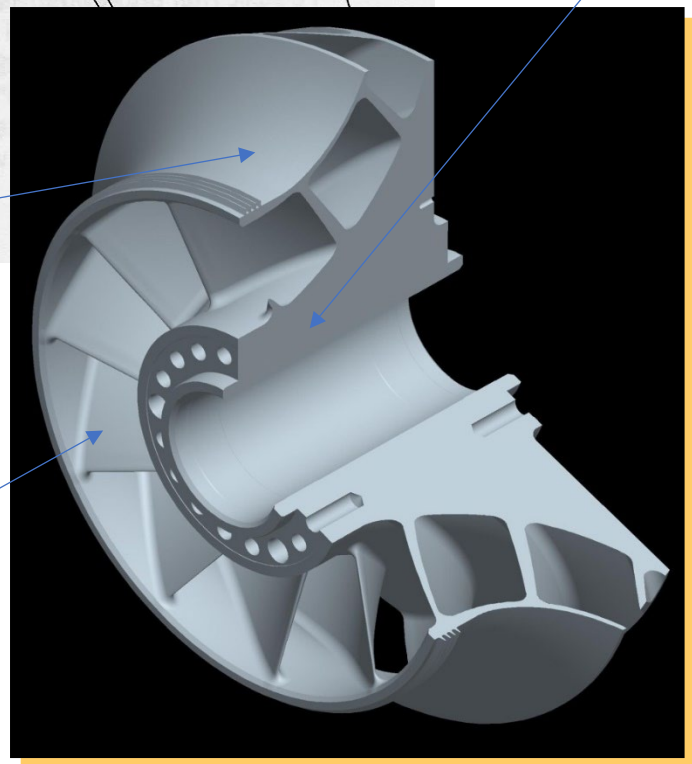
Vaneless Parallel Wall Diffusor

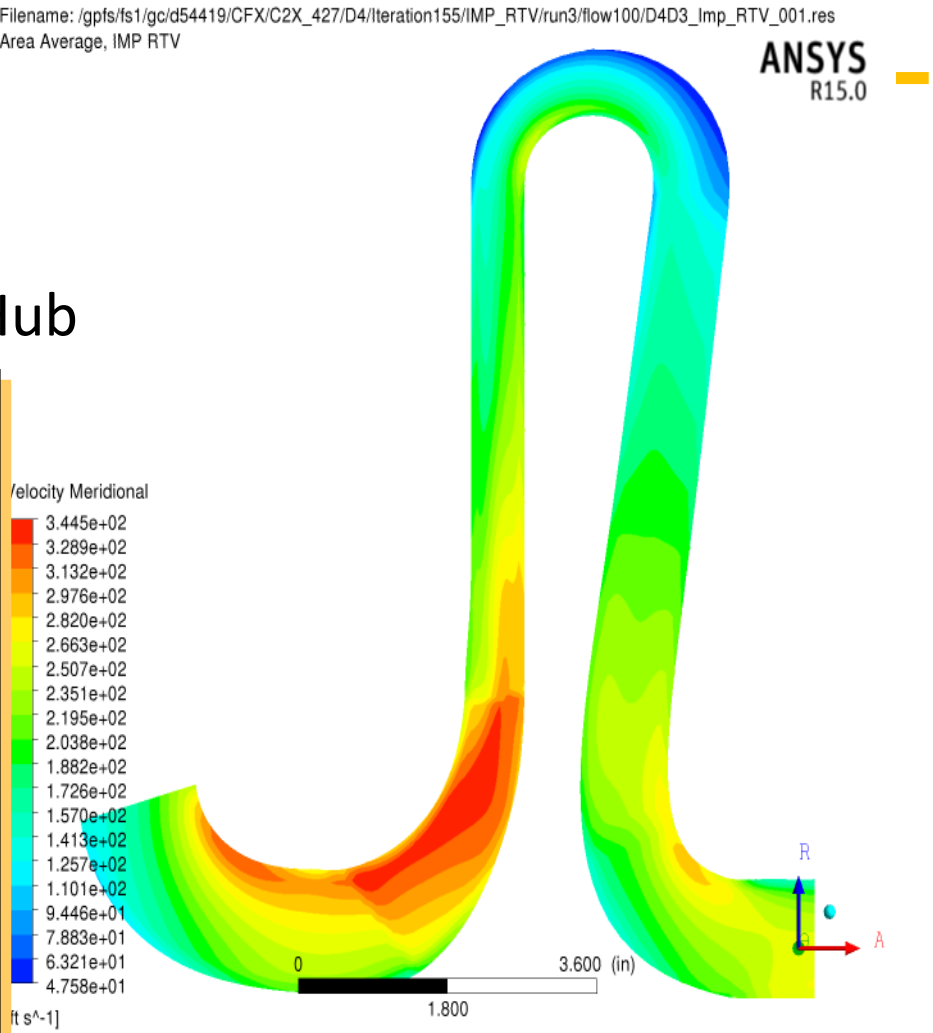


Shroud

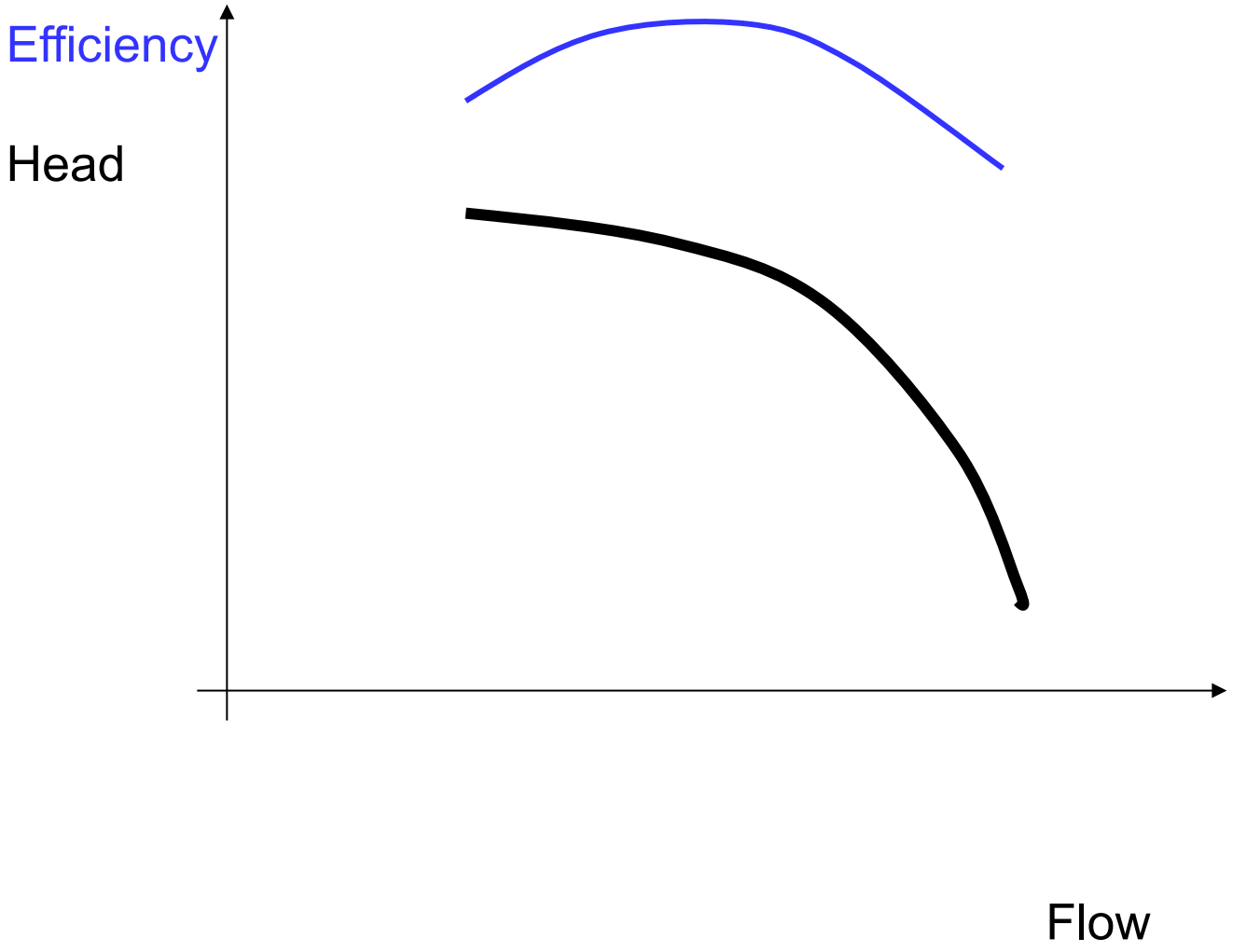
Hub

Vane

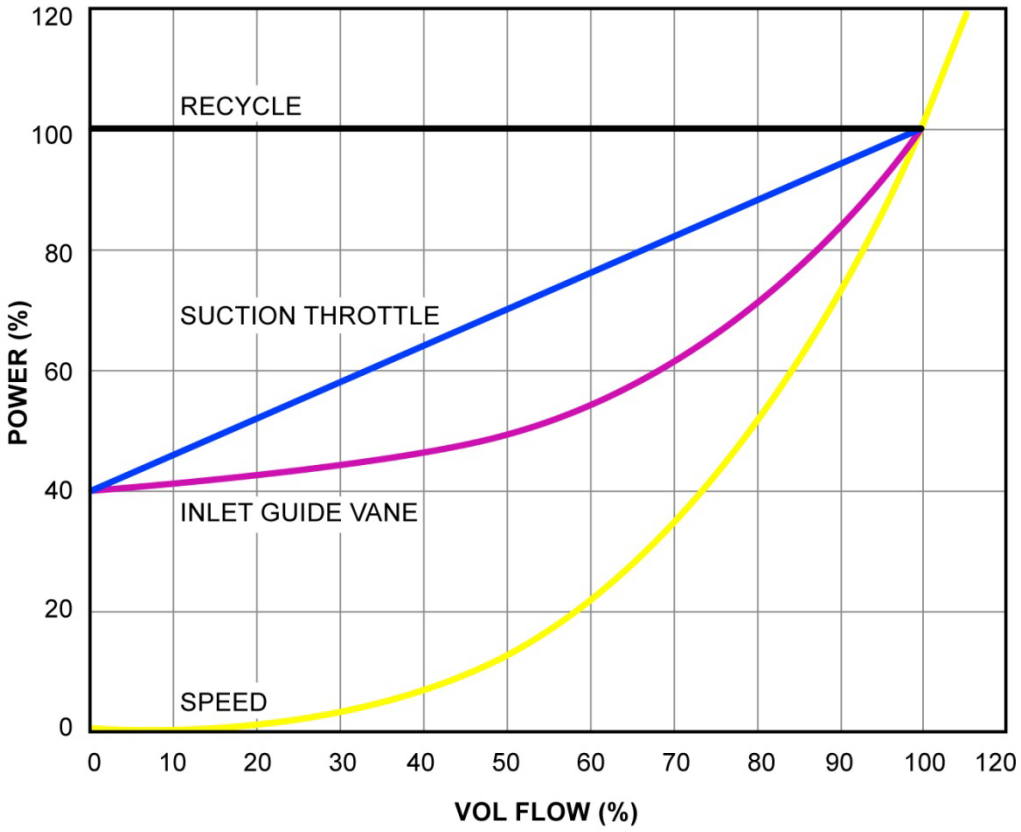


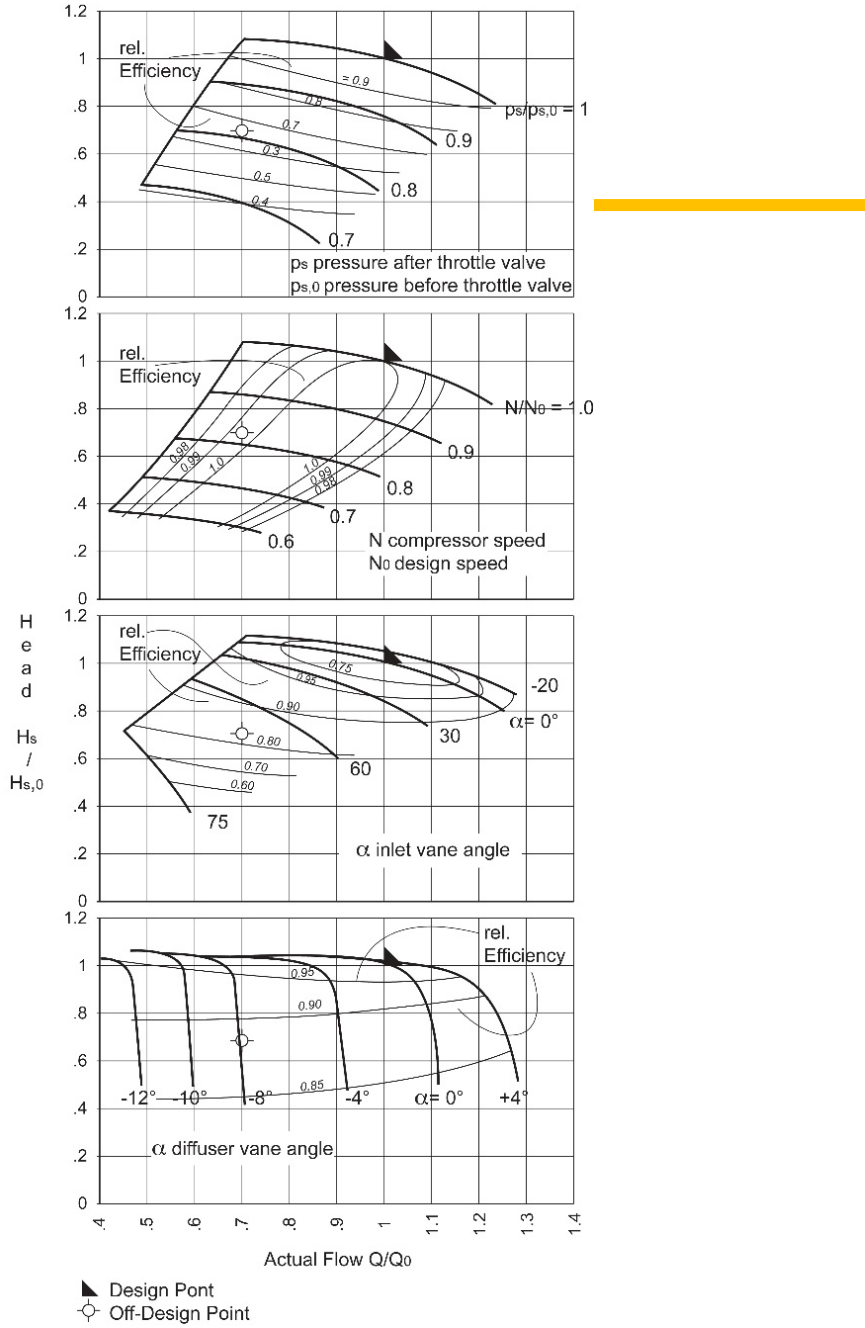


Constant Speed Map



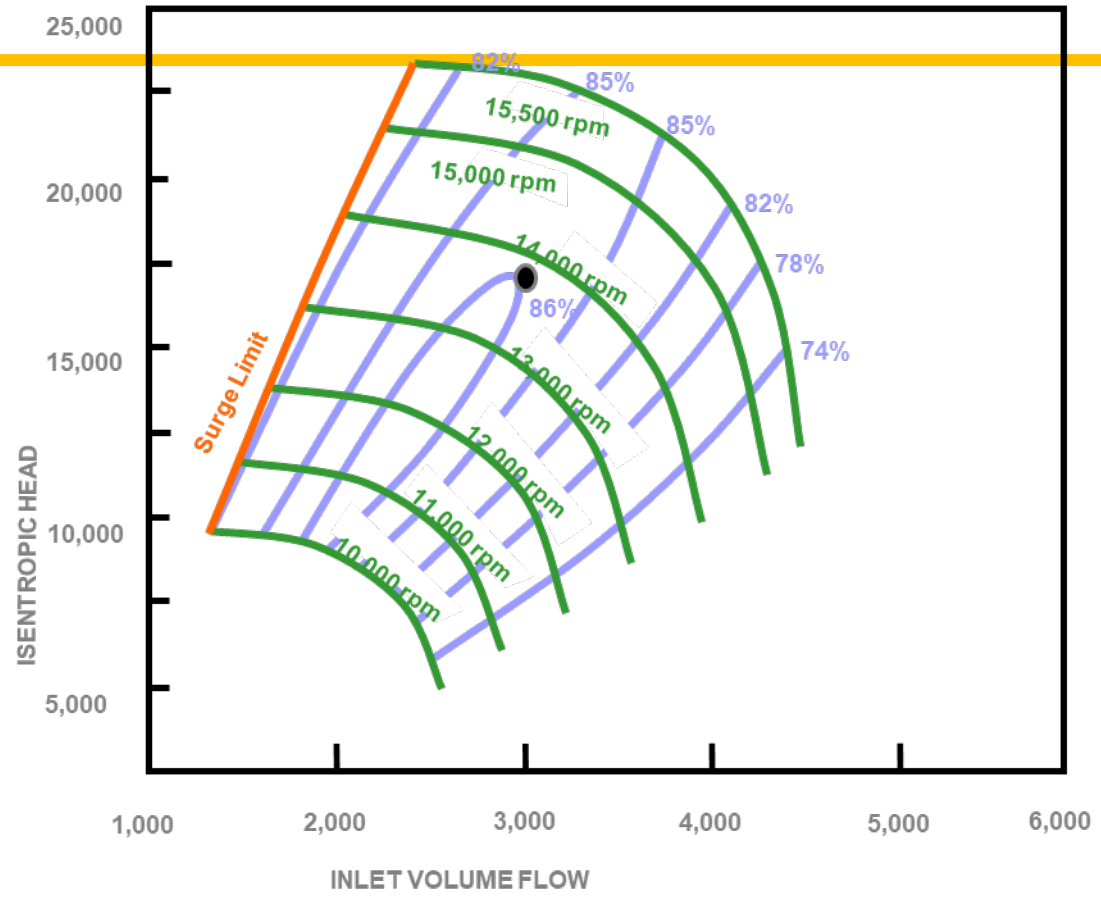
Control Methods





Variable Speed Control

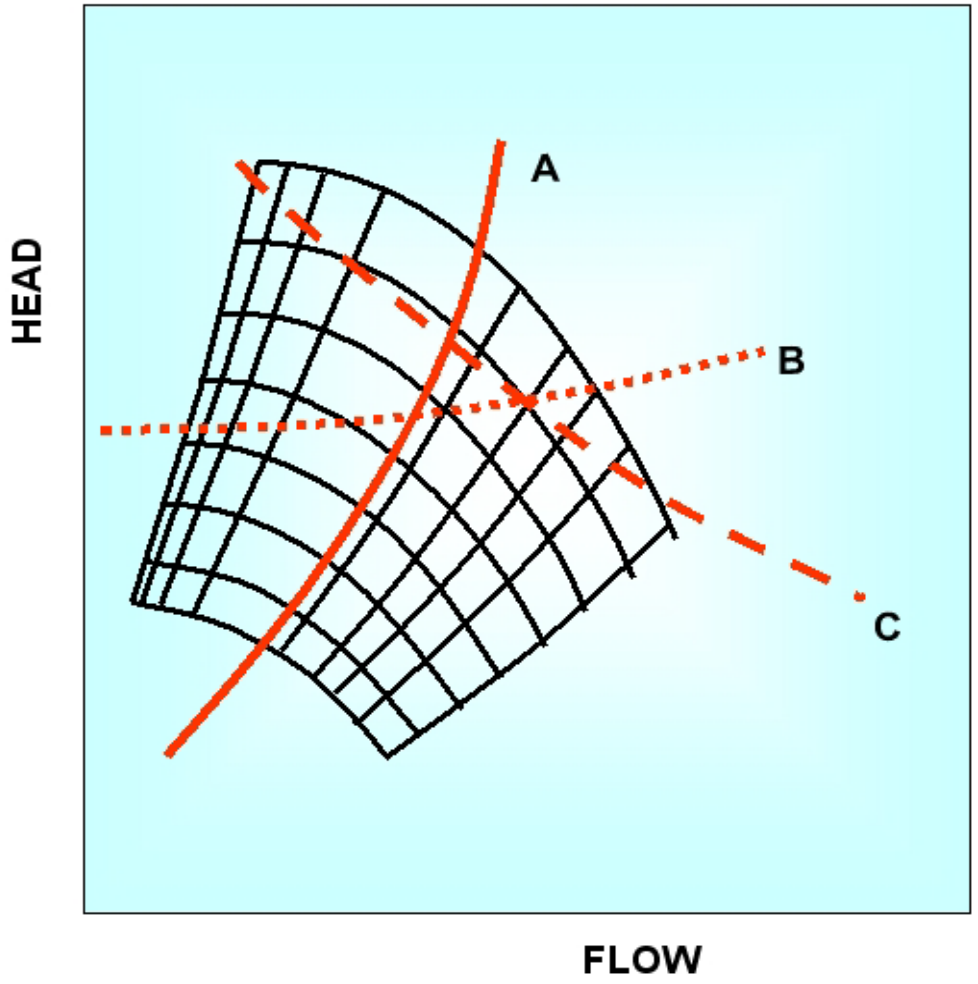
The faster it spins, the more work (head) gets imparted, but also the more flow is processed, and the more power is consumed.



Twice the speed yields twice the flow, four times the work, and eight times the power

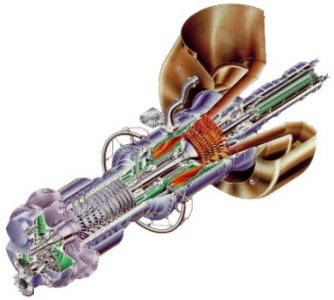
Control and System Response Ground Rule

- The system determines the pressure (often as a function of flow)
- Based on available power, the compressor reacts to suction and discharge pressure with a certain flow
- Note : we depict the system pressures in the form of an isentropic (not polytropic) head



Drivers

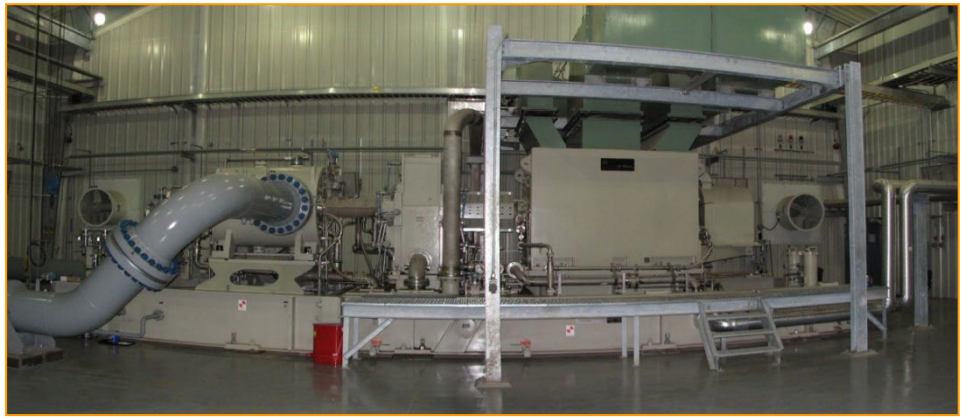
Drivers



2-shaft gas turbine

- Gas Turbines
  - Single shaft
  - Two shaft
- Electric Motors
  - Constant Speed
  - Variable Speed Drives (VFD)
  - Variable Speed Gearbox
- Steam Turbines
- Speed-Power Relationships

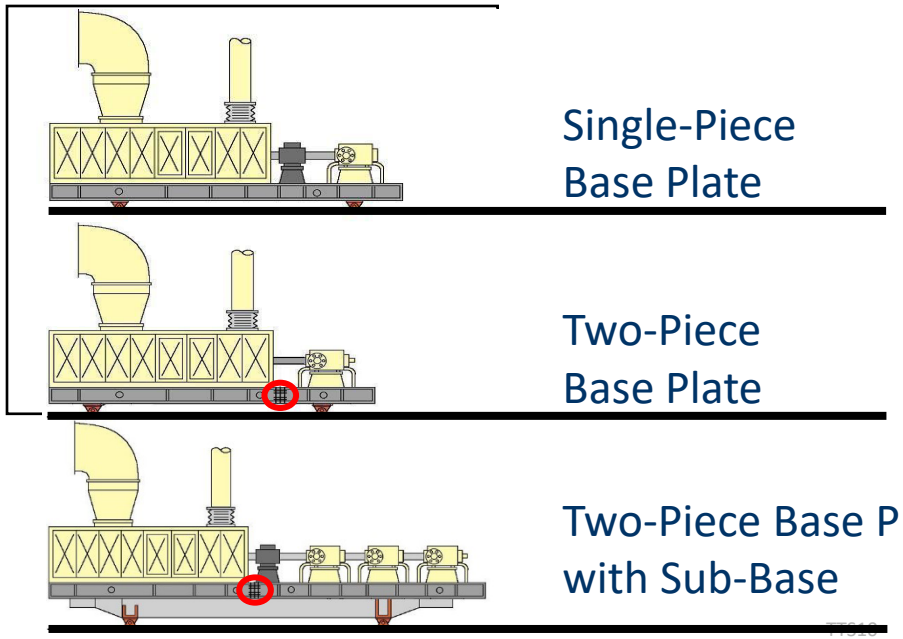
Variable speed gearbox with constant speed electric motor



Electric Motor with variable frequency (VFD) Drive

Offshore Packaging Challenges

3-Point Mount Base Plates



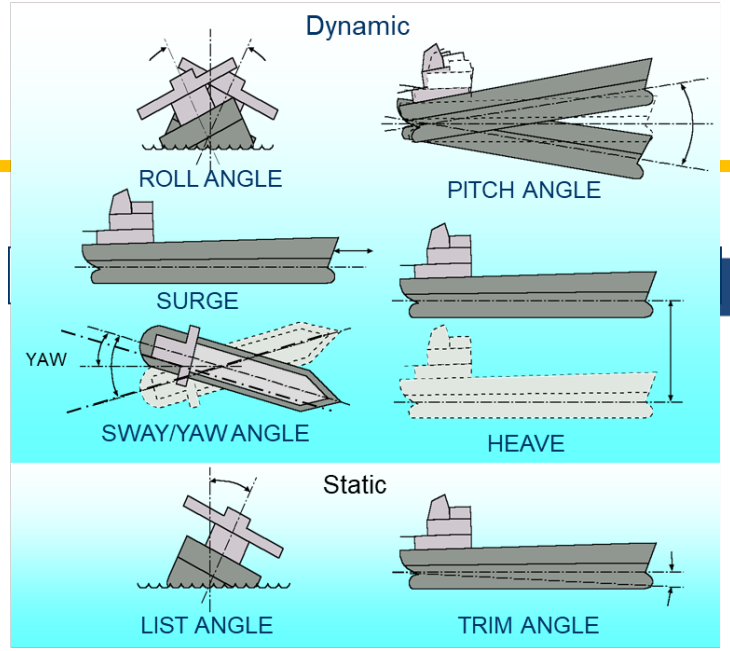
Single-Piece Base Plate

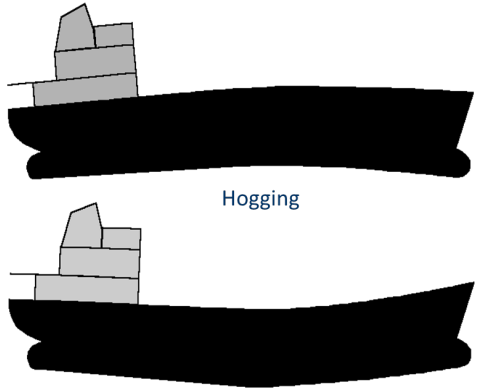
Two-Piece Base Plate

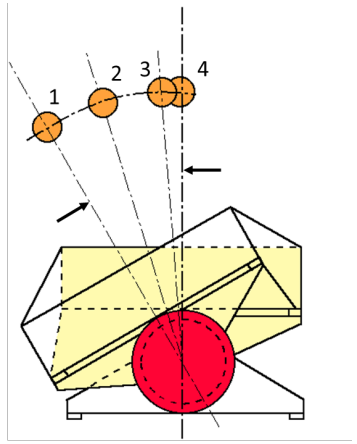
Two-Piece Base Plate with Sub-Base

5-001

Vessel Motions



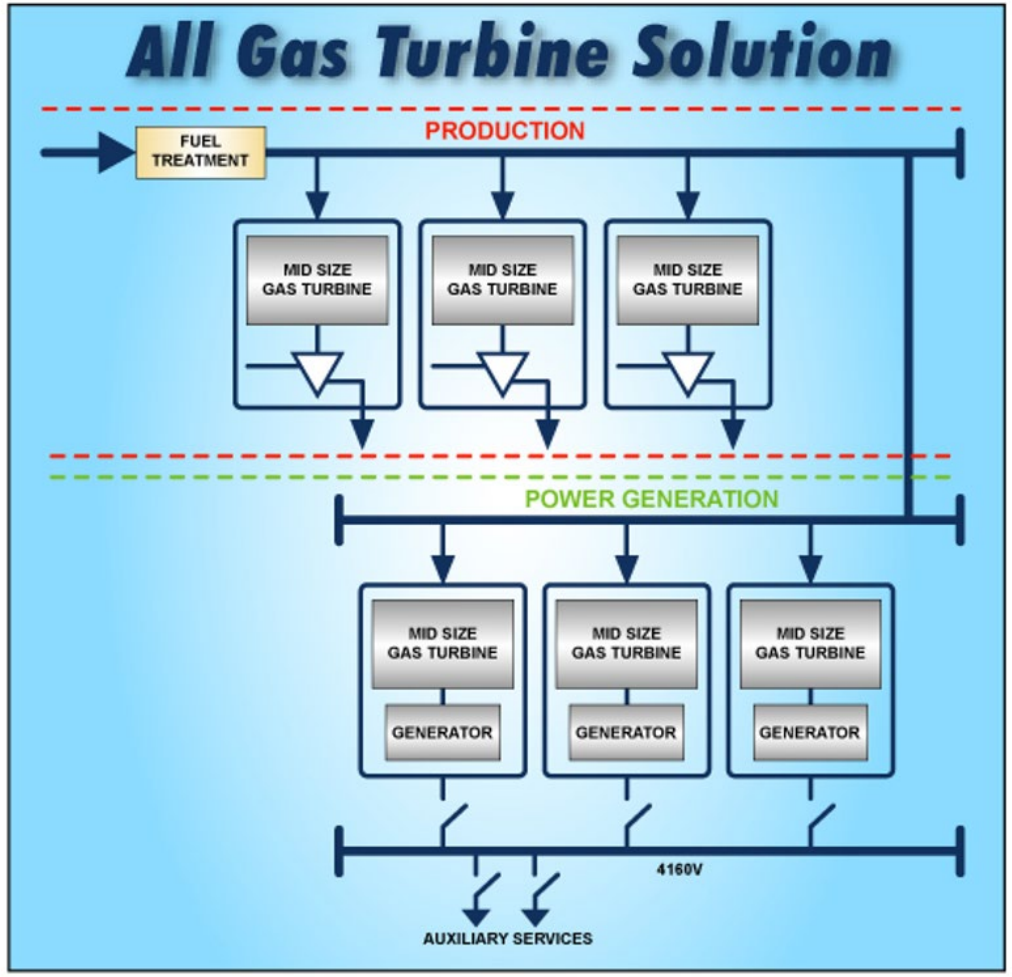


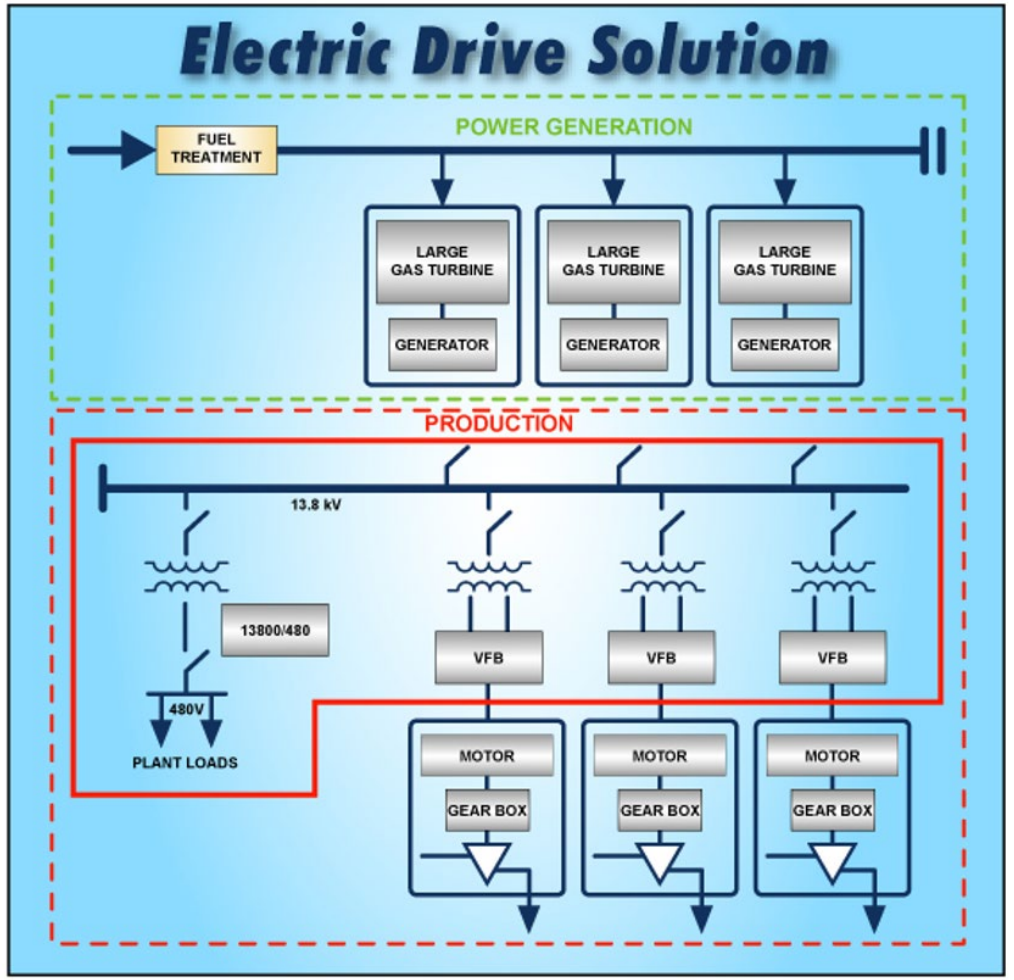


Twisting

Vessel Distortion

Gas Turbines and Electric Motors



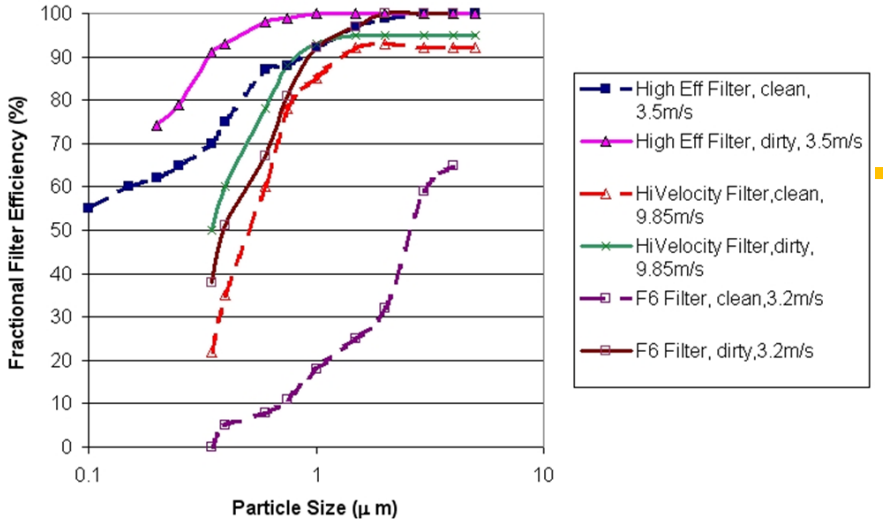


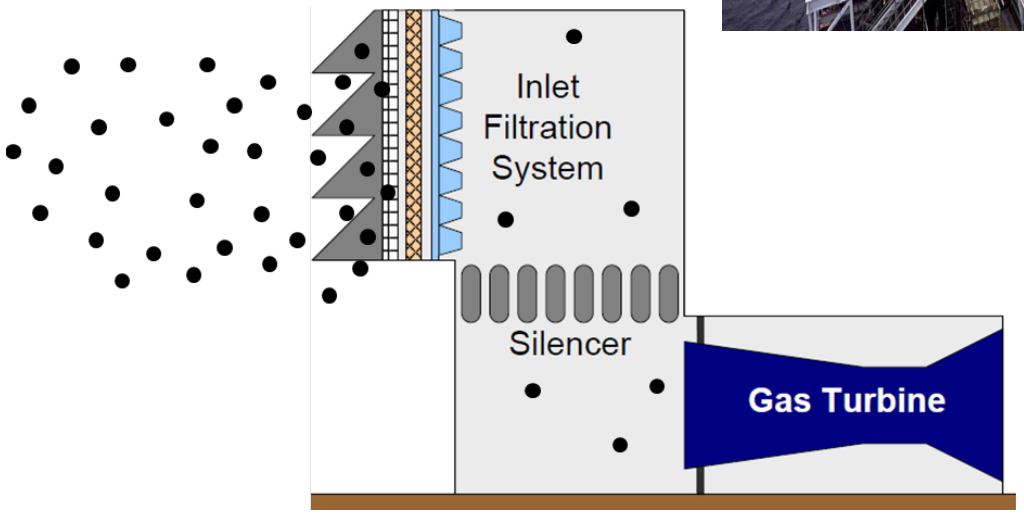
Important Fuel Properties

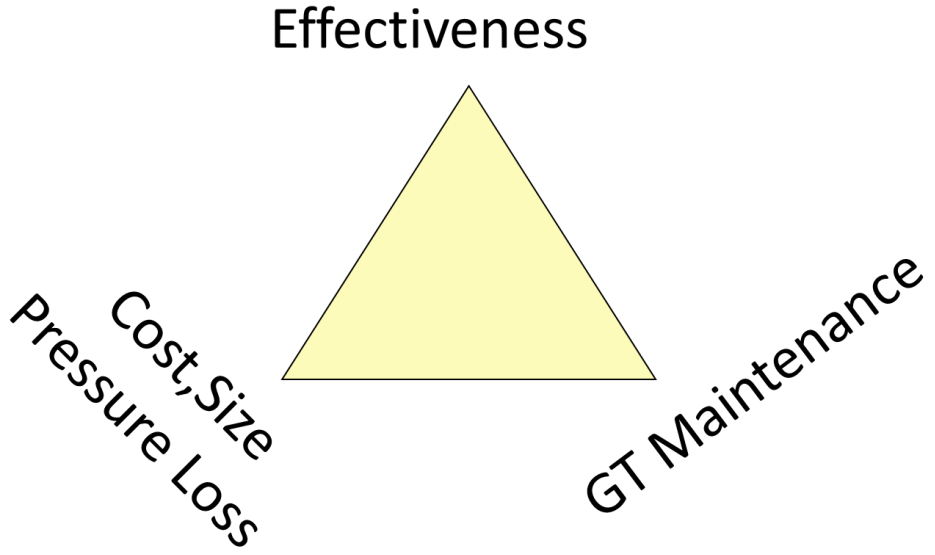
- Heating Value/Wobbe Index
- Dew Point
- Ratio of Flammability Limits
- Flame Temperature
- Blowout
- Flashback
- Laminar and Turbulent Flame Speed
- Autoignition Delay Time
- Contaminants

First Line of Defense: Inlet and Filtration System

- Prevent Airborne Contaminants from Entering the Engine
- Pressure Loss

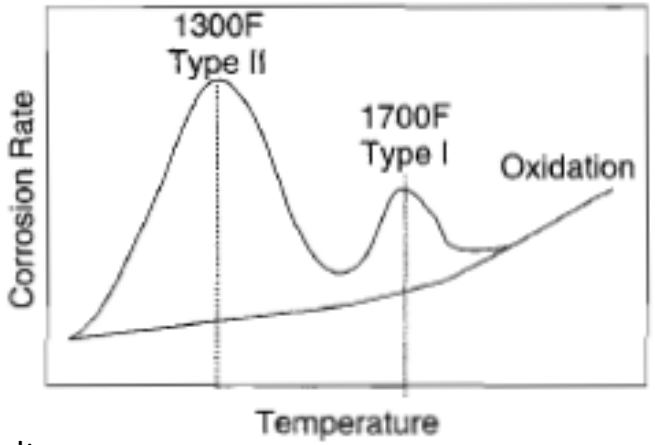




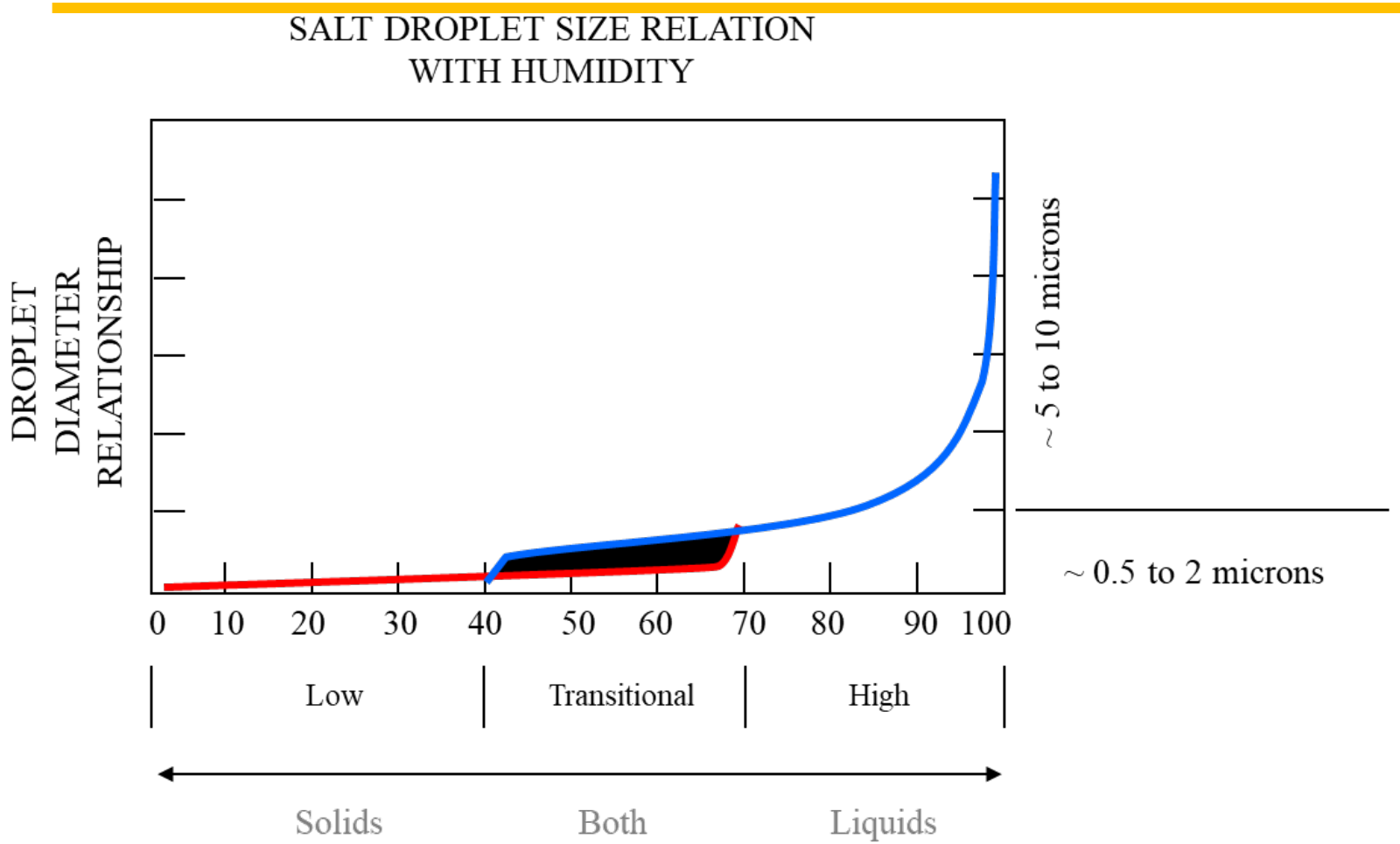


Hot Corrosion

- A form of accelerated oxidation
- 1100 to 1750F temperature range: two types
  - Type I, High Temperature (1350 – 1750F)
  - Type II, Low Temperature (1020 – 1350F)
- Na_2SO_4 commonly responsible
- Sodium intake is critical
- Potassium, vanadium, and lead also contribute to hot corrosion



Behavior of Airborne Salt with Changes in Relative Humidity



Filter has to deal with salt dissolved in water and salt particulates both in the airstream and in its surface!

Surge, Stall and Control

Complete Compressor Map

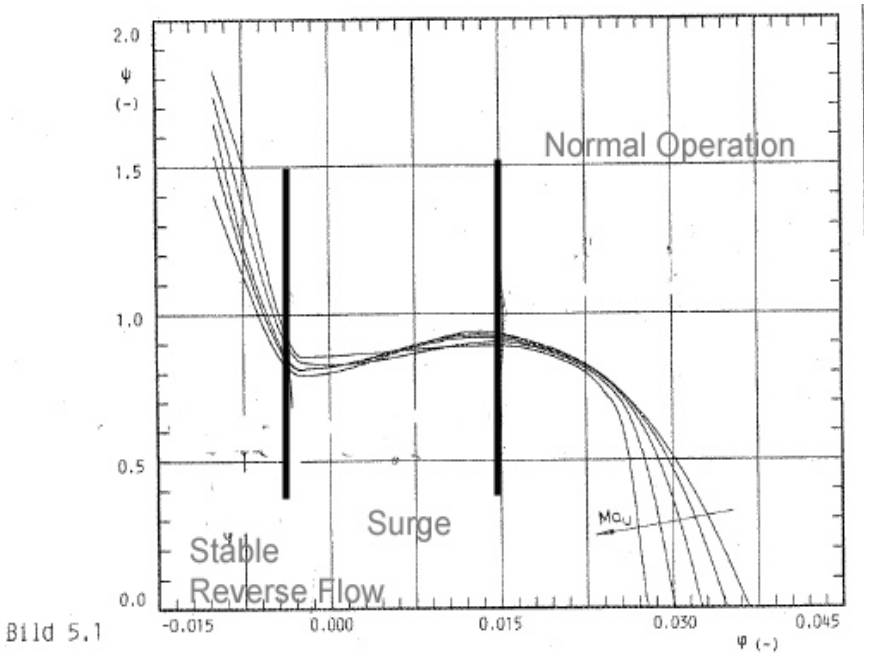
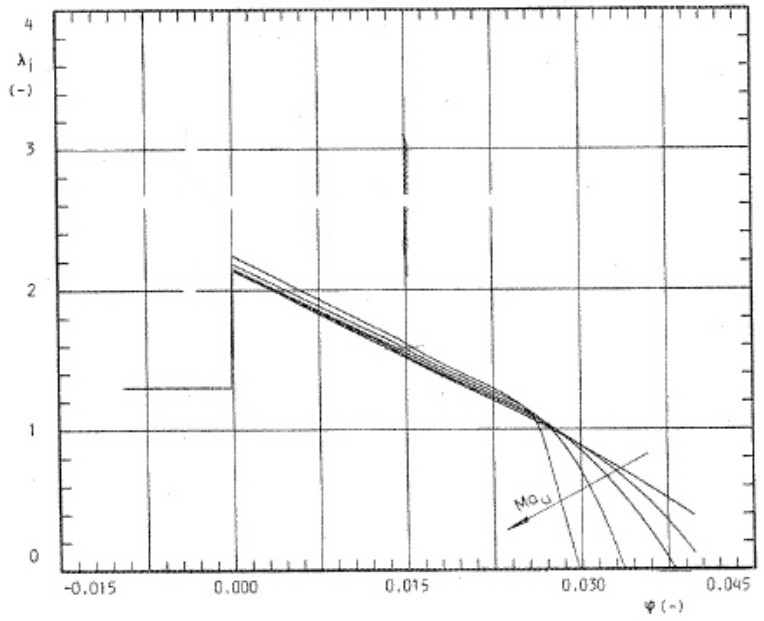


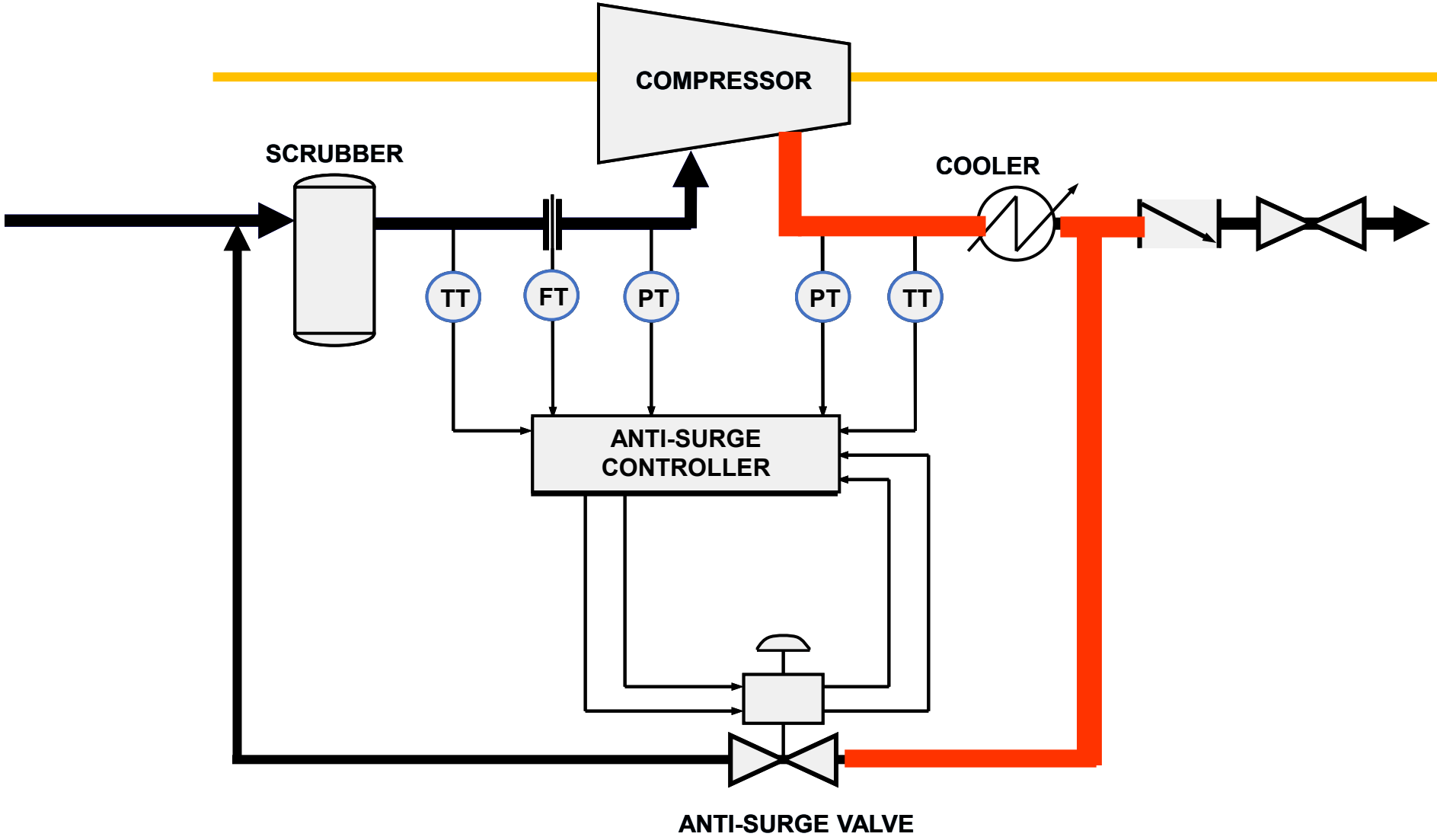
Bild 5.1

Head-Flow

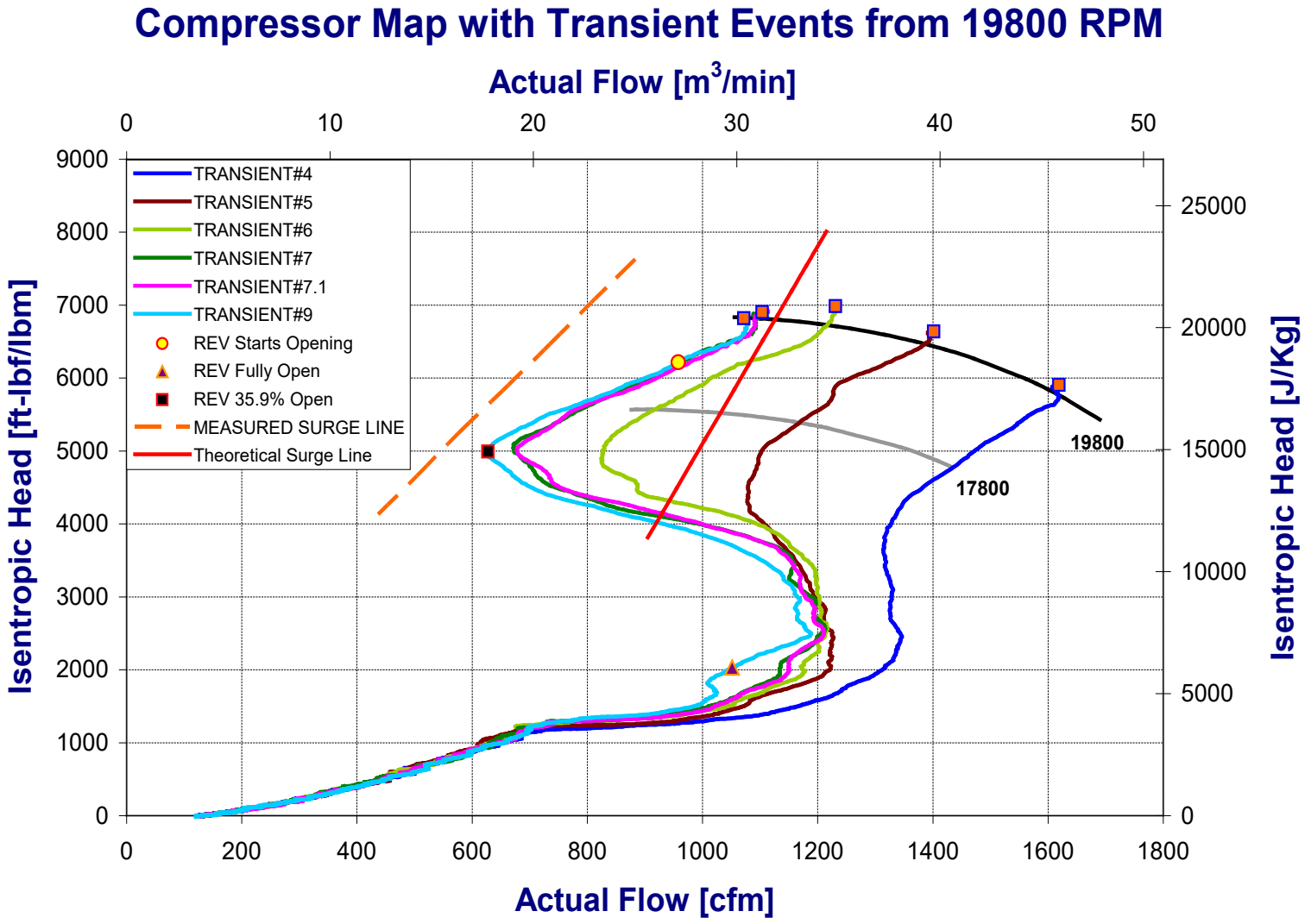


Work-Flow

Source: Aust, Diss., UBw Hamburg


COMPRESSOR
SCRUBBER
COOLER
TT
FT
PT
PT
TT
ANTI-SURGE
CONTROLLER
ANTI-SURGE VALVE

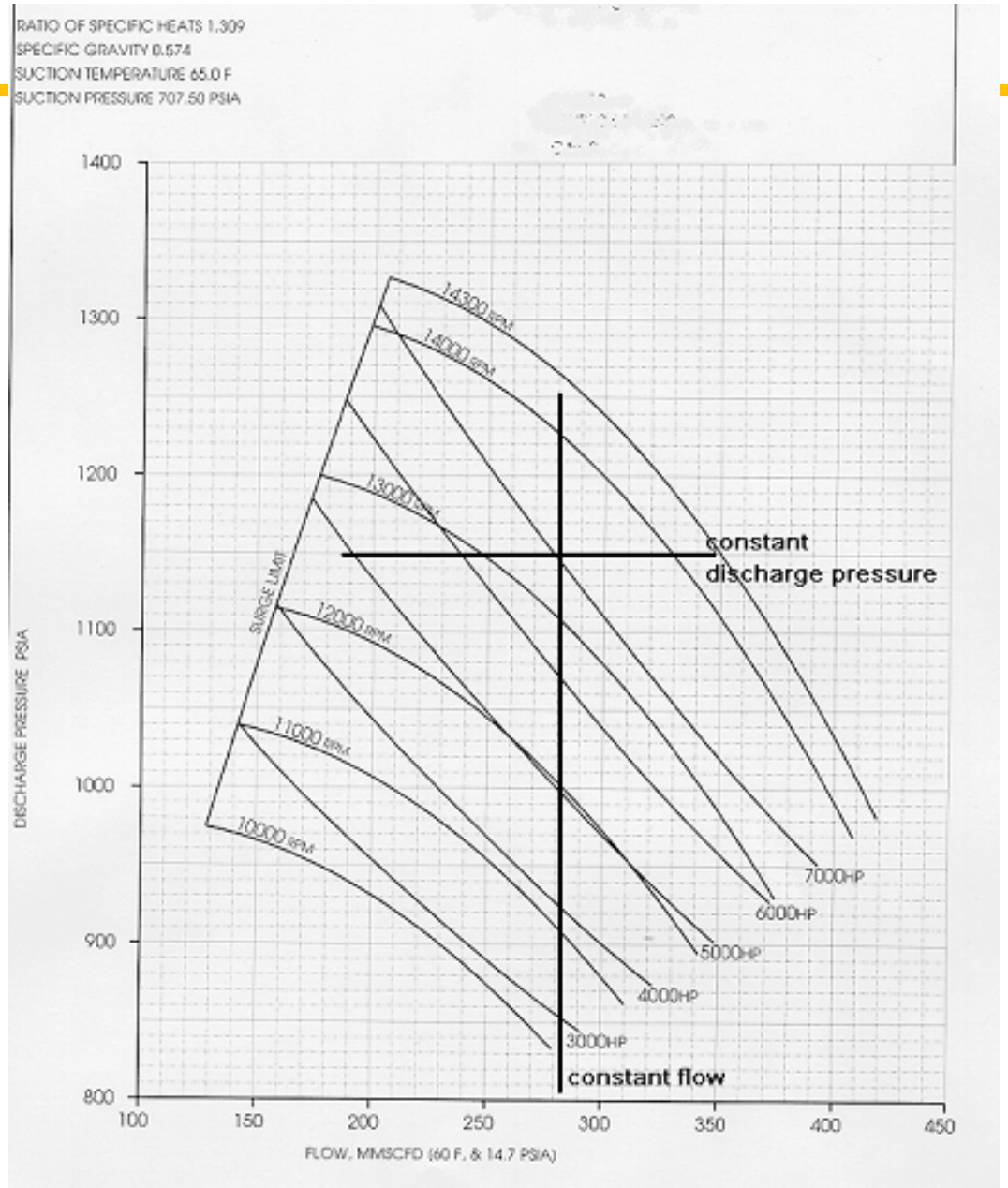
Dynamic Behavior -Emergency Shutdown



Process Control

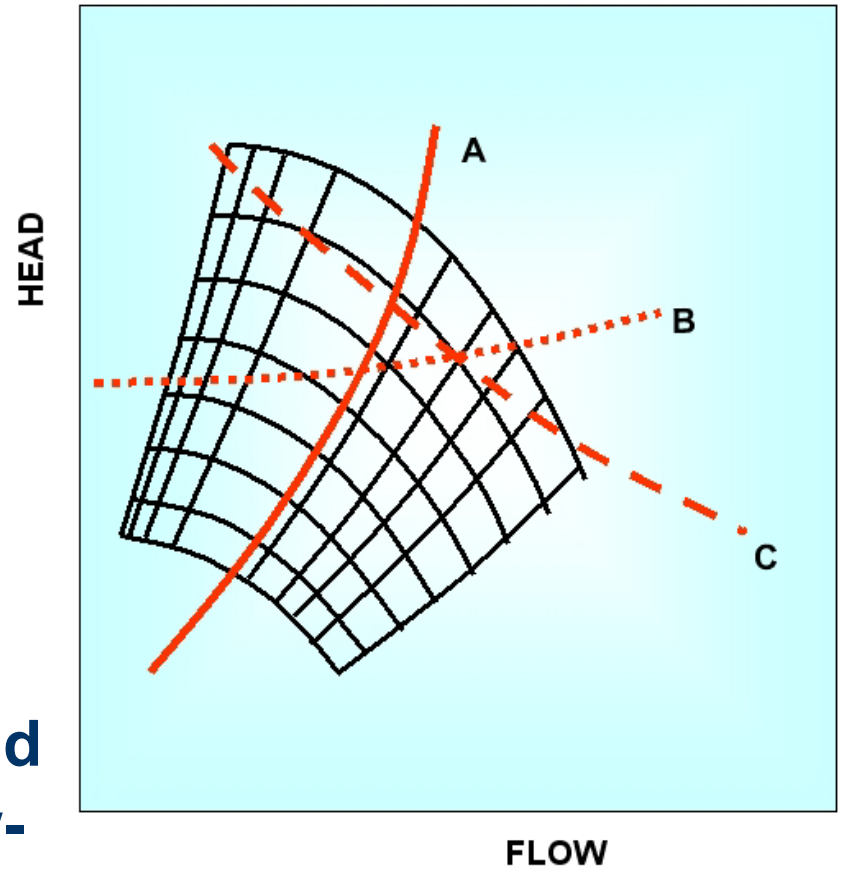
- Setpoint Disturbance
- Fuel Control
- GP increases speed, flow and temperature
- PT receives more power
- Compr/PT Speed increases

- This does not require any manual intervention!



System Characteristics and Compressor Map

A- Strong head-flow relationship
B- weak head-flow relationship
C- integrative relationship



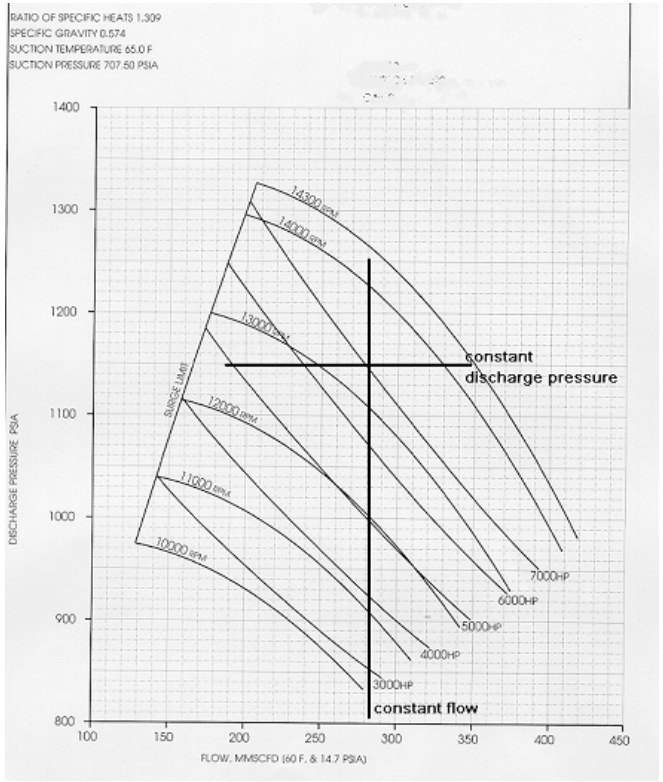
The system determines the pressures, and the compressor reacts with a certain flow- subject to the power available

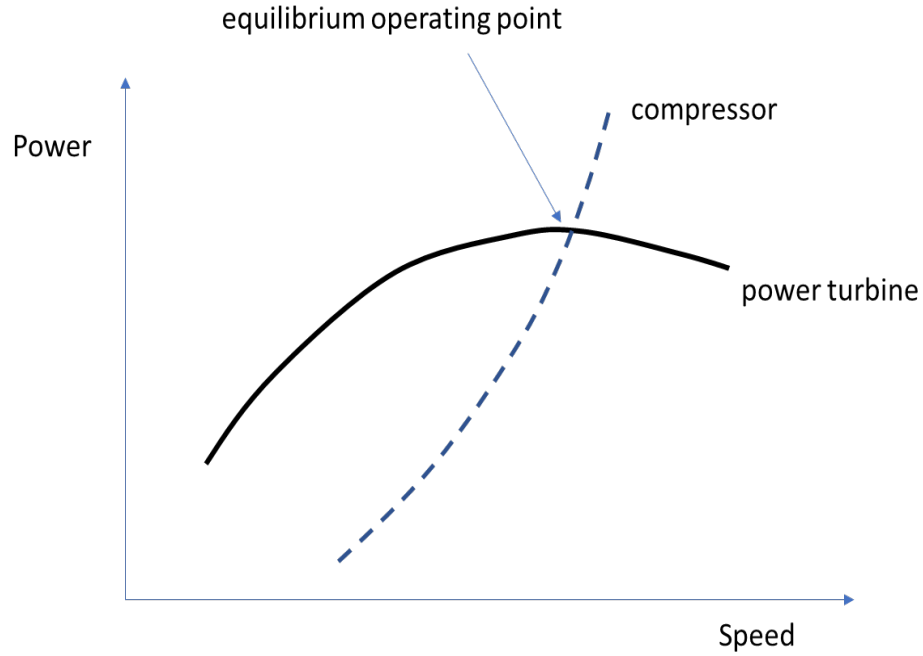
Cause and Effect

- The process determines the compressors suction and discharge pressure
- The compressor is driven by a certain amount of power
- The compressor reacts to these constraints with a certain amount of flow

Gas Turbine Driven Centrifugal Compressor

- Variable speed, controlled by power input
- Variable speed EMD: Controlled by Speed Input

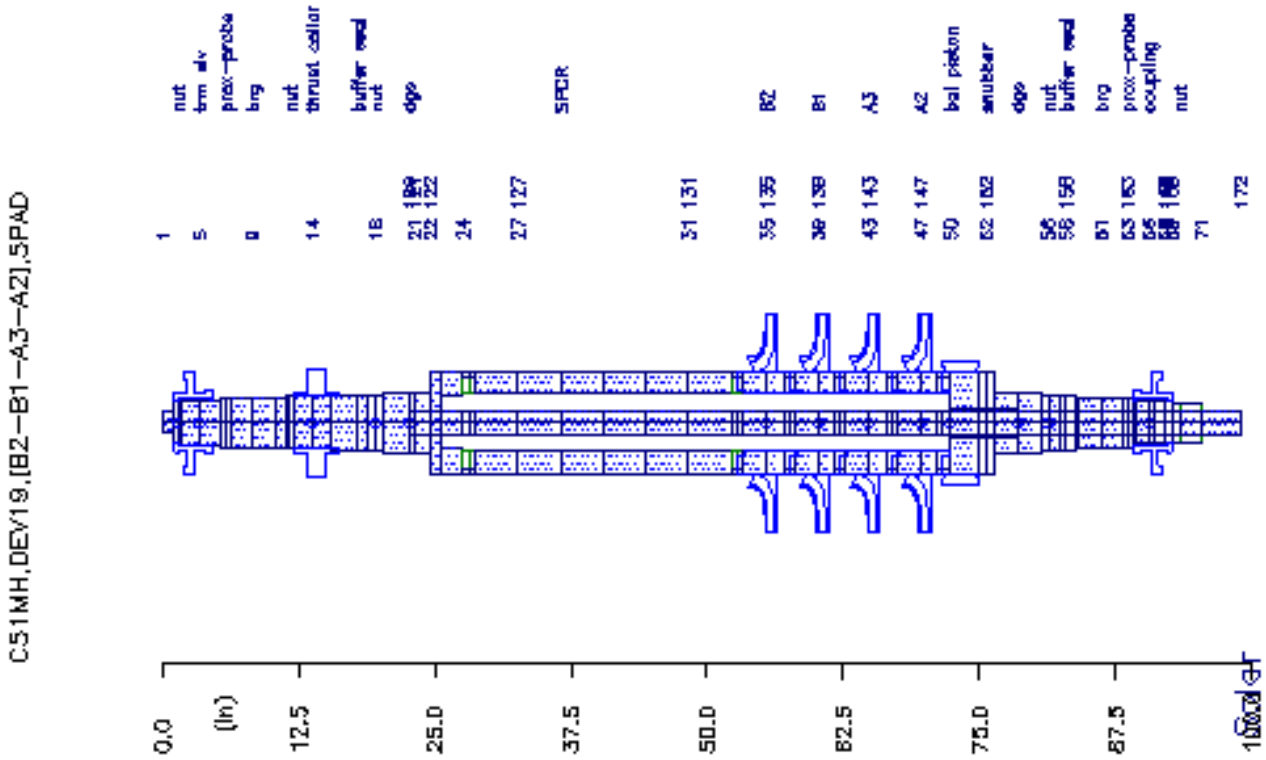




Rotordynamics

A few brief comments on Rotordynamics

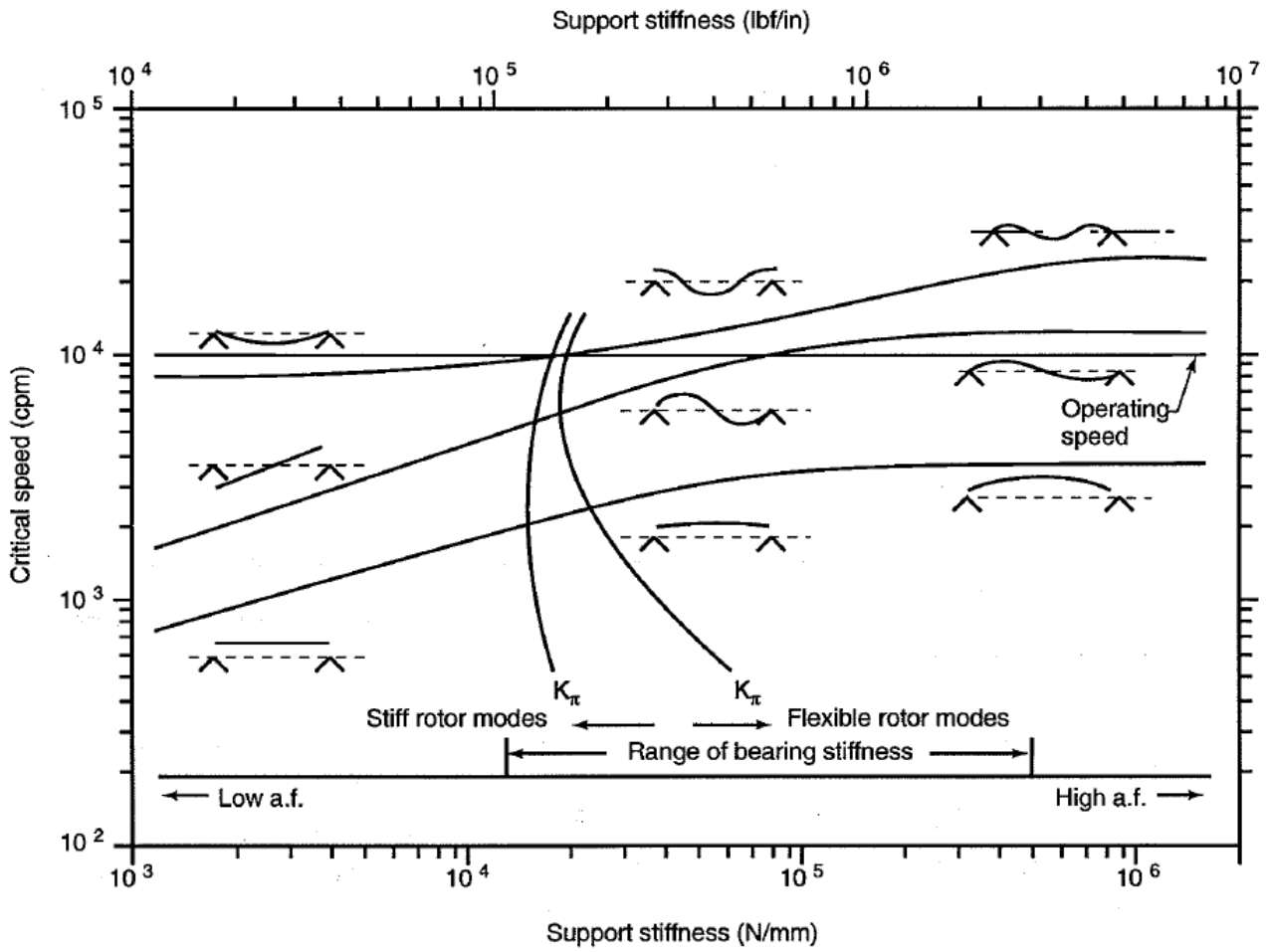
- Long and thin rotors
  - Why
- Critical Speeds
- Forces on the Rotor
  - Unbalance
  - Aero
  - Seals and bearings
- Damping



Basics

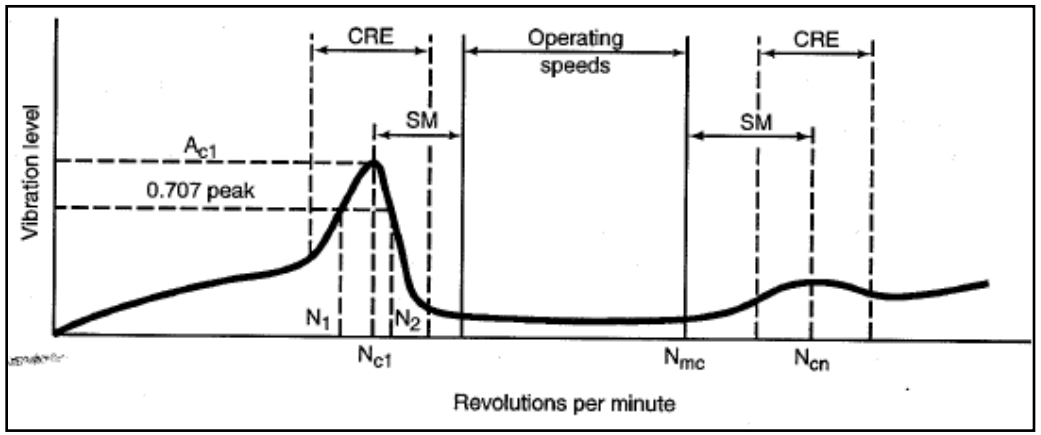
- If a structure gets exited by an alternating force that alternates at a certain frequency, it will vibrate at that frequency
- Some frequencies cause a higher response amplitude than others
- These frequencies are called natural frequencies
  - Example: If a rotor is exited with all frequencies(by a rap test), it will respond at all frequencies, but it's natural frequencies will exhibit the highest amplitude

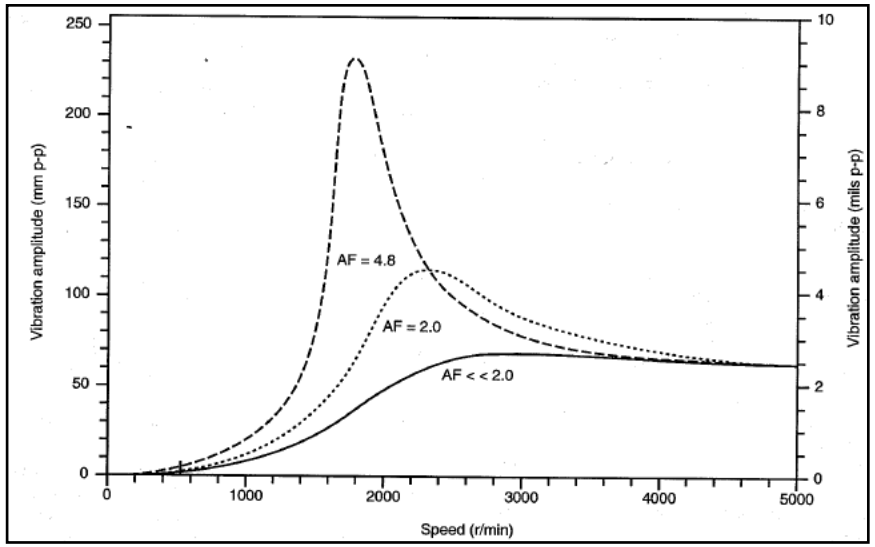
Undamped critical speed map



Lateral vibrations

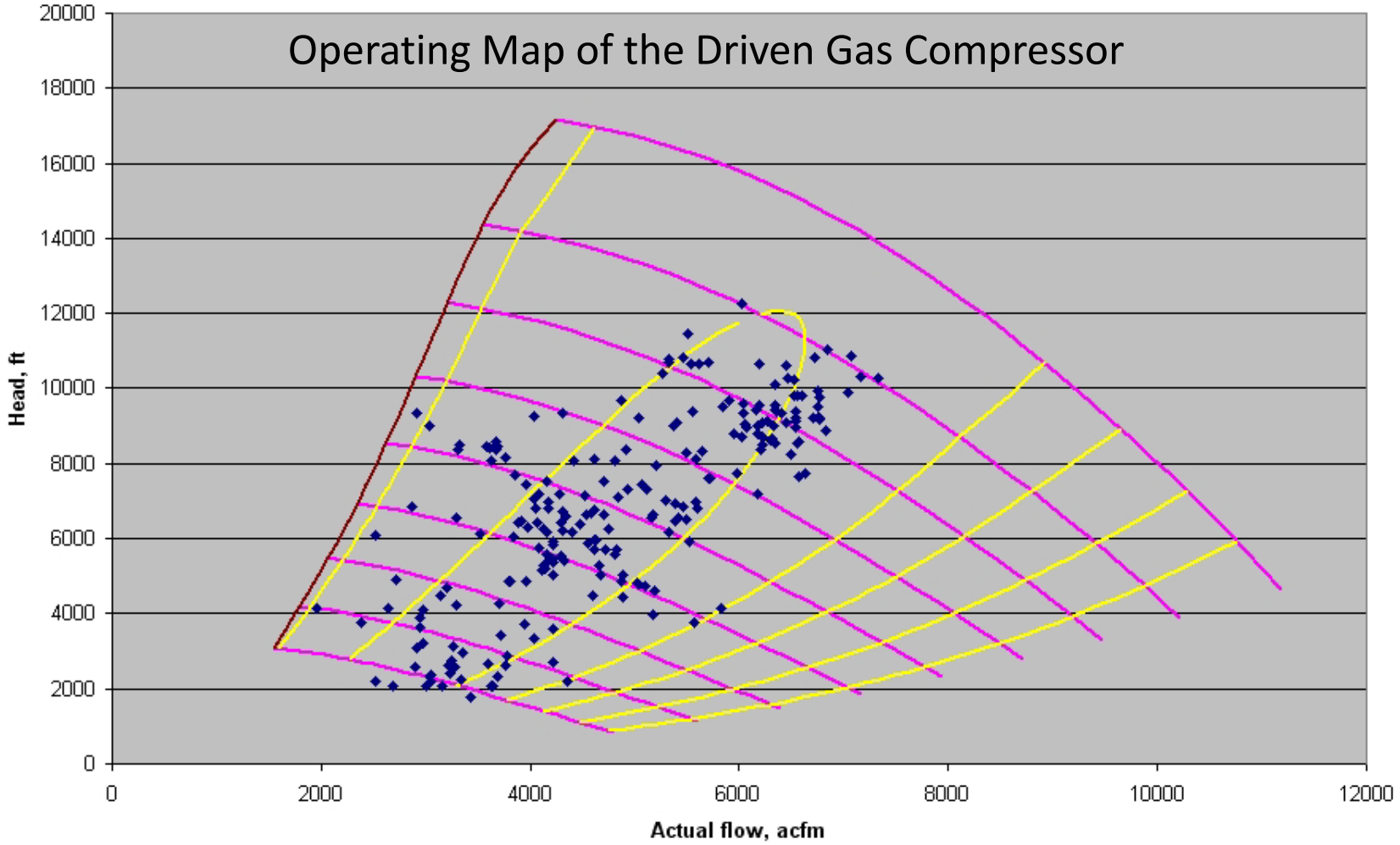
- Unbalance response
- API separation margins
- Amplification factor:
  - damping is good
  - where can I find it?



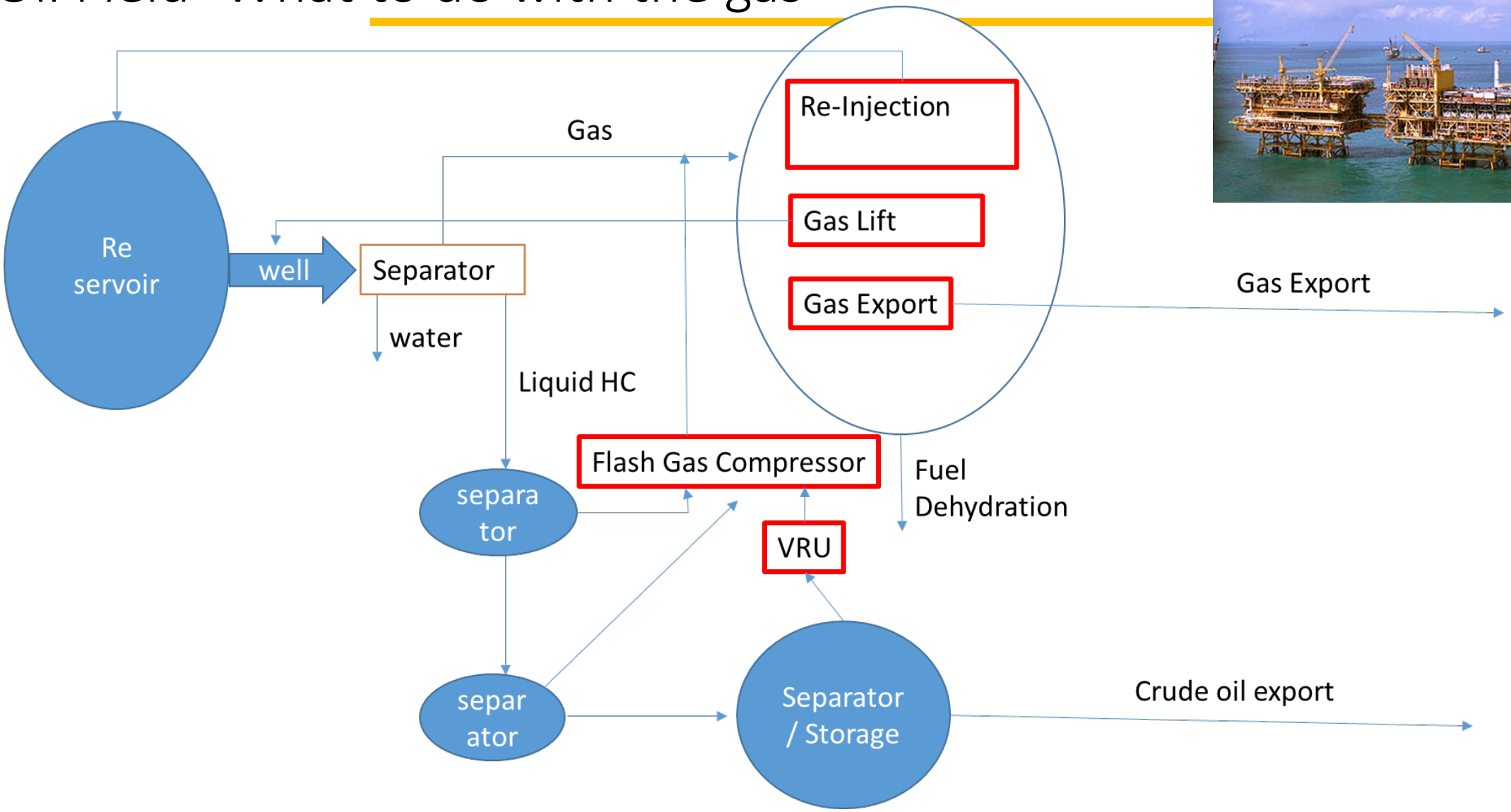


Applications

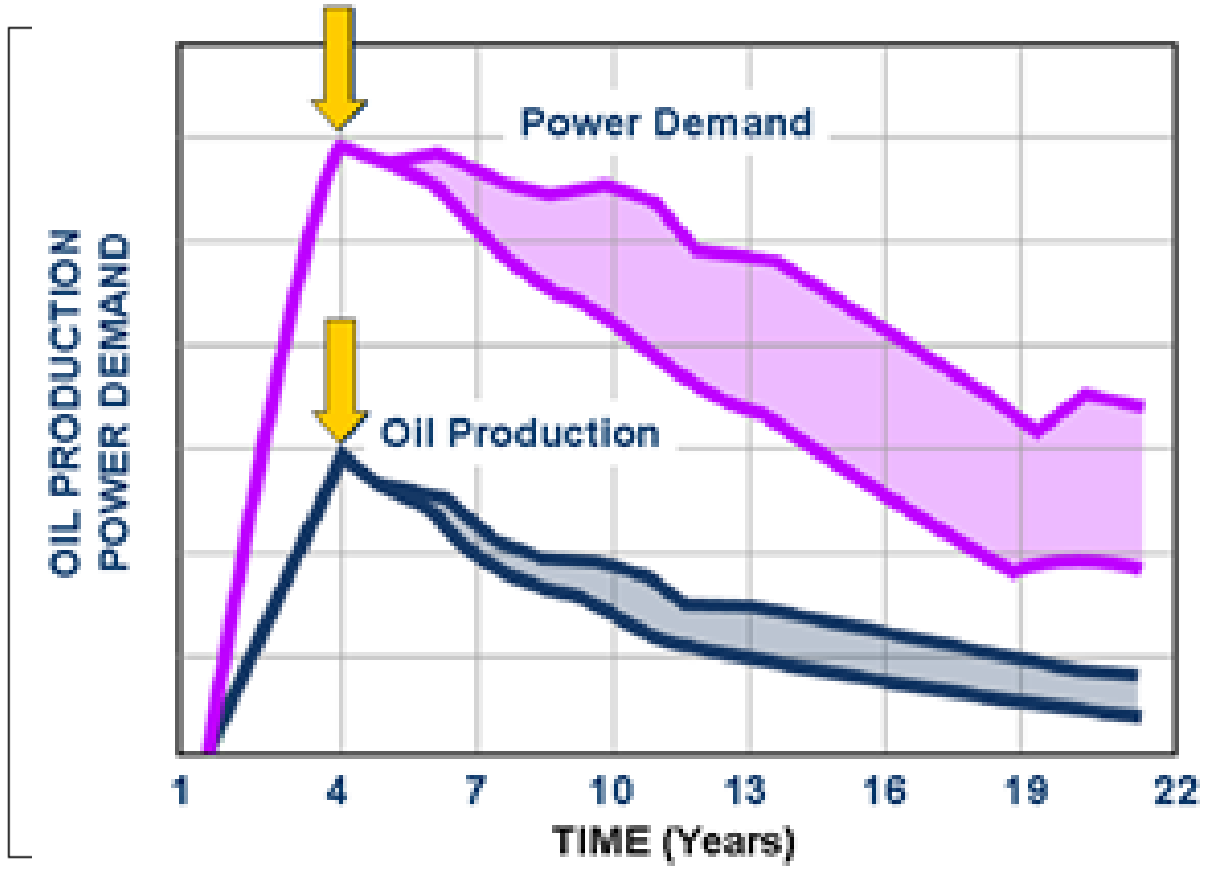
Why Process Control: Actual Operating Points



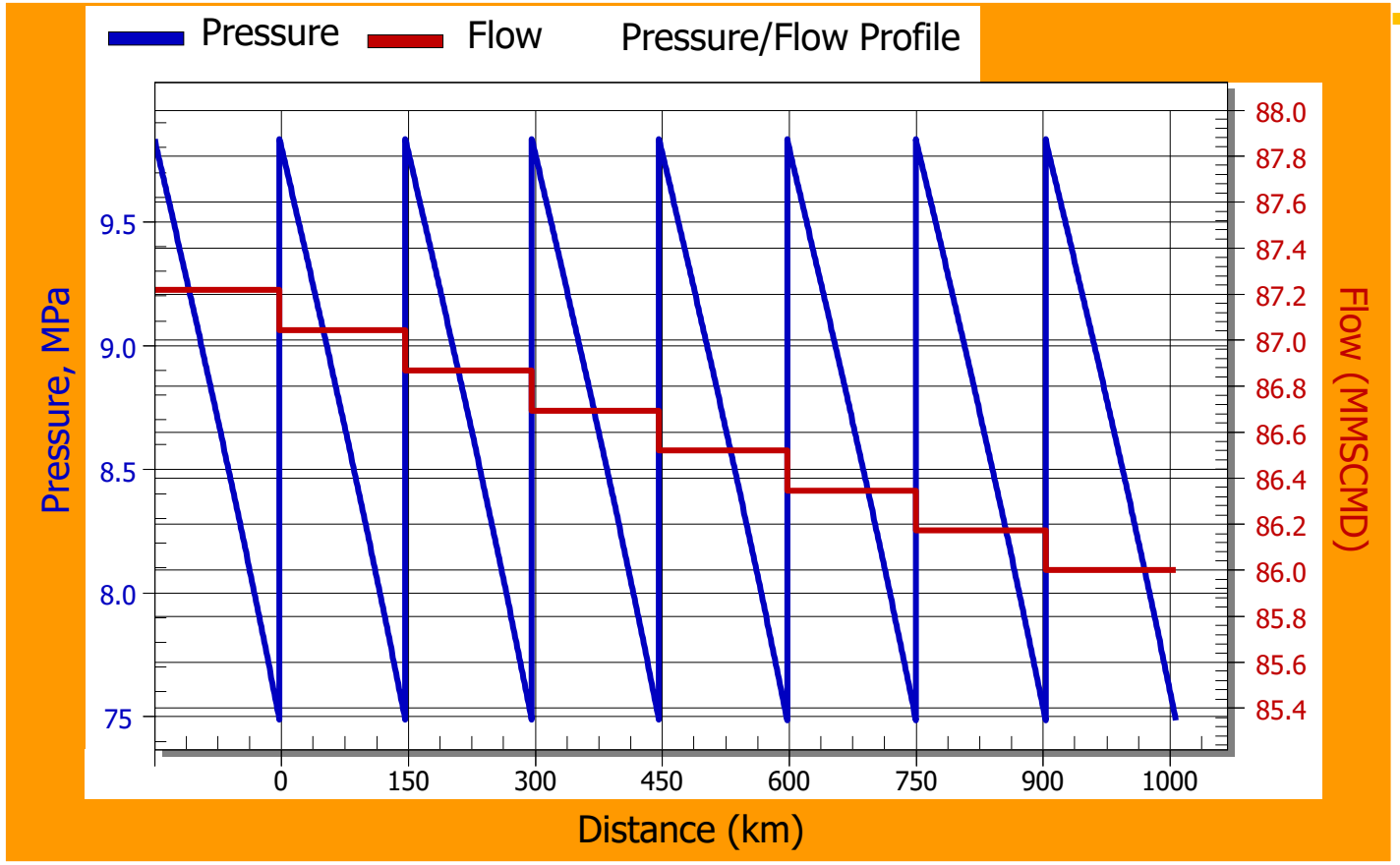
Oil Field- What to do with the gas

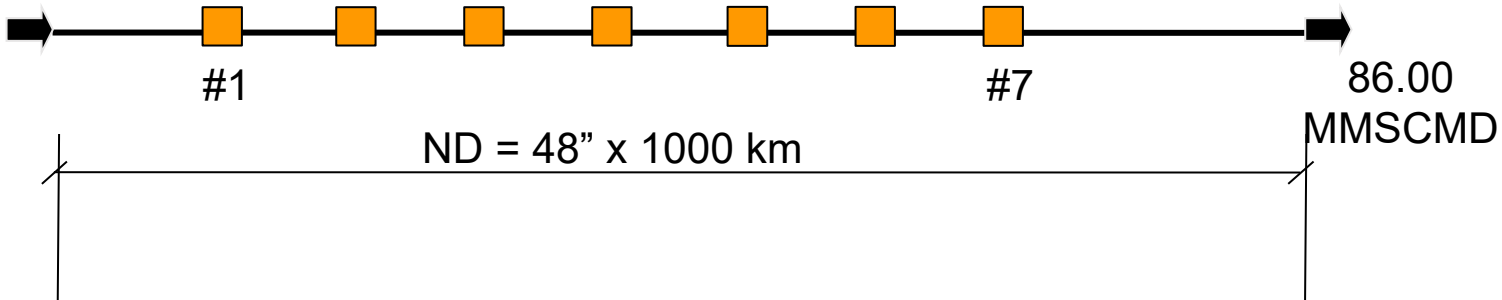


Typical Decline in Oil Production and Power Demand in an Offshore Application (Miranda et al)

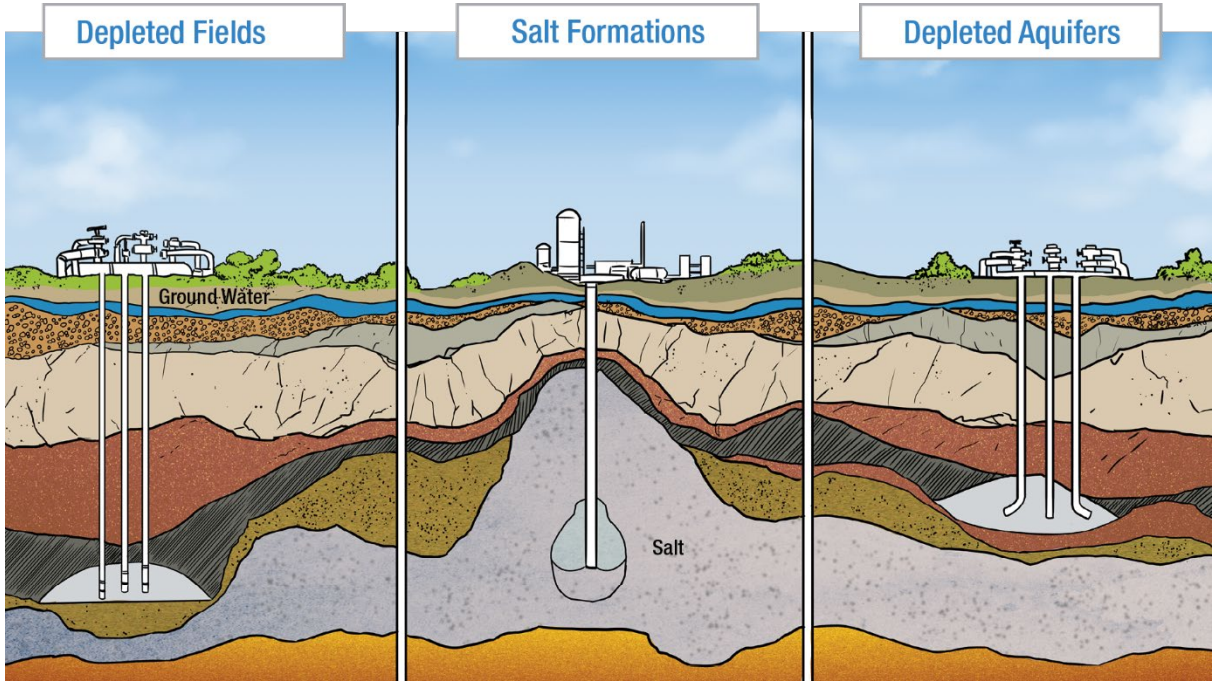


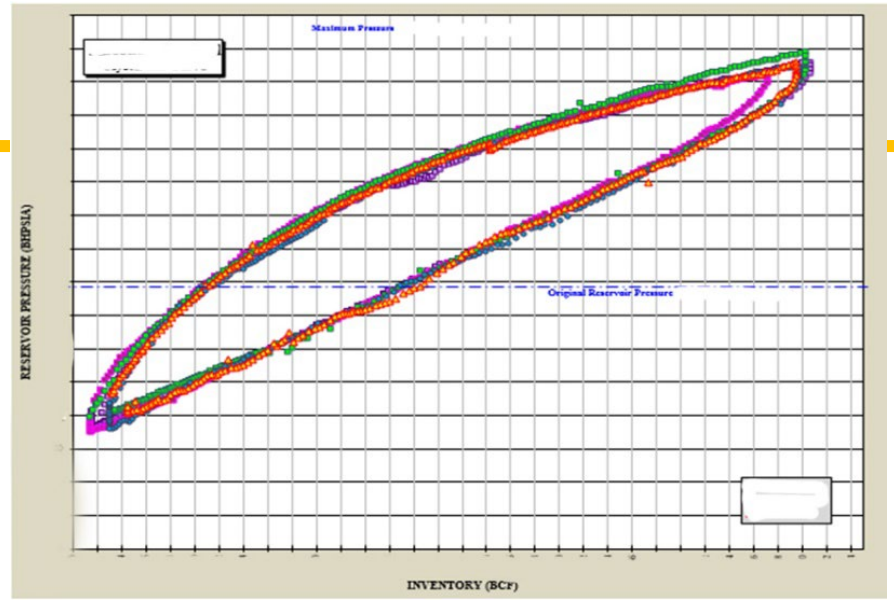
Pipelines: Thermohydraulic Results for Generic Compressor Station

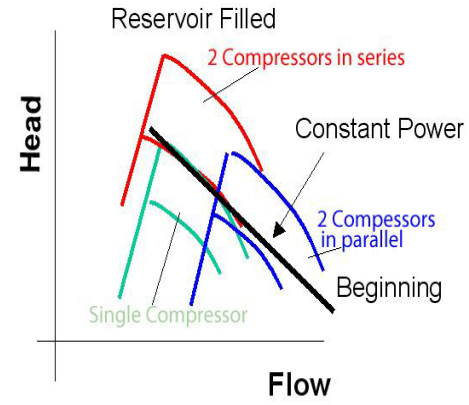


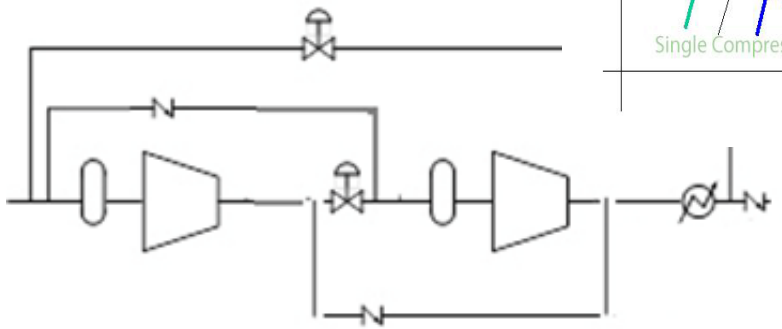


Gas Storage


Depleted Fields
Salt Formations
Depleted Aquifers
Ground Water
Salt


RESERVOIR PRESSURE (BHPSIA)
INVENTORY (BCF)


Reservoir Filled
2 Compressors in series
Constant Power
2 Compessors in parallel
Beginning
Single Compressor
Head
Flow



Summary

- Compressors
- Aero and Thermodynamics
- Drivers
- Control, Surge , Stall
- Rotordynamics
- Applications
- Summary

Questions