ADVANCED PROCESS MODELLING FORUM **2014**

Advanced Process Modelling for Oil & Gas

James Marriott, Head of PSE Oil & Gas

gFLARE

Advanced Process Modelling for Oil & Gas

What do we mean?

Advanced Process Modelling

- Oil & Gas processing plants are primarily designed for normal steady-state operation
  - standard steady-state process modelling tools aim to support this activity
    - …. for the process
    - …. for the process safety system
  - in general use for ~30 years
- Increasingly essential to consider abnormal and transient operations

"A disproportionate percentage of process safety incidents have occurred during transient operations, which include those conducted infrequently such as start-ups or shutdowns as well as abnormal or emergency events. "

Scott W. Ostrowski and Kelly K. Keim, ExxonMobil

Requirement for Advanced Process Modelling

Advanced Process Modelling in Oil & Gas

- What do we mean …?

Advanced Process Modelling involves applying detailed, high-fidelity mathematical models of process equipment and phenomena, ……..

…….. usually within an optimisation framework, to provide accurate predictive information for decision support in process innovation, design and operation

PSE website

Advanced Process Modelling in Oil & Gas

- What do we mean …?

  – Rigorous representation of physical behaviour of the system

  – Accurate dynamic analysis

  – Closely integrated systems

  – Model centric view … not just simulation

  – Supporting research and development

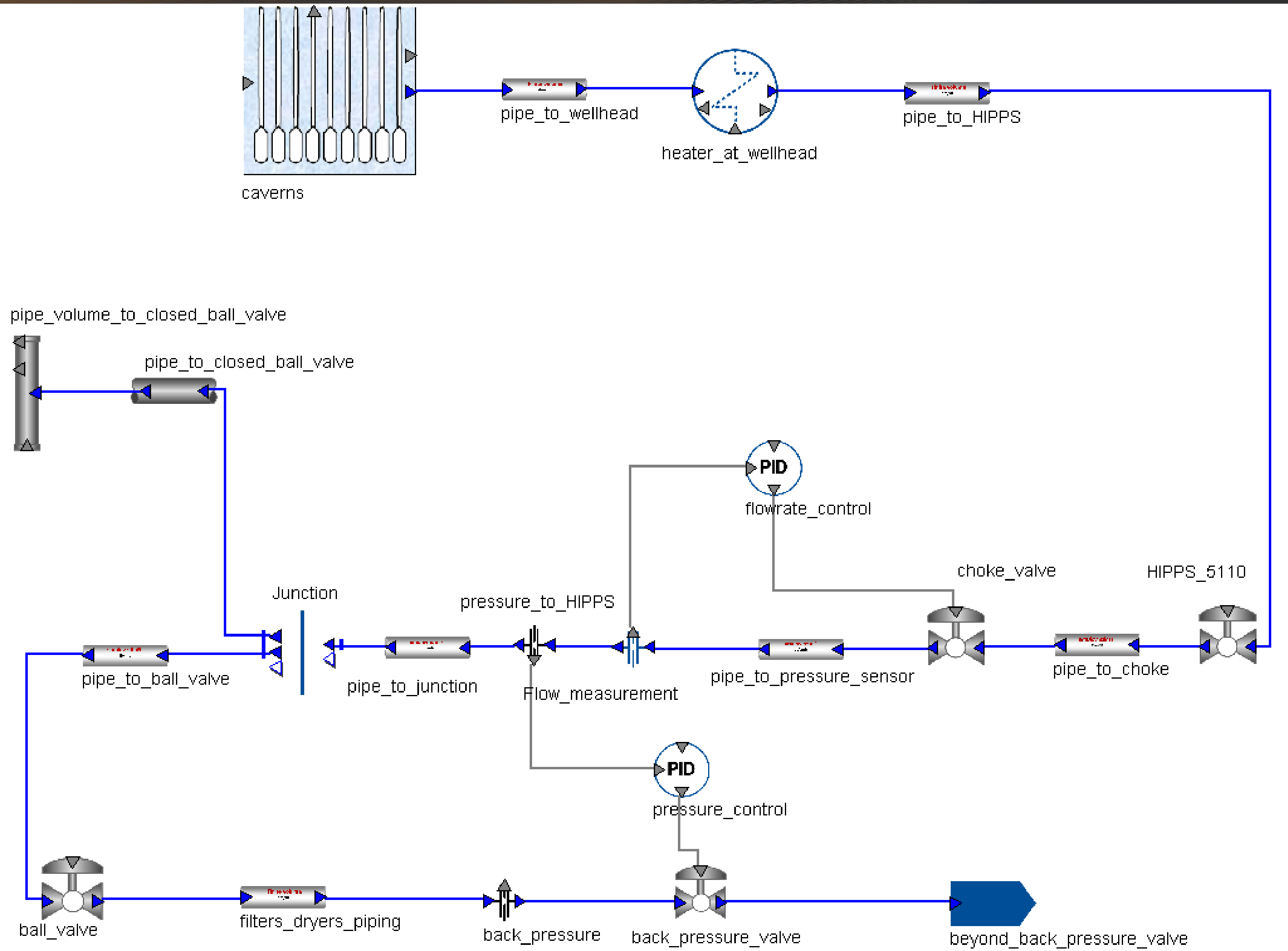
Overview

- Advanced Process Modelling
- HIPPS analysis [Apostolos Giovanoglou]
- LNG process modelling [Maarten Nauta]

Advanced Process Modelling for Oil & Gas

HIPPS

gPROMS model

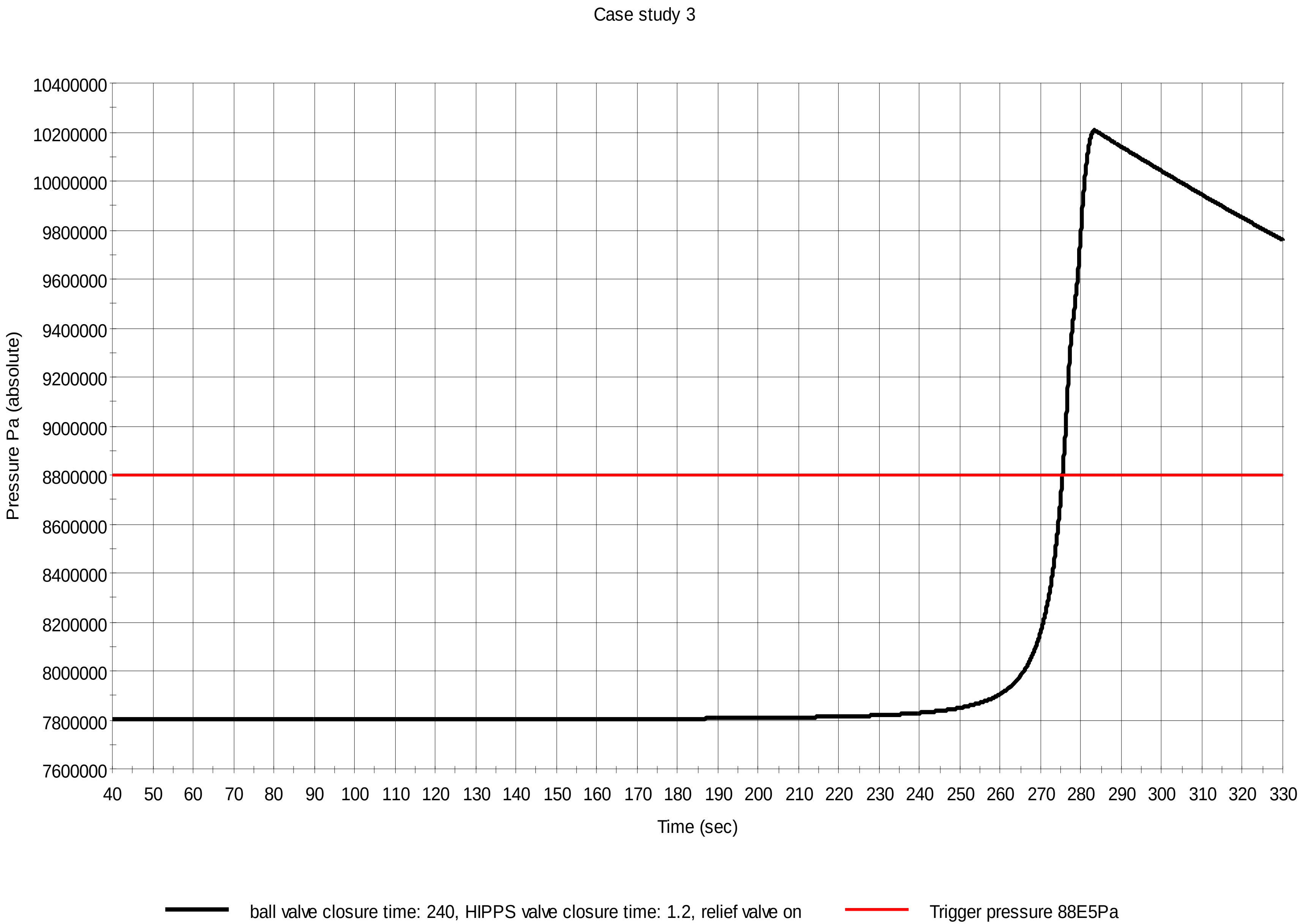


Problem statement

- Initial pressure in the caverns = 281 bar
- Gas flowrate = 37 kg/sec
- Initial pressure exactly downstream of choke valve = 78. bar
- Initial pressure exactly upstream of the back pressure valve = 76.5 bar
- Ball valve closure time = 240 sec
- Ball valve starts closing at time = 40 sec
- HIPPS valve closure time = 1.2 sec
- Trigger pressure for HIPPS = 88 bar
- Gas composition = average
- Design pressure in pipe_to_pressure_sensor = 93 bar
- Relief valve in use
- Relief valve trigger pressure 93.01300 bar

Close the ball valve and calculate the pressure profile of:
pressure_to_HIPPS sensor

Key results 1



Key results 2

- Choke valve stem position = 0.0175921
- Back pressure valve stem position = 0.1004921
- Fitting coefficient in filters_dyers_piping = 8949.876
- Trigger pressure reached at time 275.43sec
- Pmax = 10205977 Pa reached at time 283.4 compared to a design pressure of 9300000 Pa
- Pressure at time 280 sec (ball valve closed) = 9797692 Pa
- The time between the HIPPS valve is closed and the ball valve is closed is not enough to remove all the material trapped between the two valves.
- Pmax is approximately 1bar lower compared to the case when the relief valve is off
- The relief valve minimises the time during which the pipes are exposed to high pressures

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Advanced Process Modelling for LNG

A gPROMS ProcessBuilder focus sub-sector

Maarten Nauta

Overview

- LNG value chain
- Modelling of multistream heat exchangers
- Simulation of LNG liquefaction in gPROMS ProcessBuilder

LNG value chain

The LNG value chain

NG Production

15-20%

NG Purification/ Liquefaction → LNG

30-45%

LNG Transportation

10-30%

LNG Regasification

15-25%

Typical cost distribution

(Source: J. Pettersen, Statoil, 2012)

Natural Gas processing & liquefaction

Variability in NG composition

NG

50 ppm(v) CO_2
4 ppm(v) H_2S

1 ppm(w) H_2O

0.01 µg/m^3 Hg

Receive NG → ***Remove Acid Gases*** → ***Dehydrate*** → ***Remove Mercury*** → ***Fractionate Hydrocarbons*** → ***Liquefy***

Condensate

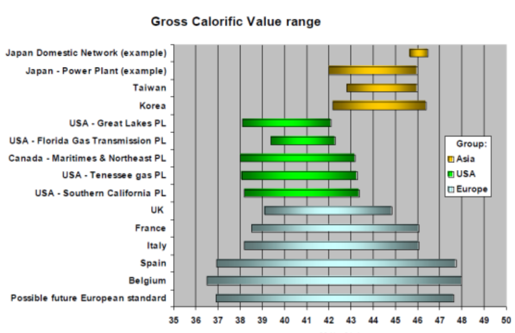
CO_2
H_2S

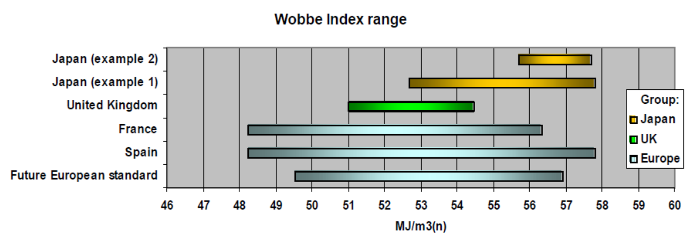
H_2O

Mercury

Ethane
LPG

LNG to transport vessel



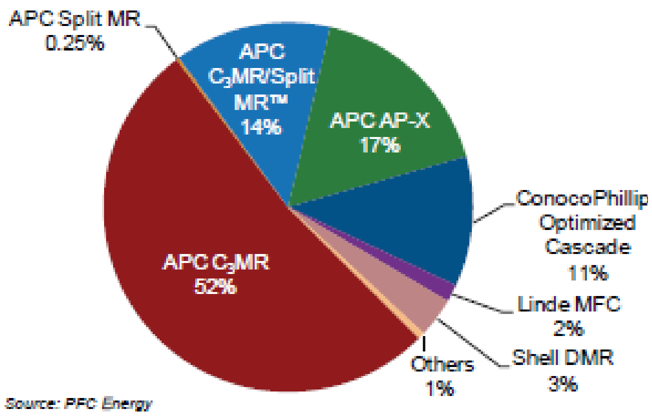


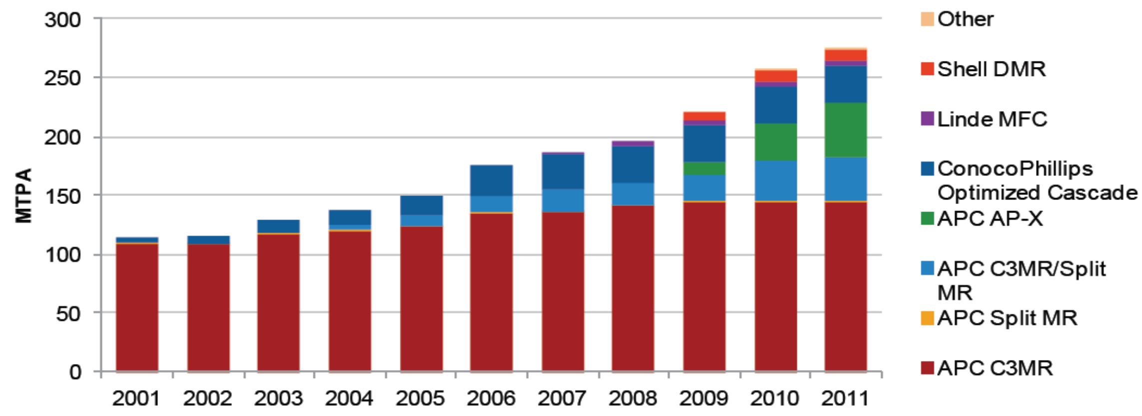
Variability in LNG specification

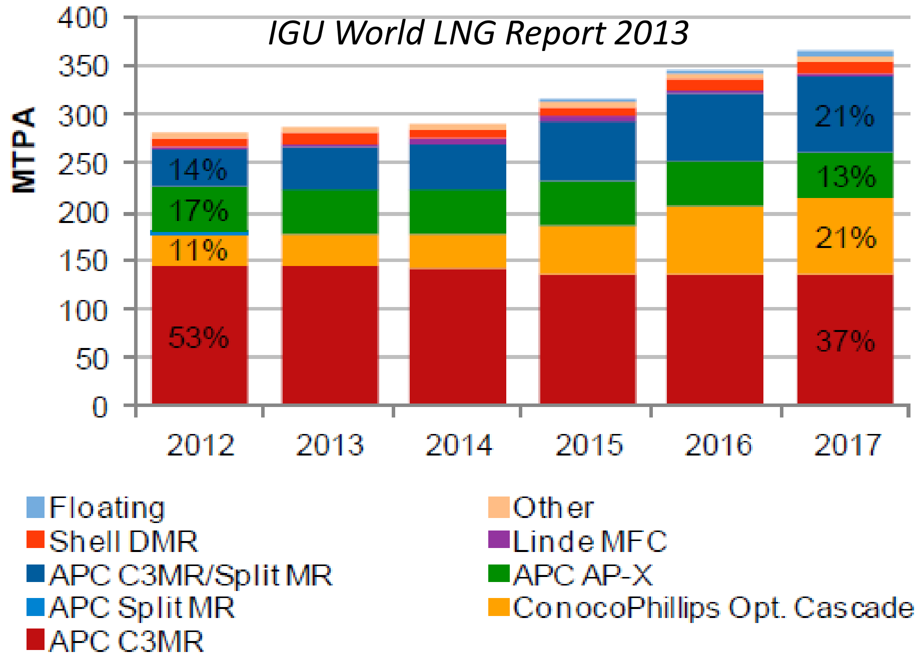
Liquefaction technology

International Gas Union: World LNG Reports

IGU World LNG Report 2011 (June 2012)

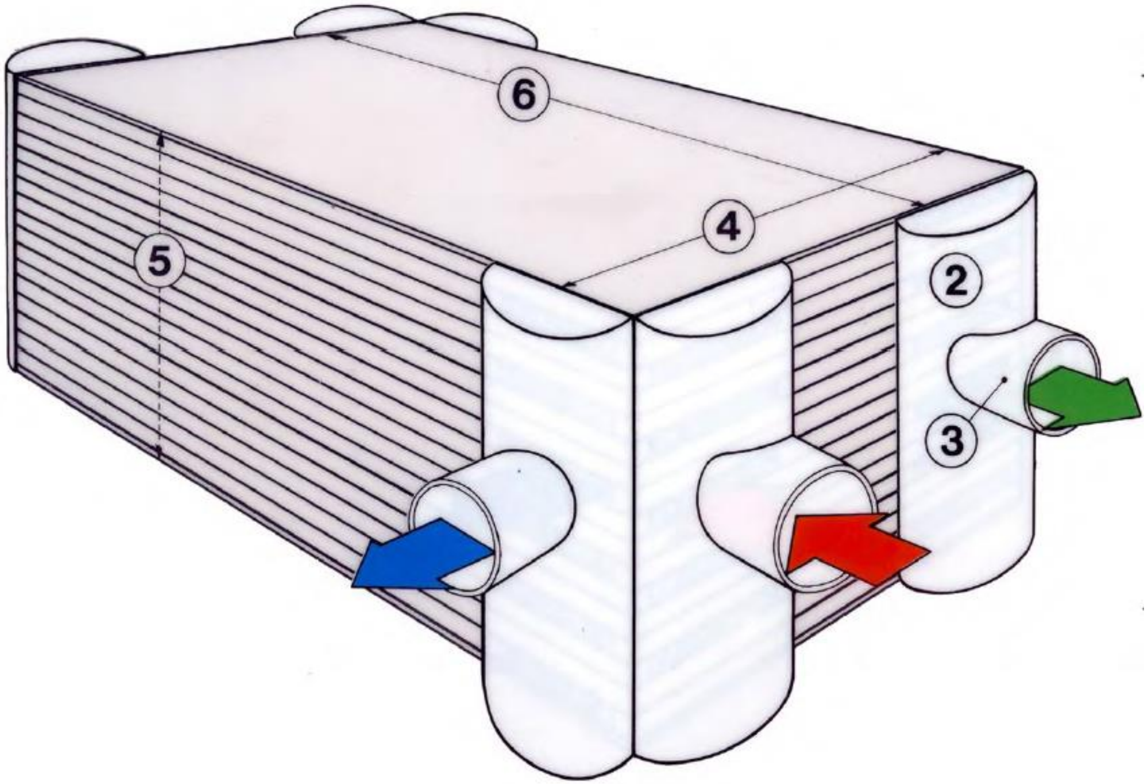






Coil Wound Heat Exchanger

Plate Fin Heat Exchanger



Modelling of multistream heat exchangers

Modelling of multistream heat exchangers

- Highly proprietary IP
  - Air Products & Chemicals Inc.
  - Linde AG
- … incorporated in proprietary & complex computer codes
  - e.g. Linde's GENIUS
- …used for detailed equipment design

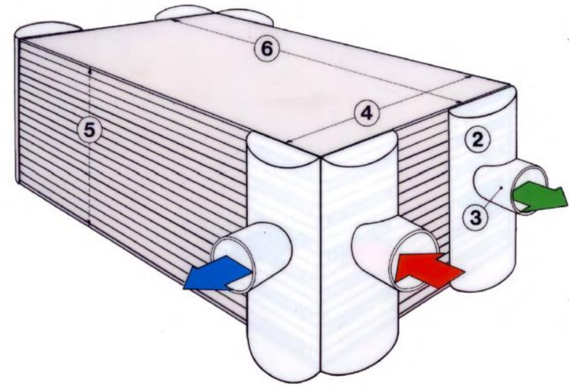
- Most models in the open literature are too simplistic, e.g.
  - assume no phase change either for hot and cold fluid
  - assume constant physical properties along exchanger
- **Need: <u>medium</u> fidelity models**

  ➔ meaningful optimisation of <u>complete</u> process

Plate Fin Heat Exchanger (PFHX)

Model basis

- Multistream/single pass heat exchanger
  - N_c cold streams + N_h hot streams
  - one pass per stream
  - streams flow co/counter-currently through multiple parallel channels
- Given…
  - inlet stream properties (hot and cold)
  - PFHX design and operating conditions
- Calculate…
  - outlet stream properties (hot and cold)
  - PFHX performance and operating conditions
  - sizing parameters



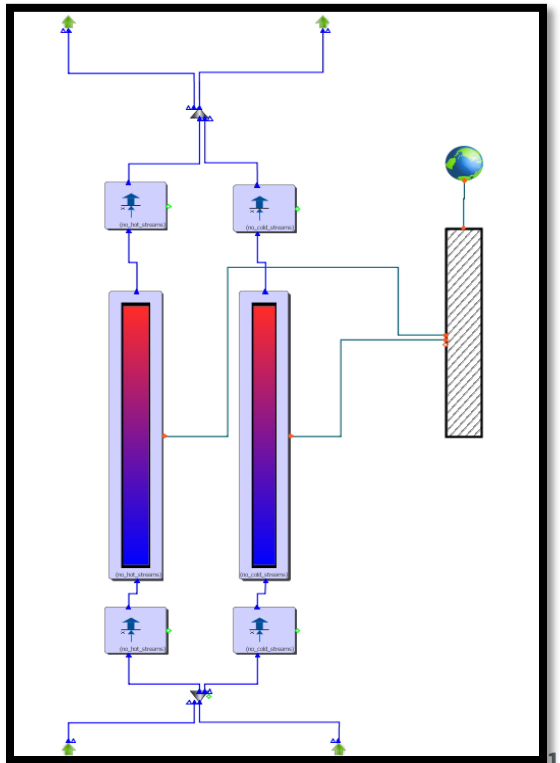
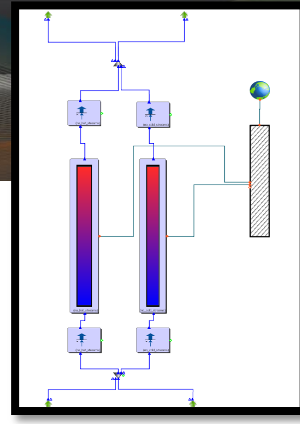


Plate Fin Heat Exchanger

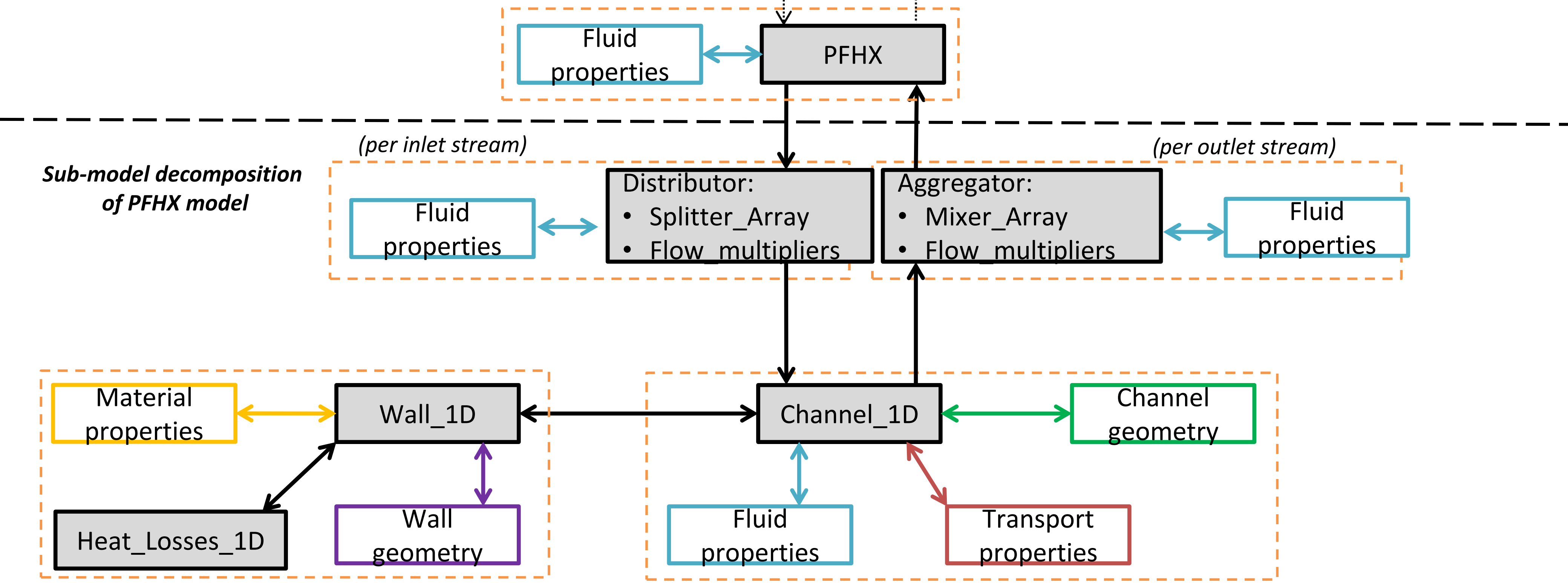
Model architecture



User perspective – PFHX model used for flowsheeting

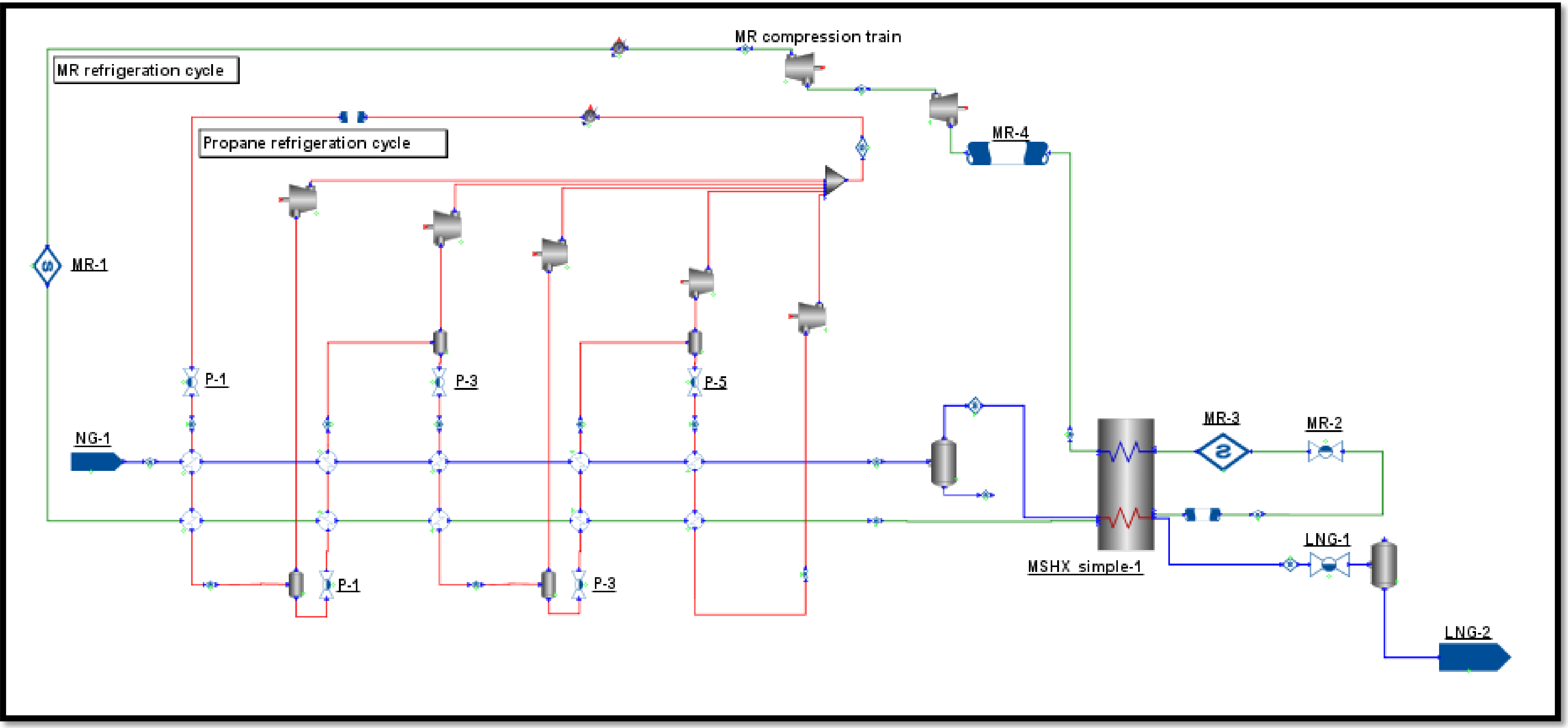
N_c cold fluids	N_h hot fluids
Inlet temperature	Inlet temperature
Inlet flowrate	Inlet flowrate

N_c cold fluids	N_h hot fluids
Outlet temperature	Outlet temperature
Outlet flowrate	Outlet flowrate

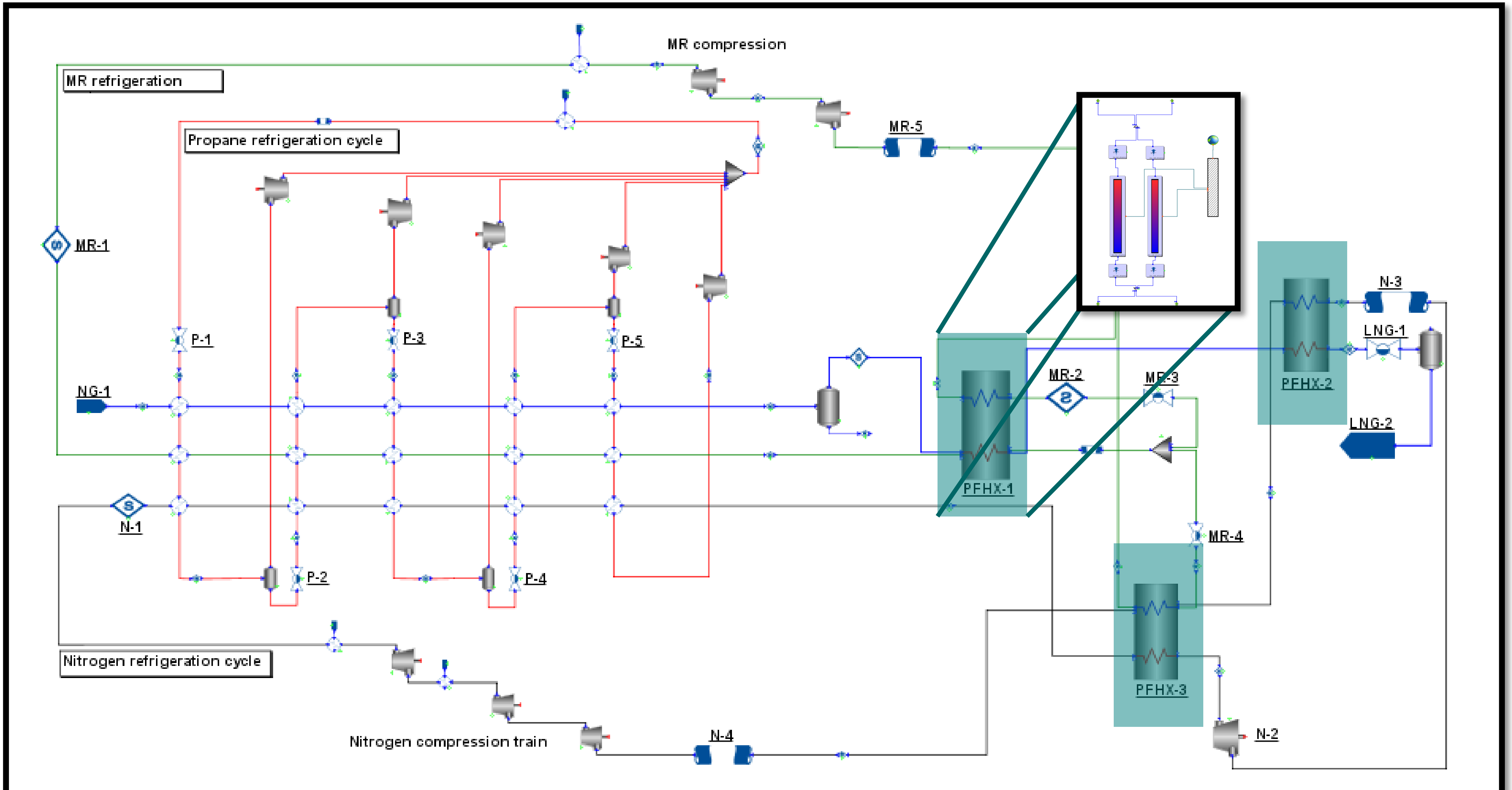


C3/MR process (Air Products & Chemicals Inc.)

Mathematical model in gPROMS ProcessBuilder



AP-X™ process (Air Products & Chemicals Inc.)
Mathematical model in gPROMS ProcessBuilder

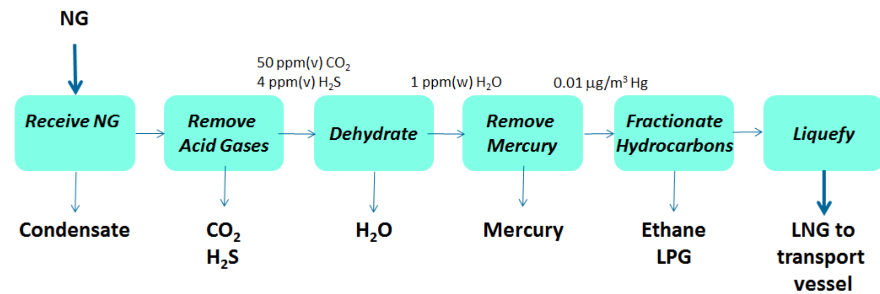


LNG modelling in the gPROMS ProcessBuilder

- Main focus to date
  - Steady-state modelling of liquefaction process
  - Modelling of main cryogenic exchanger (MCE)
    - plate & fin designs
- Work done using early version of gPROMS ProcessBuilder

  ➔ need to take advantage of latest developments

- **Project #1: Liquefaction**
  - Dynamics of liquefaction process
  - Improved modelling of MCE
- **Project #2: NG processing plant**



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Thank you