# Engineering Simulation: The Future and its Impact on Education

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Mechanical Engineering

# What is an Engineer?

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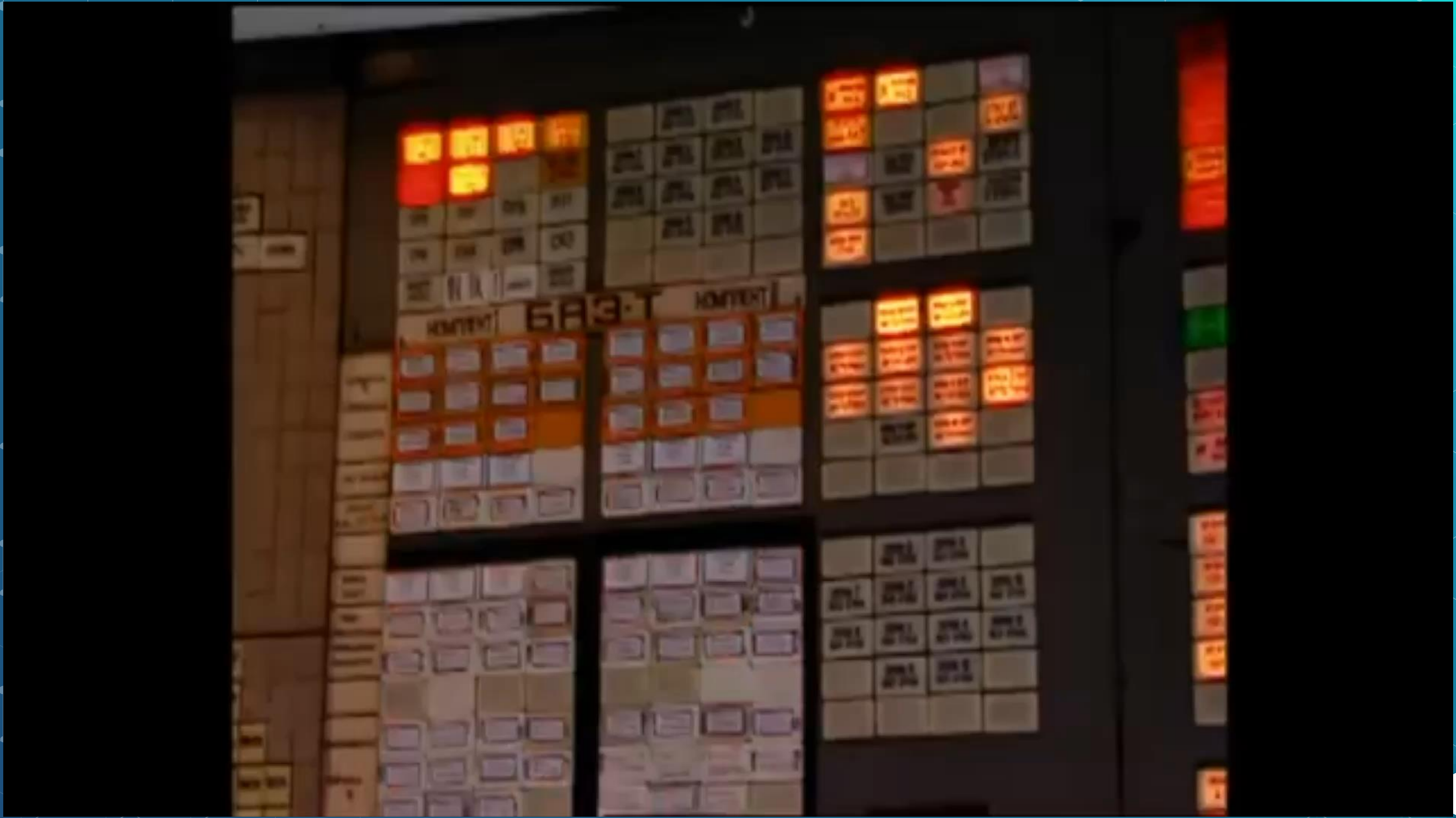
- Problem Solver (industry problems)
- Design and Synthesis (industry experience)
- Engineering is the synthesis of real-life industry and science
- Applied vs Fundamental research

“In the early days of aviation,
the aircraft designers
were also the test pilots.
This had the effect
of weeding out the bad designers”

Was this good or bad?

# 2 Why Engineering Simulation?

## Three Historic Examples


БАЗ-Т

# What is Engineering Simulation

The creation of a virtual reality scenario
based on actual reality
using computers
to enable the evaluation of the performance of an item, device or system
without having to physically build any hardware.

(HvdW)

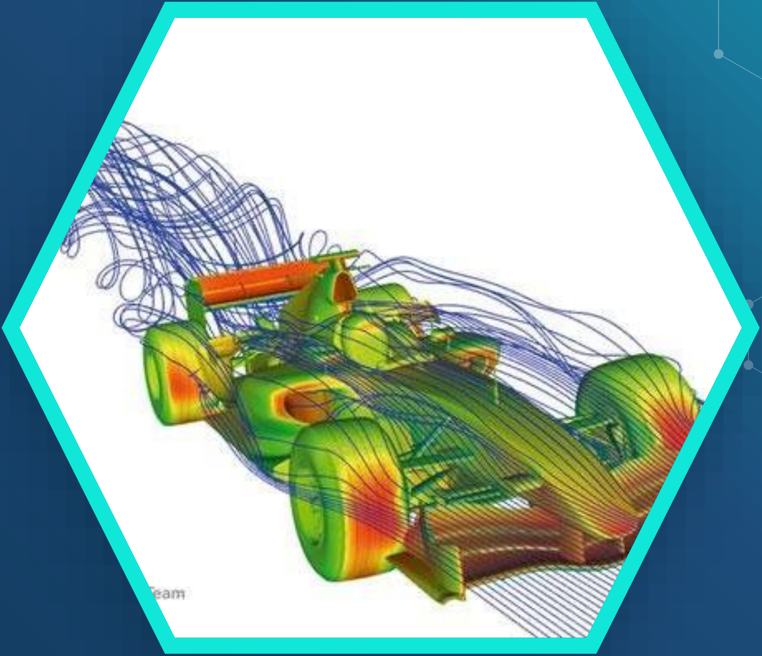
# 4 Computational Fluid Dynamics (CFD)

# CFD

## Computational Fluid Dynamics

Finite Volume or Finite Element Analysis of complex ThermoFluid Systems

**Formula 1 Race Car**

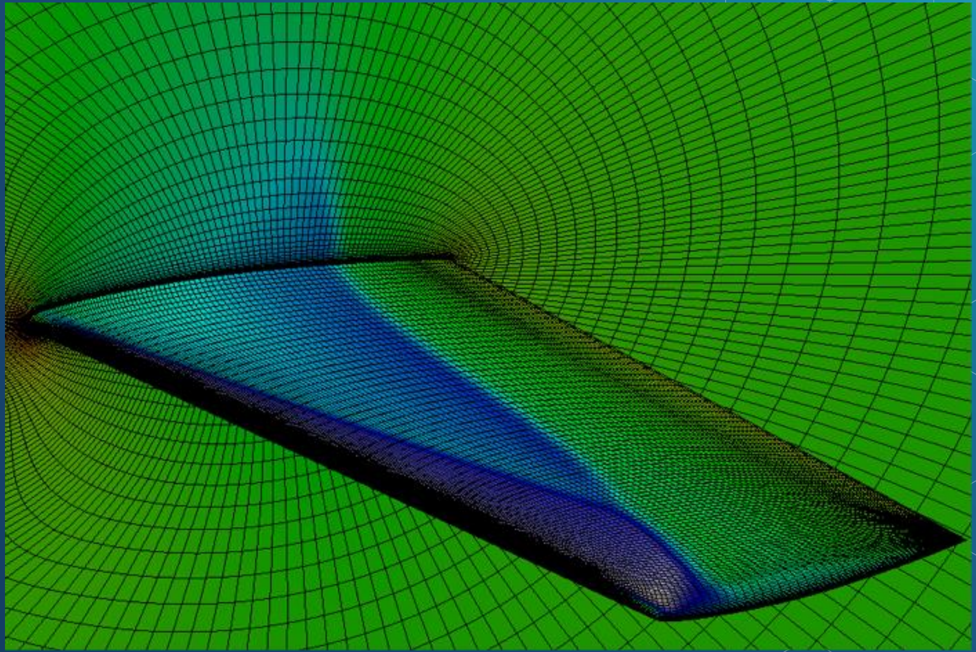


# CFD

## Computational Fluid Dynamics

Finite Volume or Finite Element Analysis of complex ThermoFluid Systems

- **Conservation of Mass**
- **Conservation of Energy**
- **Conservation of Momentum**



# CFD – Conservation Equations

$$\frac{d}{dt}\int_{\mathrm{CV}} \rho \, d\mathcal{V} + \sum_{\mathrm{out}} \int_A \rho V_n \, dA - \sum_{\mathrm{in}} \int_A \rho V_n \, dA = 0$$

$$\frac{dB_{\mathrm{sys}}}{dt} = \frac{d}{dt}\int_{\mathrm{CV}} \rho b \, d\mathcal{V} + \int_{\mathrm{CS}} \rho b \vec{V} \cdot \vec{n} \, dA$$

$$\sum \vec{F} = \frac{d}{dt}\int_{\mathrm{CV}} \rho \vec{V} \, d\mathcal{V} + \int_{\mathrm{CS}} \rho \vec{V} (\vec{V}_r \cdot \vec{n}) \, dA$$

# CFD – Conservation Equations

*x-component of the incompressible Navier–Stokes equation:*

$$\rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right) = -\frac{\partial P}{\partial x} + \rho g_x + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$$

*y-component of the incompressible Navier–Stokes equation:*

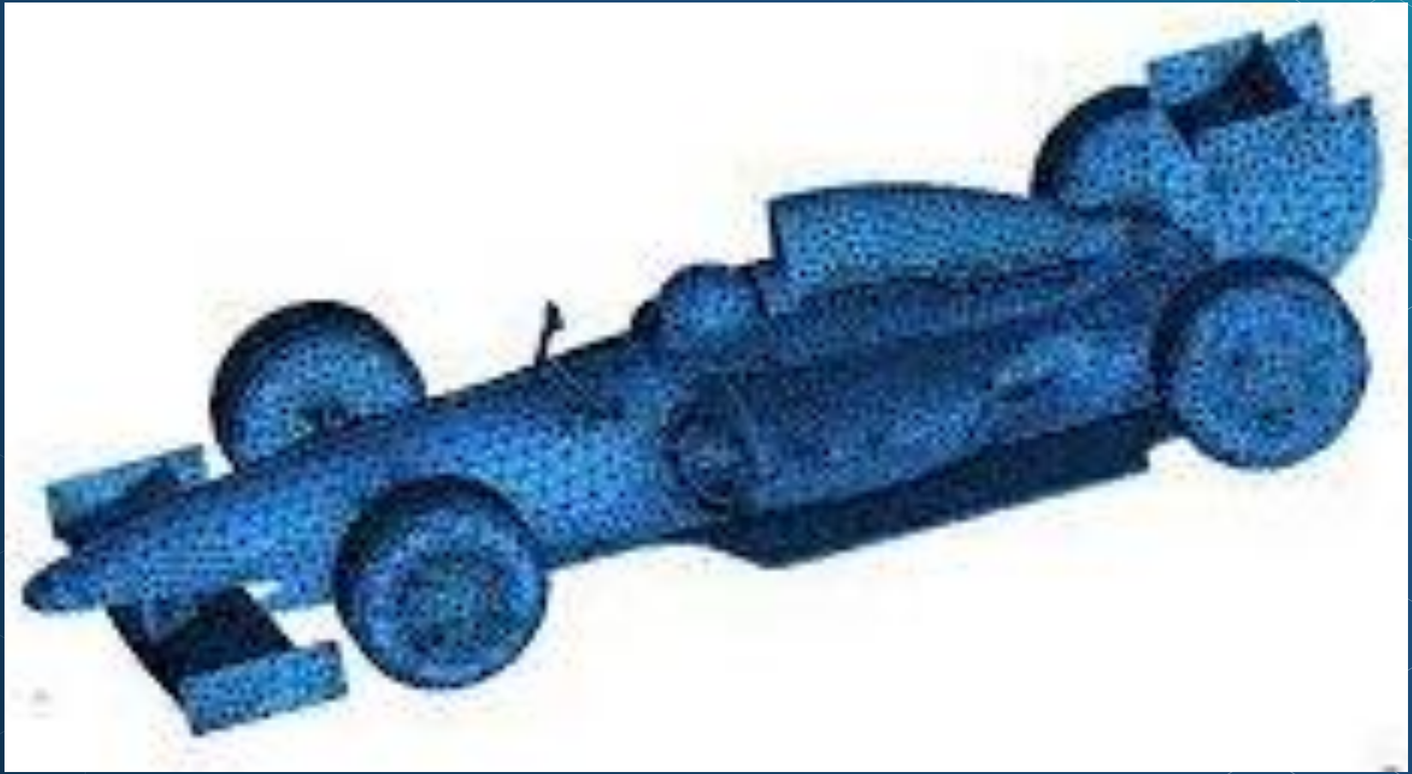
$$\rho\left(\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right) = -\frac{\partial P}{\partial y} + \rho g_y + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right)$$

*z-component of the incompressible Navier–Stokes equation:*

$$\rho\left(\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial P}{\partial z} + \rho g_z + \mu\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right)$$

A typical CFD model for an F1 car requires 1,150 computer cores and generates nearly 550 million data points for each model. To run a single simulation typically takes 5 hours.

# F1 Car



# My Field of Research:
# Systems CFD: 1-D CFD

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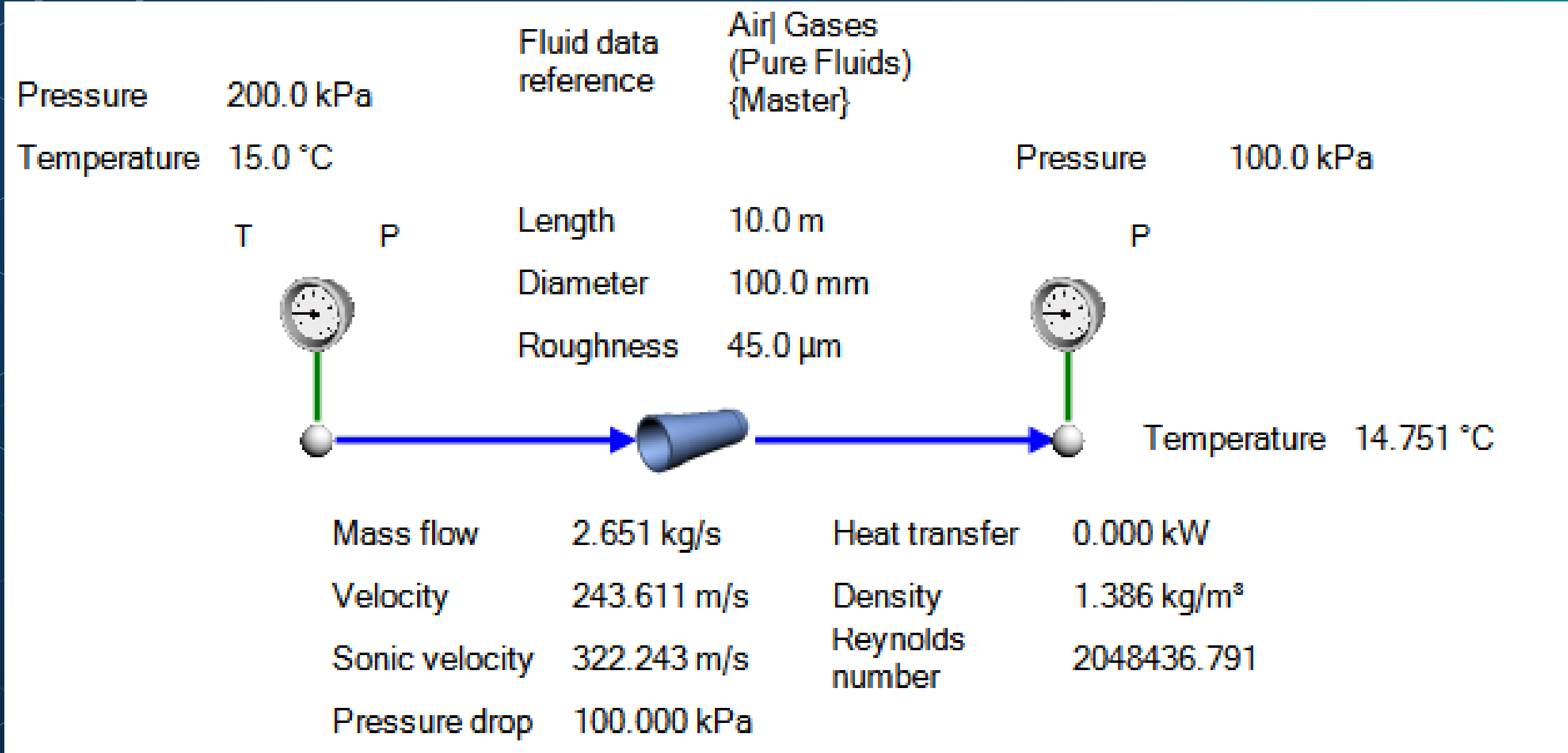
- Full 3-D CFD is often too complex and slow
- Systems-CFD approaches real-life engineering problems as blocks of problems connected together. Advantages are:
  - Speed of specifying the problem domain
  - Reuse of previously created blocks
  - Speed of solution – typically seconds on PC

# Systems CFD

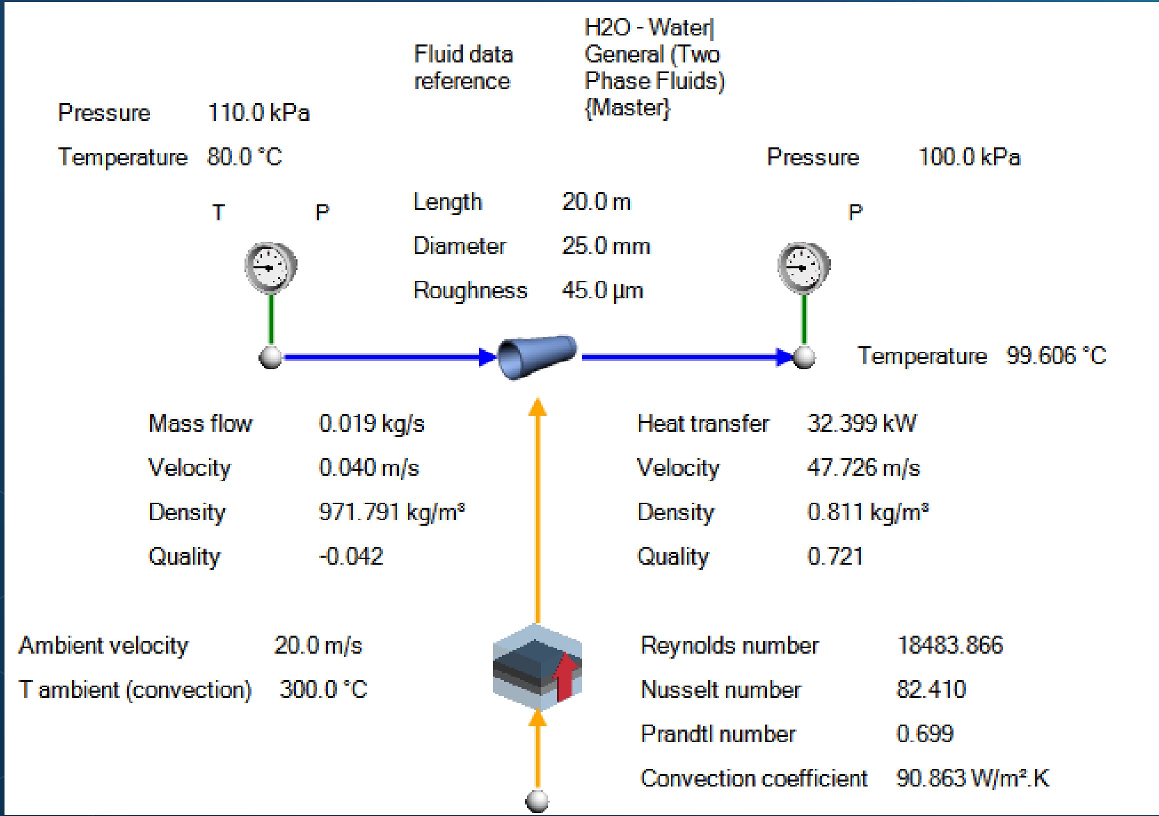
## Simple Pipe Flow

- Graphical
- Boundary conditions



# Systems CFD

## Simple Pipe with Heat Transfer



# Systems CFD - Real Examples

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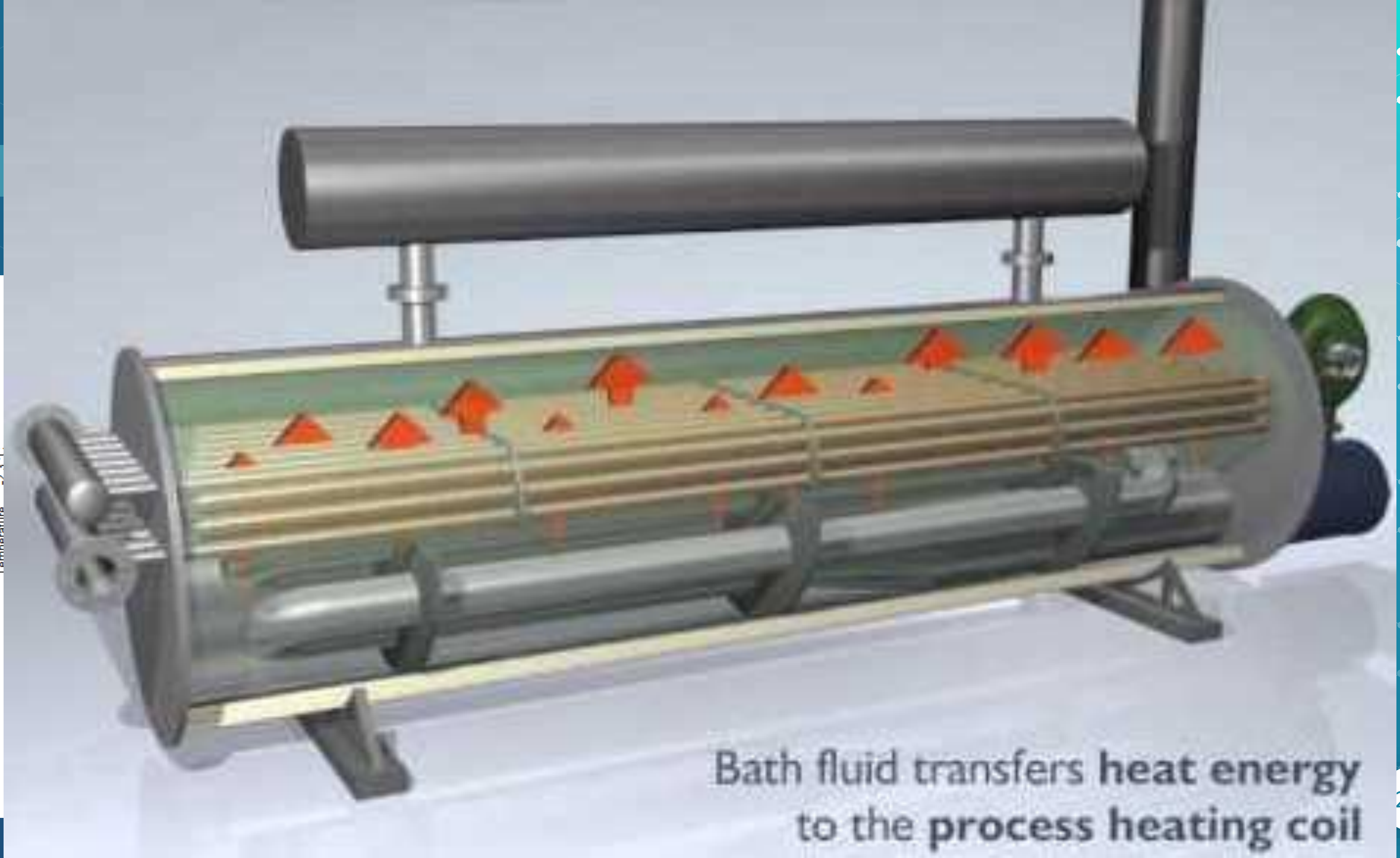
## Natural Gas Facility: Blowdown Temperature Calculation

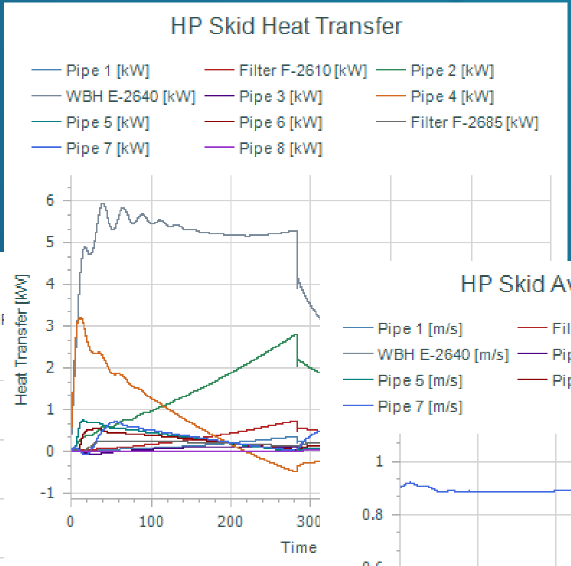
# Natural Gas Facility Blowdown Temperatures

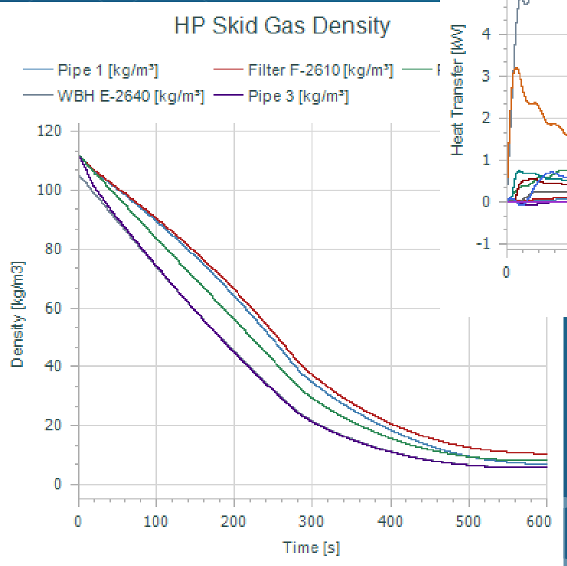
High Pressure:
15 000 kPa

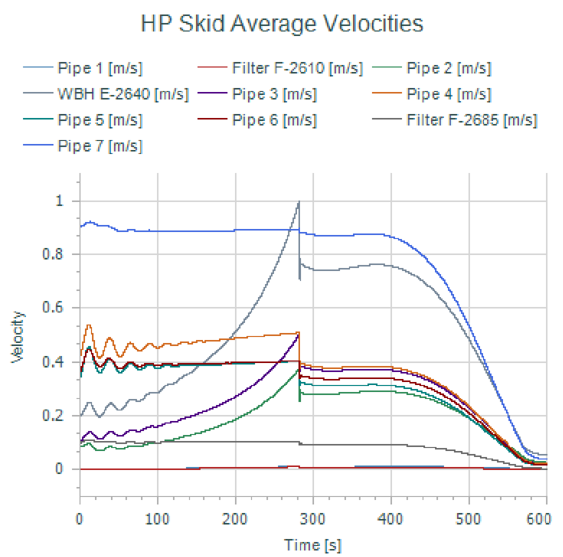
Blowdown Gas Temperature
-100°C

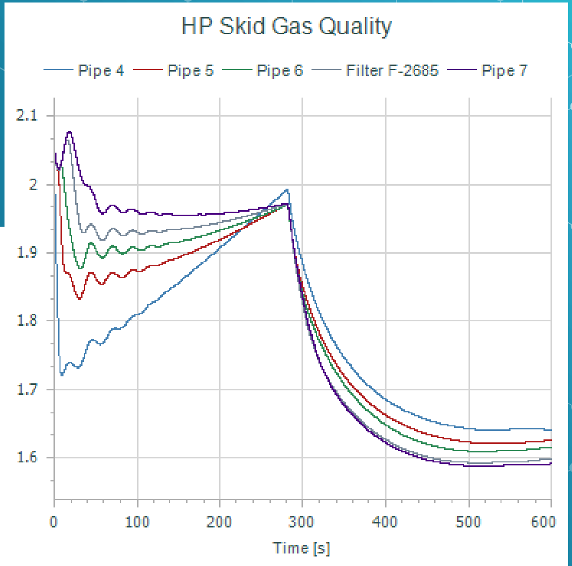

Bath fluid transfers heat energy
to the process heating coil

# Natural Gas Facility Blowdown Temperatures

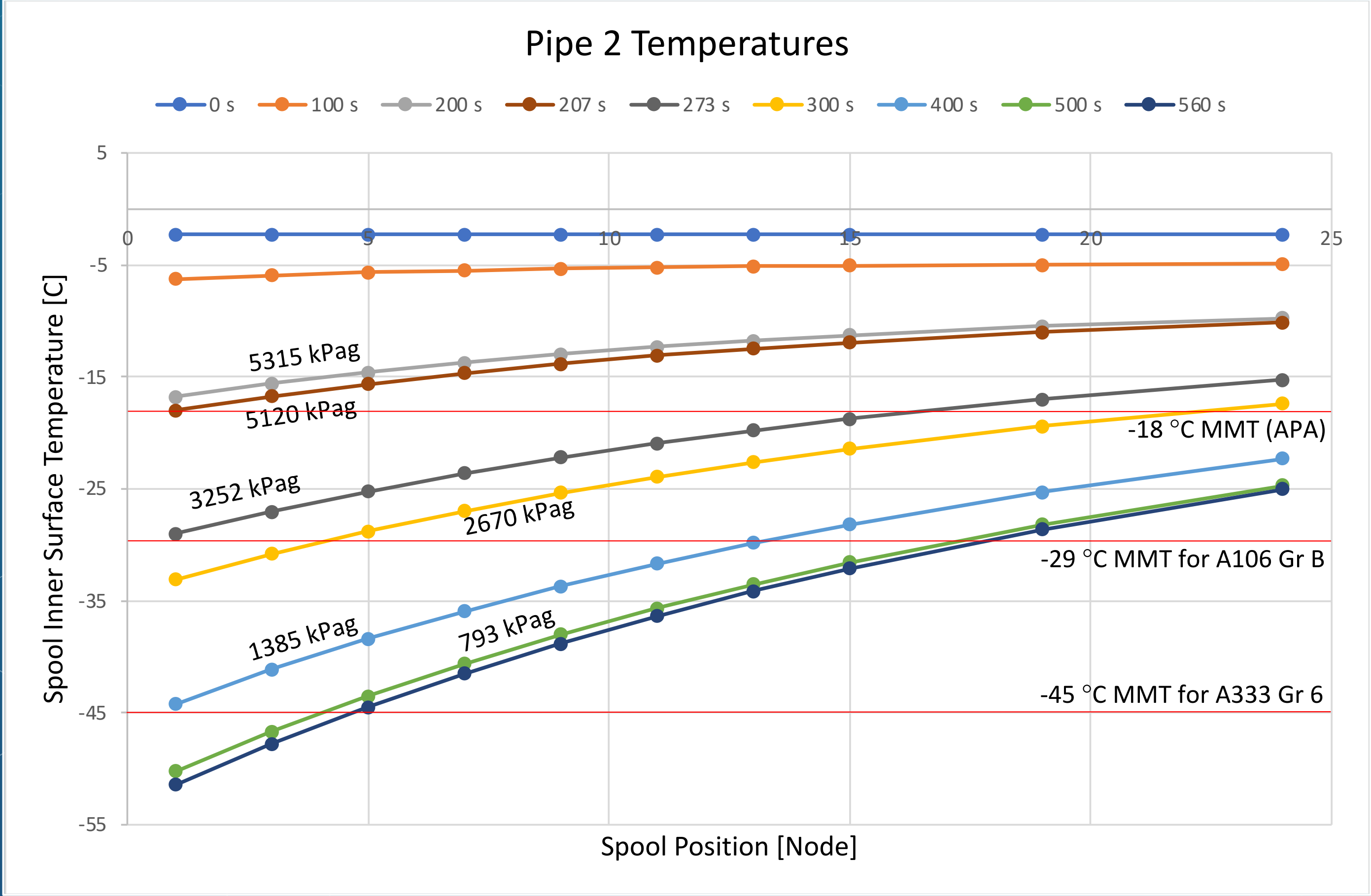


# Natural Gas Facility Blowdown Temperatures



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# Systems CFD - Real Examples

## Medical Retort
## Ethylene Oxide Sterilisation Cycle

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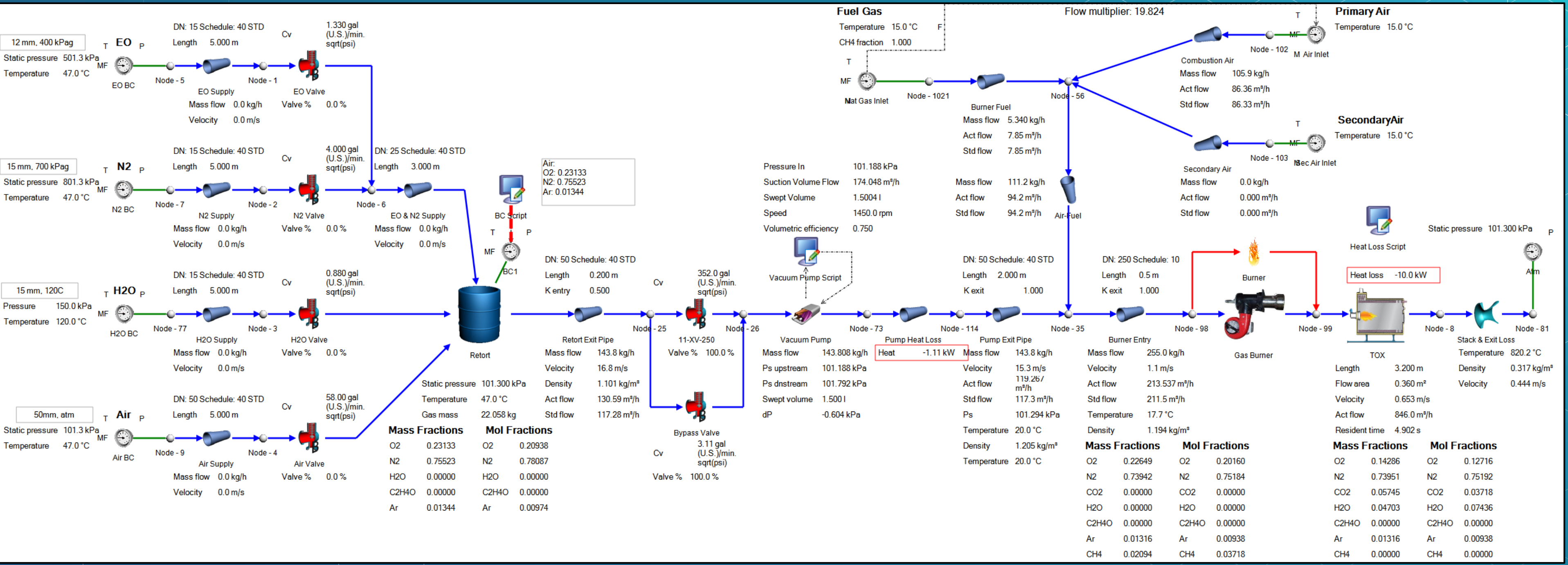
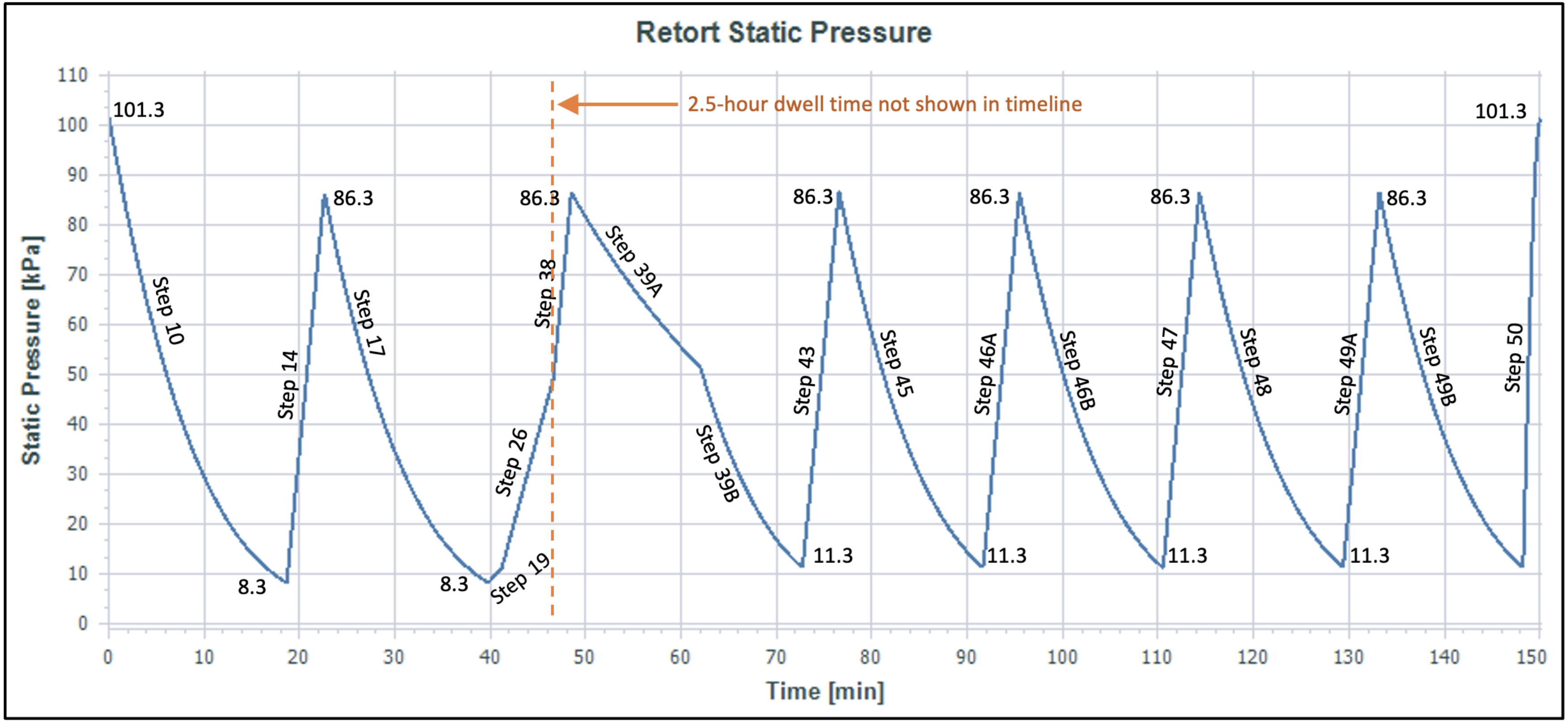
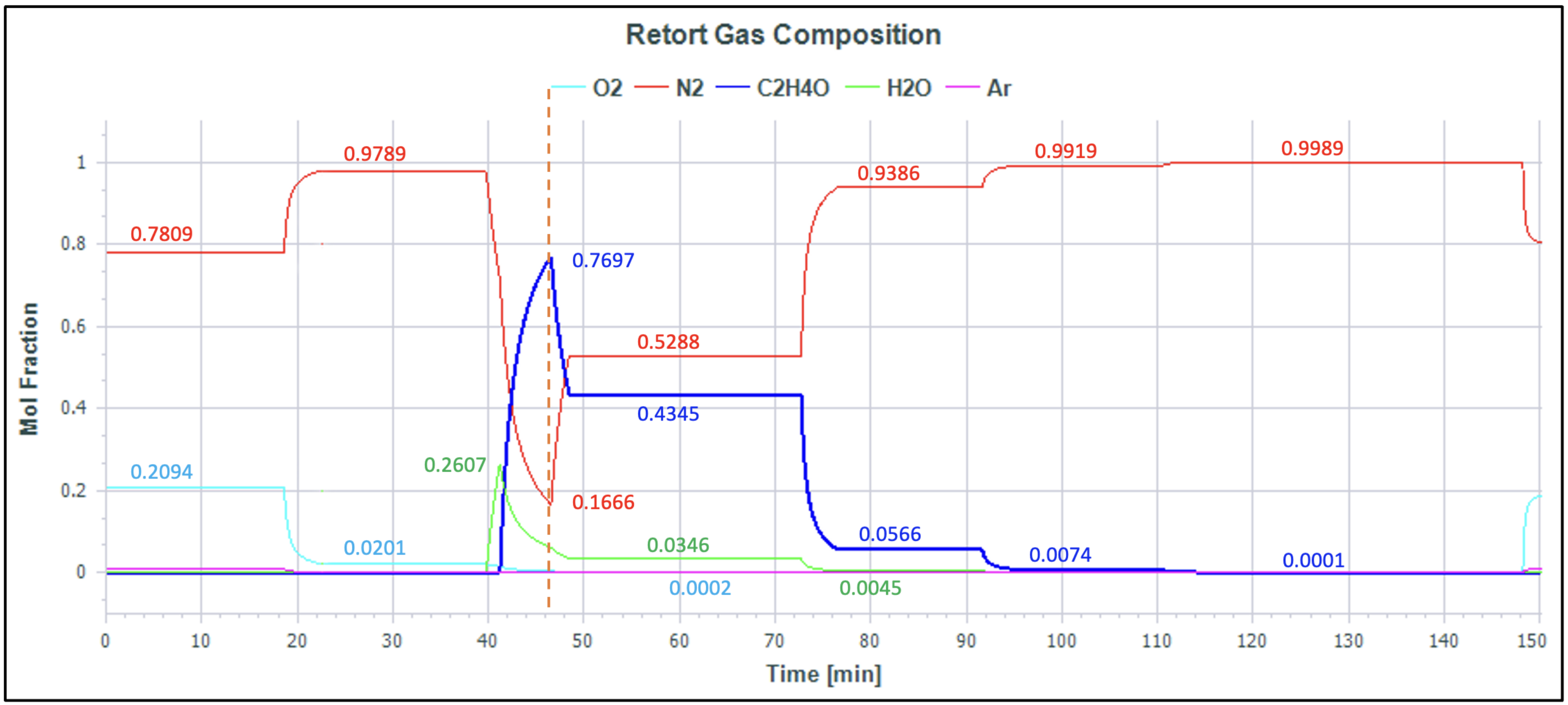


# Medical Retort Ethylene Oxide Sterilisation Cycle



# Medical Retort Ethylene Oxide Sterilisation Cycle



# Education

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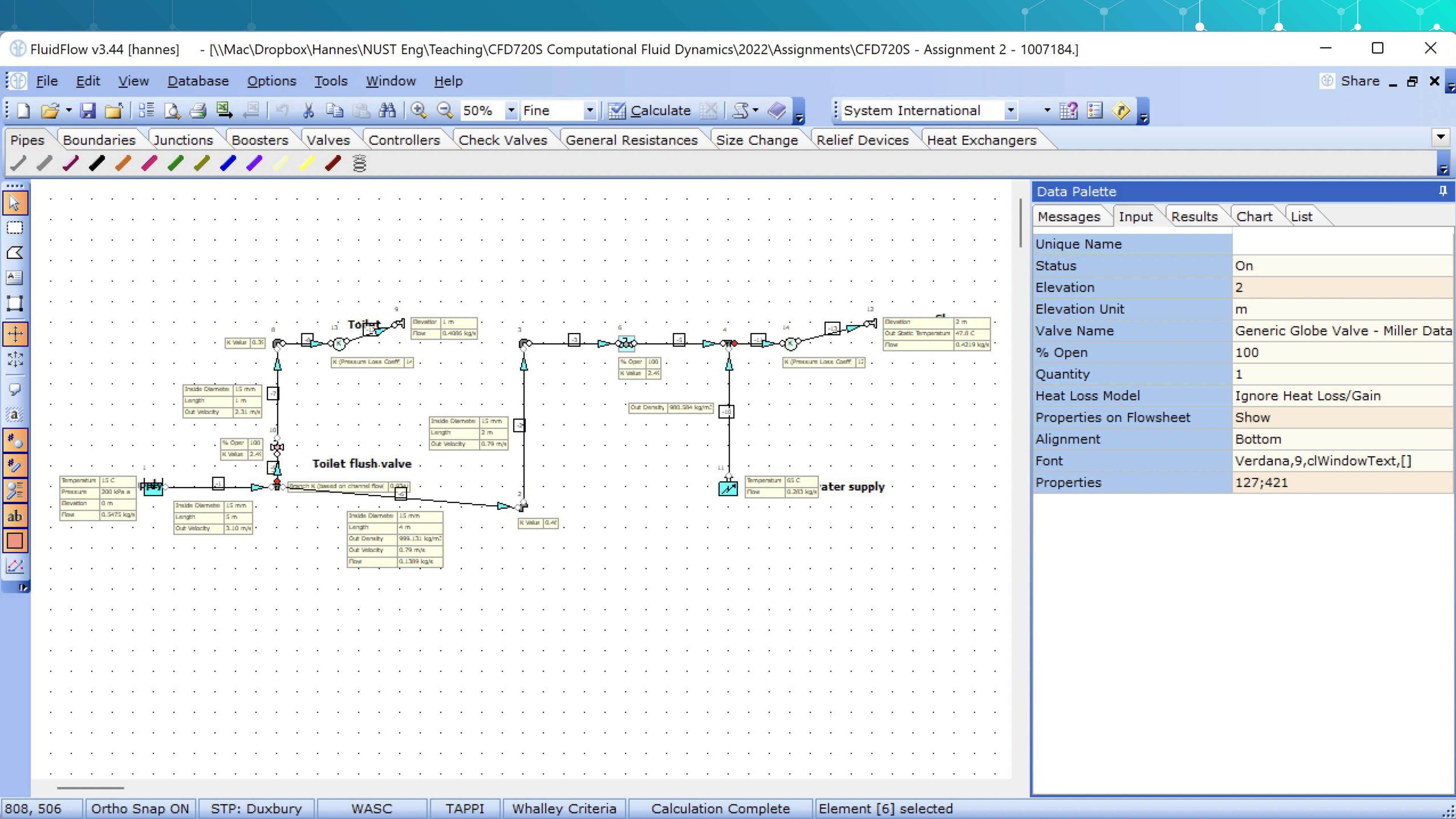
# And Engineering Simulation

# Education – And Engineering Simulation

- Engineering graduates MUST be introduced to Engineering Simulation
- Universities need to employ or contract relevant and competent engineering staff:
  - Staff with applicable skills
  - Staff with significant and relevant industry experience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File
Edit
View
Database
Options
Tools
Window
Help
Share
50%
Fine
Calculate
System International
Pipes
Boundaries
Junctions
Boosters
Valves
Controllers
Check Valves
General Resistances
Size Change
Relief Devices
Heat Exchangers
Toilet flush valve
ater supply
Data Palette
Messages
Input
Results
Chart
List
Unique Name
Status
On
Elevation
2
Elevation Unit
m
Valve Name
Generic Globe Valve - Miller Data
% Open
100
Quantity
1
Heat Loss Model
Ignore Heat Loss/Gain
Properties on Flowsheet
Show
Alignment
Bottom
Font
Verdana,9,clWindowText,[]
Properties
127;421
808, 506
Ortho Snap ON
STP: Duxbury
WASC
TAPPI
Whalley Criteria
Calculation Complete
Element [6] selected

# Education – And Engineering Simulation

You cannot teach a student how to design and build a bridge if you have not personally designed and built a bridge. There is no substitute for experience (HvdW)

Questions?