Surge Control Strategy

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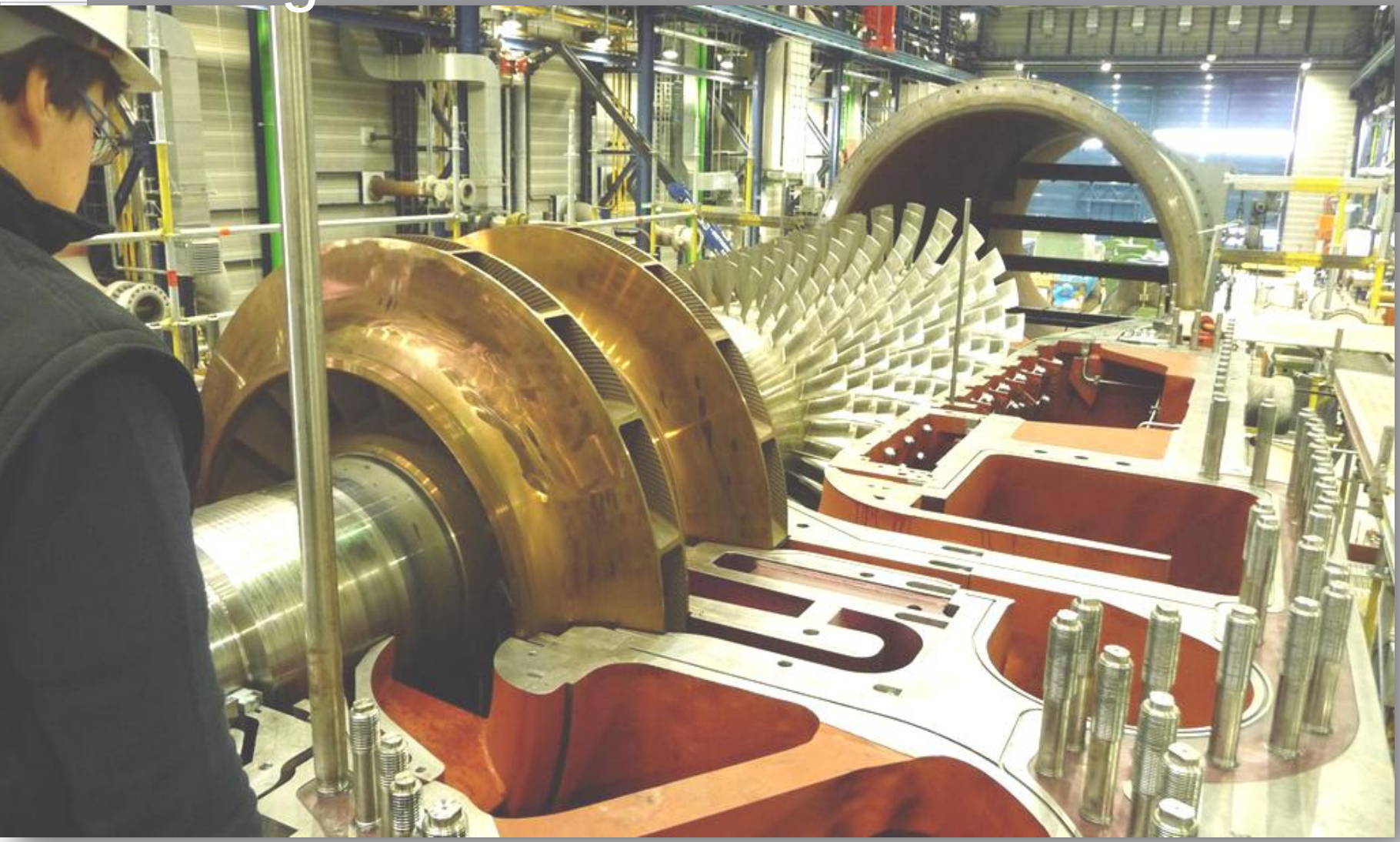
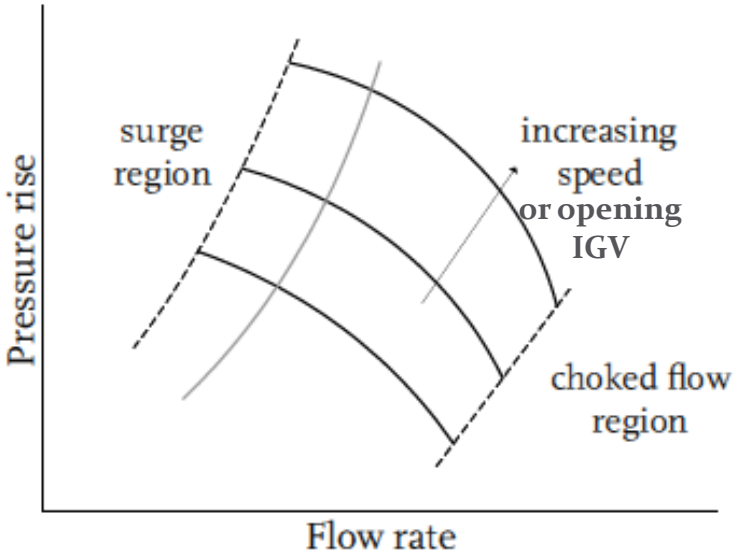
Summary

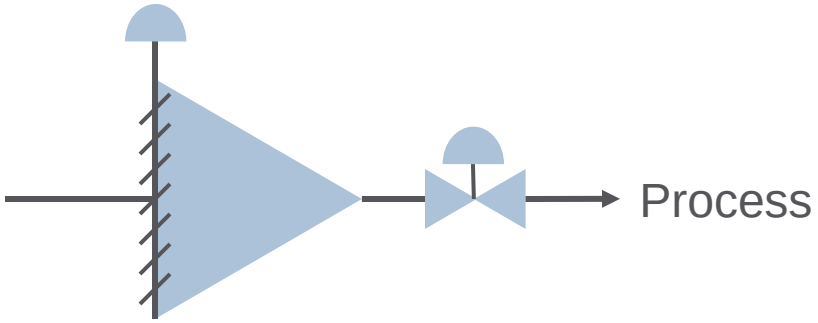
- Surge Phenomenon & Effect
  - Phenomenon
  - Effect on Industrial Compressor
- Surge Protection
  - Basic principle
  - Surge control systems comparison
- Air Liquide Application

Surge Phenomenon & Effect



Surge Phenomenon



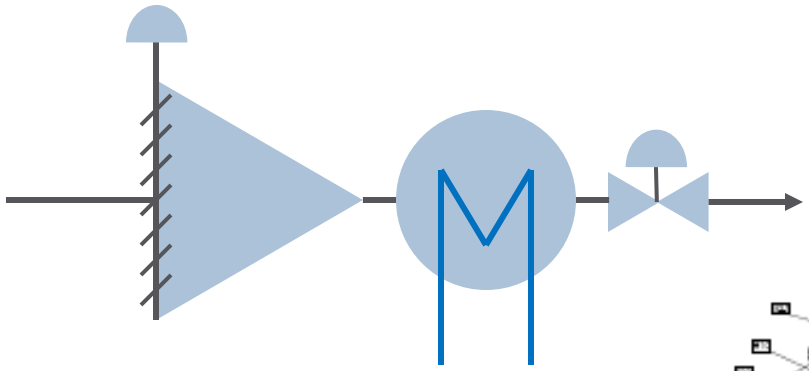


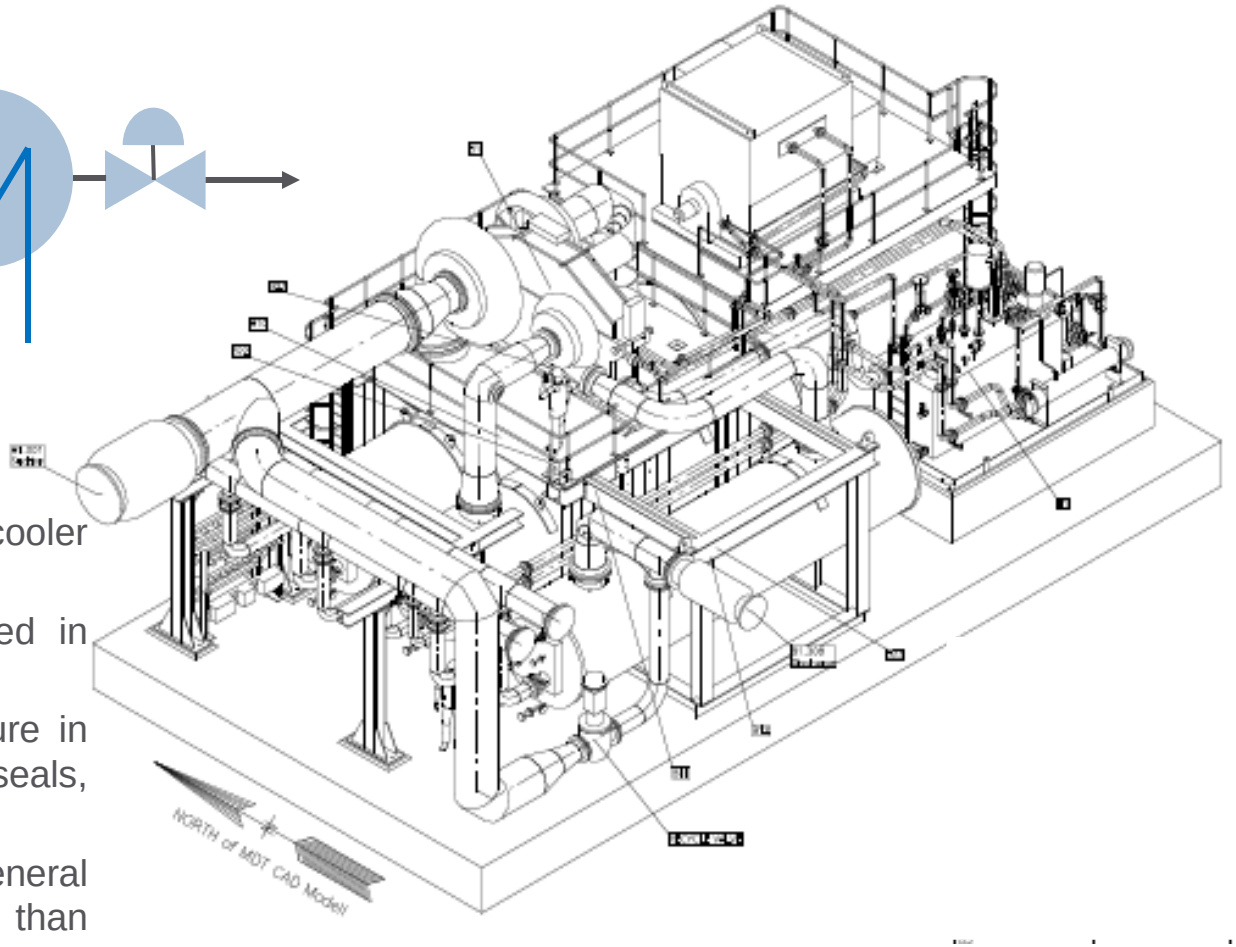
- The term “surge” is used to denote an uncontrolled flow process in the compressor. It is defined as the operating point at which the compressor peak head capability and minimum flow limit are reached. At this point, the compressor loses the ability to maintain the peak head and the entire system becomes unstable. This results in conveyed fluids flowing back from the discharge side to the suction side resulting in admissible load reversals on the blading.

GHH Borsig. “Application Software Anti-surge Control ASC”. October 1996.

- At constant speed or IGV opening, increasing the discharge pressure will reduce the volumic flow through the compressor . The operating point is moving towards the surge area.

Surge Effect on Industrial Compressor

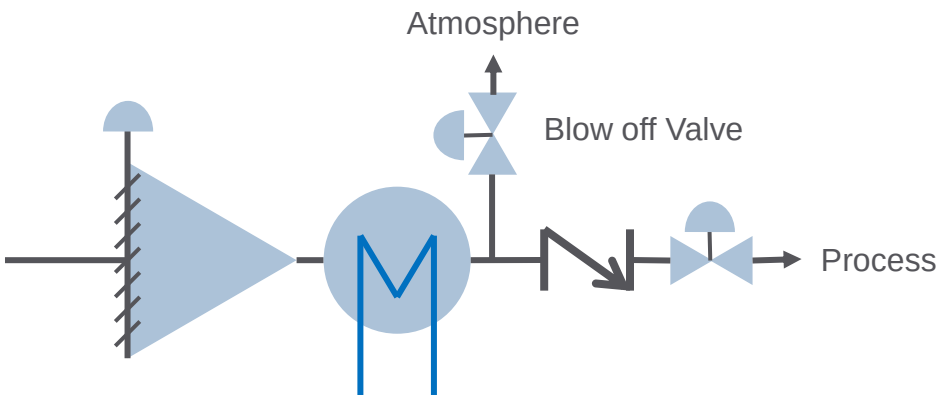


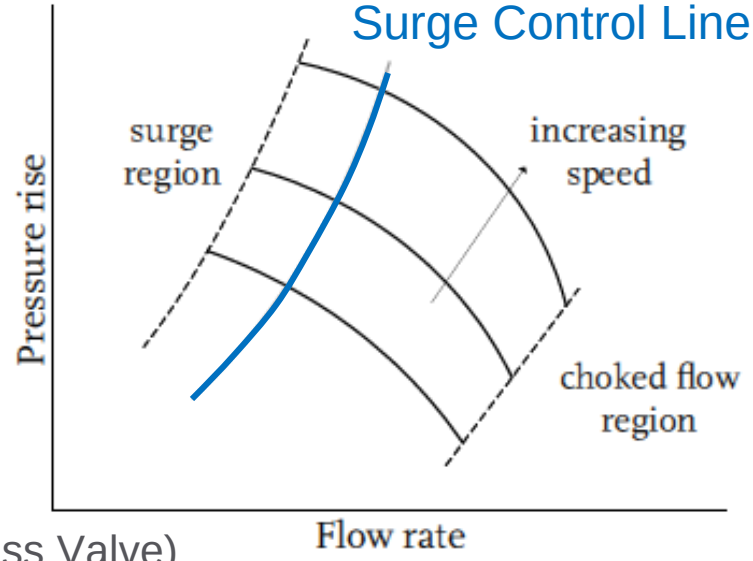


- The discharge piping and aftercooler is a huge volume.
- High potential energy is stored in this volume.
- Risk of major mechanical failure in case of surge event (blading, seals, thrust collars…)
- Axial compressors are in general more sensitive to surge than centrifugal ones.

Surge Protection

Surge Protection – basic principle





- Anti-Surge Valves (Blow Off Valve and/or ByPass Valve)
  - *Surge Control Line: Pressure ratio = f(suction volumic flow),*
  - *When the operating point is approaching the surge control line, the discharge pressure is reduced by venting the discharge flow to the atmosphere,*
  - *The BOV shall be Full Flow sized,*
  - *The BOV shall be of quick opening time (<2s),*
  - *Cycling time of control system shall be fast enough (maxi 100ms),*
- Surge detector / Surge counter
  - *Quick variation of the discharge pressure is detected as a surge event. (∂P/∂t is monitored),*
  - *After X detections of surge event, the compressor is tripped*

Surge Protection – system comparison

	Anti-surge control in the plant DCS	Surge Detector	Advanced controller (CCC, AVI Comp…)
Pros	•Little to no costs •Easy to use and to modify •Tuning achieved by ALE •ALE knows control logic •Potential to become standard	• Not expensive • Simple to install and use; only two DO and one AI are connected • Control logic is easily understood ; • 1st surge detection; no alarm • 2nd surge detection; 1st level alarm unloads compressor • 3sd surge detection; 2nd level alarm trips compressor	•Has advanced knowledge on surge control for compressors •Can implement both surge control and detection •Compressor runs at optimum performance •Two measures are in place for surge detection without an increase in costs, as compared to SCAUT system which uses only one measure
Cons	• For small upsets DCS will be able to control surge; for large upsets DCS is problematic (long DCS cycling time) • Compressor commissioning team onsite may not have knowledge to control surge through DCS and training must be implemented • Compressor not well protected against surge if quick tuning is not established	• Blackbox (password) • Compressor trips if transmitter fails • Not suitable to control the anti-surge valves • Correct tuning is depending on the supplier supervisor => reliability issue	•Blackbox •Expensive •Even with the best controller, the surge protection is limited by the opening time of the valve and so, in case of very quick event, the surge may happen
	AL Prefered solution	Required by AL only for axial and oxygen compressor Most of the suppliers requires it for all compressors	Used mainly on third customer request

Air Liquide Application

Air Liquide application

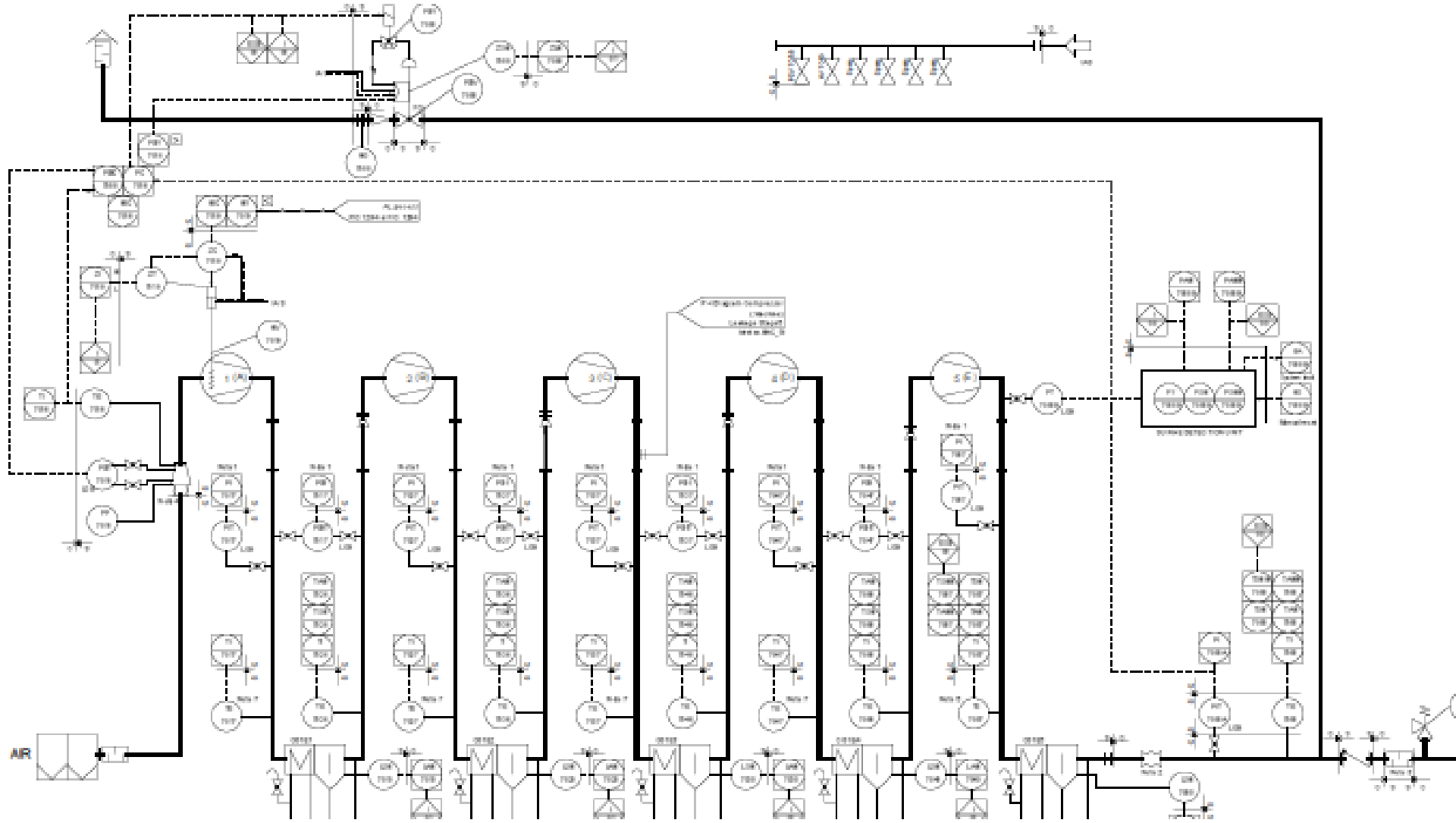
- Main Air Compressor
  - Suction volumic flow strongly depending on ambient temperature
  - Blow off valve to unload the compressor
- Booster Air Compressor
  - ByPass and Blow off valves to unload the compressor
- Cryogenic Expander/Booster
  - Variable speed
- Oxygen compressor and Axial compressors
  - Surge detector is mandatory
- Flue gas compressor
  - Variable Molecular Weight

Air Liquide application - MAC

- Main Air Compressor
  - “Flow” measurement: PDT in the suction cone
  - Suction volumic flow strongly depending on ambient temperature: PDT value is corrected with suction temperature
  - Suction pressure is constant
  - BOV is:
    - Full flow sized
    - Quick opening (<2s) / slow closing 1%/s
    - Failure open to improve surge control reliability
  - Valve sizing shall also allow a continuous operation with low flow (plant startup) without induced vibration

$$P_0 = A\sqrt{T_i}\sqrt{\Delta P} + B$$

Air Liquide application - MAC



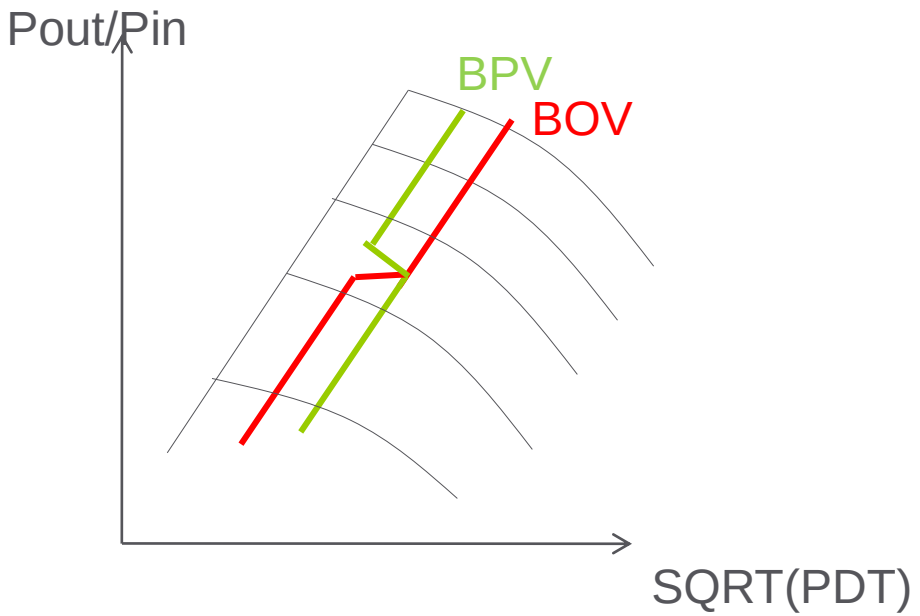
Air Liquide application - BAC

- Booster Air Compressor
  - “Flow” measurment: PDT in the suction cone
  - Suction temperature is nearly constant => no need for temperature correction
  - BPV is:
    - Full flow sized
    - Quick opening (<2s) / slow closing (1%/s)
    - Failure close (to avoid risk of leaks during normal operation
    - Solenoïd valve is used (bypass of the positioner) to reduce the opening time
  - BOV is:
    - Full flow sized
    - Quick opening (<2s) / slow closing (1%/s)
    - Failure open (to improve surge control reliability)

Air Liquide application - BAC

- Booster Air Compressor
  - Quick closing of a downstream valve (expander QCV) => wall effect => a large amount of molecule has to be recirculated to the suction => increase of the suction pressure => trip or mechanical failure of the compressor
  - Air Liquide strategy aims to first vent these molecules rather than recirculate them in order to avoid any suction pressure increase.
  - BPV is the first to open during plant startup or in plant turndown mode (to minimize power loss and noise)
  - BOV is the first to open when:
    - Pout > 0.95 Pnominal
    - Expander is running
    - BPV opening < 5%

$$\frac{P_0}{P_i} = A\sqrt{\frac{T_i}{P_i}}\sqrt{\Delta P} + B + HIC$$



Air Liquide application - BAC

- Main Air Compressor
  - Suction volumic flow strongly depending on ambient temperature
  - Blow off valve to unload the compressor

Air Liquide application – Expander/Booster

- Expander booster
  - Variable speed not considered (speed correction not required by suppliers)
  - An strong approximation formula (but robust) is implemented:

$$\frac{P_0}{P_i} = A\Delta P$$

Air Liquide application – Expander/Booster

- Oxygen compressor
  - Surge detector is required by Air Liquide for safety reason
  - The surge test is done with Nitrogen. The compressor is naturally overprotected during operation with Oxygen
  - For more turndown capability, the surge control line can be modified with respect to the different molecular weight of N2 and O2. In this case, the reliability of the control line has to be check during O2 operation.

AIR LIQUIDE
GLOBAL E&C SOLUTIONS

End of presentation

Thank you for your attention