WANDA
Deltares
Enabling Delta Life
Wanda 4 Gas

Wanda 4 Gas
Motivation

- Transient phenomena in gas systems
  - Abrupt
  - Wave phenomena
  - Non-isothermal processes
  - Convection, expansion, conduction

- Applications
  - Gas wells
    - > Choke valve break out
    - > Blow out
  - Pneumatic systems
  - Air conditioning systems

Wanda 4 Gas Models

- Pipeline
- Valve
- Compressor
- Reservoir
- Checkvalve
- …

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Pipeline model

- Conservation of mass $$\frac{1}{C^2}\left(\frac{\partial P}{\partial t}+V\frac{\partial P}{\partial x}\right)+\rho\frac{\partial V}{\partial x}=\frac{1}{c_p T}\left(\frac{4\tau_w V}{D}+\frac{\phi}{A}\right)$$
- Conservation of momentum $$\rho\left(\frac{\partial V}{\partial t}+V\frac{\partial V}{\partial x}\right)+\frac{\partial P}{\partial x}=-\frac{4\tau_w}{D}-\rho g\sin\theta$$
- Conservation of energy $$\rho c_p\left(\frac{\partial T}{\partial t}+V\frac{\partial T}{\partial x}\right)=\left(\frac{\partial P}{\partial t}+V\frac{\partial P}{\partial x}\right)+\frac{4\tau_w V}{D}+\frac{\phi}{A}$$
- Equation of state $$P=ZR\rho T$$
- Wave speed $$C=\sqrt{Z\,k\,RT}$$
- Wall friction $$\tau_w = f\frac{\rho}{8}V|V|$$
- Heat conduction $$\phi = L_T\left(T_a - T\right)$$

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Wanda 4 Gas Valve model

- 8 unknowns $P_1 \quad V_1 \quad \rho_1 \quad T_1 \quad P_2 \quad V_2 \quad \rho_2 \quad T_2$
- Conservation of mass $\rho_1 V_1 - \rho_2 V_2 = 0$
- Conservation of momentum $W \left(= \rho_1 A_1 V_1\right) = A_v Y \sqrt{X P_1 \rho_1}$
  - Discharge coefficient $A_v = 7.6 \times 10^{-7} C_v$
  - Pressure ratio $X = \left(P_1 - P_2\right) / P_1$
  - Gas expansion fact. $Y = 1 - \dfrac{X}{3 F_k X_T} \qquad Y_{\text{critical}} = 1 - \dfrac{1}{3 F_k} \qquad F_k = k / k_{\text{air}} = k / 1.4$
- Conservation of energy $\left(c_p T_1 + \dfrac{V_1^2}{2} \right) - \left(c_p T_2 + \dfrac{V_2^2}{2} \right) = 0$
- Equation of state $P = Z R \rho T$

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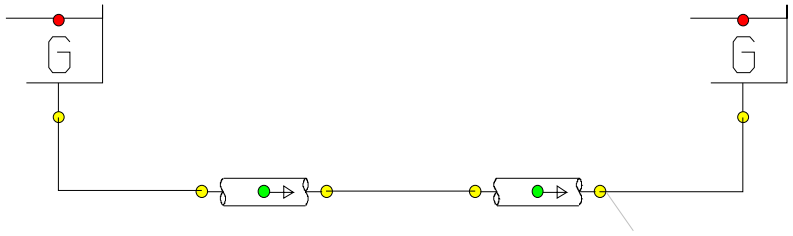
Validation example: shock tube

Two tubes with different initial pressures and temperatures are separated by a membrane

Membrane breaks



P1
ip: 1 (barg)
it: 75 (°C)
l: 10 (m)
r: 1.001 (kg/m3)

P2
ip: 0.1 (barg)
it: 5.7 (°C)
l: 10 (m)
r: 0.125 (kg/m3)

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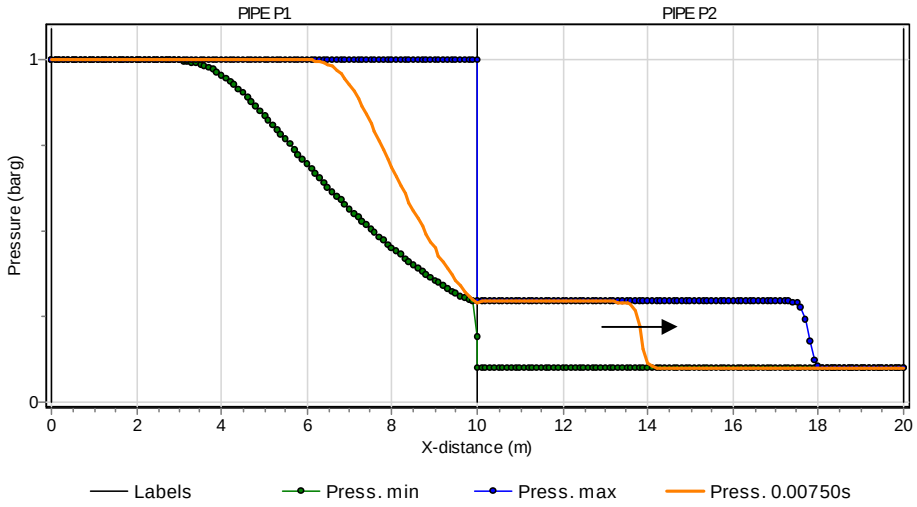

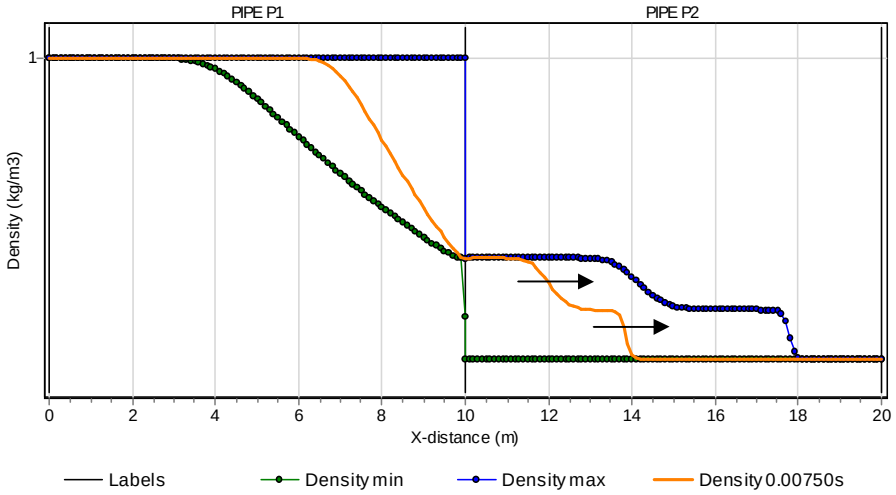

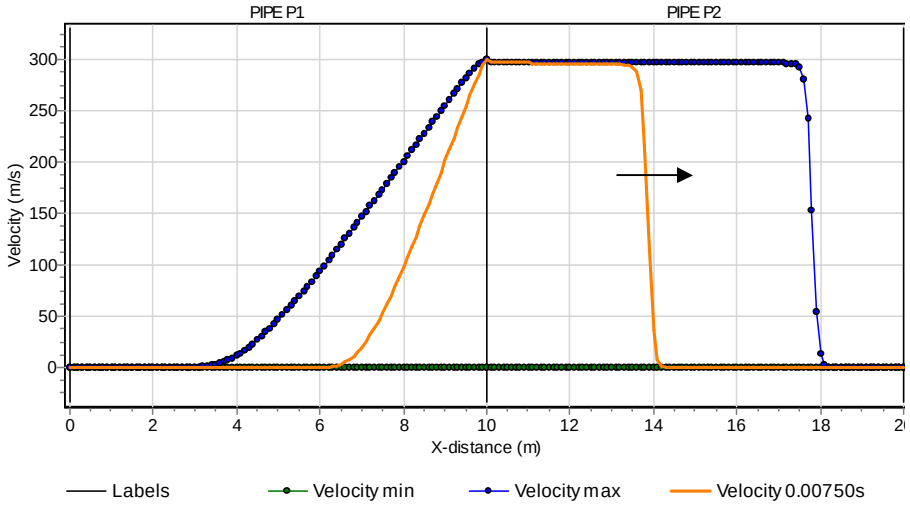

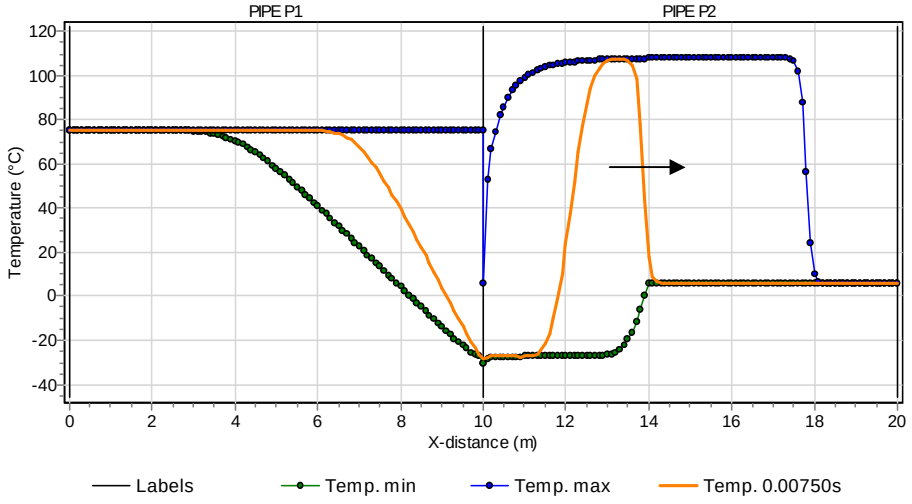

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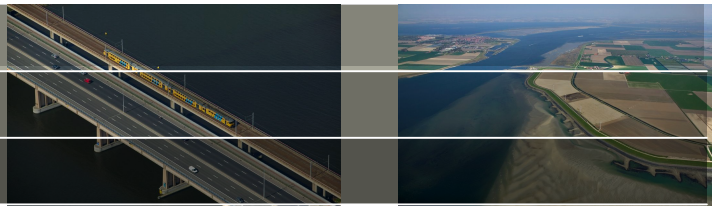
Example: free convection

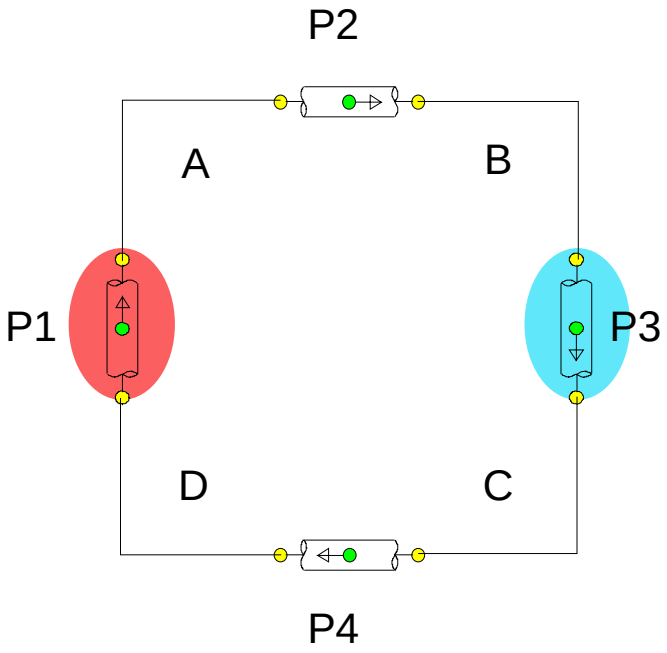


Vertical loop of 4 tubes (side view)

Left tube is heated, right tube is cooled

First a expansion-compression flow sets in

Afterwards a circular convection develops



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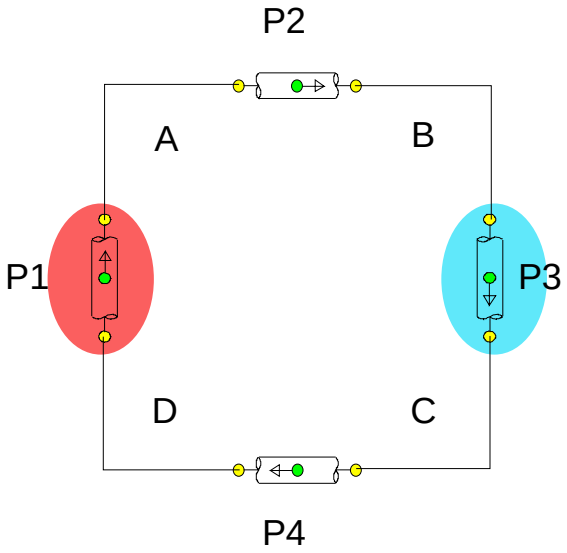

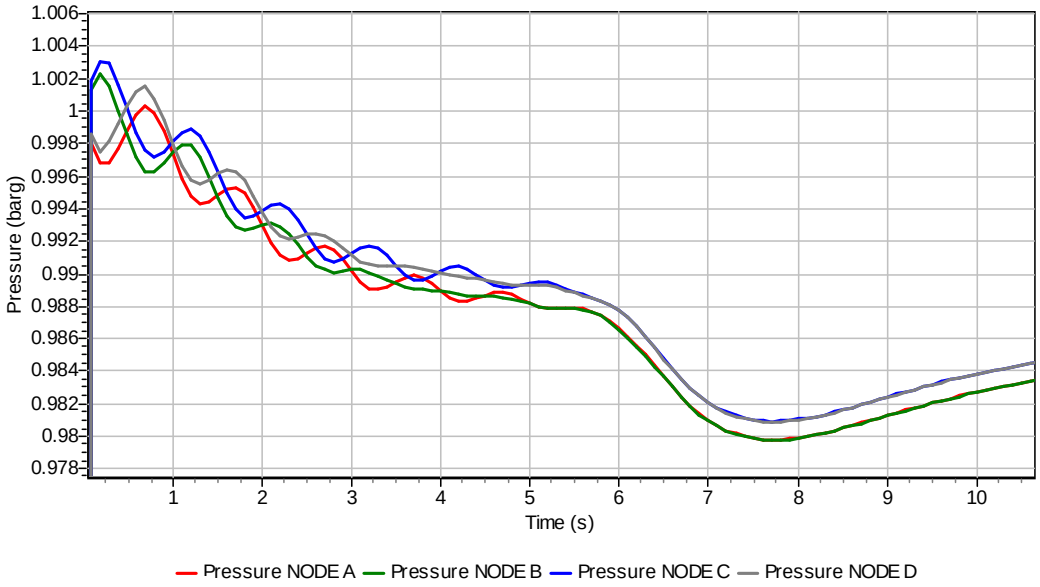

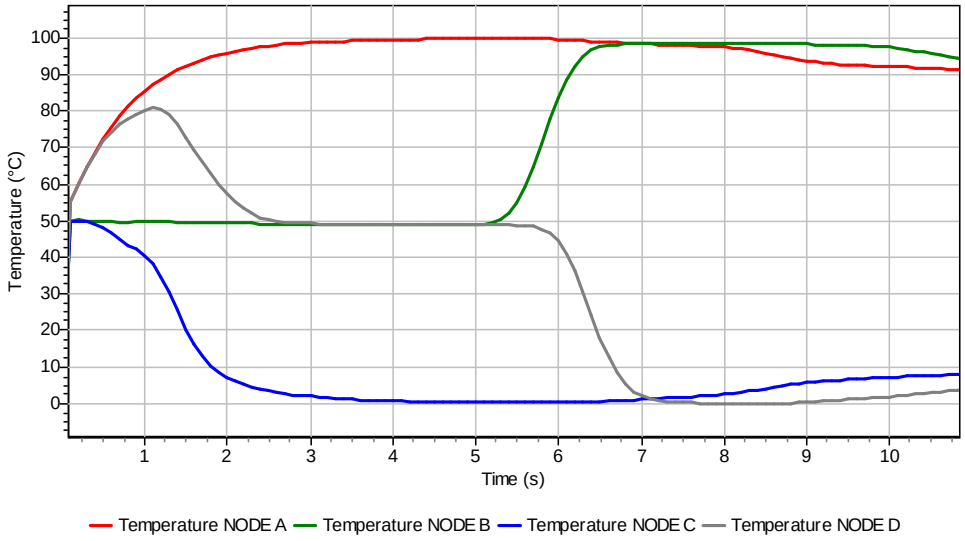

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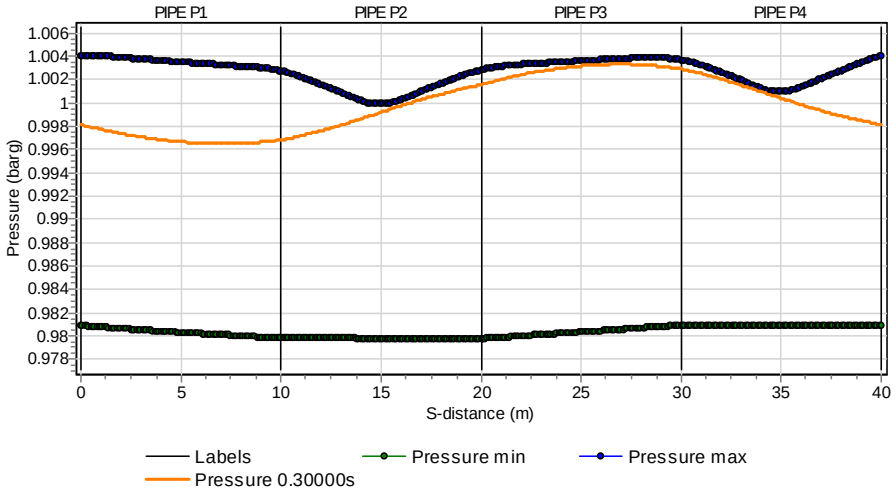

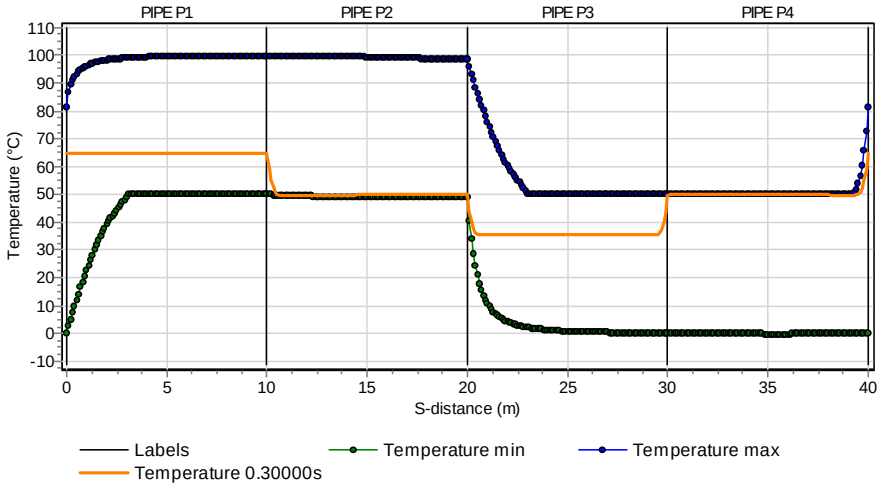

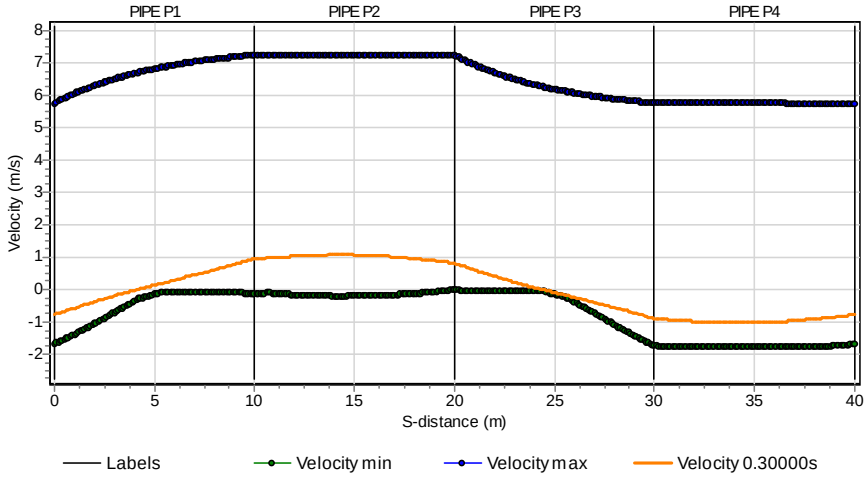

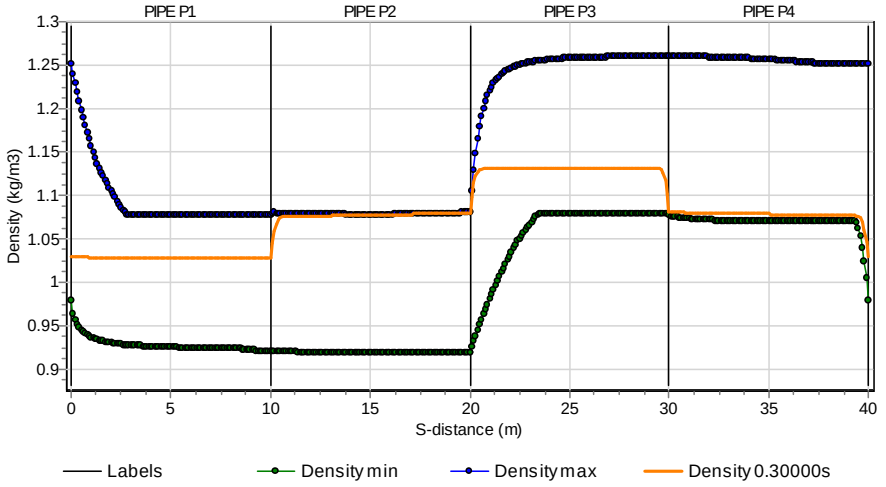

Expansion en compression after 0.3 s

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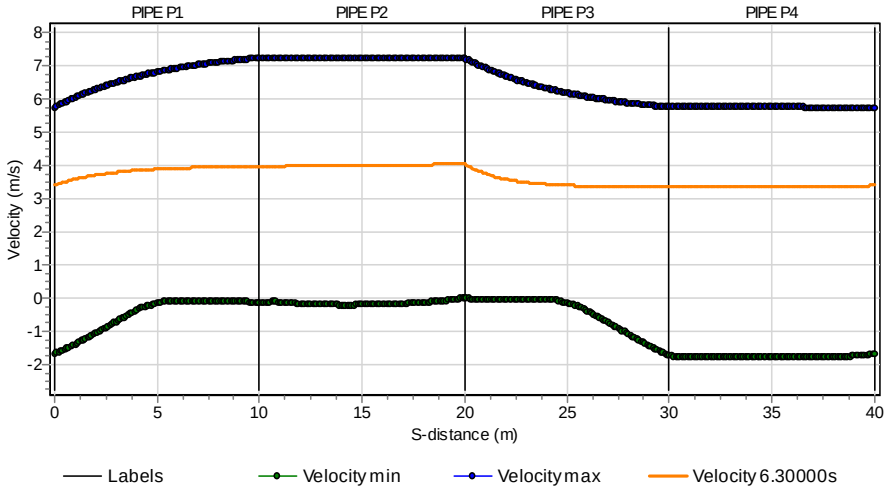
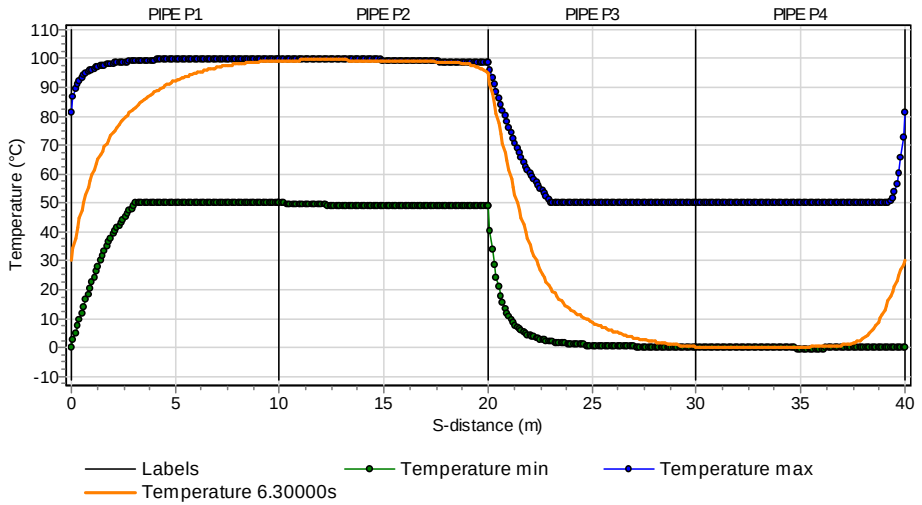
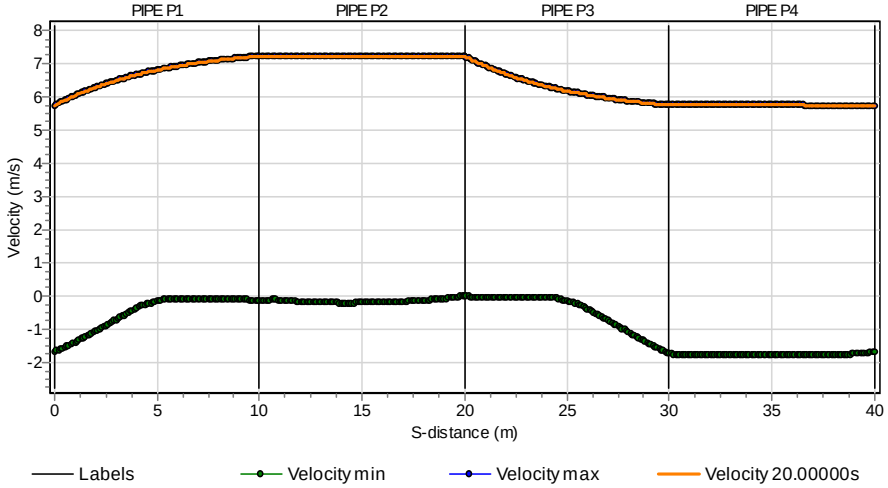
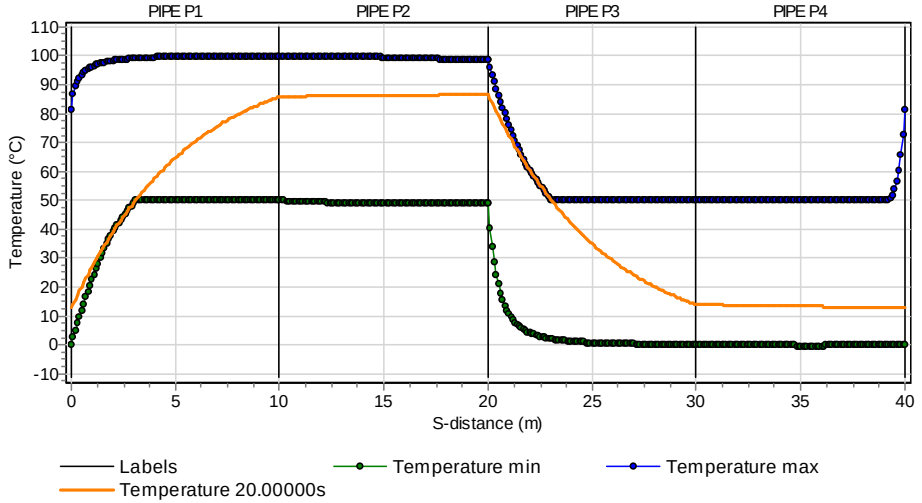
Example: free convection





Convection after 6.3 s





Convection after 20 s

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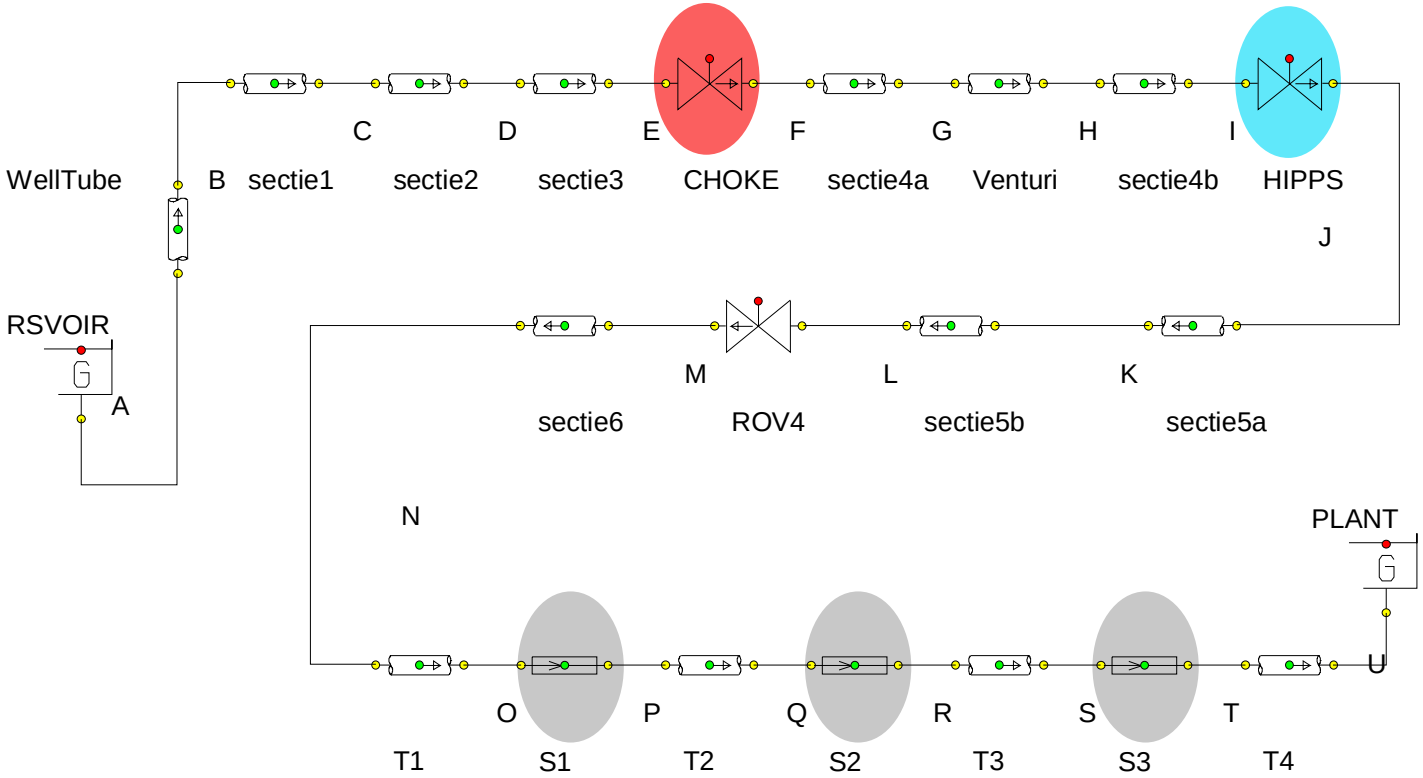
Example: HIPPS calculation

Oil well with Choke valve, pipeline network, and transportline

Choke valve breaks out

HIPPS valve closes in 2 seconds



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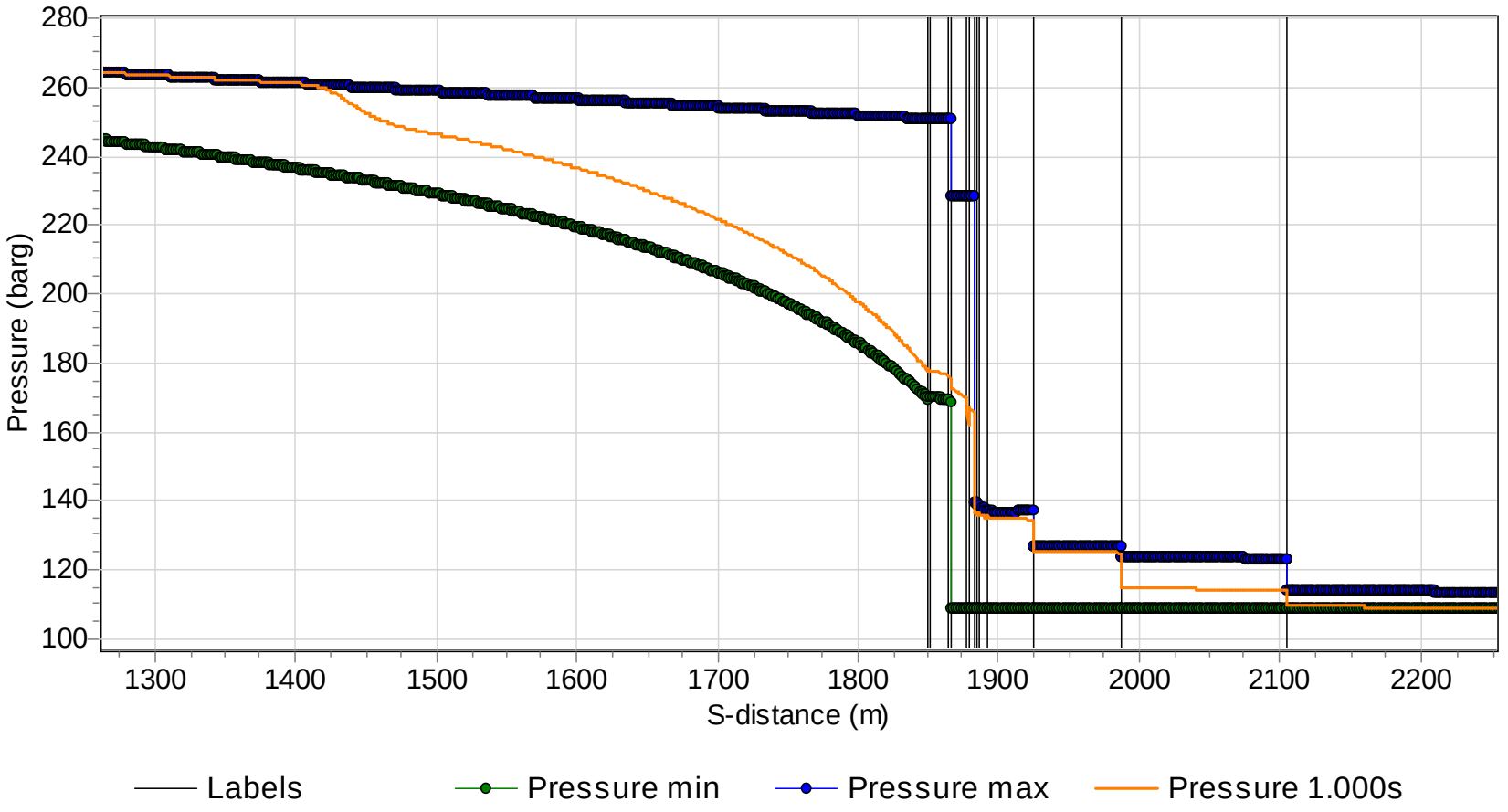

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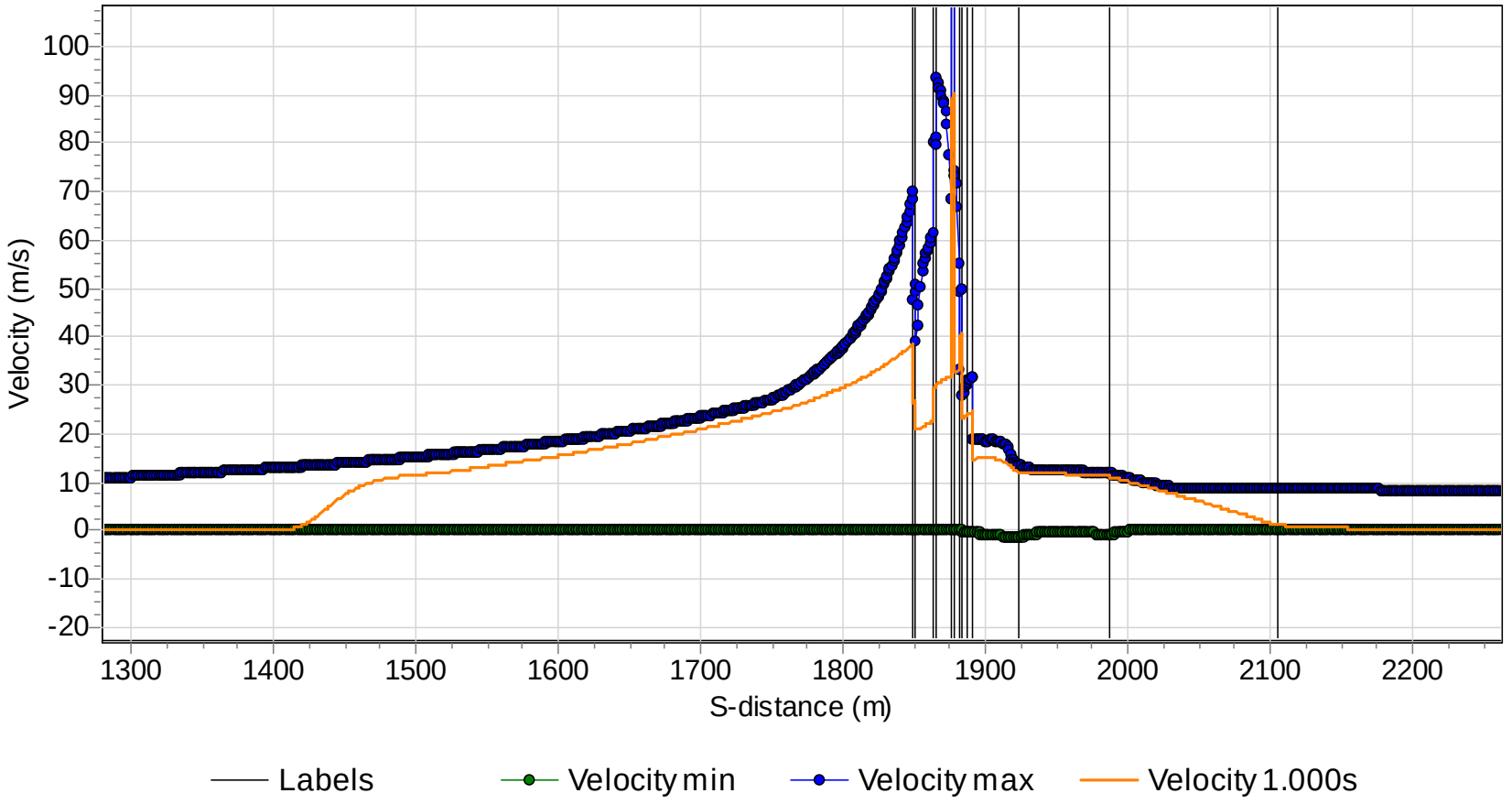

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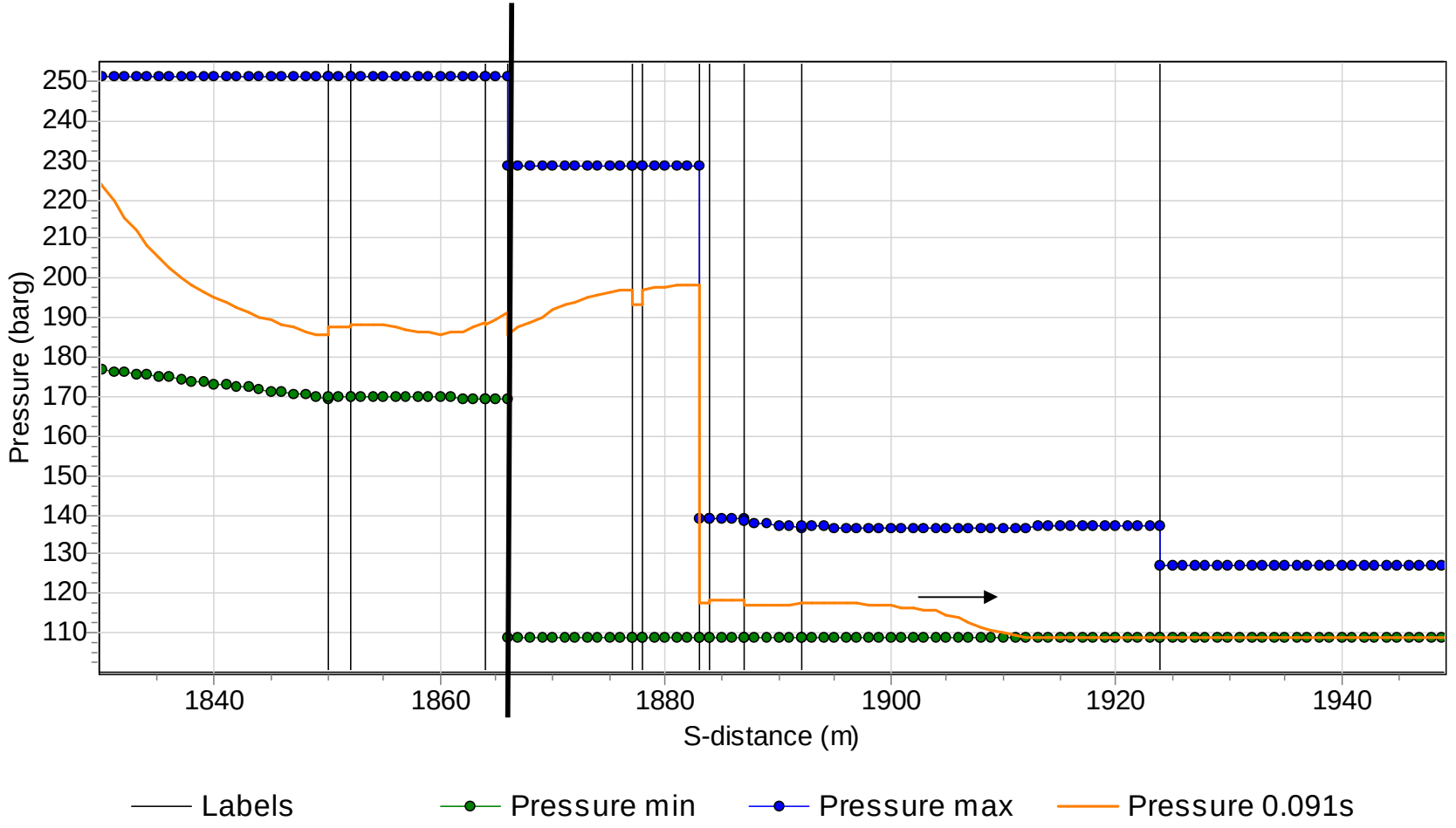

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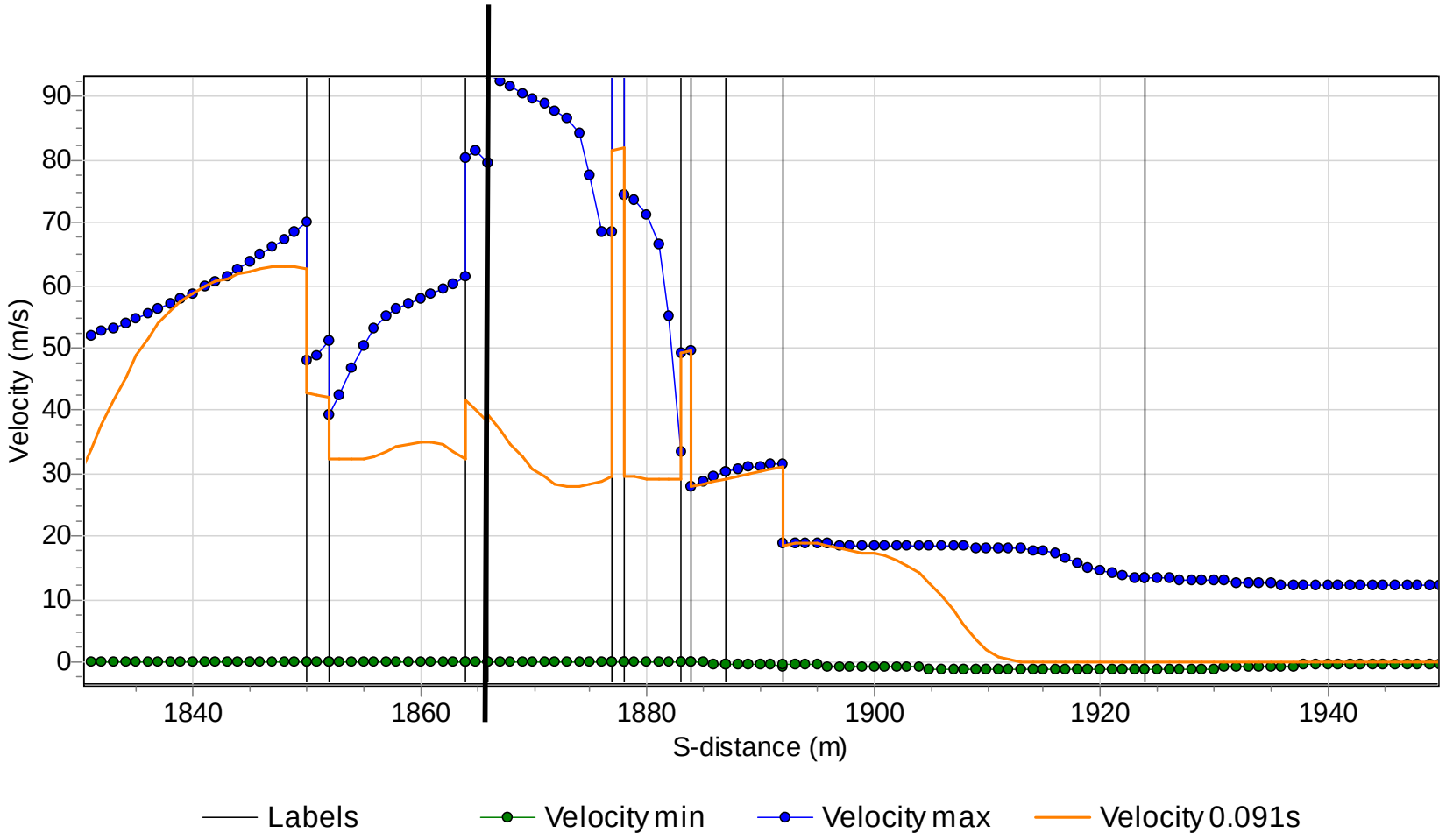

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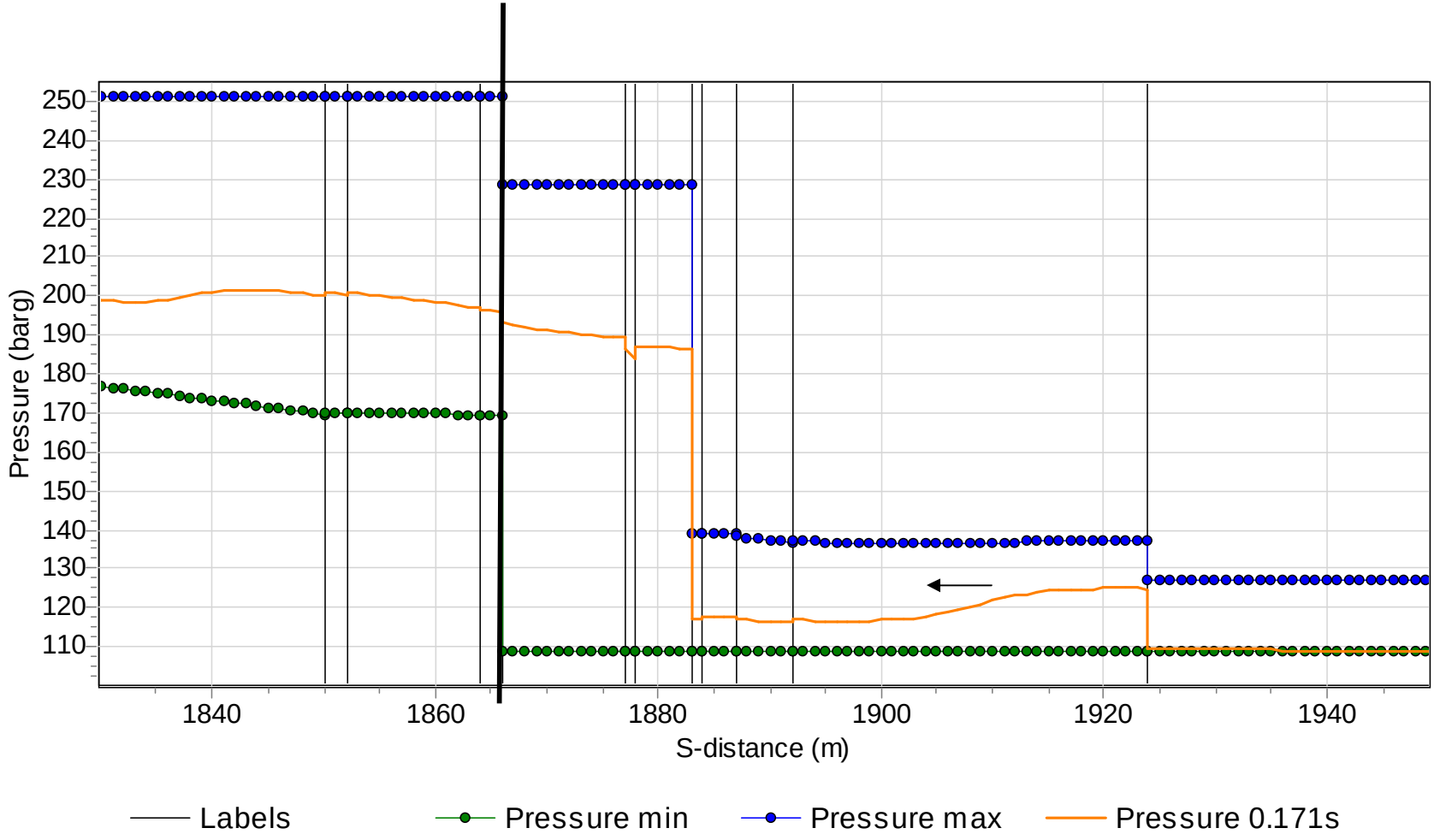

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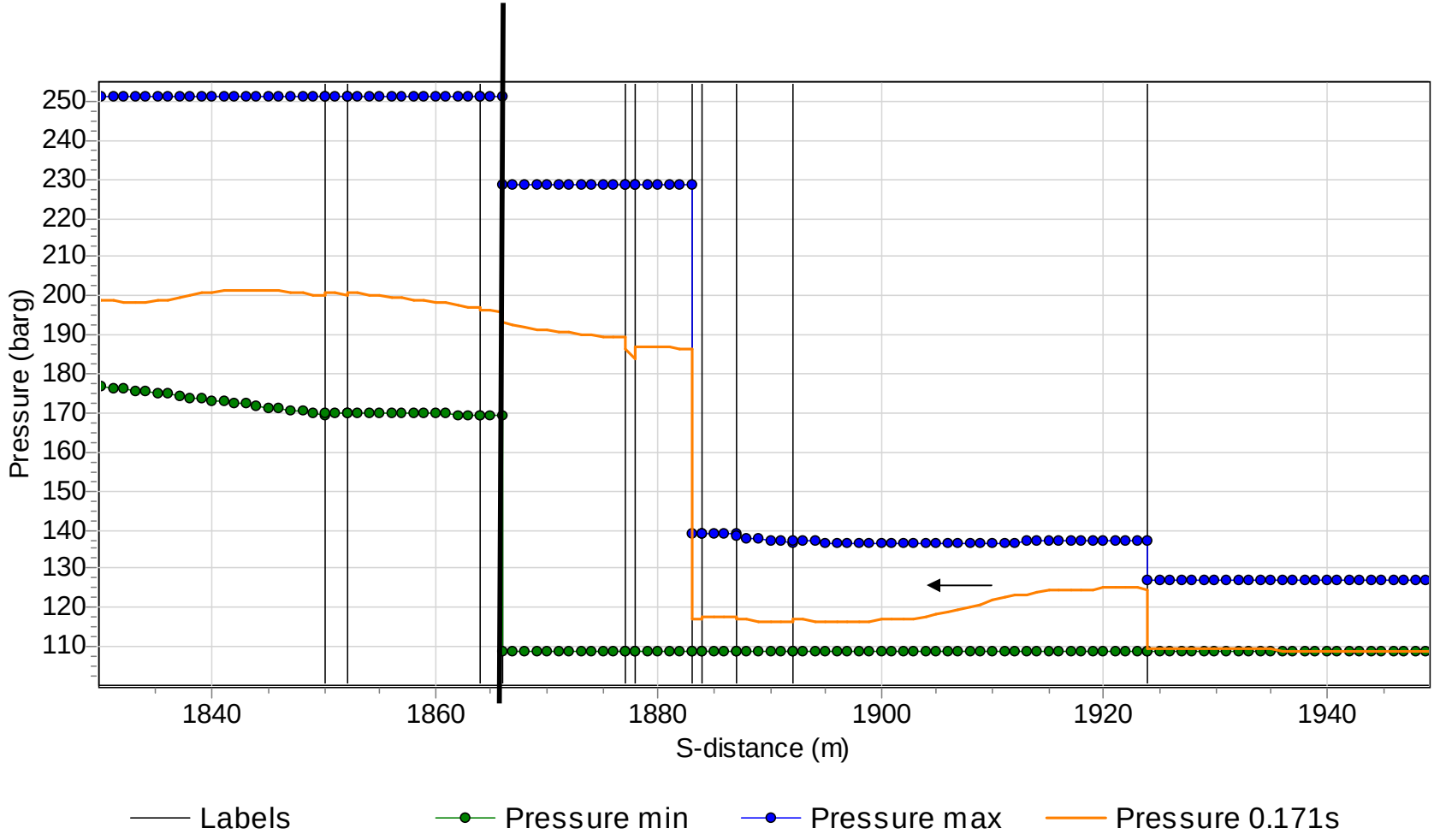

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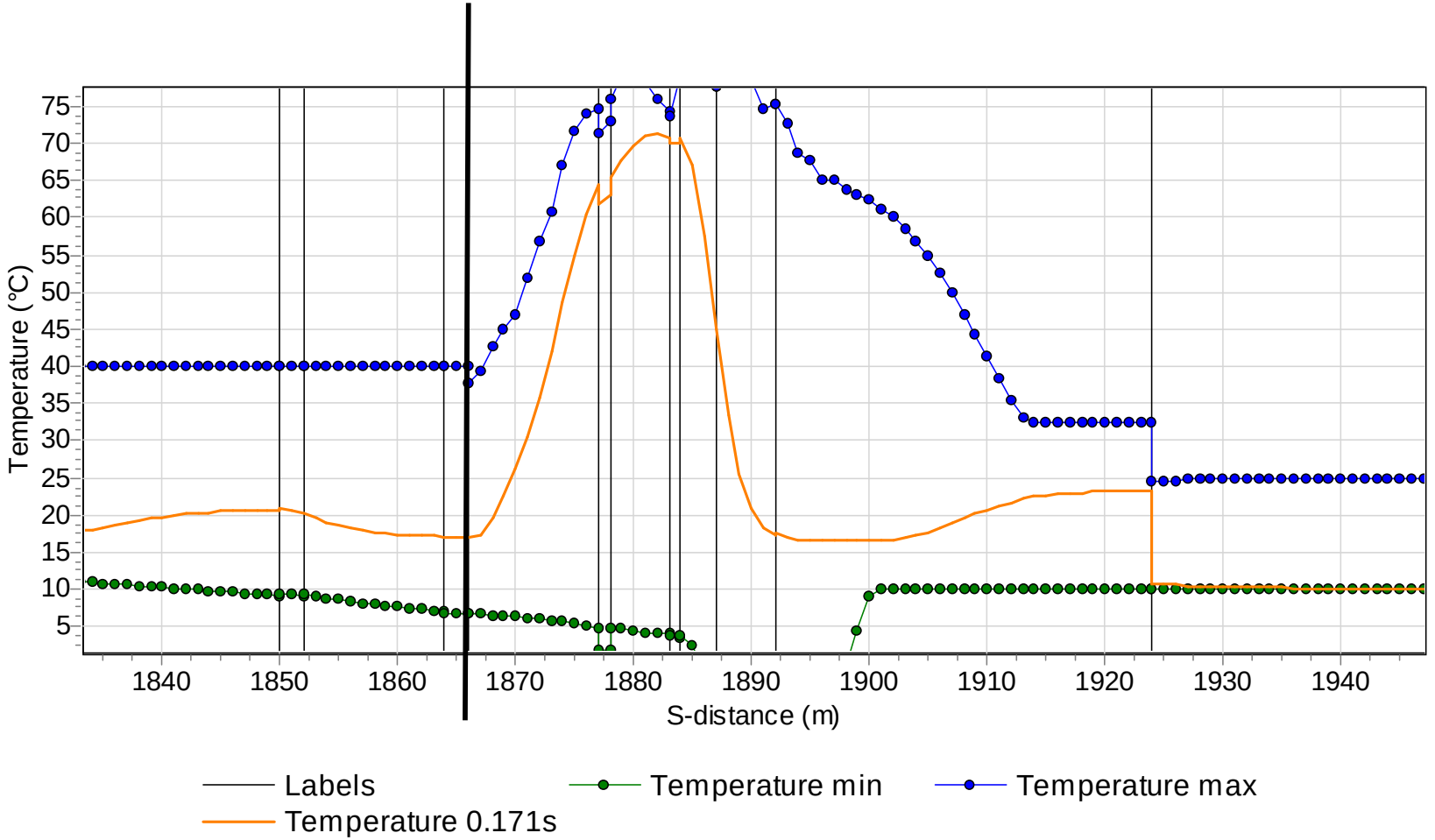

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