

The background of the slide is a photograph of an industrial facility, likely a water treatment plant. It features numerous large, white, curved pipes and machinery. In the foreground, a large white pump or valve is prominent, connected to a red motor. The pipes run in parallel rows, receding into the distance. The overall scene is industrial and complex.

# WANDA

**Deltares**  
Enabling Delta Life

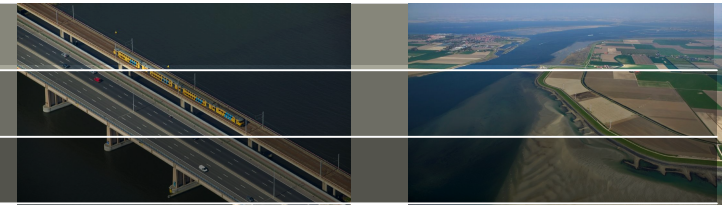
The Deltares logo consists of a stylized blue wave or 'S' shape.

## Wanda 4 Gas

9 maart 2010

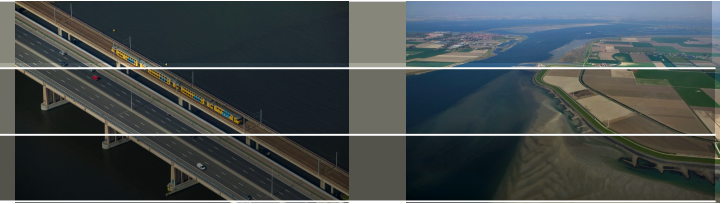
# Wanda 4 Gas

## Motivatie



- Transiente verschijnselen in gassystemen
  - Kortdurend
  - Golfverschijnselen
  - Niet isotherm
  - Convectie, expansie, conductie
- Toepassingen
  - Gasputten
    - > Choke valve break out
    - > Blow out
  - Pneumatische systemen
  - Airconditioning systemen

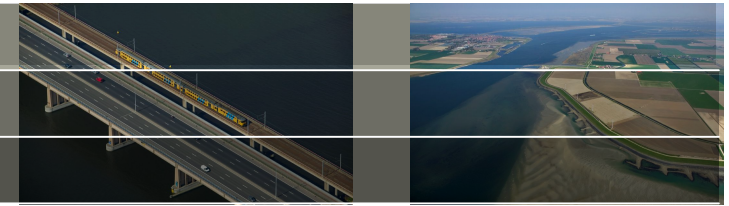
# Wanda 4 Gas Modellen



- Pijpleiding
- Klep
- Compressor
- Reservoir
- Terugslagklep
- ...

# Wanda 4 Gas

## Model leiding



- Massabehoud

$$\frac{1}{C^2} \left( \frac{\partial P}{\partial t} + V \frac{\partial P}{\partial x} \right) + \rho \frac{\partial V}{\partial x} = \frac{1}{c_p T} \left( \frac{4\tau_w V}{D} + \frac{\phi}{A} \right)$$

- Impulsbehoud

$$\rho \left( \frac{\partial V}{\partial t} + V \frac{\partial V}{\partial x} \right) + \frac{\partial P}{\partial x} = -\frac{4\tau_w}{D} - \rho g \sin \theta$$

- Energiebehoud

$$\rho c_p \left( \frac{\partial T}{\partial t} + V \frac{\partial T}{\partial x} \right) = \left( \frac{\partial P}{\partial t} + V \frac{\partial P}{\partial x} \right) + \frac{4\tau_w V}{D} + \frac{\phi}{A}$$

- Toestand (gaswet)

$$P = Z R \rho T$$

- Golfsnelheid

$$C = \sqrt{Z k R T}$$

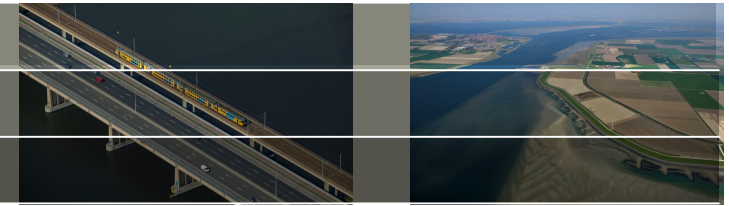
- Wandwrijving

$$\tau_w = f \frac{\rho}{8} V |V|$$

- Warmtegeleiding

$$\phi = L_T [T_a - T]$$

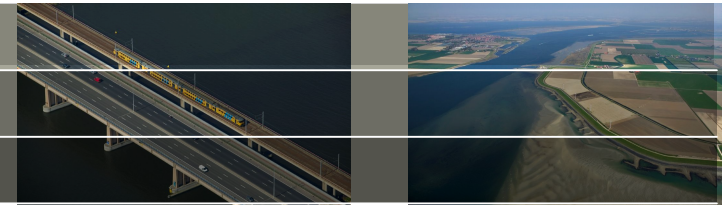
# Wanda 4 Gas Model klep



- 8 onbekenden  $P_1 \quad V_1 \quad \rho_1 \quad T_1 \quad P_2 \quad V_2 \quad \rho_2 \quad T_2$
- Massabehoud  $\rho_1 V_1 - \rho_2 V_2 = 0$
- Impulsbehoud  $W \left[ \rho_1 A_1 V_1 \right] = A_v Y \sqrt{X P_1 \rho_1}$ 
  - Afvoercoefficient  $A_v = 7.6 \times 10^{-7} C_v$
  - Drukverhouding  $X = (P_1 - P_2) / P_1$
  - Gasexpansiefact.  $Y = 1 - \frac{X}{3 F_k X_T} \quad Y_{\text{critical}} = 1 - \frac{1}{3 F_k} \quad F_k = k / k_{\text{air}} = k / 1.4$
- Energiebehoud  $\left[ c_p T_1 + \frac{V_1^2}{2} \right] - \left[ c_p T_2 + \frac{V_2^2}{2} \right] = 0$
- Toestand (gaswet)  $P = Z R \rho T$

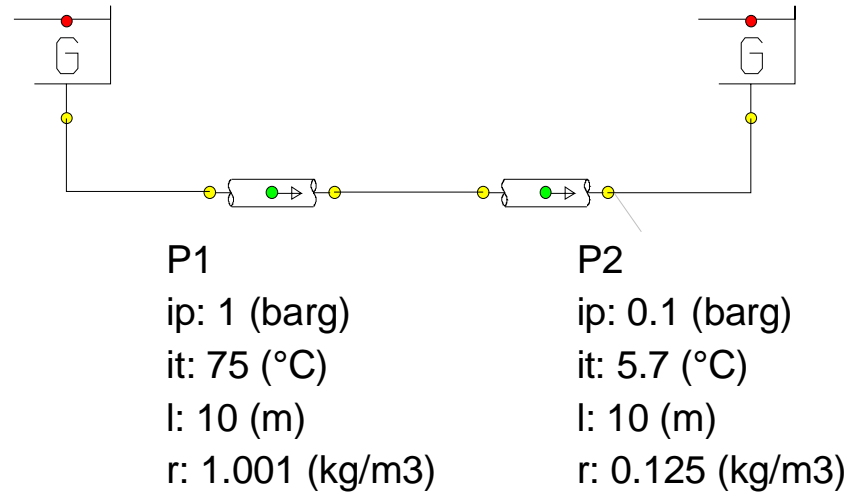
# Wanda 4 Gas

## Validatie voorbeeld shocktube



Twee buizen met verschillende druk en temperatuur initieel  
gescheiden door een membraan

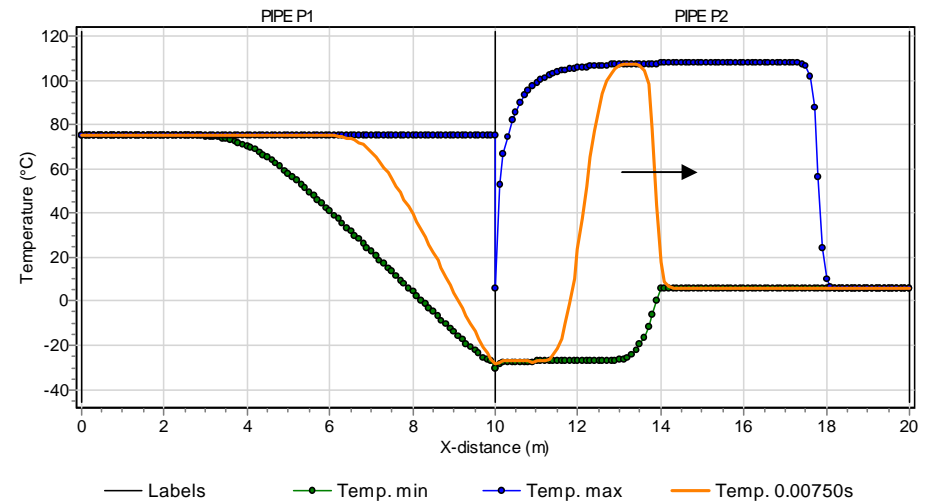
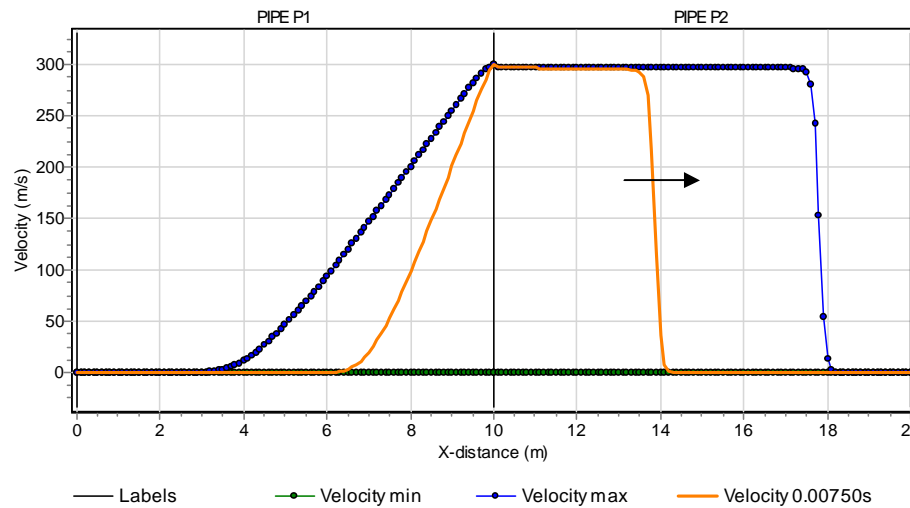
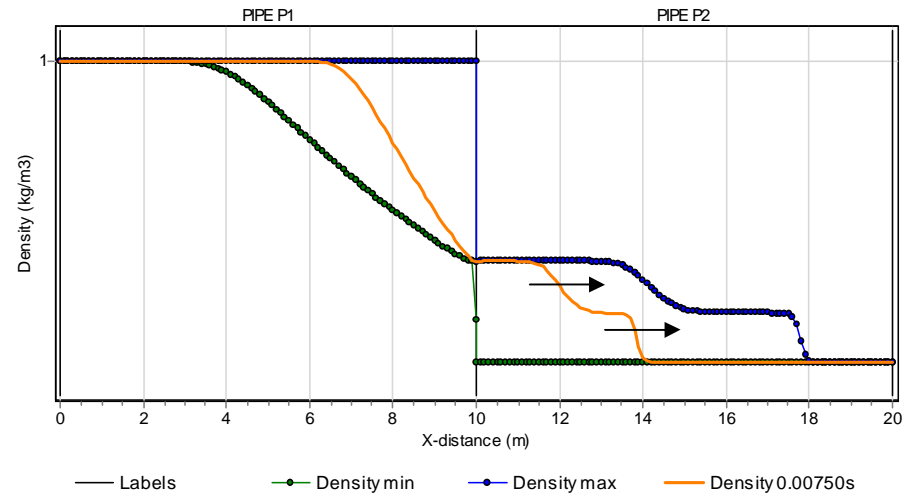
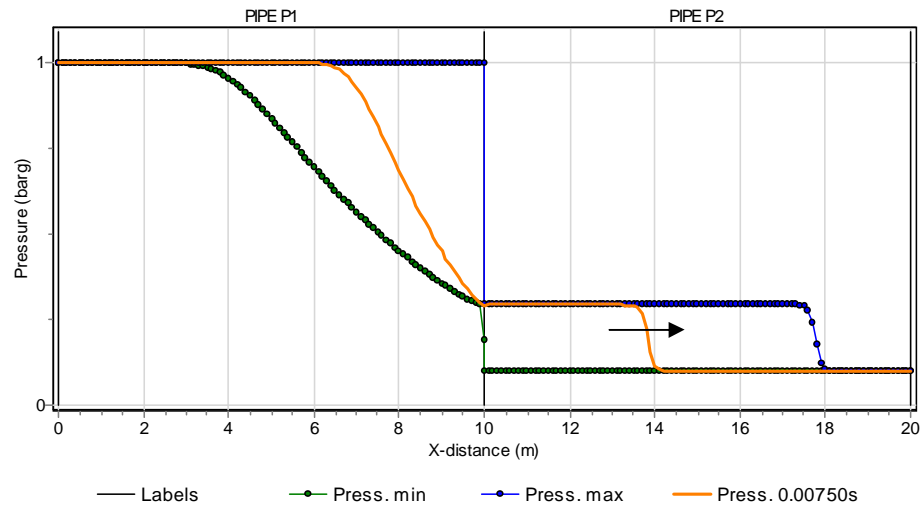
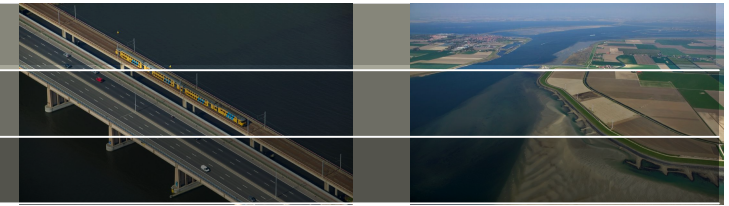
Membraan breekt





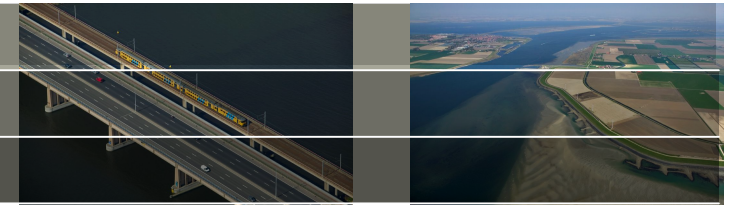
# Wanda 4 Gas

## Validatie voorbeeld shocktube



# Wanda 4 Gas

## Voorbeeld vrije convectie

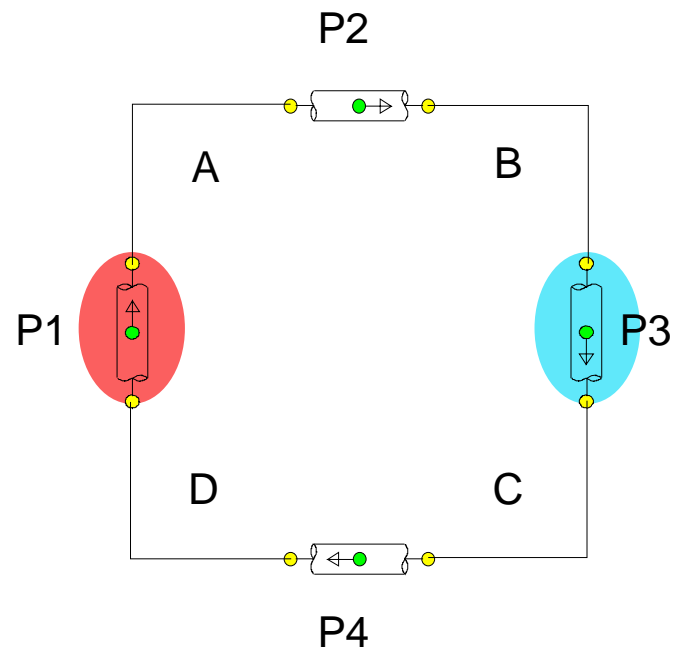


Verticale loop van 4 buizen (zij-aanzicht)

Linker buis verwarmd, rechter buis afgekoeld

Eerst ontstaat stroming tussen expansie en inkrimping

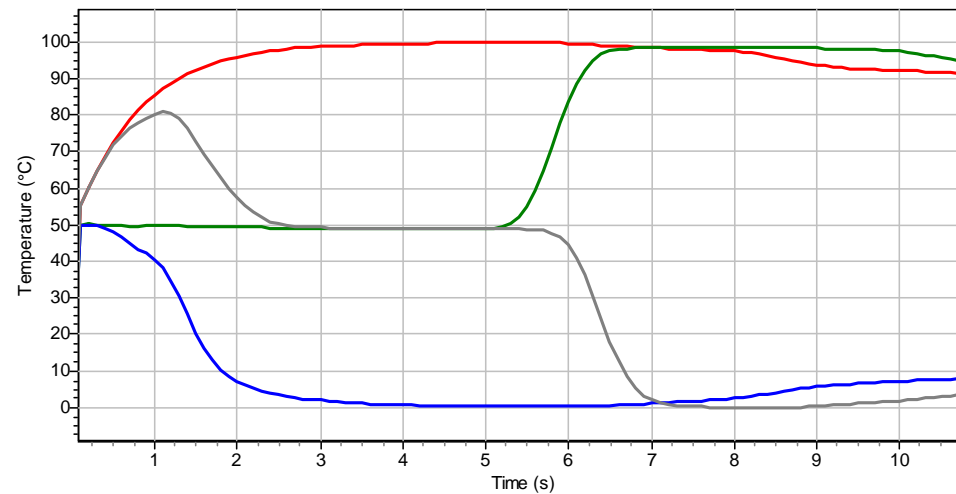
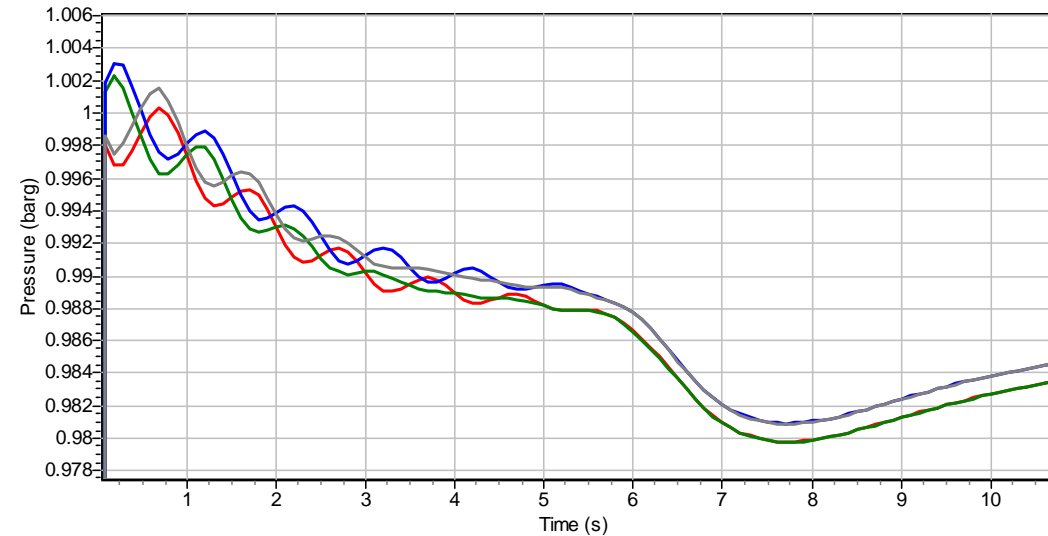
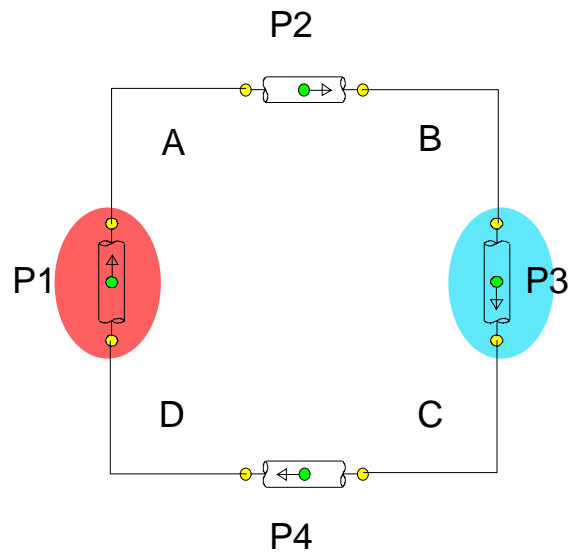
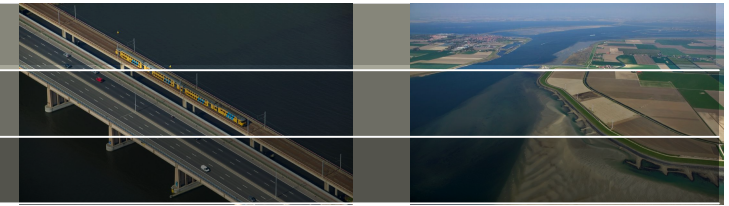
Daarna ontwikkelt zich een circulaire convectie





# Wanda 4 Gas

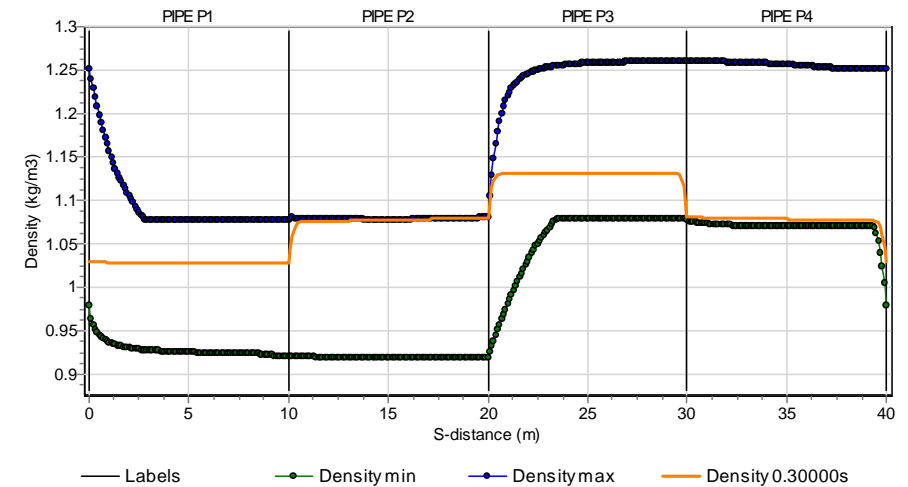
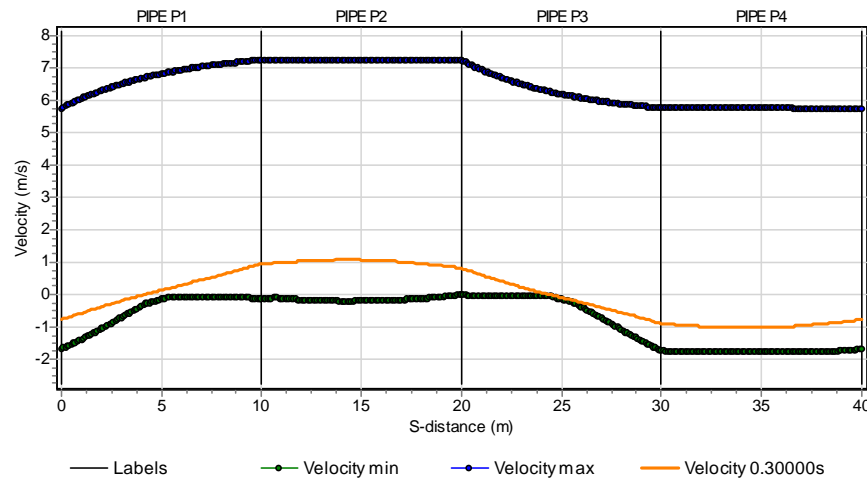
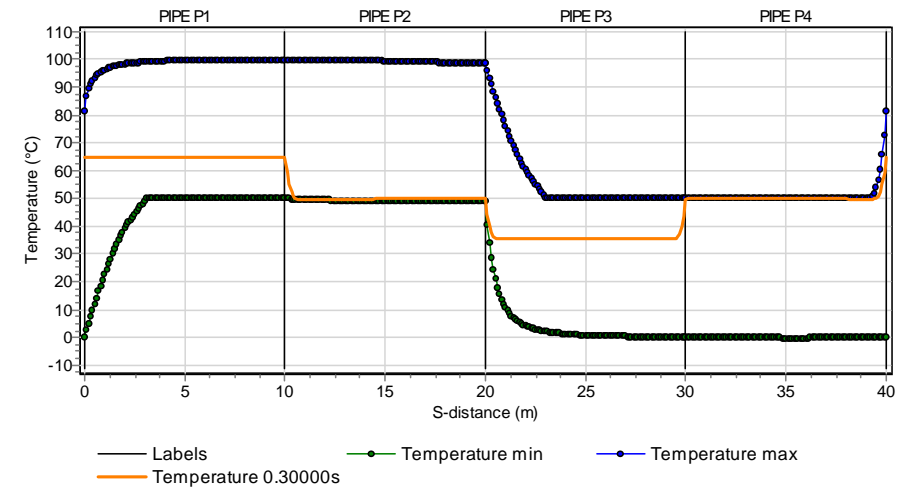
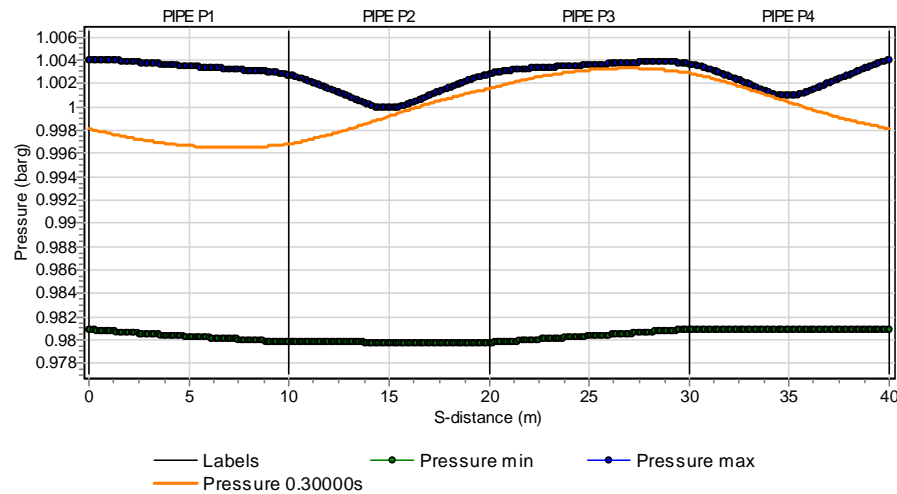
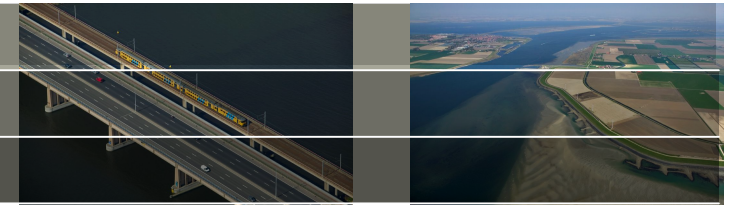
## Voorbeeld vrije convectie



— Temperature NODE A — Temperature NODE B — Temperature NODE C — Temperature NODE D

# Wanda 4 Gas

## Voorbeeld vrije convectie



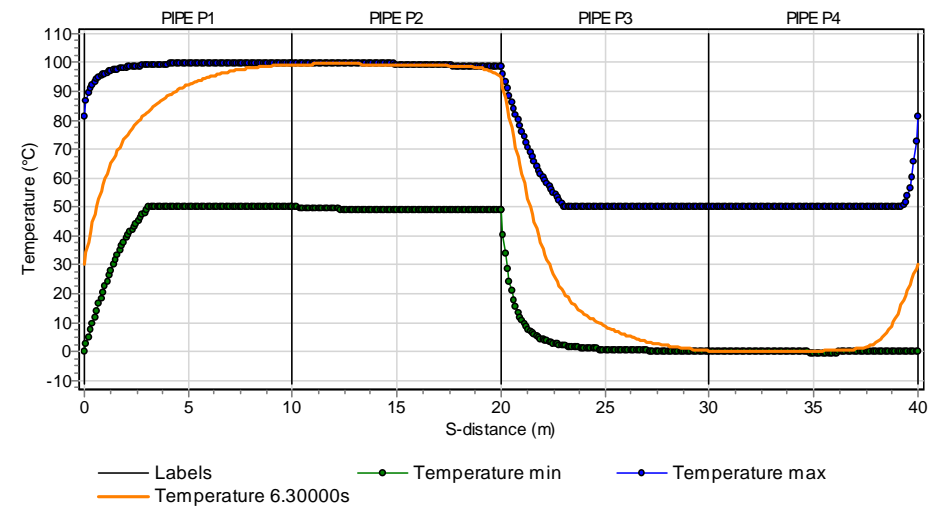
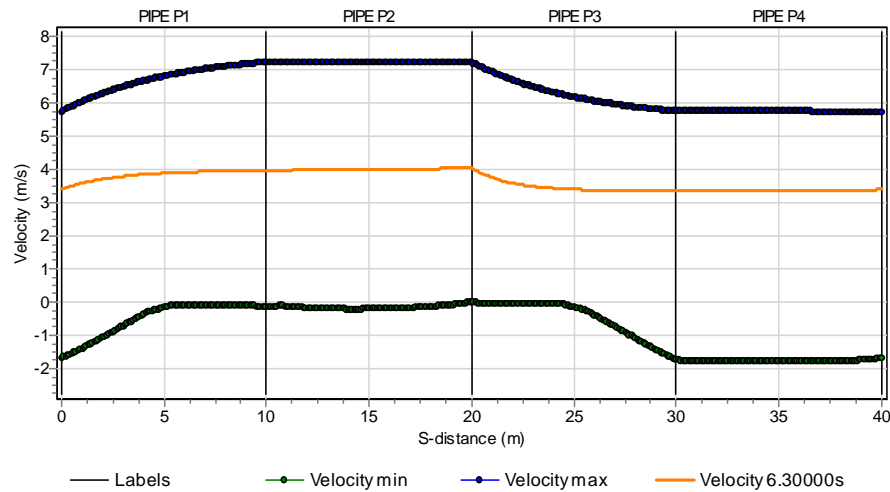
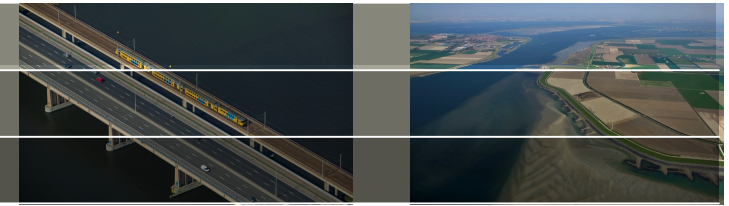
Expansie en inkrimping na 0.3 s

9 maart 2010

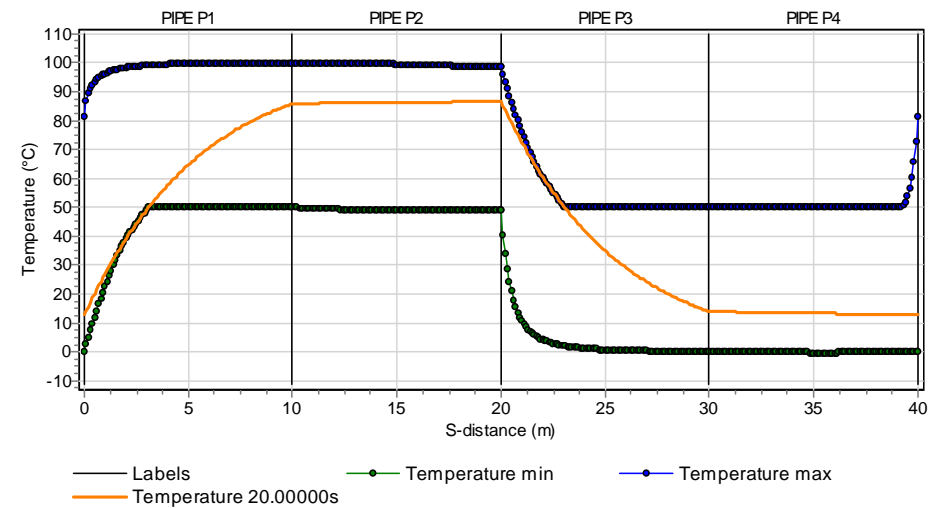
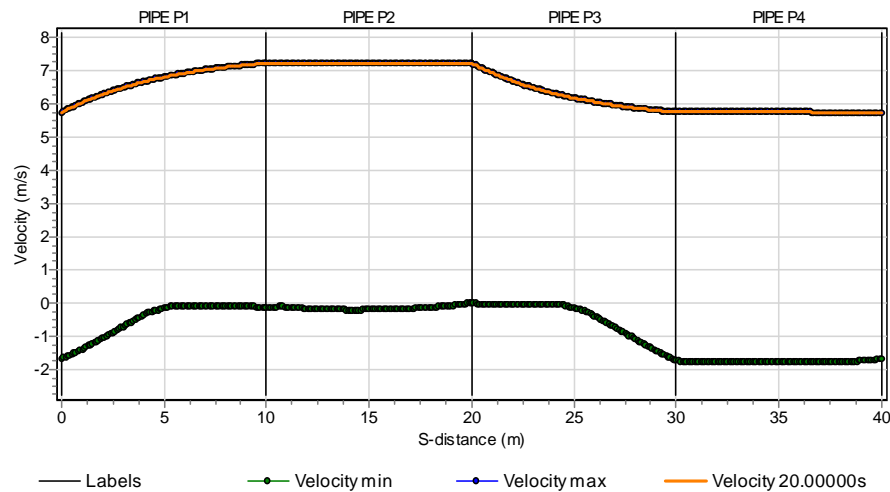
Deltares

# Wanda 4 Gas

## Voorbeeld vrije convectie



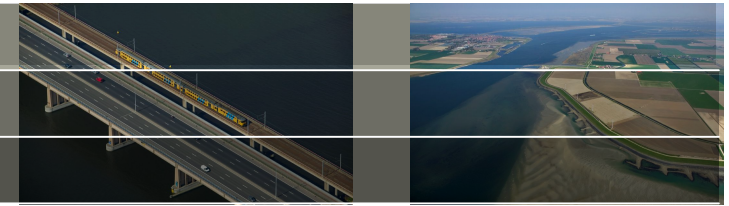
Convectie na 6.3 s



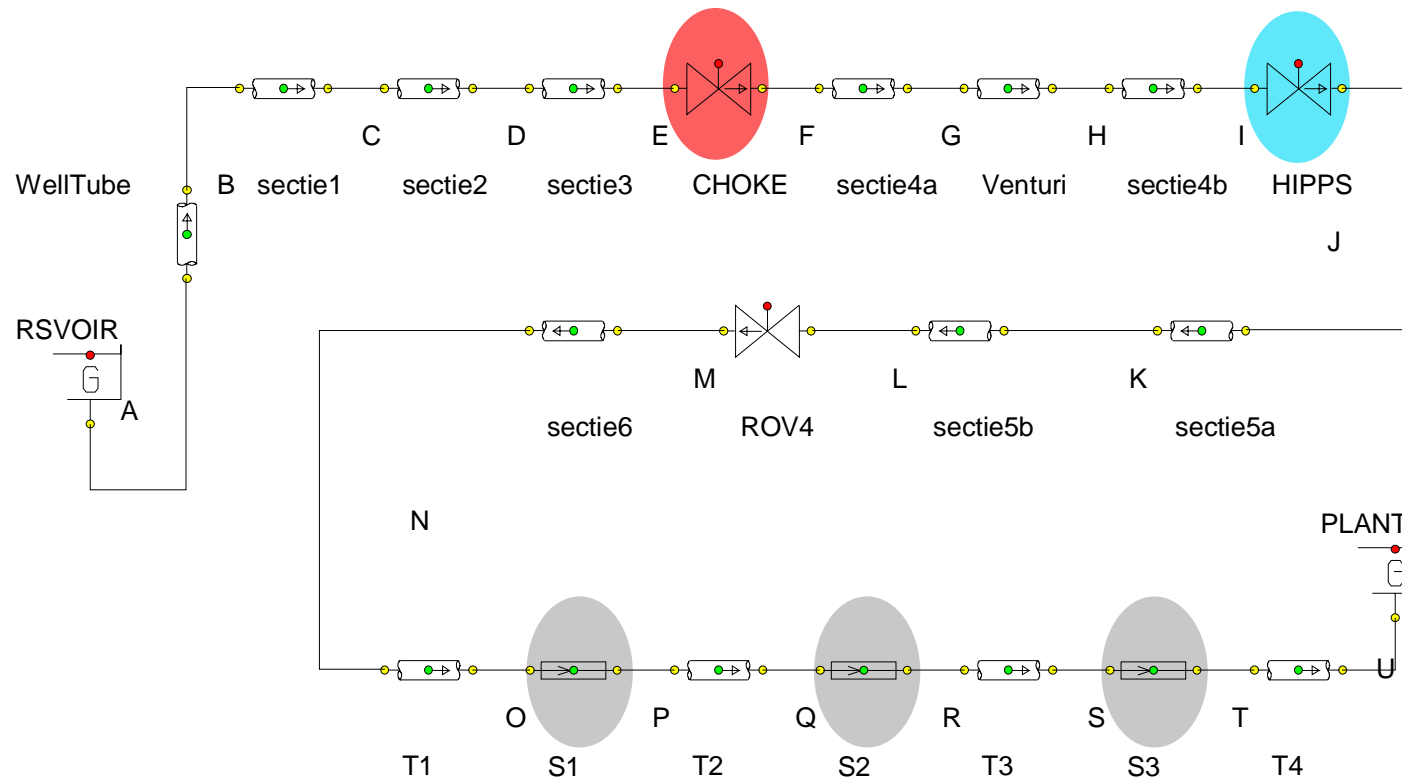
Convectie na 20 s

# Wanda 4 Gas

## Voorbeeld HIPPS studie

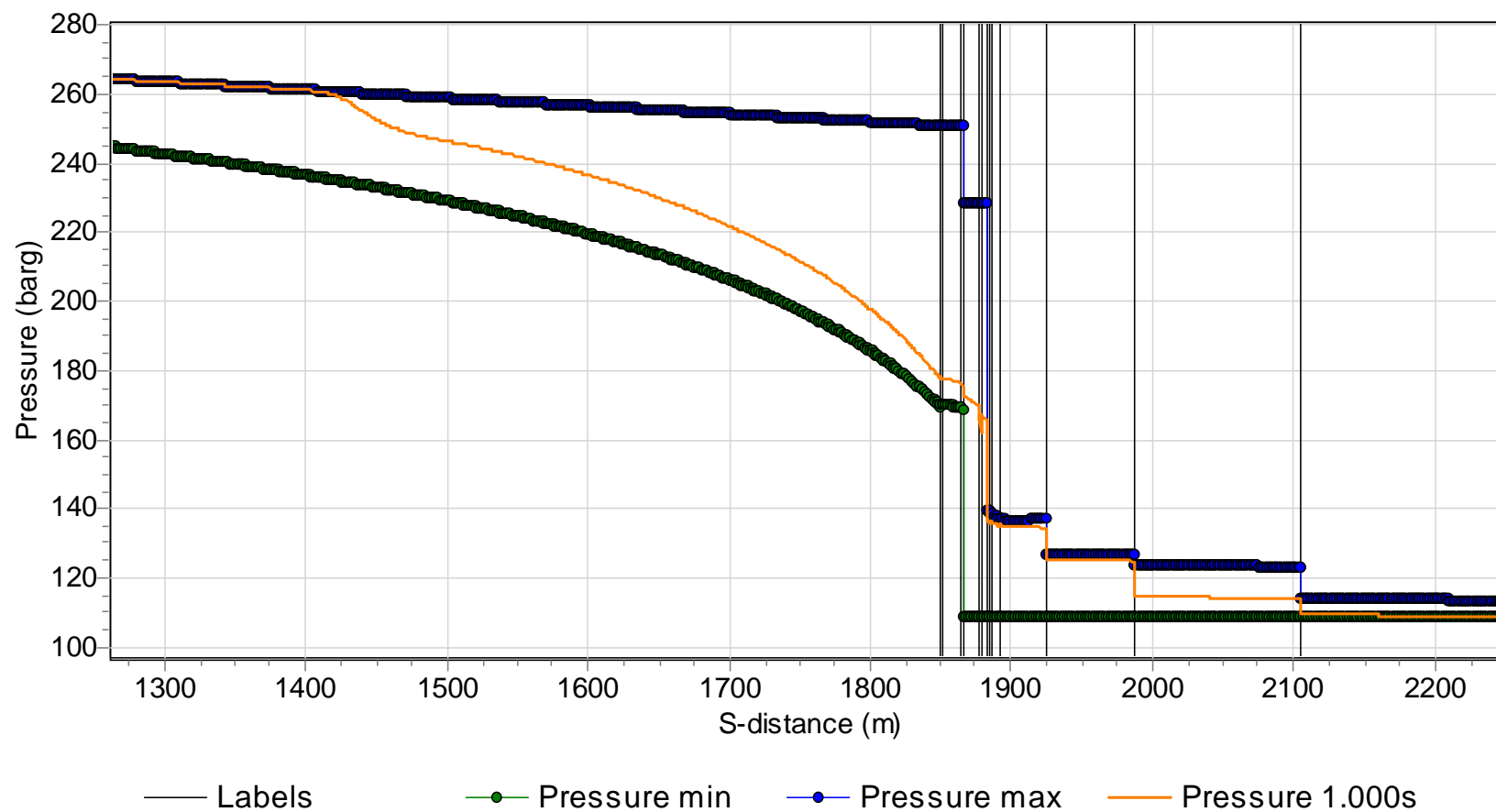
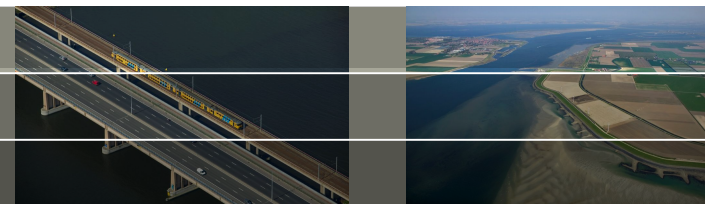


Gasput met Choke valve, leidingwerk, en transportleiding  
Choke valve breekt uit  
HIPPS valve sluit in 2 seconden



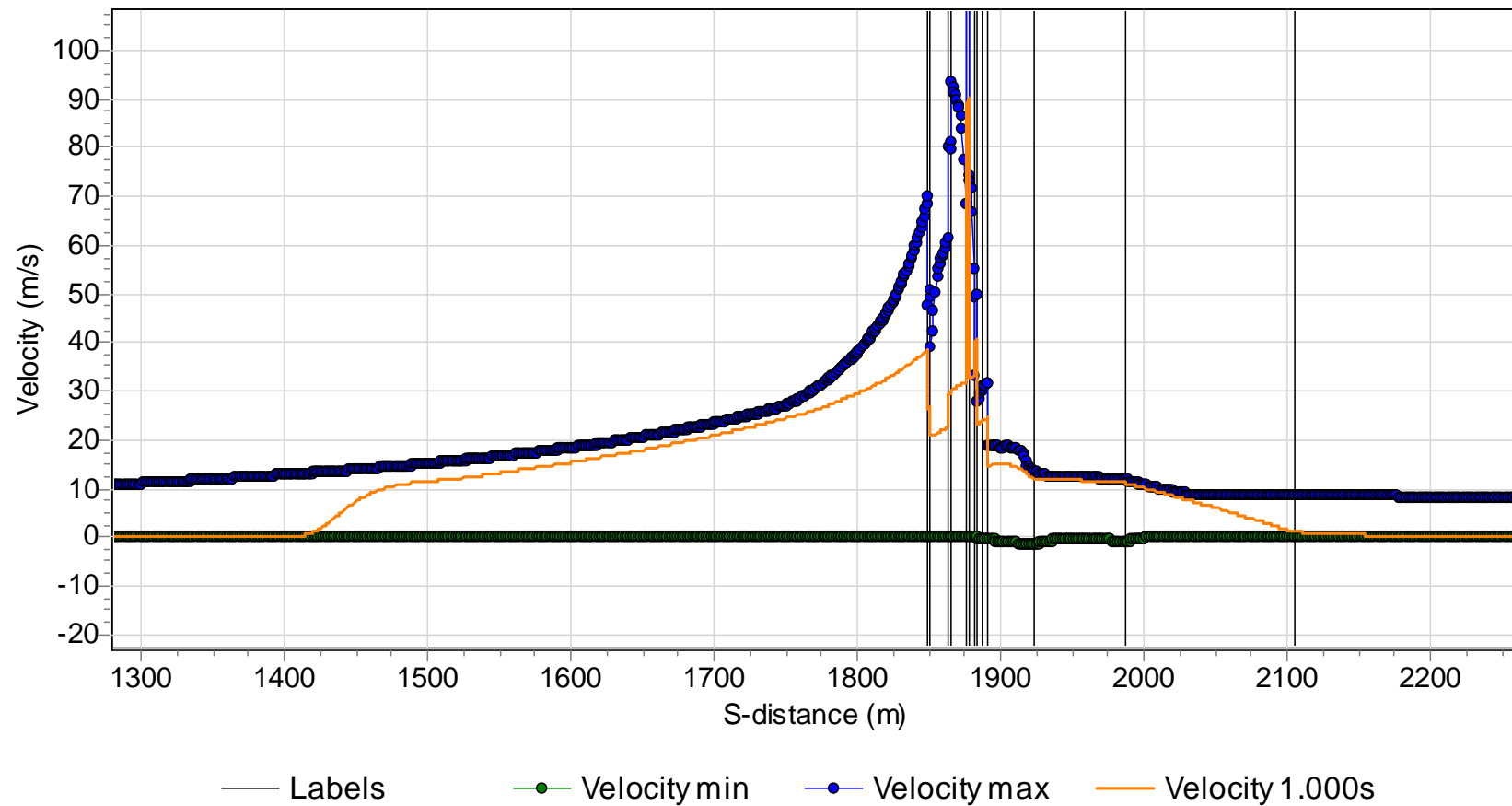
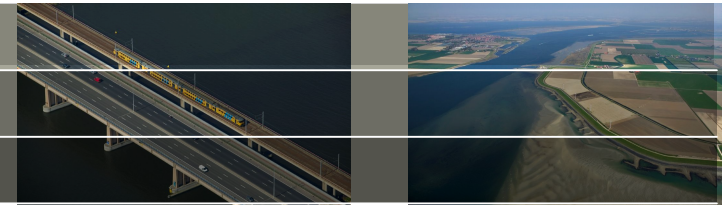
# Wanda 4 Gas

## Voorbeeld HIPPS studie



# Wanda 4 Gas

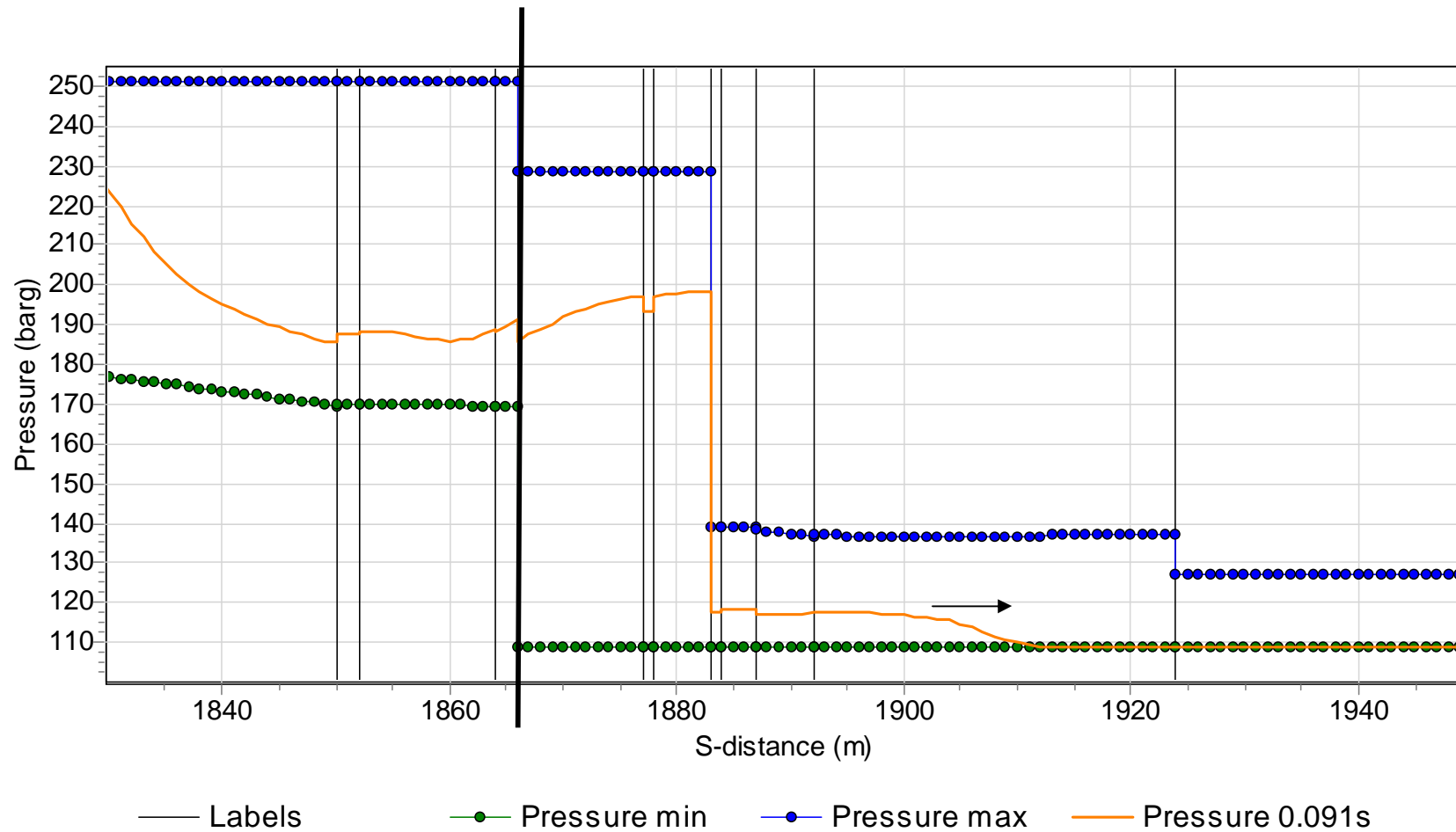
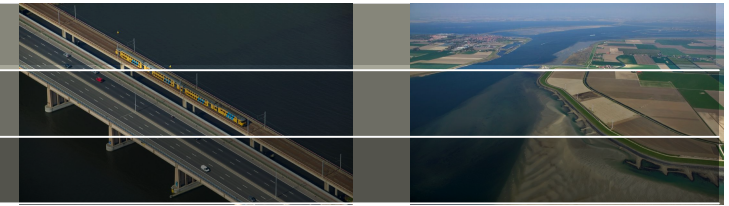
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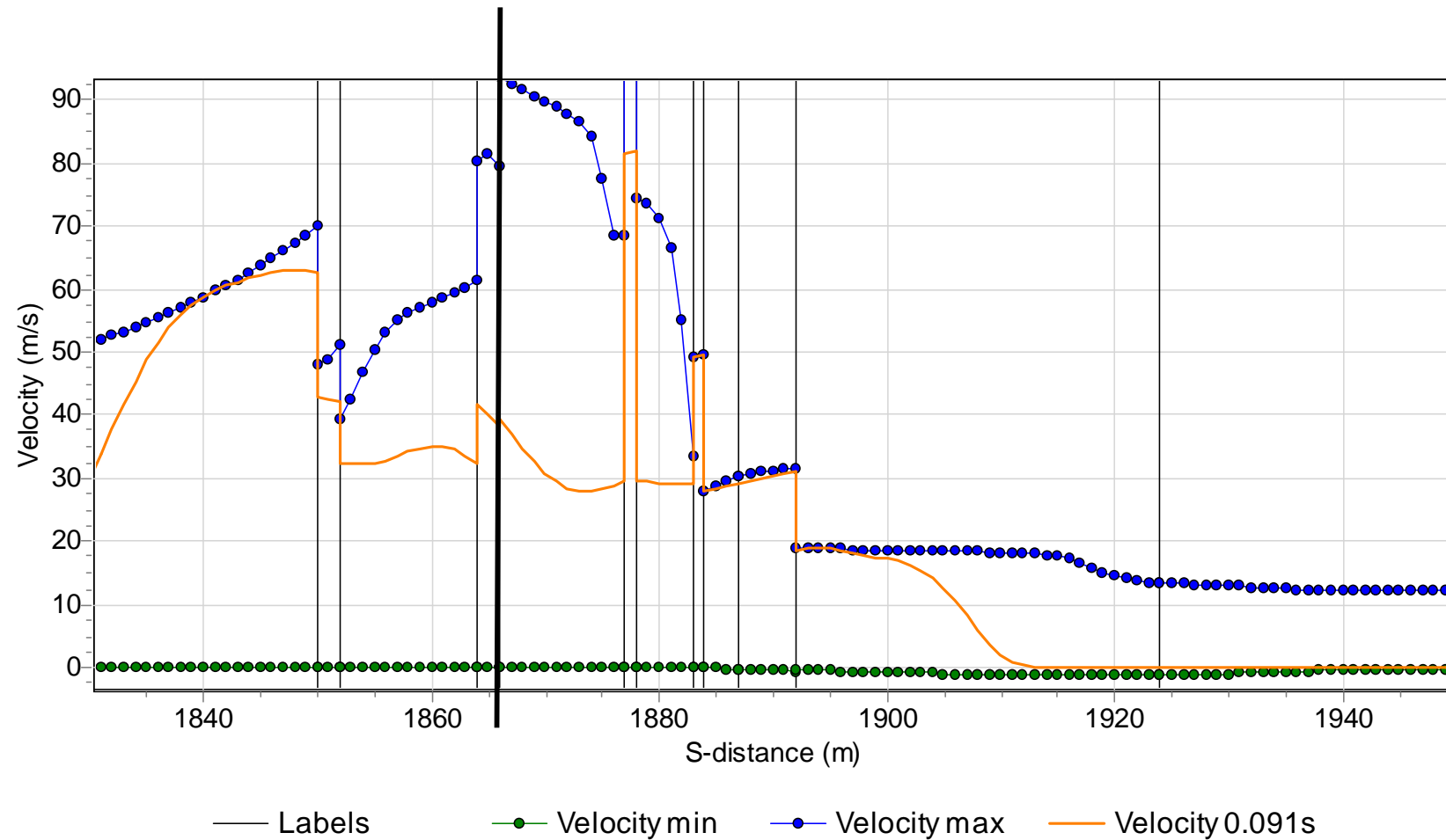
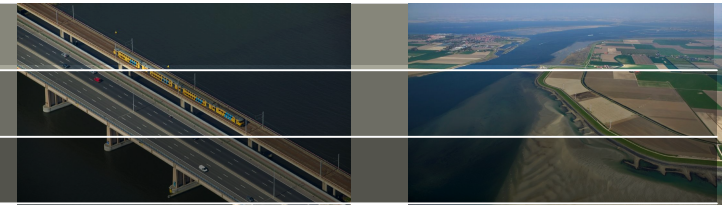
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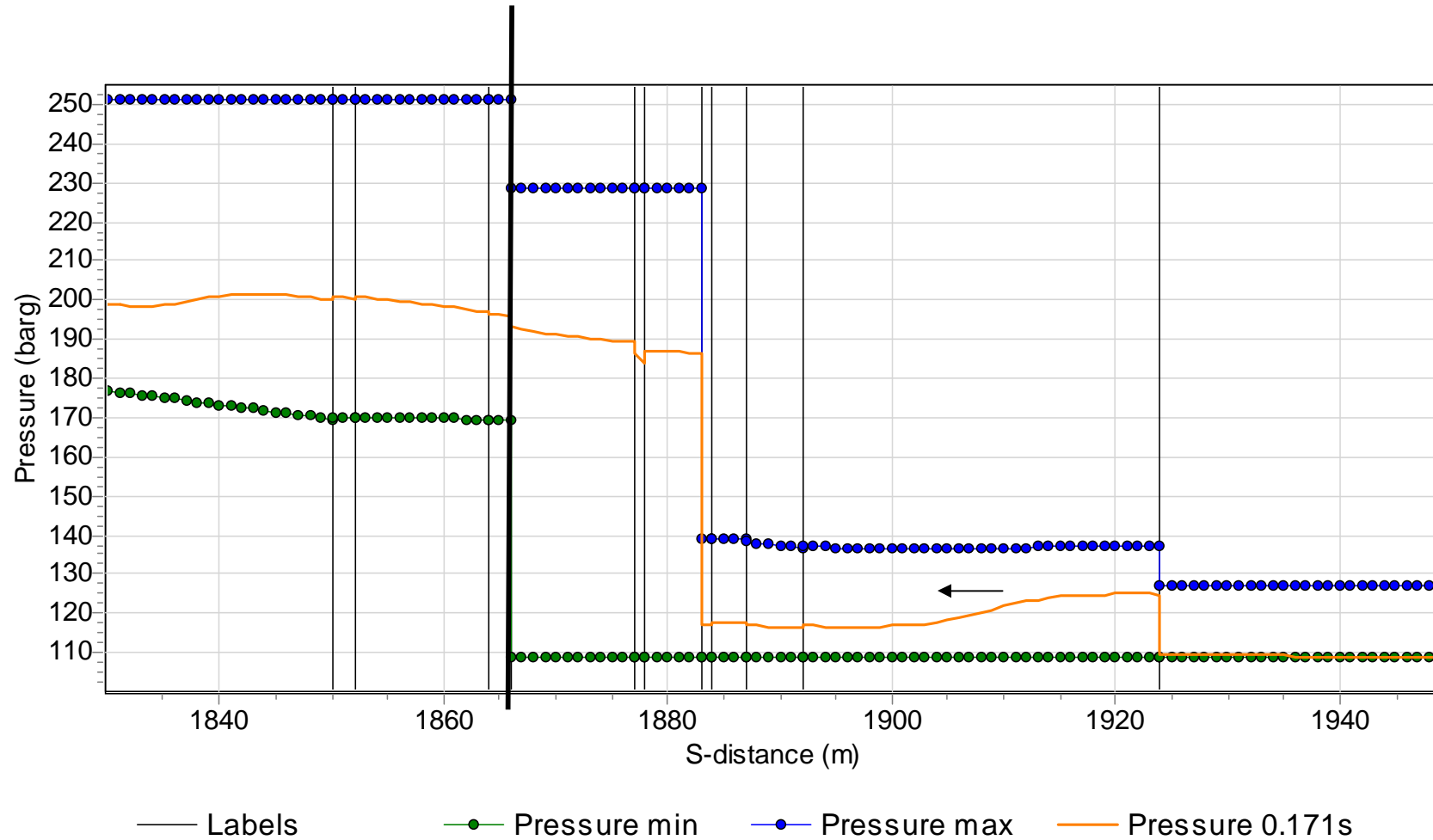
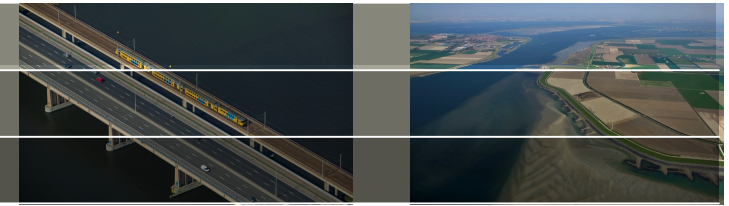
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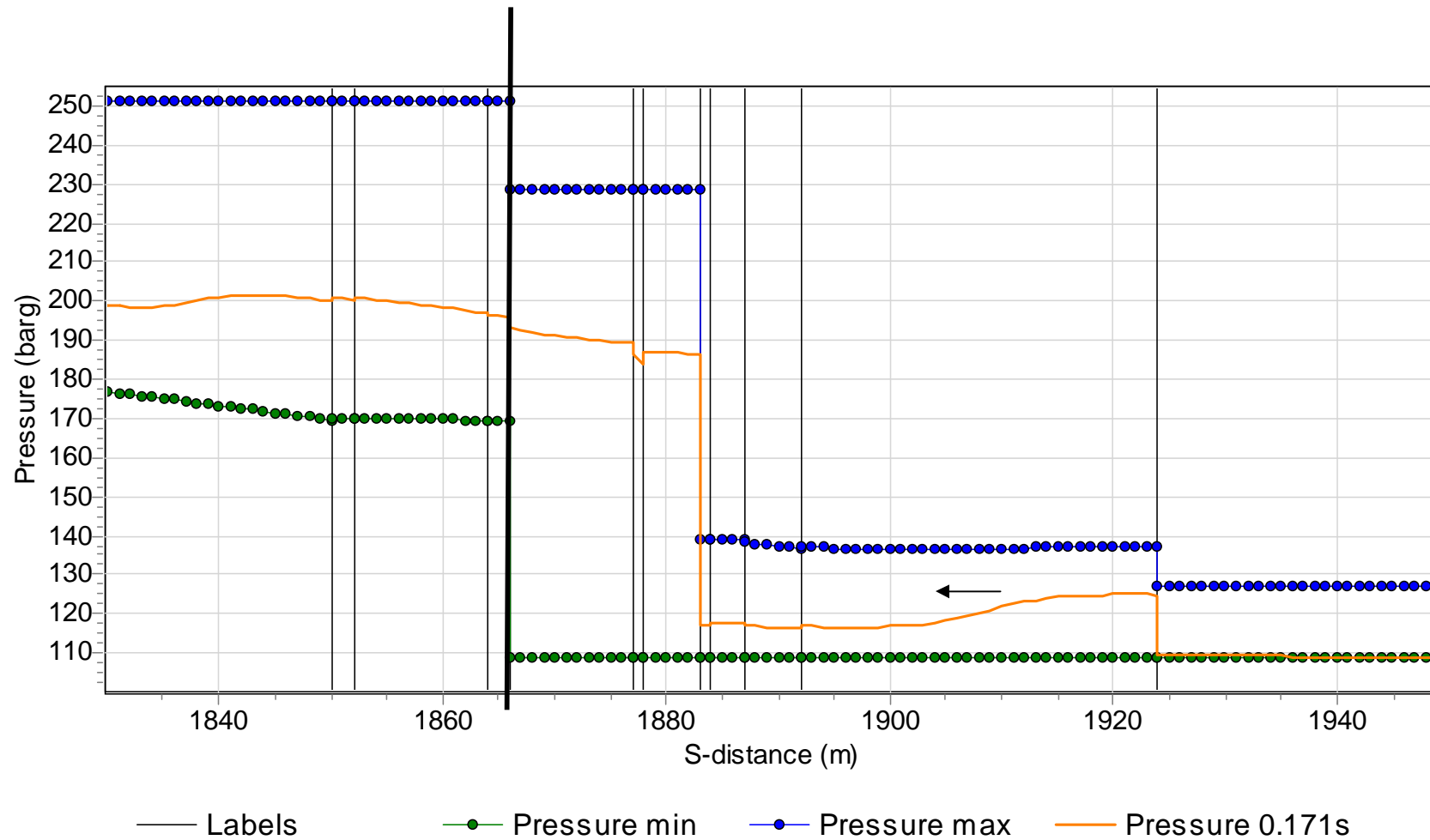
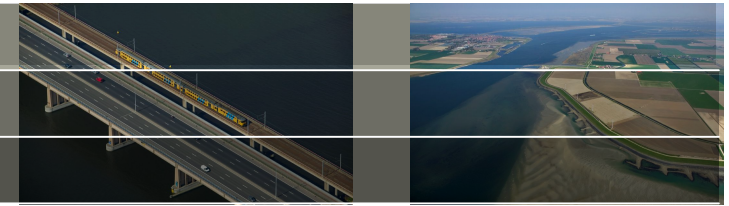
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