


# FluidFlow Slurry Demonstration

# Discussion Outline

1. FluidFlow Modules
2. FluidFlow: Hydraulic Calculation Software Objectives
3. FluidFlow User Interface
4. FluidFlow Database
5. FluidFlow Design and Rating Case Mode
6. FluidFlow Slurry Module
7. Basic and Advanced Training

# FLUIDFLOW MODULES

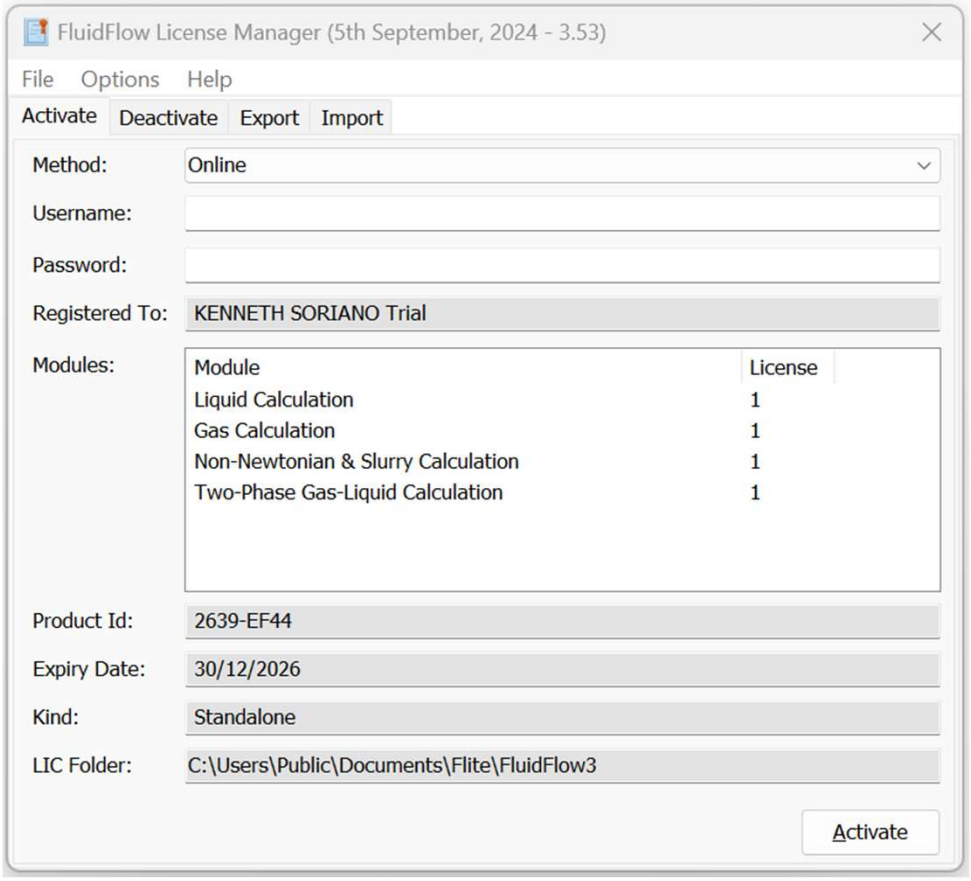
# FluidFlow Modules

Liquid

Gas

Slurry

Two Phase Flow

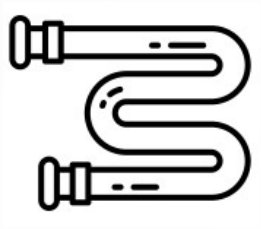


# FluidFlow Modules

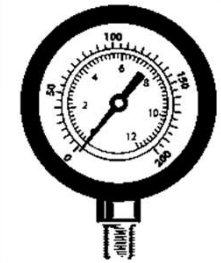
- ✓ Liquid and slurry pipeline hydraulic calculations
- ✓ Pipeline pressure drop and velocity calculations
- ✓ Pump sizing and selection
- ✓ Total dynamic head and pump power calculations
- ✓ Piping network and system curve analysis
- ✓ Slurry flow modelling considering solids concentration and slurry properties
- ✓ Basic and detailed engineering calculations and reporting

# FLUIDFLOW:
# HYDRAULIC CALCULATION SOFTWARE OBJECTIVES

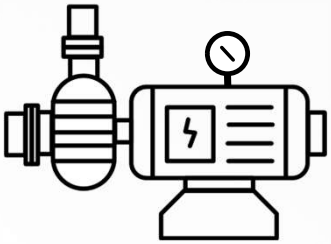
# FluidFlow: Hydraulic Calculation Software Objectives



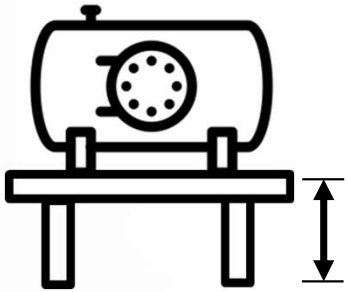
LINE SIZING



OPERATING PRESSURE



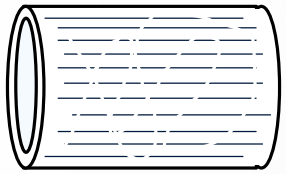
EQUIPMENT SPECIFICATION



ELEVATION



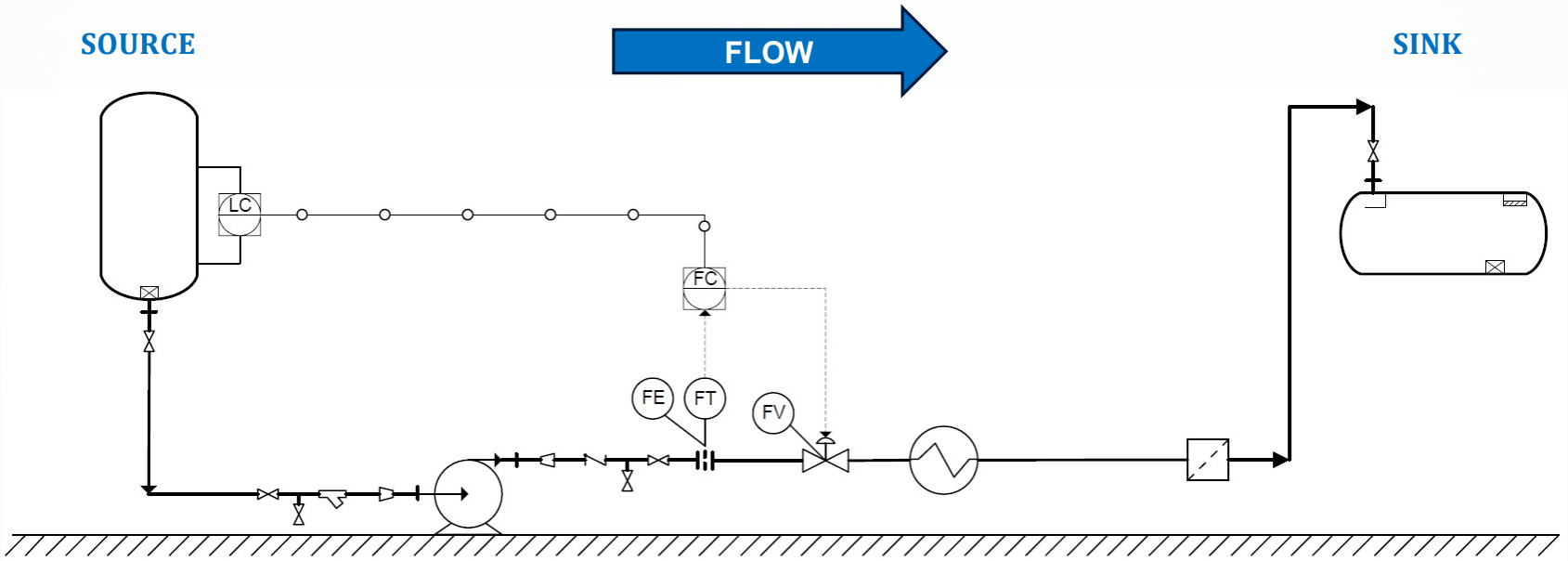
INSTRUMENT SPECIFICATION



FLOW REGIME (FOR TWO-PHASE)

# FluidFlow: Hydraulic Calculation Software Objectives

- To **ensure delivery of fluid** from source to sink



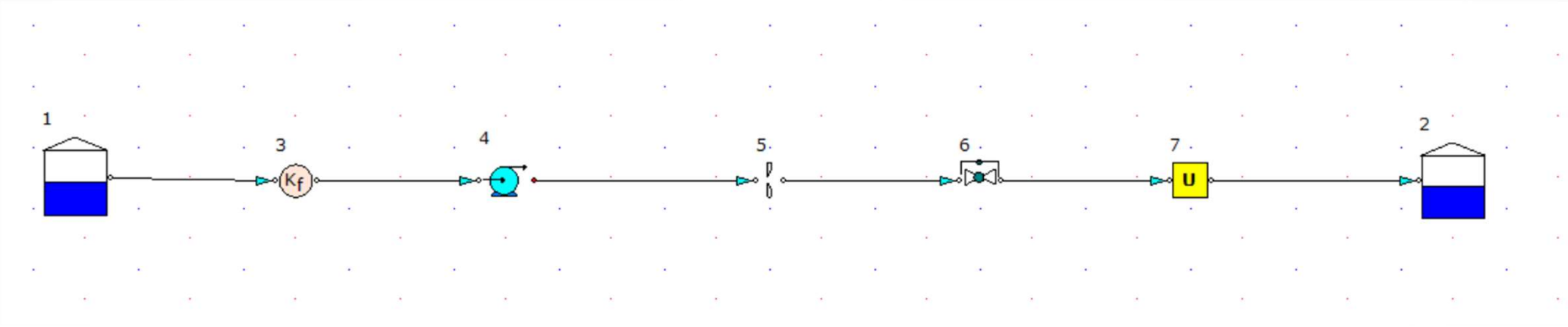
# FluidFlow: Hydraulic Calculation Software Objectives

- To **ensure delivery of fluid** from source to sink

SOURCE

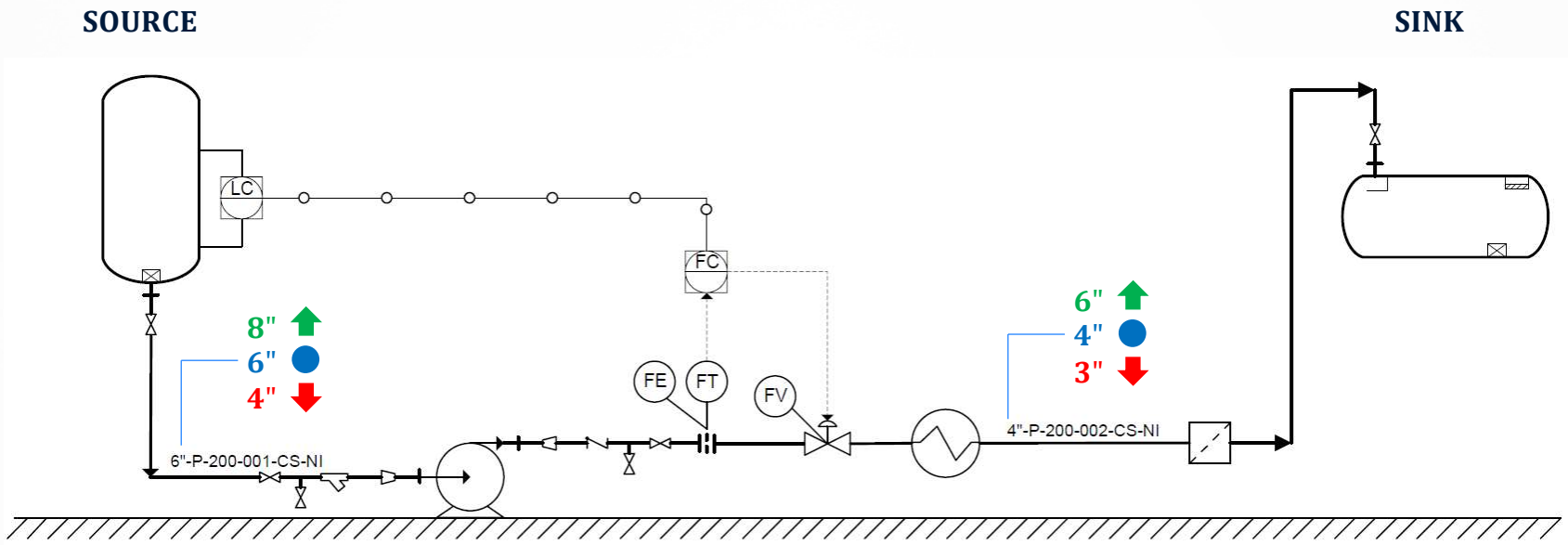
FLOW

SINK



# FluidFlow: Hydraulic Calculation Software Objectives

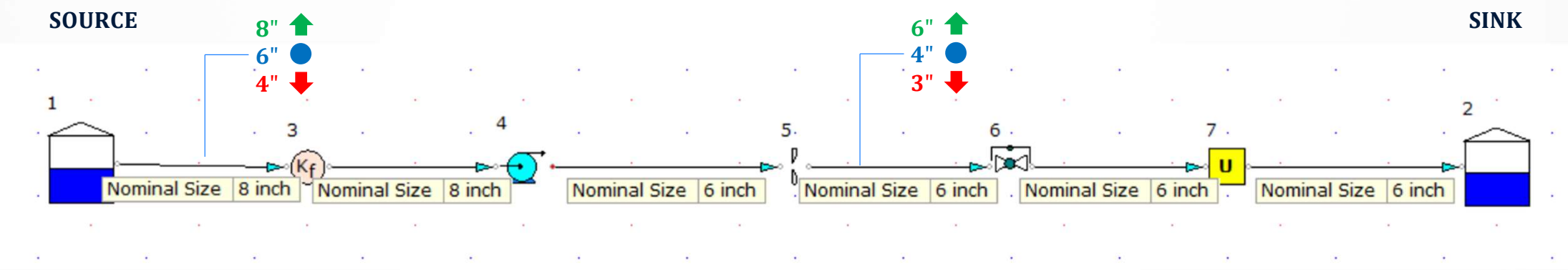
- To determine the **optimum line size**



# FluidFlow: Hydraulic Calculation Software Objectives

- To determine the **optimum line size**

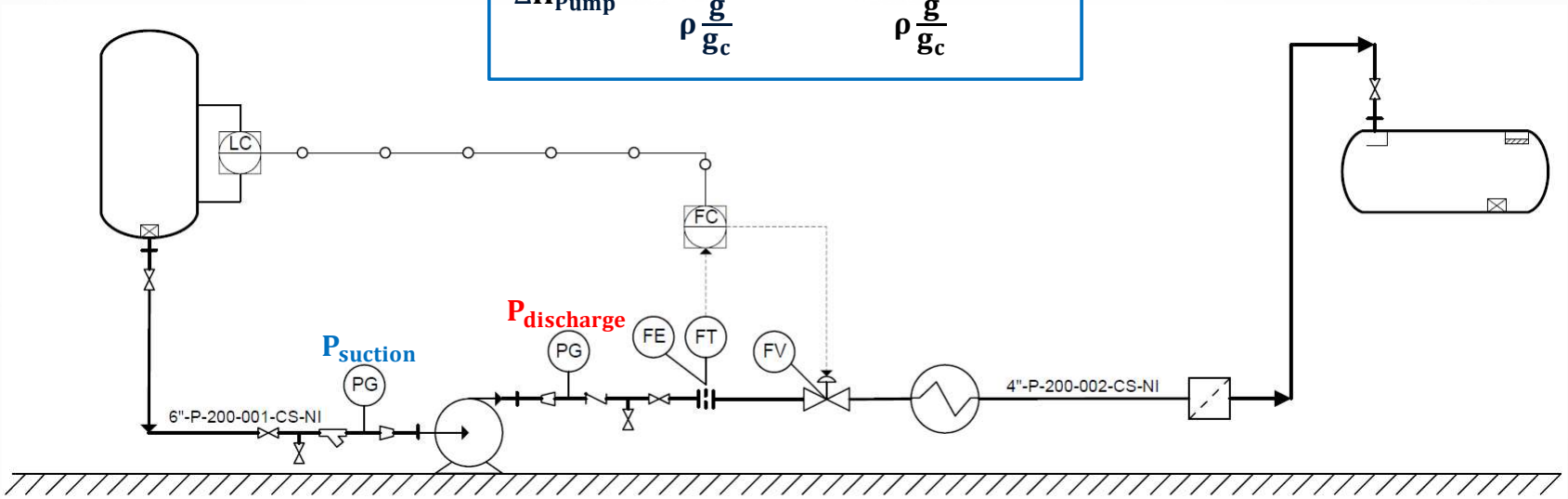


# FluidFlow: Hydraulic Calculation Software Objectives

- To determine the **pump head**

$$\Delta H_{Pump} = \frac{\Delta P_{Pump}}{\rho \frac{g}{g_c}} = \frac{P_{discharge} - P_{suction}}{\rho \frac{g}{g_c}}$$

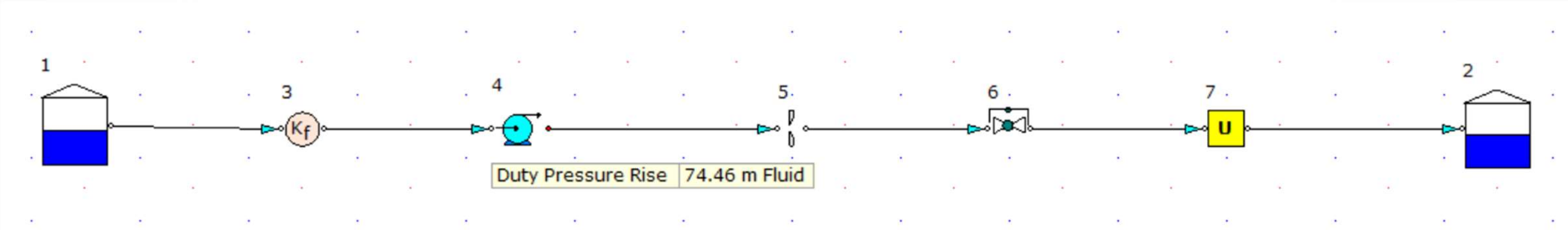


# FluidFlow: Hydraulic Calculation Software Objectives

- To determine the **pump head**

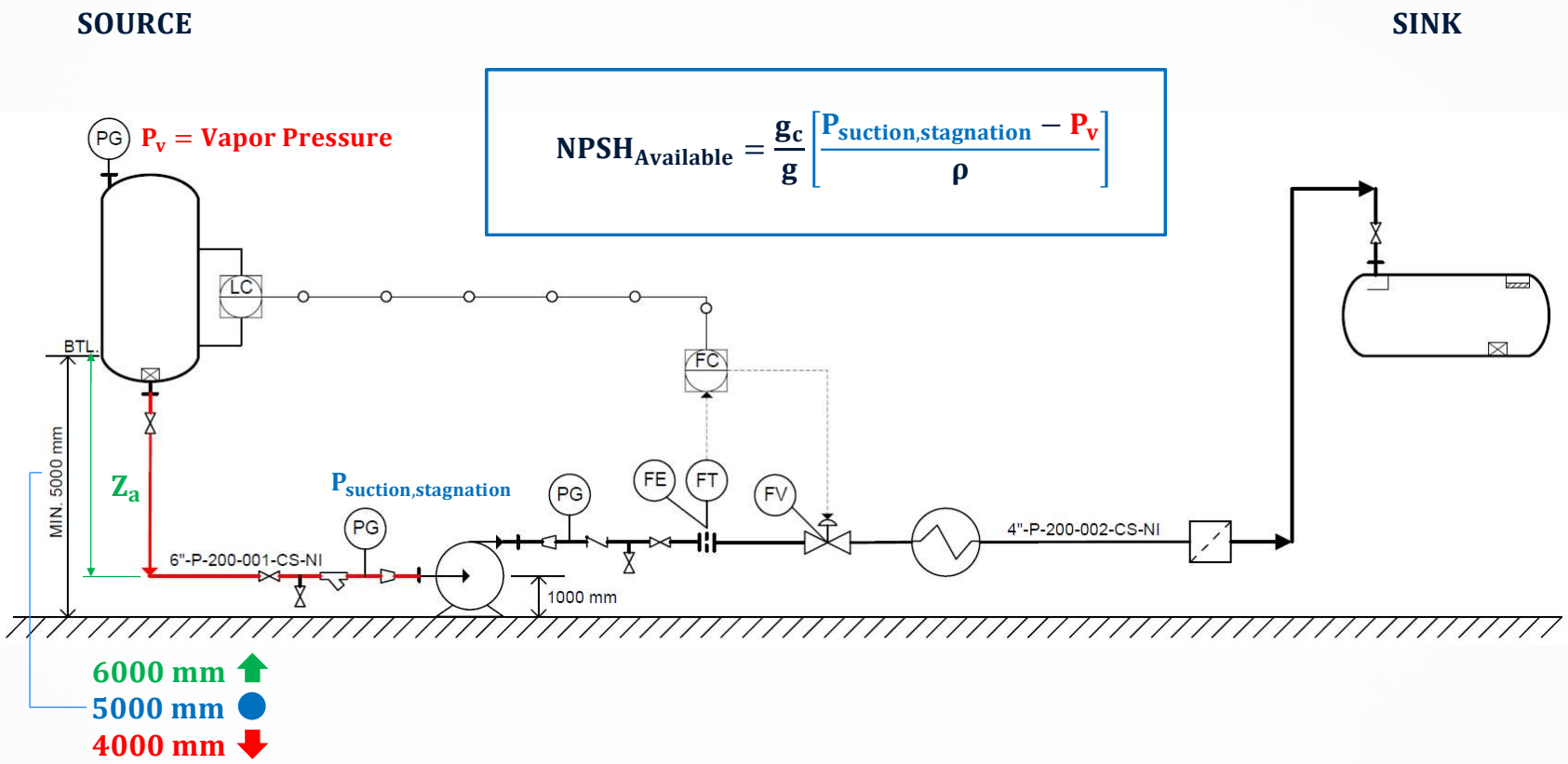
$$\Delta H_{Pump} = \frac{\Delta P_{Pump}}{\rho \frac{g}{g_c}} = \frac{P_{discharge} - P_{suction}}{\rho \frac{g}{g_c}}$$

**SOURCE** **SINK**



# FluidFlow: Hydraulic Calculation Software Objectives

- To determine the **pump suction vessel height** by checking the **pump NPSHA**

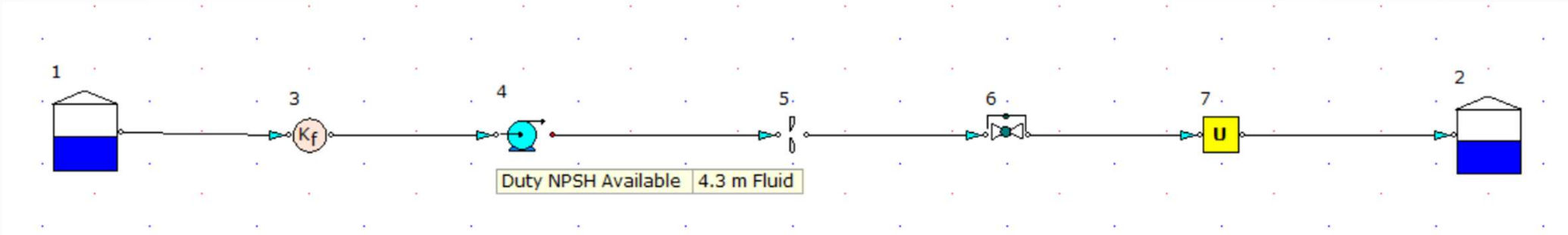


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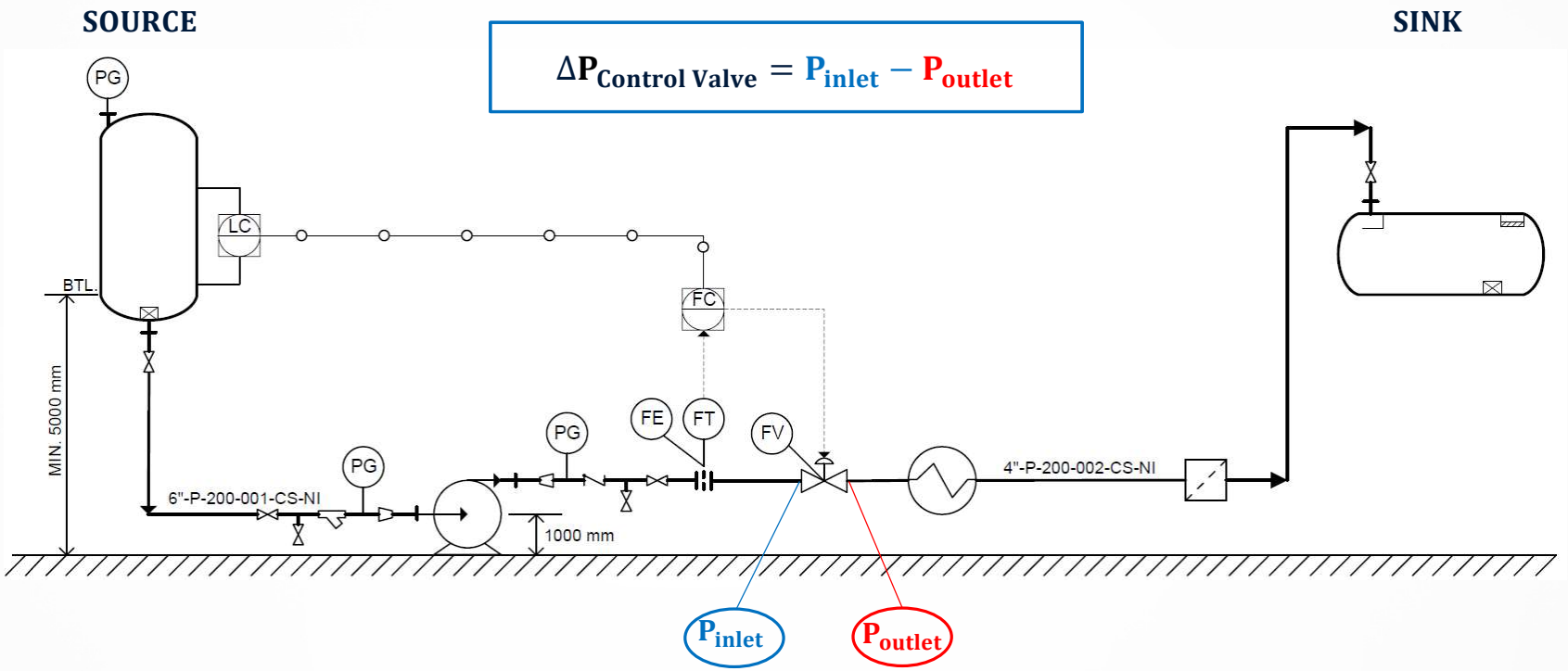
$$NPSH_{Available} = \frac{g_c}{g}\left[\frac{P_{suction,stagnation} - P_v}{\rho}\right]$$

**SOURCE** **SINK**



# FluidFlow: Hydraulic Calculation Software Objectives

- To calculate the **control valve pressure drop** and **calculate the Cv value.**

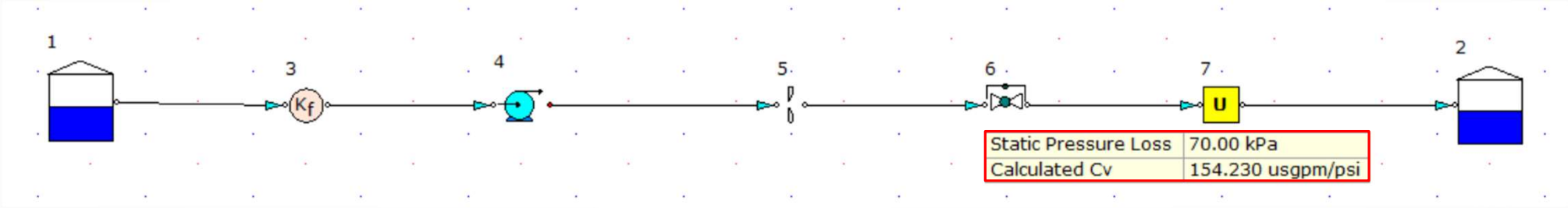


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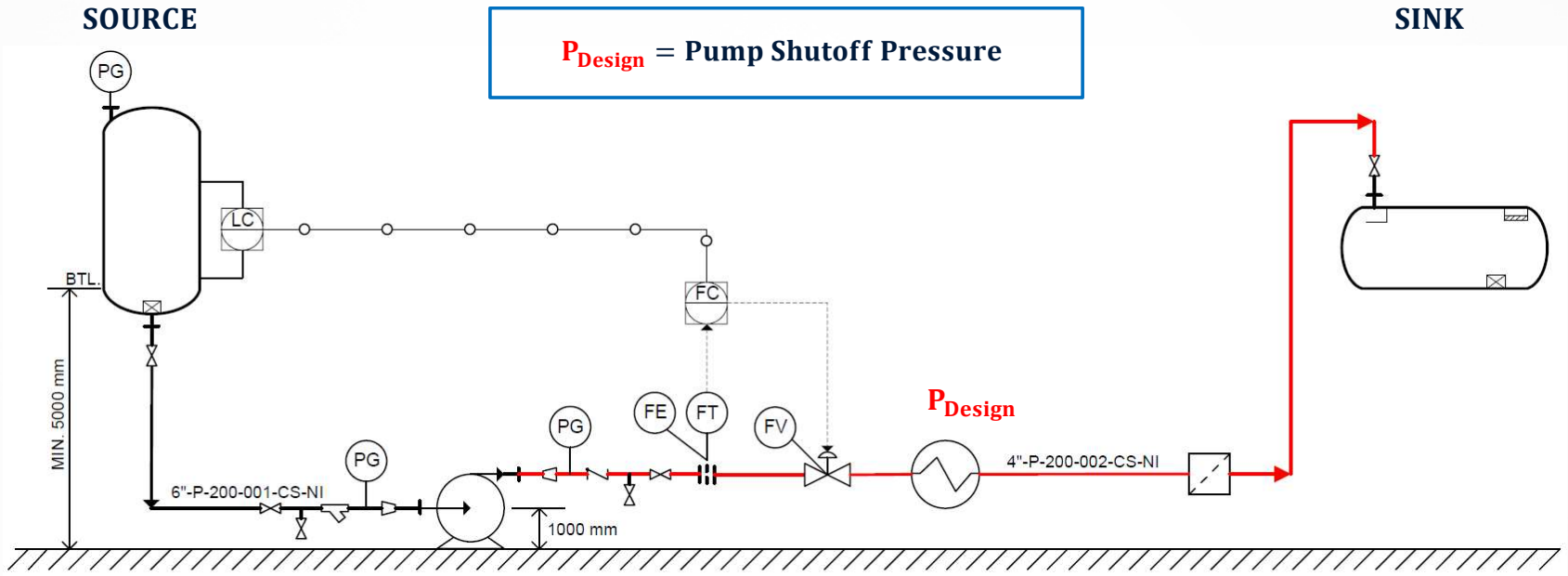
$$\Delta P_{\text{Control Valve}} = P_{\text{inlet}} - P_{\text{outlet}}$$

**SOURCE** **SINK**



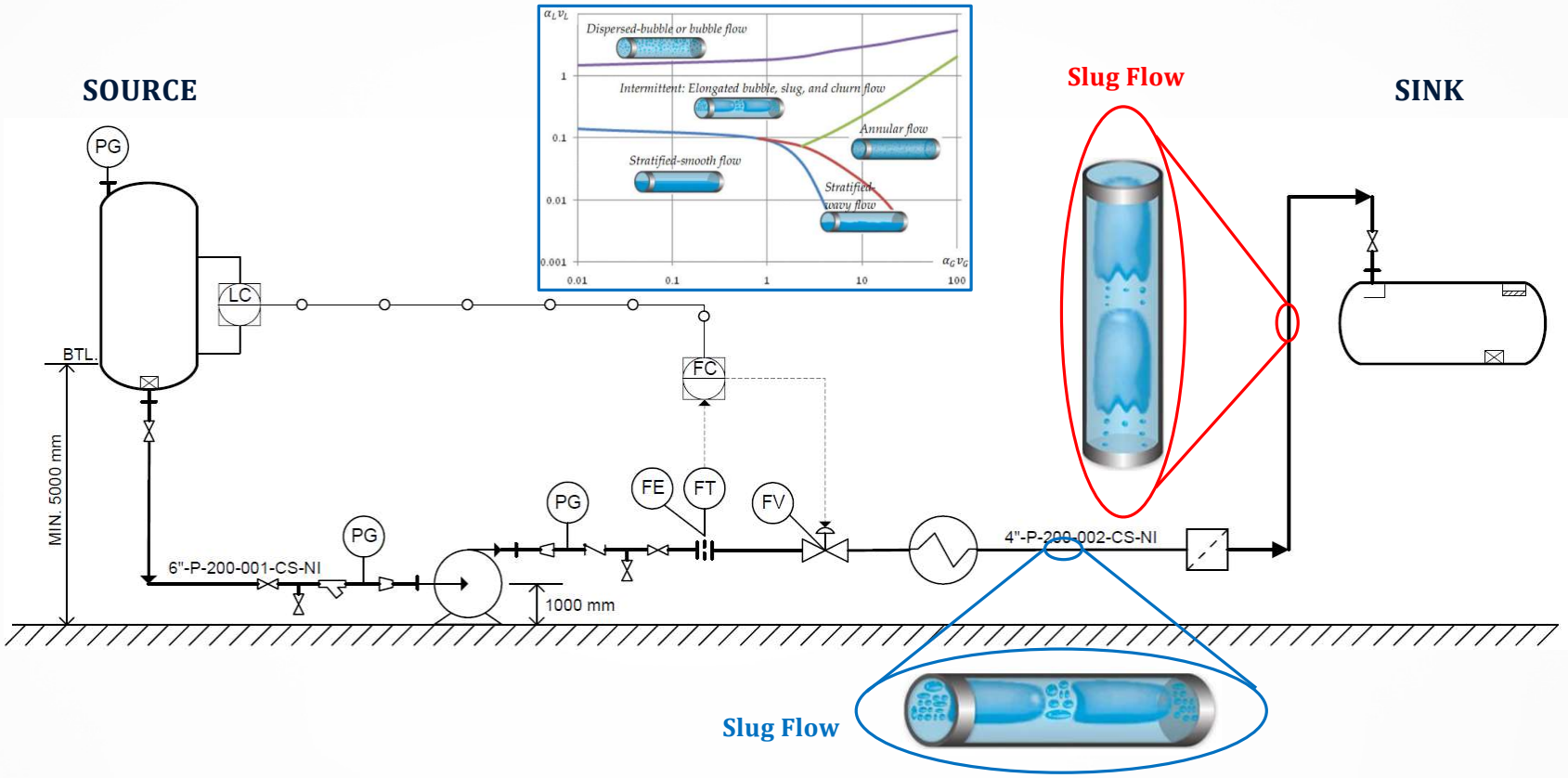
# FluidFlow: Hydraulic Calculation Software Objectives

- To determine the **design pressure** in the pump discharge line/equipment



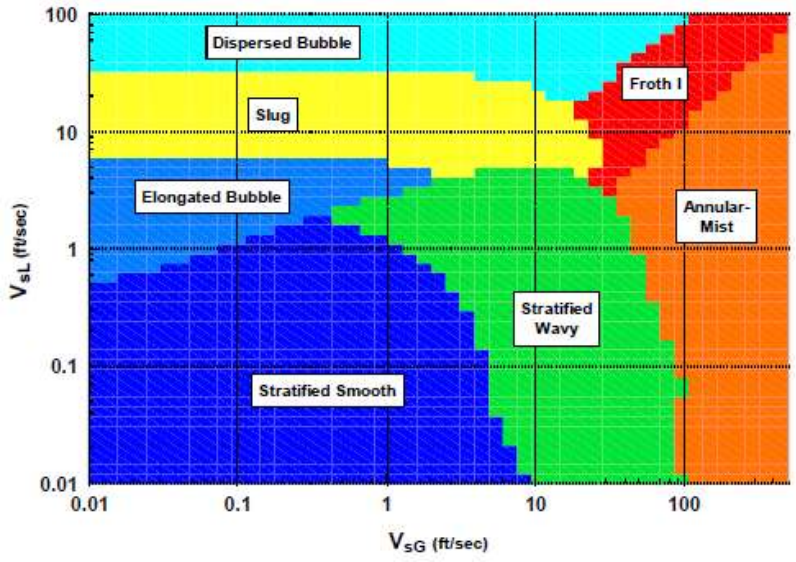
# FluidFlow: Hydraulic Calculation Software Objectives

- To check the flow pattern (**for two-phase flow**)

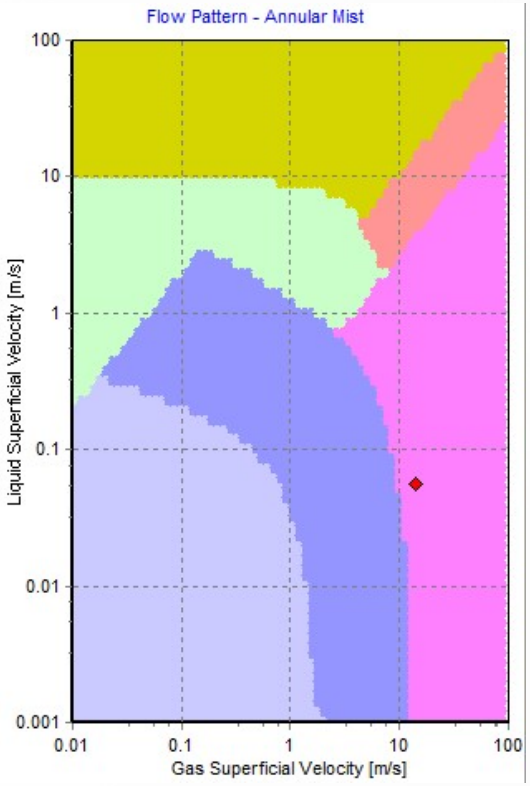


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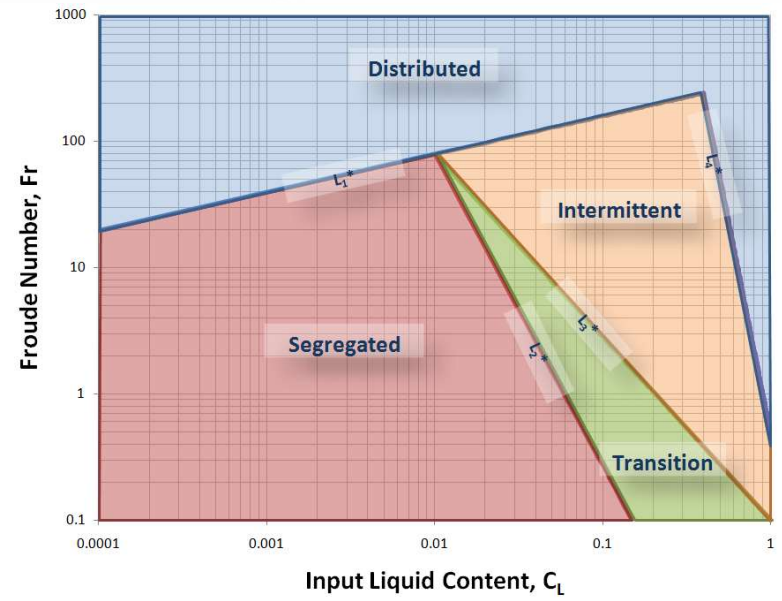


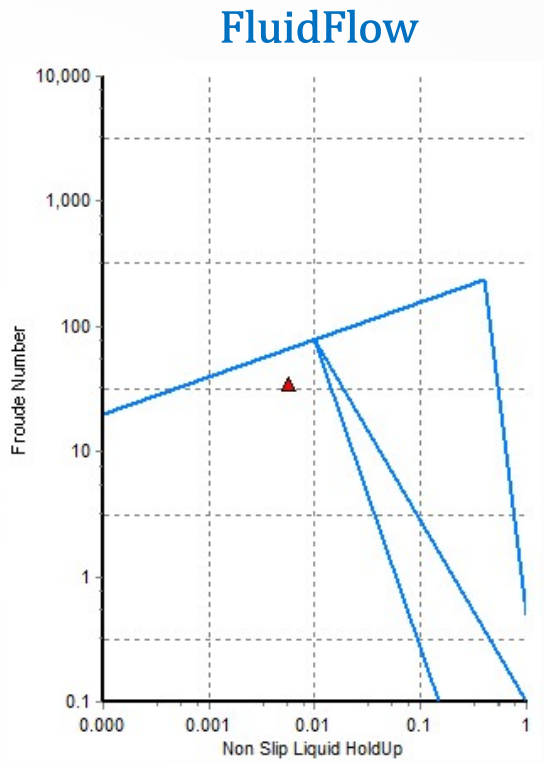

FluidFlow



# FluidFlow: Hydraulic Calculation Software Objectives

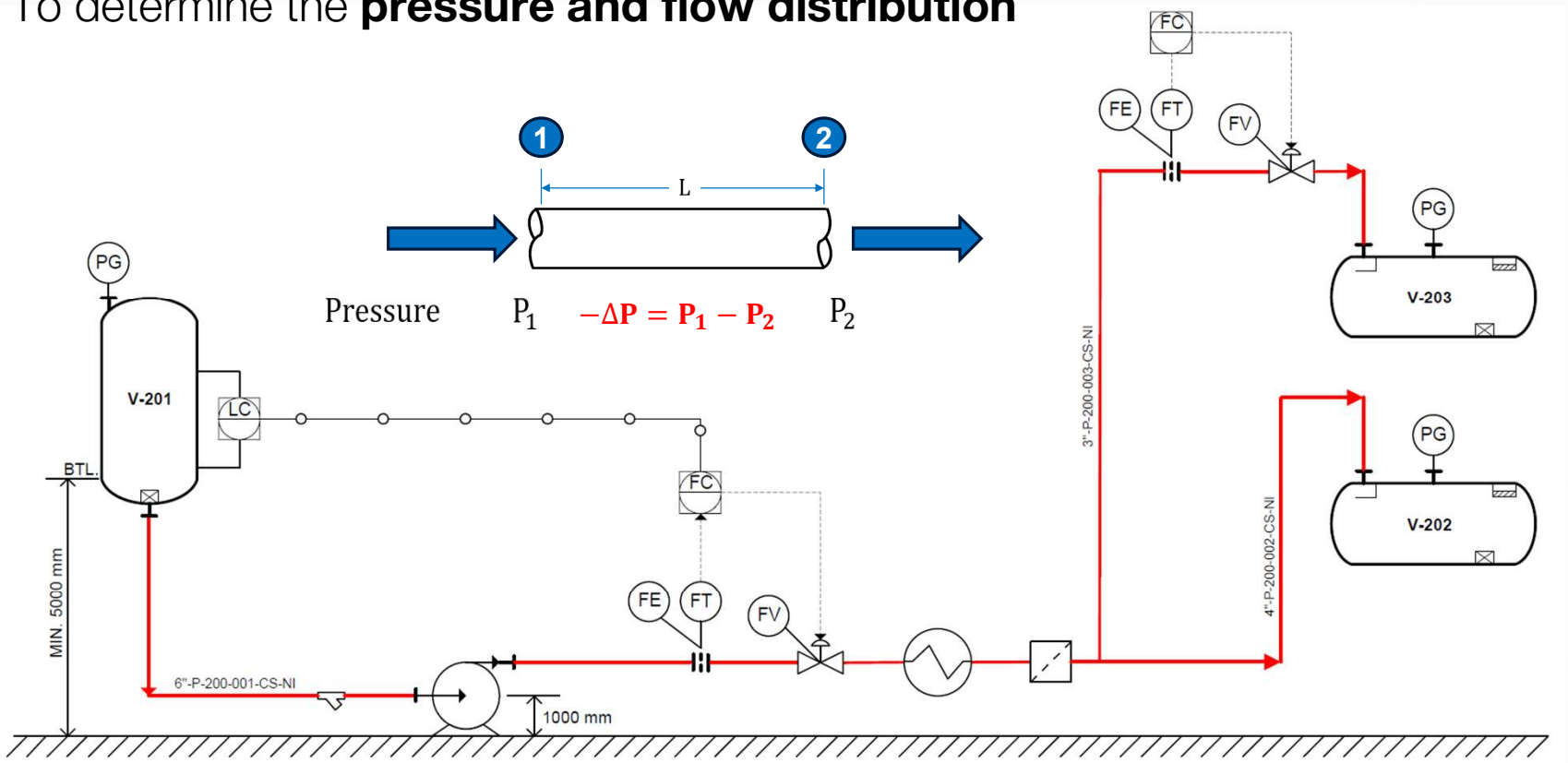
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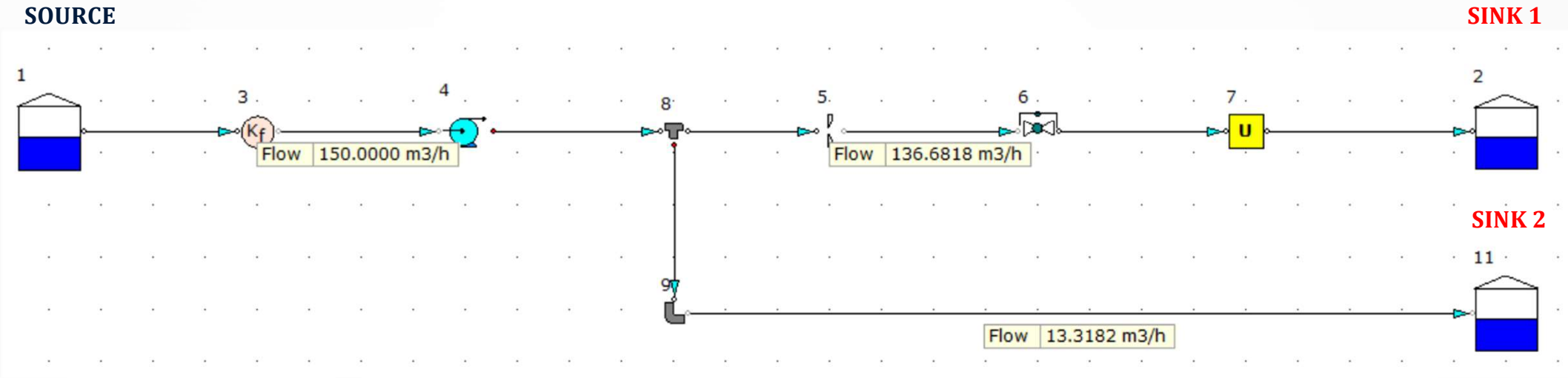
# FluidFlow: Hydraulic Calculation Software Objectives

- To determine the **pressure and flow distribution**



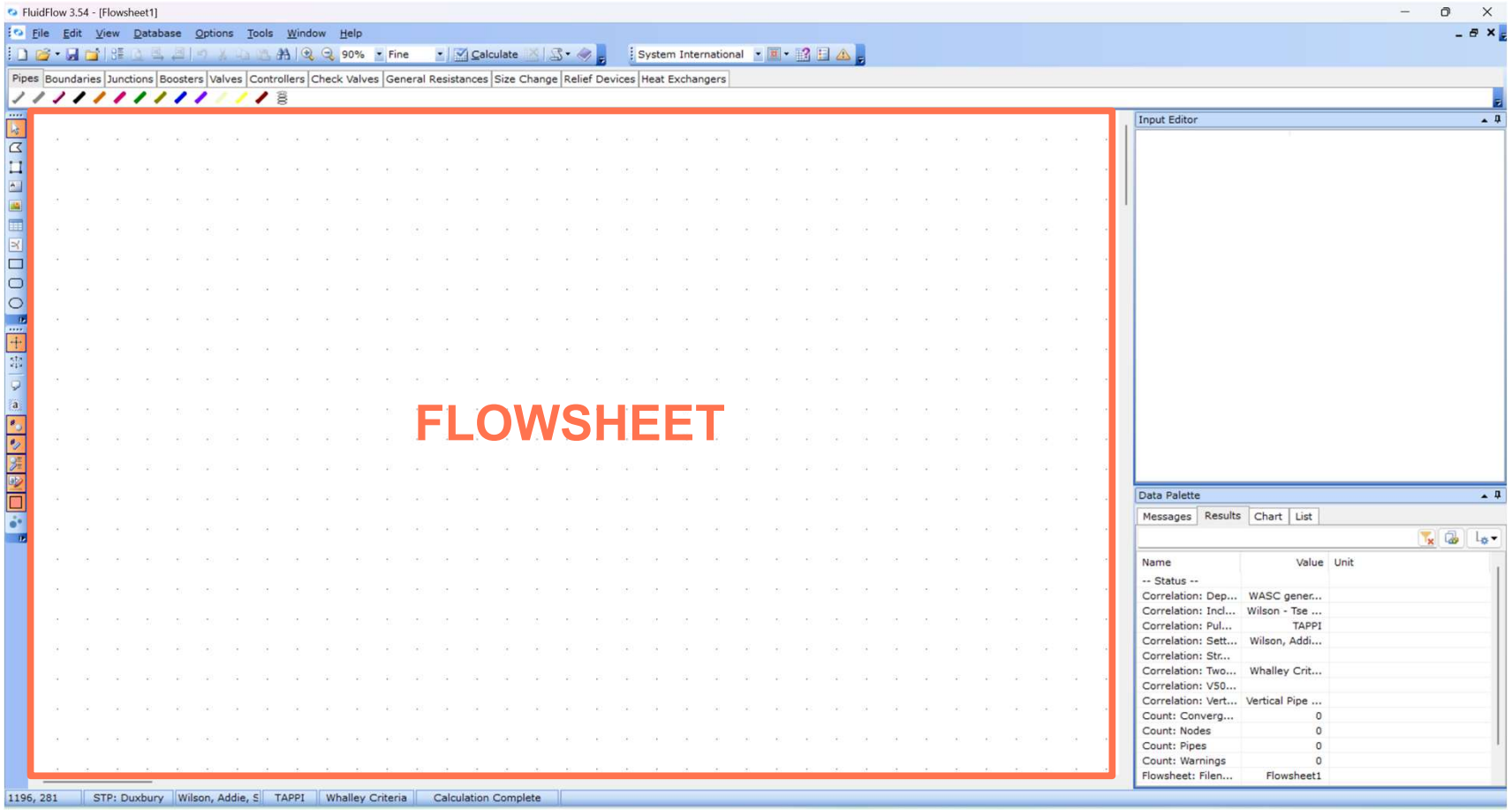
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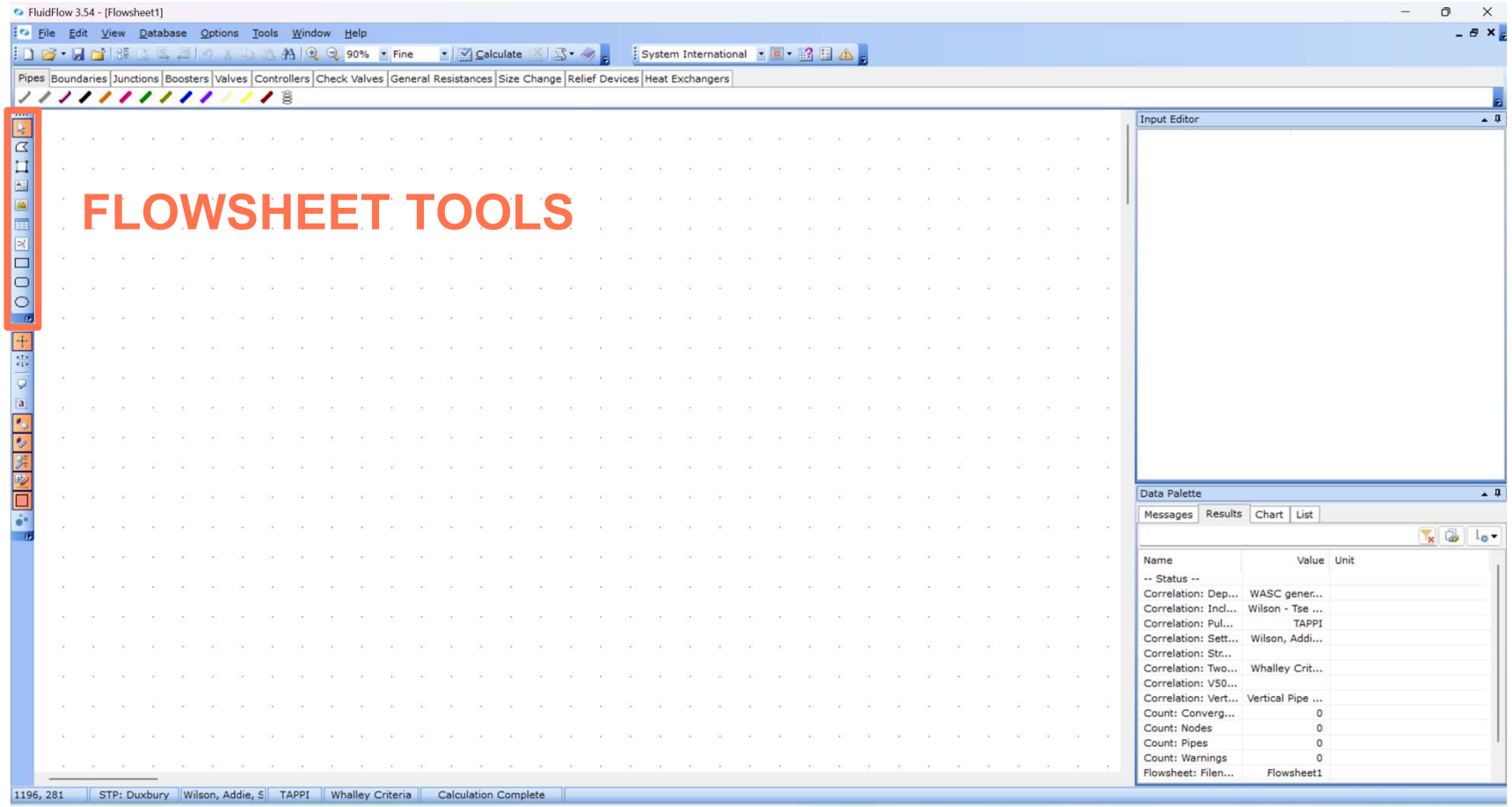


# FLUIDFLOW USER INTERFACE

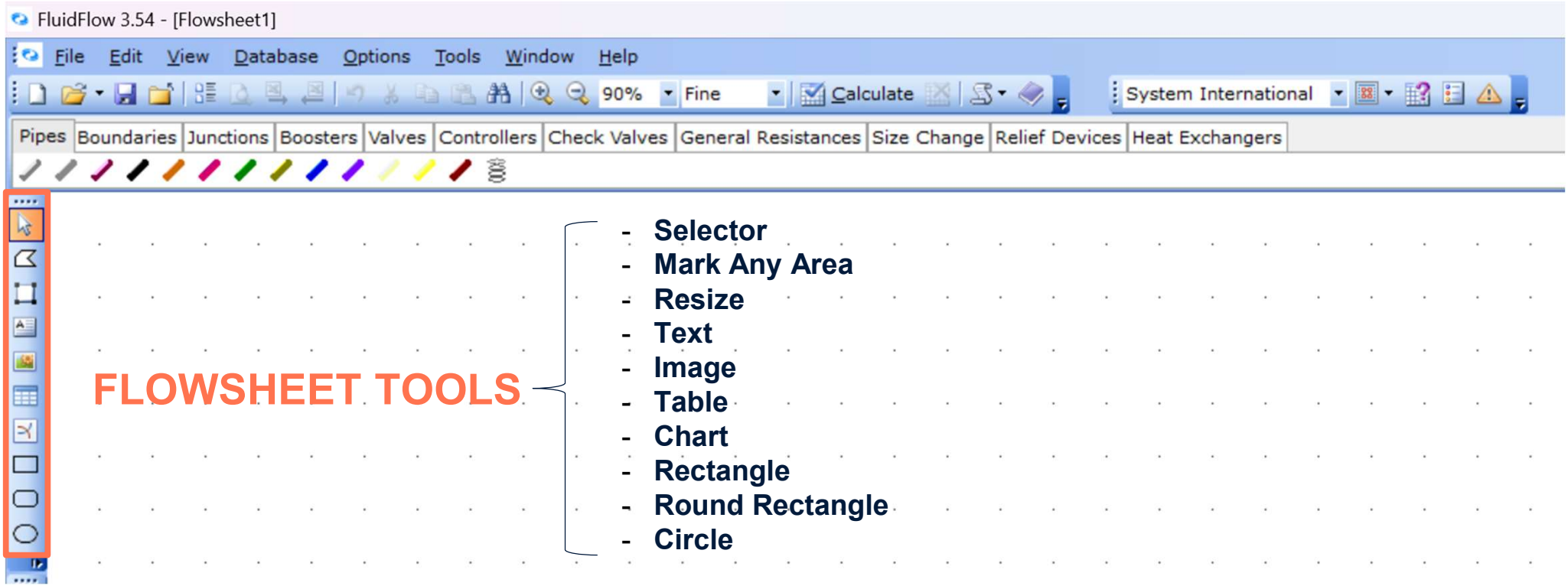
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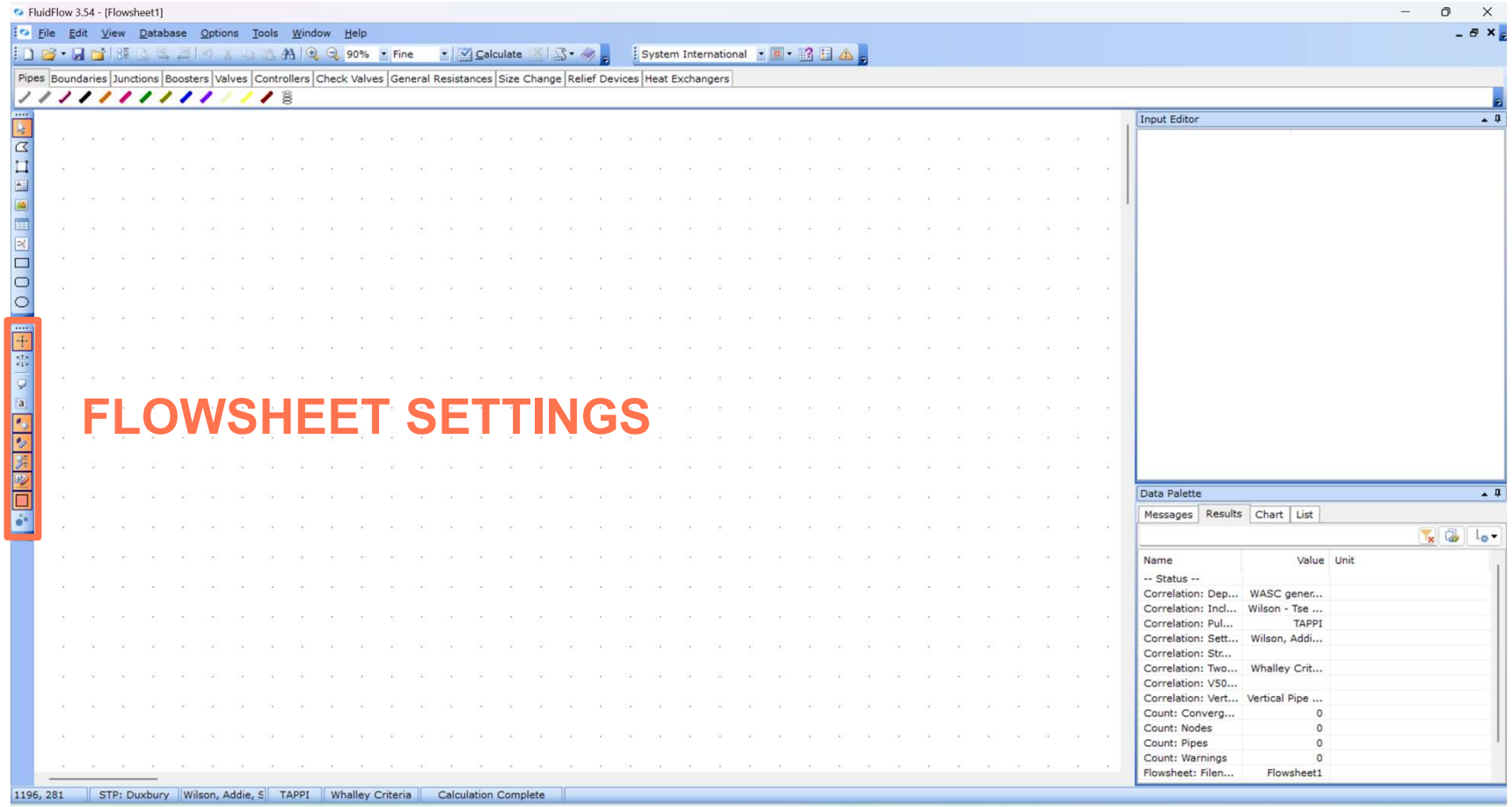
# FluidFlow User Interface



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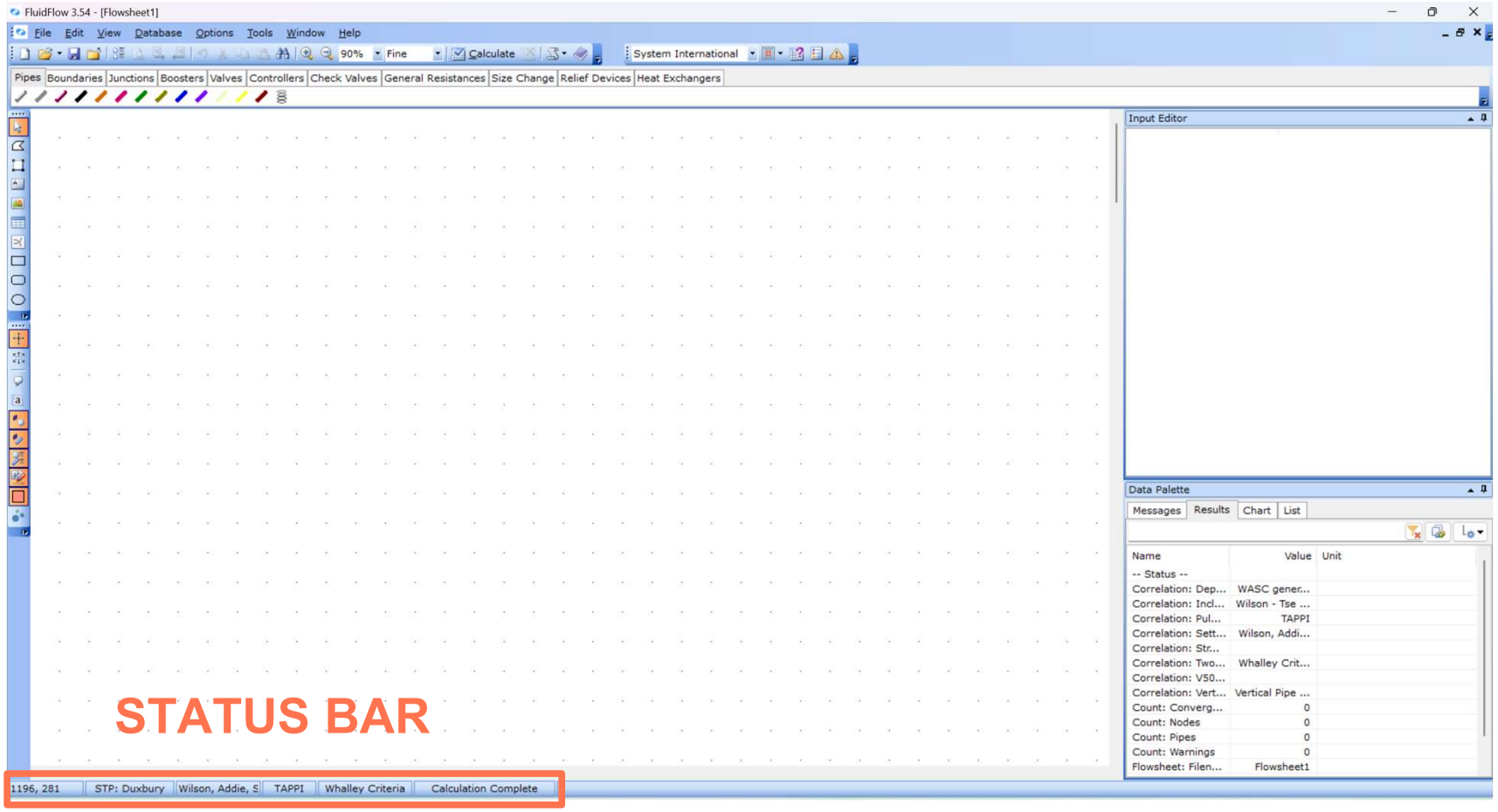
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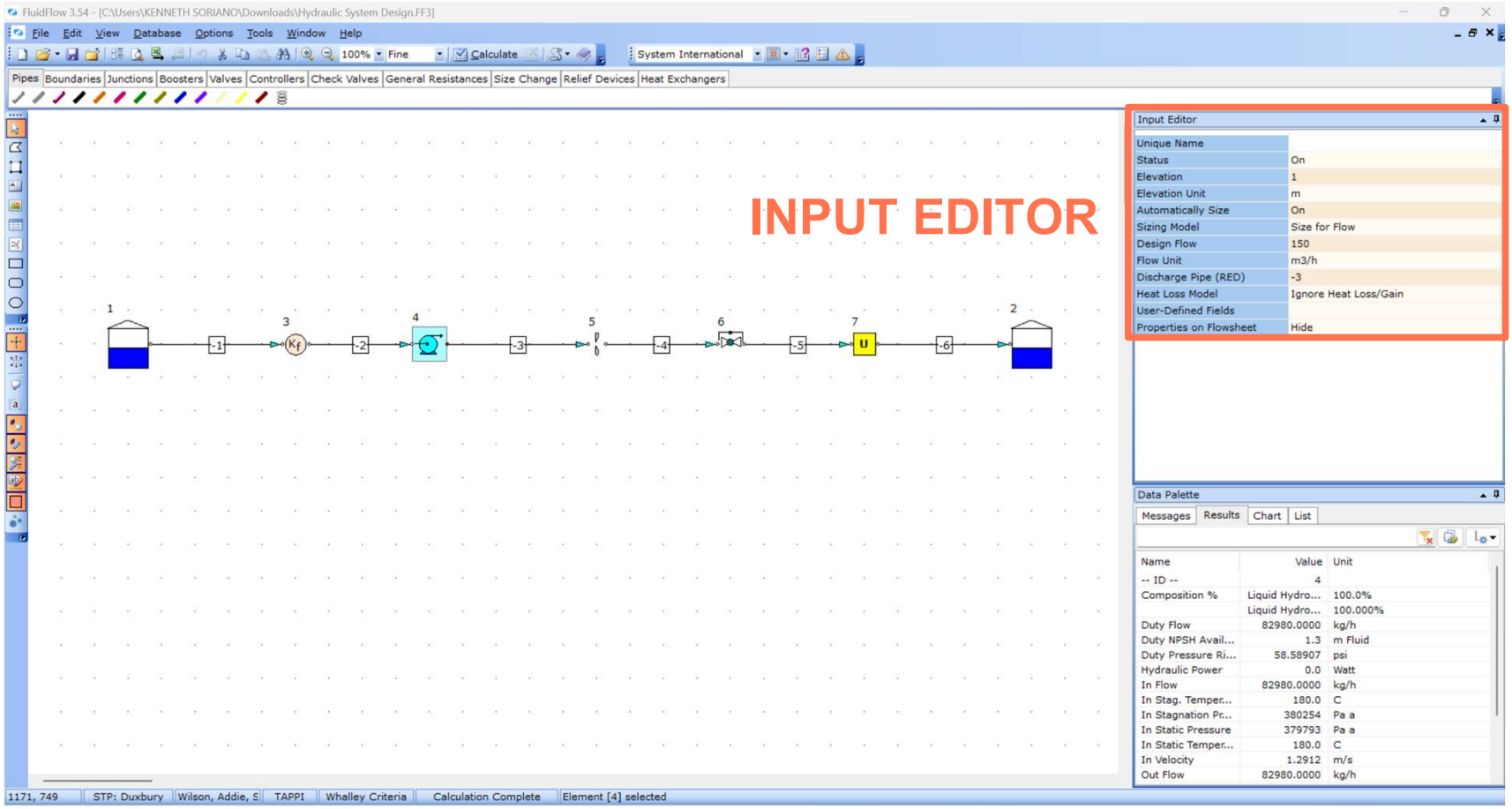
## FLOWSHEET SETTINGS

- Orthogonal Cross-Hairs
- Isometric Cross-Hairs
- Show Flyby
- Show or Hide Node Numbers
- Show or Hide Pipe Numbers
- Show or Hide Properties on Flowsheet
- Show or Hide Text Objects
- Show or Hide Warning Highlight
- Use Minimized Node Icons

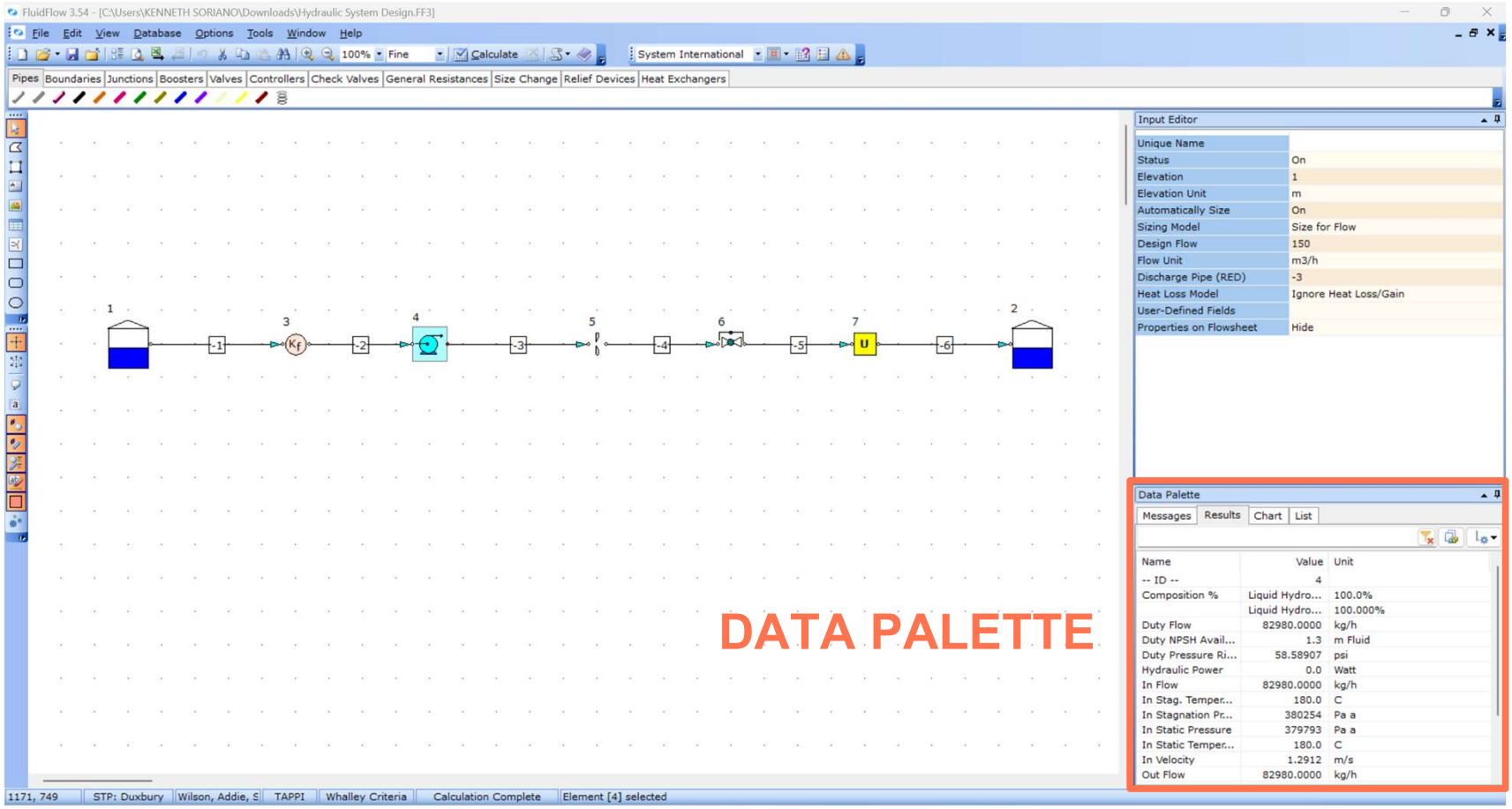
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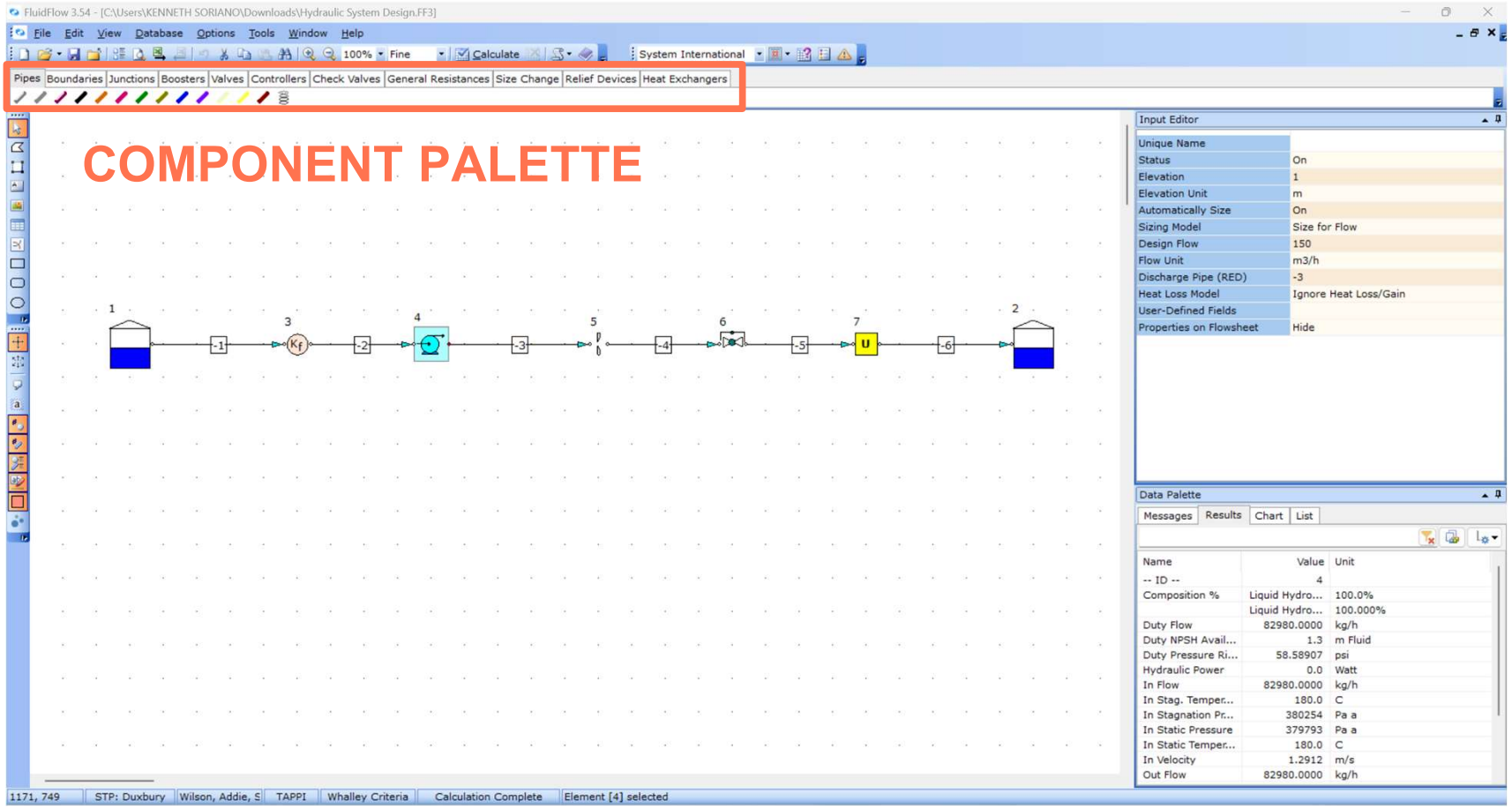
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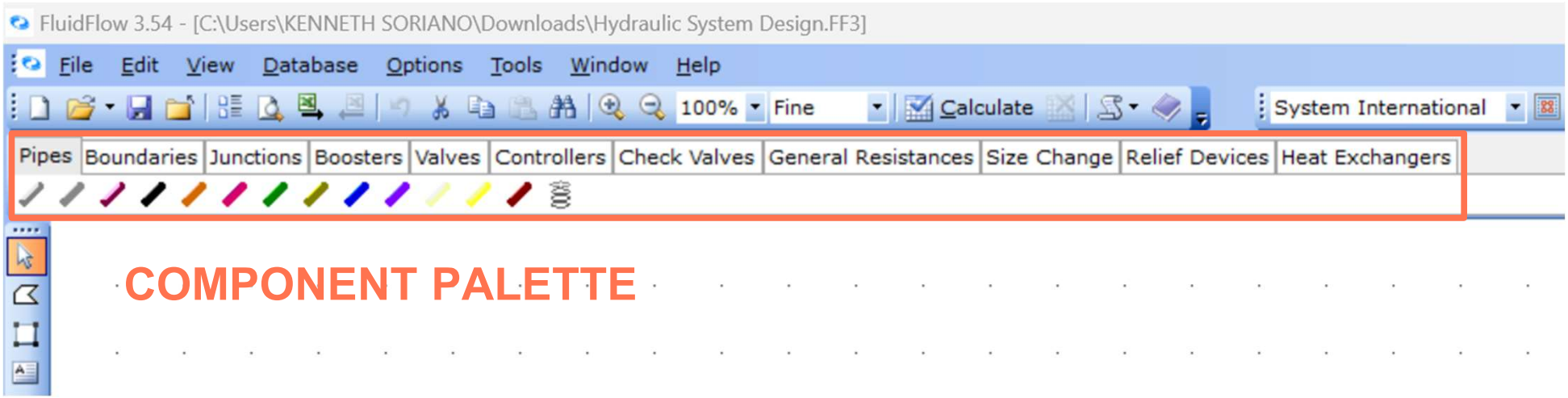
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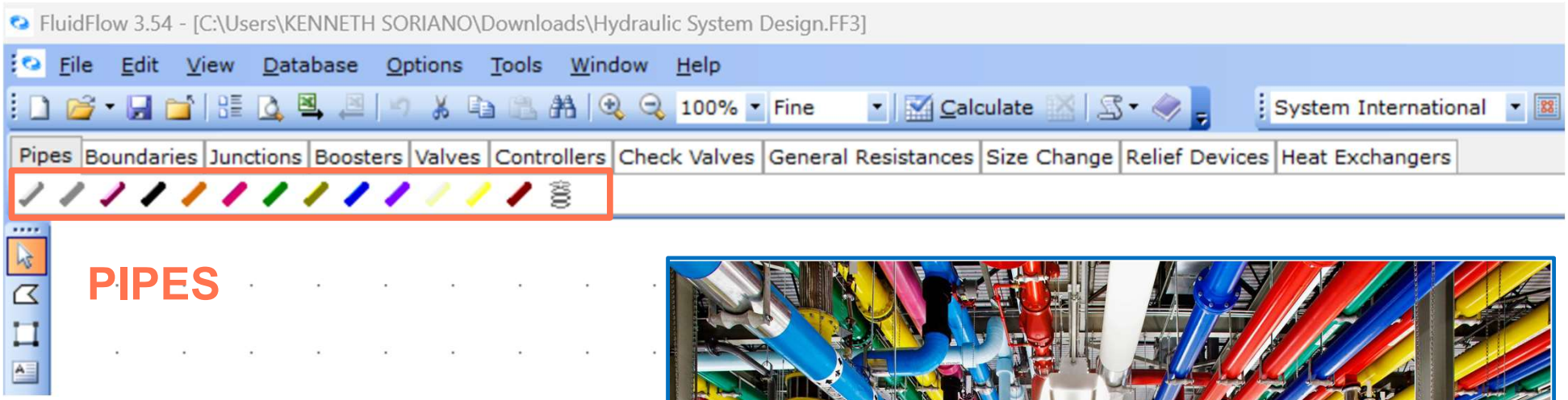
# FluidFlow User Interface



# FluidFlow User Interface



# FluidFlow User Interface




## PIPES



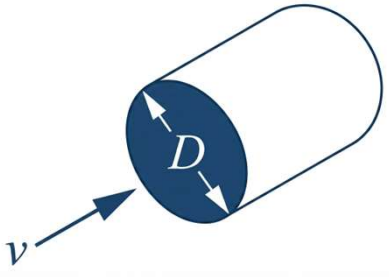
- Steel Pipe or Duct (Carbon Steel)
- Stainless Steel Pipe or Duct
- Ductile Iron Pipe
- Cast Iron Pipe
- Copper Pipe
- Aluminum Pipe or Duct
- ABS Pipe
- PVC Pipe or Duct
- PE Pipe or Duct
- PP or PFA Pipe or Duct
- Glass Pipe
- Concrete Pipe
- Asbestos Cement Pipe
- Flexible Smooth or Corrugated Hose

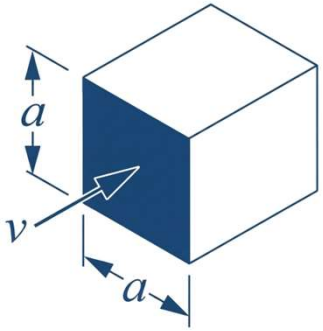
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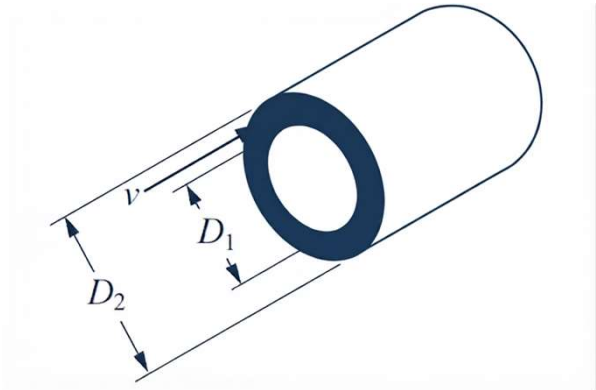
## PIPES/DUCTS

Input Editor

| | |
|---|---|
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| Length Unit | m |
| Geometry | Cylindrical |
| Use Database Size | Cylindrical / Rectangular/Square / Annulus |
| Nominal Size | |
| Classification | Schedule 40 |
| Friction Model | Moody |
| Use Database Roughness | Yes |
| Roughness Description | Clean or new |
| Use Database Scaling | No |
| Scaling (0 to 50%) | 0 |
| Sizing Model | Economic Velocity |
| Heat Loss Model | Ignore Heat Loss/Gain |
| User-Defined Fields | |

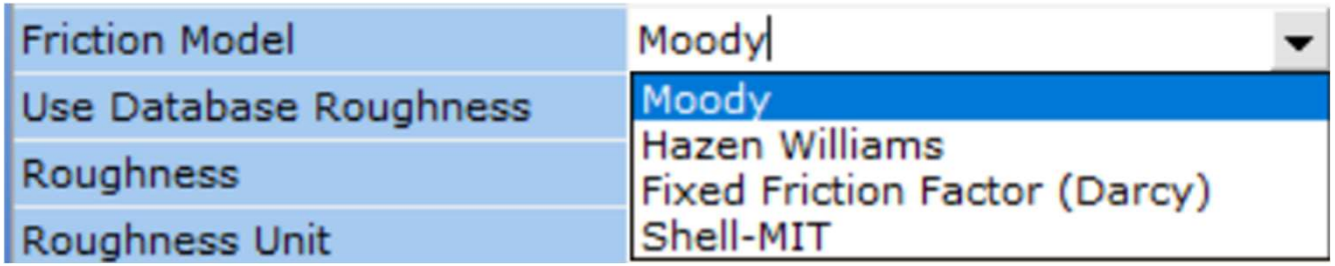


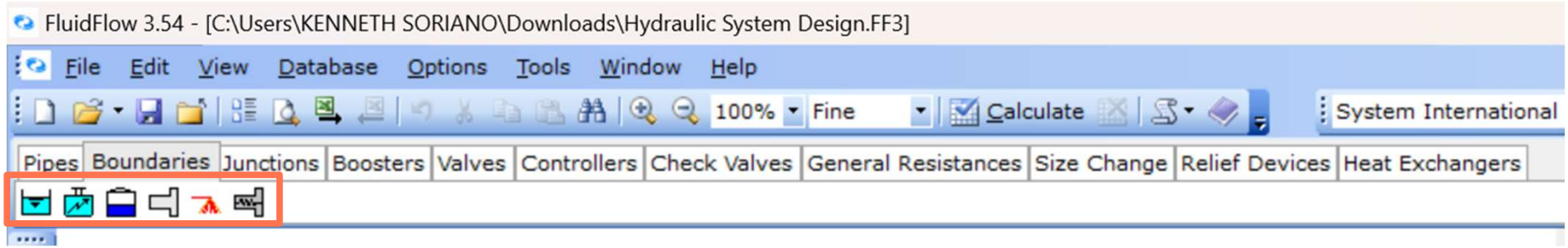



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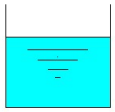
## PIPES/DUCTS



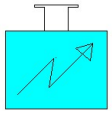
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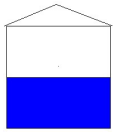

## BOUNDARIES



**Known or Assigned Pressure**



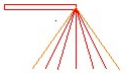
**Known or Assigned Flow**



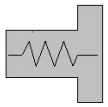
**Reservoir / Accumulator / Vessel**



**Open Pipe**

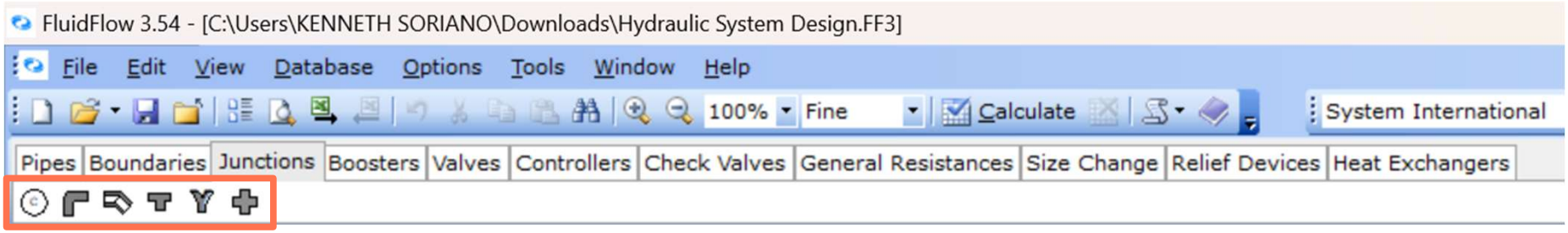


**Sprinkler**

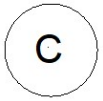


**Known Resistance**

# FluidFlow User Interface




## JUNCTIONS




Connector (No Resistance)



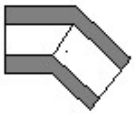
Symmetric Wye



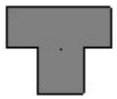
Bend



Cross Junction



Mitre Bend



Tee Junction

# FluidFlow User Interface

## JUNCTIONS

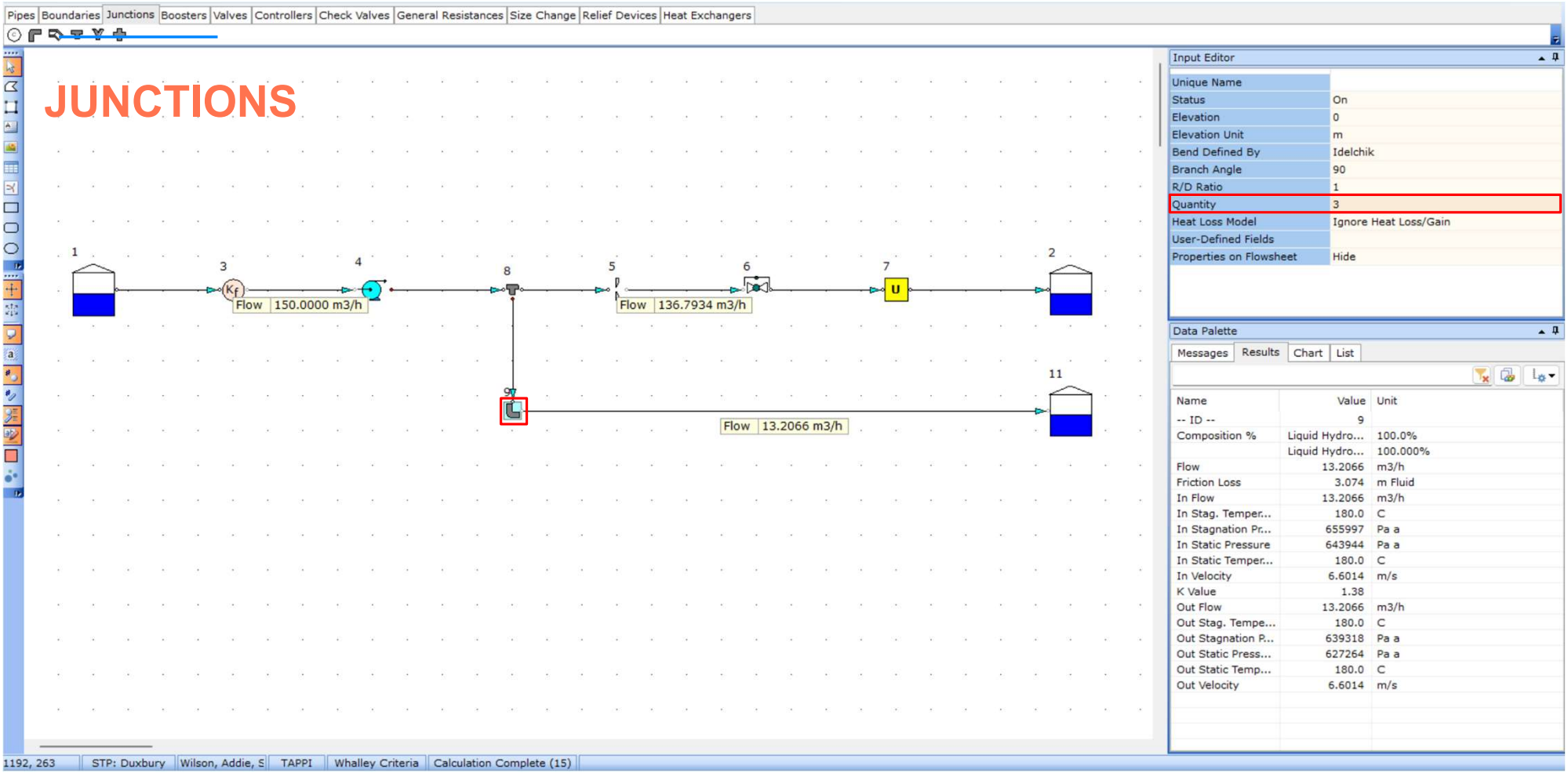


Bend

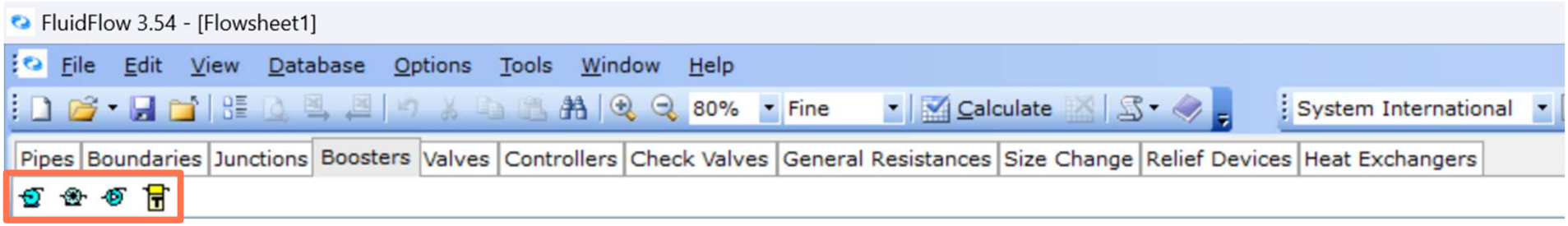
Input Editor

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| Unique Name | |
| Status | On |
| Elevation | 0 |
| Elevation Unit | m |
| Bend Defined By | Idelchik |
| Branch Angle | 90 |
| R/D Ratio | 1 |
| Quantity | 5 |
| Heat Loss Model | Ignore Heat Loss/Gain |
| User-Defined Fields | |
| Properties on Flowsheet | Hide |

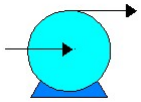
# FluidFlow User Interface



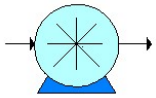
# FluidFlow User Interface



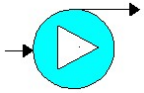

## BOOSTERS



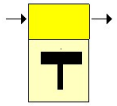
**Centrifugal Pump**



**Rotating Positive Displacement Pump**



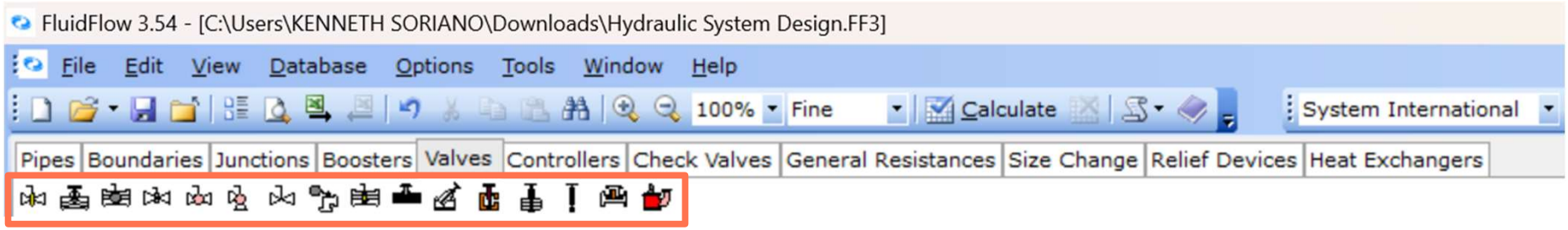
**Fan or Compressor**



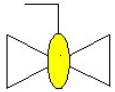
**Positive Displacement Pump or Compressor**

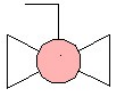


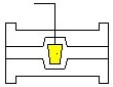
# FluidFlow User Interface

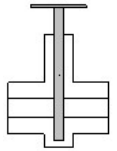


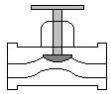

## VALVES

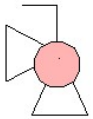

Butterfly Valve

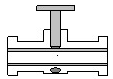

Globe Valve


Plug Valve

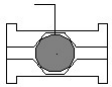

Slide Valve

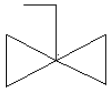

Diaphragm Valve


Angle Valve


Pinch Valve

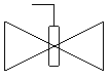

Penstock

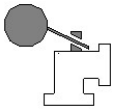

Ball Valve


V2 Unspecified

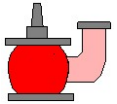

Y Globe Valve


3-Way Valve

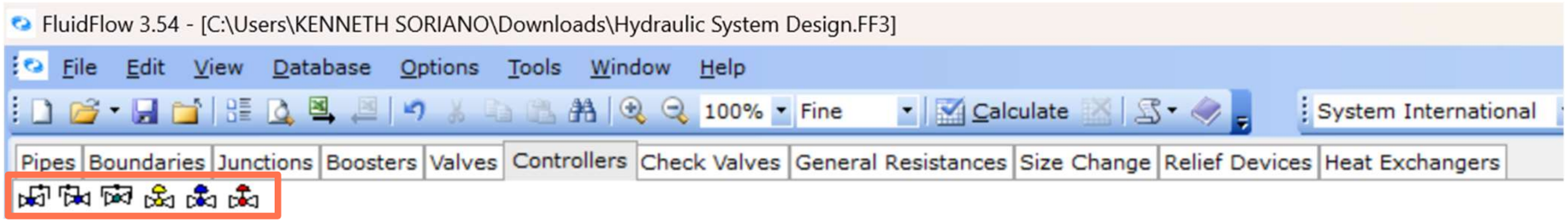

Gate Valve


Ball Float Valve

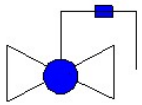

Needle Valve


Fire Hydrant

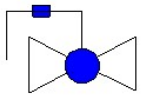
# FluidFlow User Interface



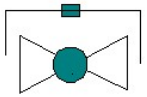

## CONTROL VALVES (CONTROLLERS)



**Self-Acting Pressure Reducer**



**Self-Acting Pressure Sustainer**



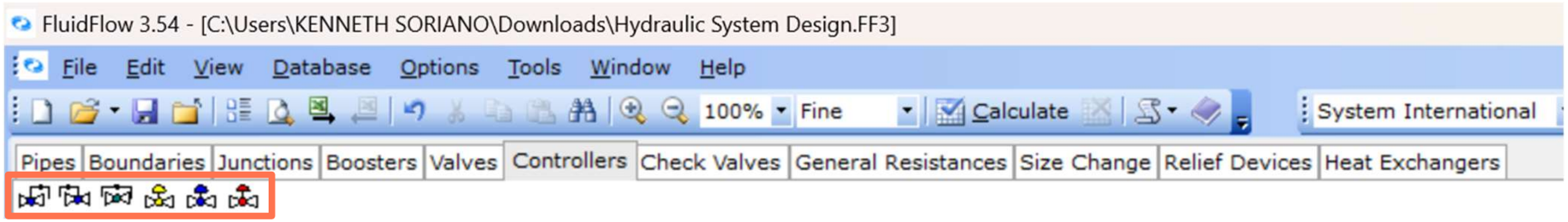
**Self-Acting Diff. Pressure Control Valve**



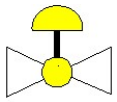




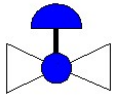
# FluidFlow User Interface



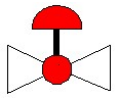

## CONTROL VALVES (CONTROLLERS)



**Flow Control Valve**



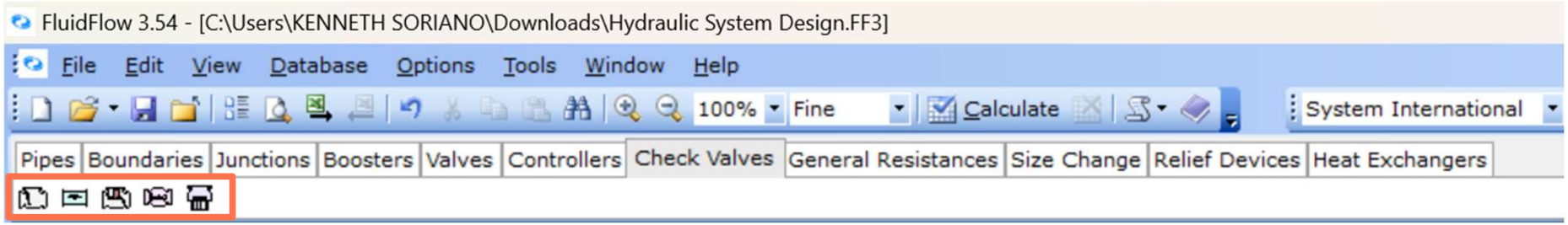
**Pressure Control Valve**



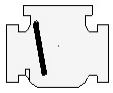
**Gas Regulator**



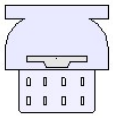
# FluidFlow User Interface



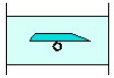

## CHECK VALVES



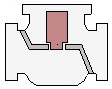
Swing Check Valve



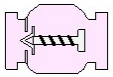
Foot-Operated Check Valve



Tilting Disk Check Valve

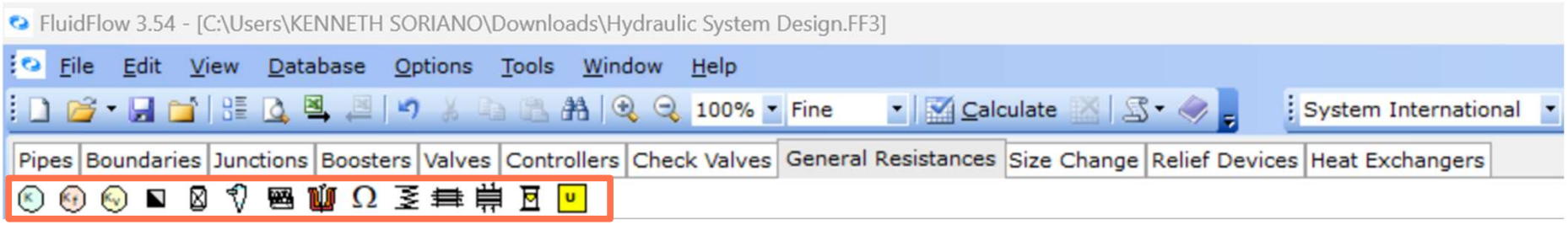


Piston-Operated Check Valve



Spring-Loaded Check Valve

# FluidFlow User Interface




## GENERAL RESISTANCES

- K [Pressure Loss Coefficient]
- Kf [Equivalent Length (L/D)]
- Kv / Cv [Flow Coefficient]
- Inline Filter
- Packed Bed
- Cyclone
- Labyrinth Seal
- Centrifuge

# FluidFlow User Interface

## GENERAL RESISTANCES

K [Pressure Loss Coefficient]

**In terms of Pressure Drop**

$$\Delta P = (\rho)\left(\frac{f_{Darcy} L}{D}\right)\left(\frac{\bar{v}^2}{2g_c}\right)$$

$$\Delta P = (\rho)(K)\left(\frac{\bar{v}^2}{2g_c}\right)$$

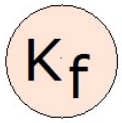
K ↑ ΔP ↑

Input Editor

| | |
|---|---|
| Unique Name | |
| Status | On |
| Elevation | 0 |
| Elevation Unit | m |
| Use K from Database | No |
| K (Pressure Loss Coeff) | 5 |
| Quantity | 1 |
| Loss Basis | Upstream Velocity |
| Heat Loss Model | Ignore Heat Loss/Gain |
| User-Defined Fields | |
| Properties on Flowsheet | Hide |

# FluidFlow User Interface

## GENERAL RESISTANCES

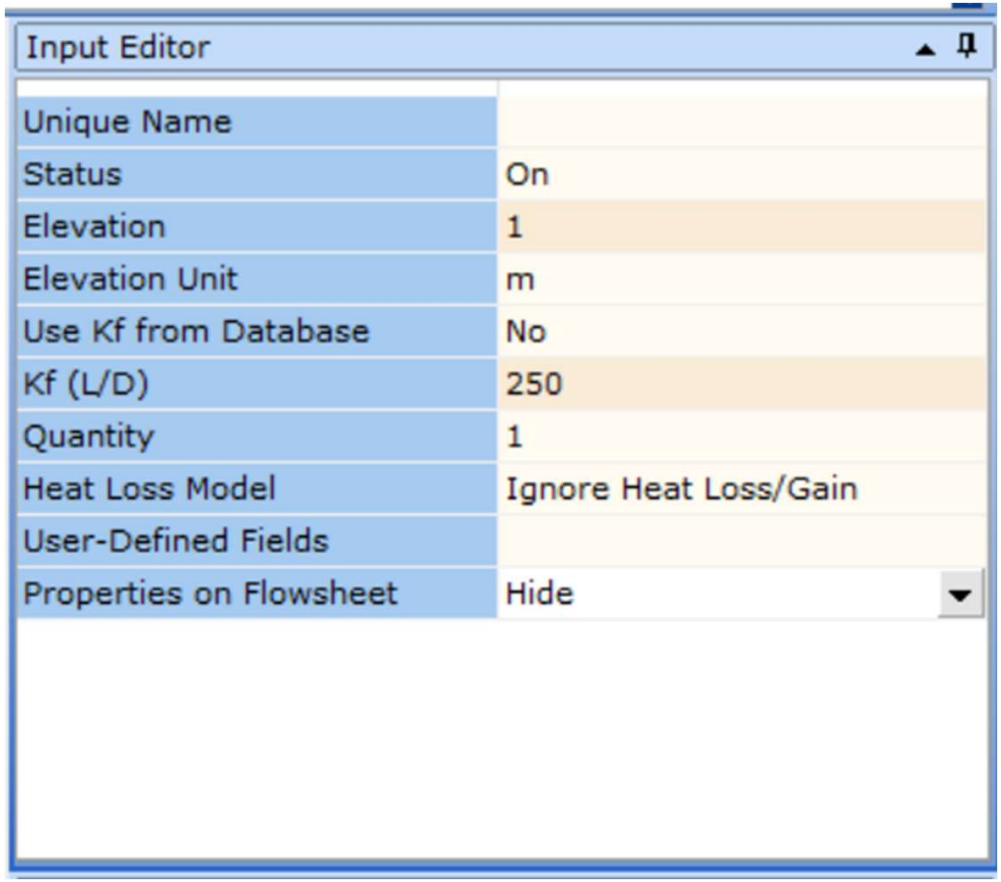



Kf [Equivalent Length (L/D)]

**In terms of Pressure Drop**

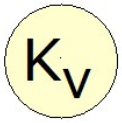
$$\Delta P = (\rho)\left(\frac{L}{D} \cdot f_{Turbulent}\right)\left(\frac{\bar{v}^2}{2g_c}\right)$$

$$\Delta P = (\rho)(K_f \cdot f_{Turbulent})\left(\frac{\bar{v}^2}{2g_c}\right)$$



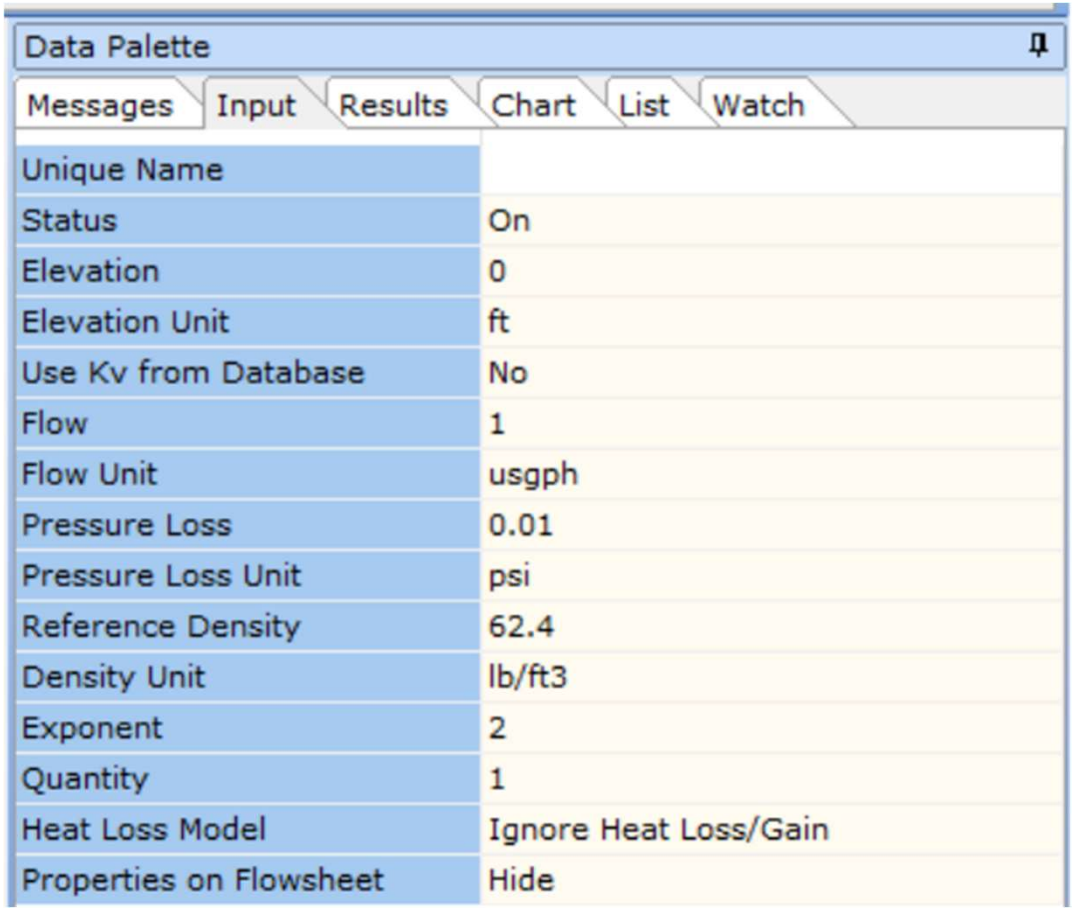
# FluidFlow User Interface

## GENERAL RESISTANCES




Kv / Cv [Flow Coefficient]

$$\Delta P = \left(\frac{\rho_{Ref}}{\rho}\right)^{n-1} \left(\frac{m}{m_{Ref}}\right)^{n} \Delta P_{Ref}$$

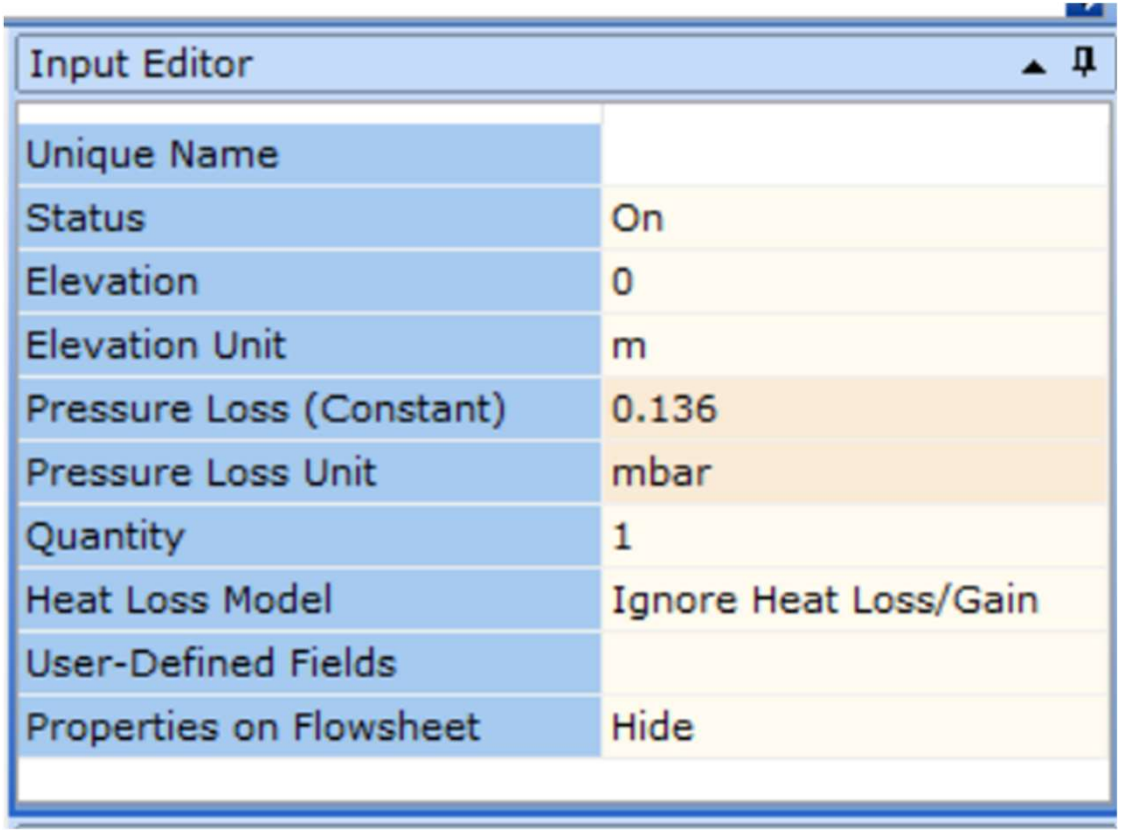


# FluidFlow User Interface

## GENERAL RESISTANCES



Constant Head Loss



# FluidFlow User Interface

## GENERAL RESISTANCES

**U** User-Defined Generic

**For a user-defined generic component, the pressure drop is calculated using this empirical formula:**

$$\Delta P = K + ABQ^n + CDQ^m$$

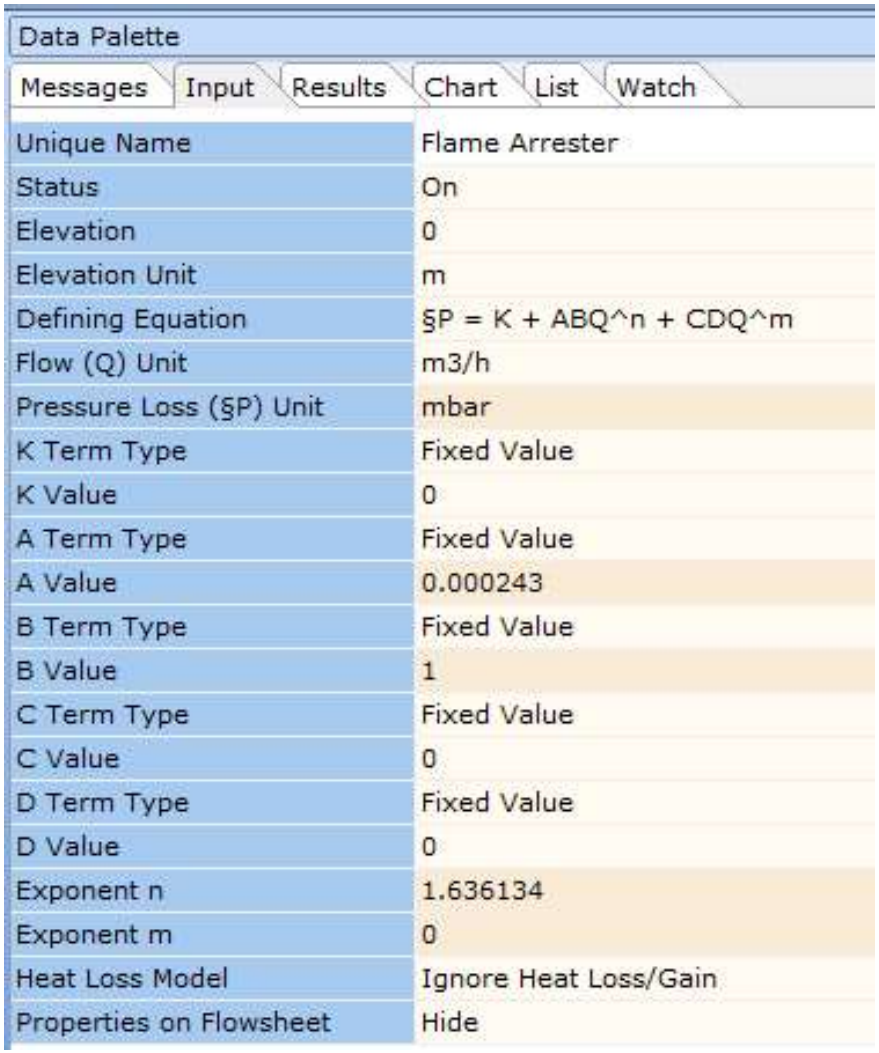
**Where:**

**ΔP is the pressure drop**

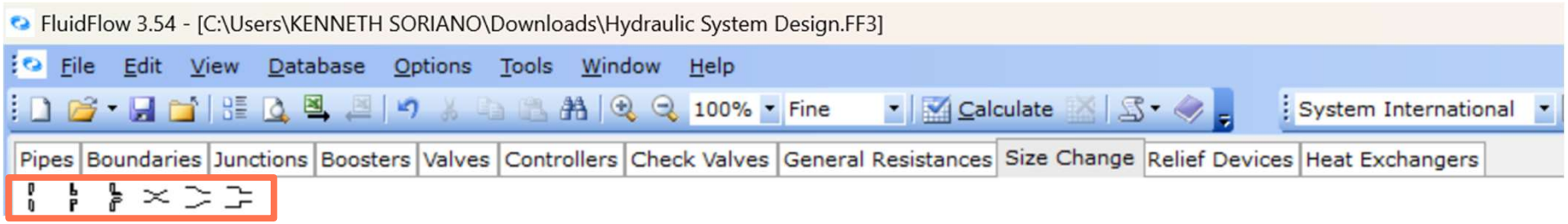
**Q is the flow rate**

**A, B, C, D, and K are the equation constants**

**m, n are the exponents**



# FluidFlow User Interface




## SIZE CHANGE



**Thin Sharp-Edged Orifice**



**Thick Orifice**



**Inline Nozzle**



**Venturi Tube**

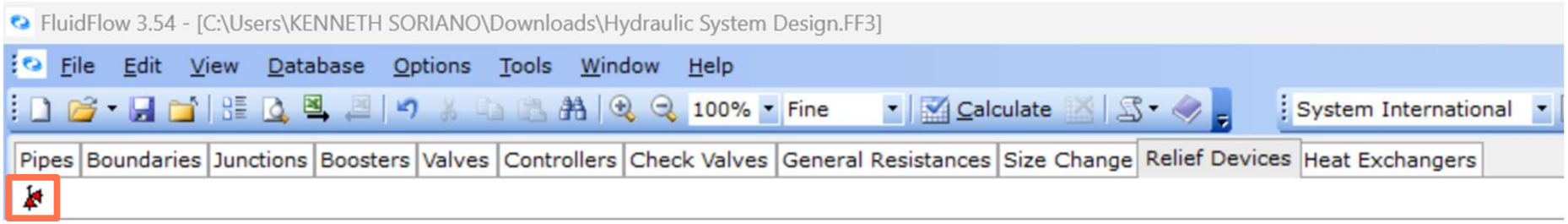


**Reducer / Expander**



**Abrupt Size Change**

# FluidFlow User Interface

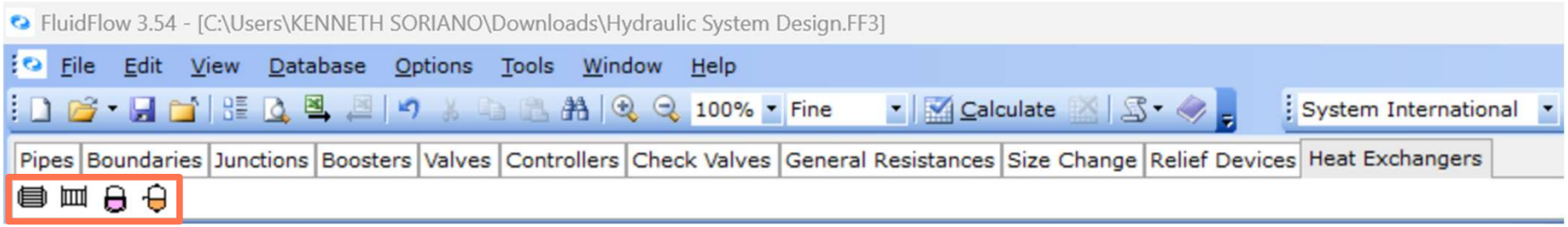



## RELIEF DEVICE

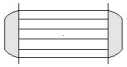


**Relief Valve Only / Bursting Disc Only / Relief Valve and Bursting Disc**

# FluidFlow User Interface



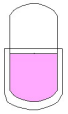

## HEAT EXCHANGERS



**Shell and Tube Heat Exchanger**



**Plate Heat Exchanger**



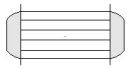
**Jacketed Vessel (Process Side Only)**



**Knock Out Pot (Vapor/Liquid Separator)**

# FluidFlow User Interface

## HEAT EXCHANGERS



### Shell and Tube Heat Exchanger

Input Editor

| | |
|---|---|
| Unique Name | |
| Status | On |
| Elevation | 0 |
| Elevation Unit | m |
| Pressure Loss Model | Standard Relationships |
| Fluid Side | Tubeside |
| Number of Tubes | 20 |
| Number of Tube Passes | 1 |
| Tube Diameter | 20 |
| Diameter Unit | mm |
| Tube Length | 4 |
| Length Unit | m |
| Heat Loss Model | Ignore Heat Loss/Gain |
| User-Defined Fields | |
| Properties on Flowsheet | Hide |

Input Editor

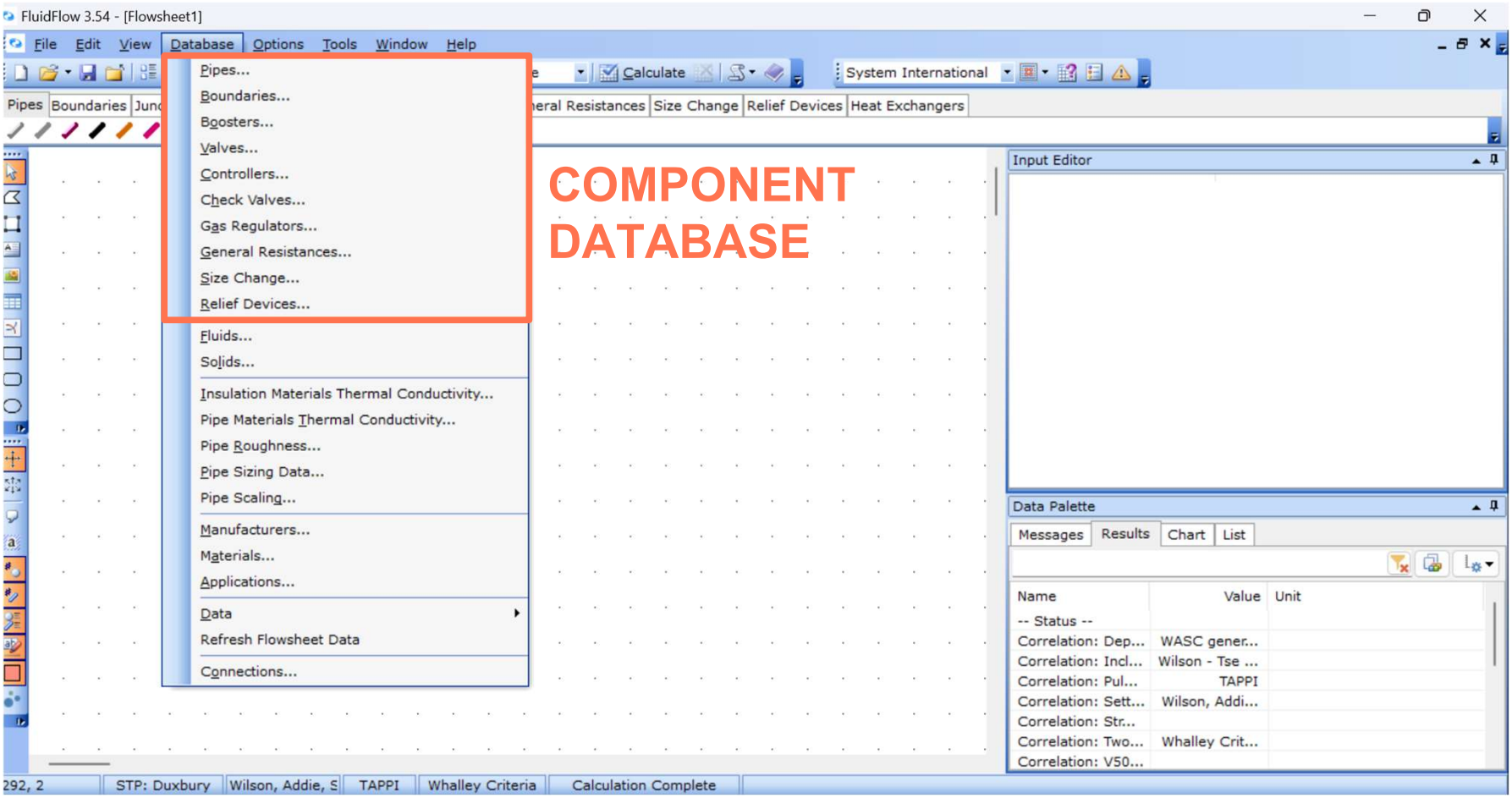
| | |
|---|---|
| Unique Name | |
| Status | On |
| Elevation | 0 |
| Elevation Unit | m |
| Pressure Loss Model | Manufacturer Loss Data |
| Flow | 1 |
| Flow Unit | m3/h |
| Pressure Loss | 1 |
| Pressure Loss Unit | Pa |
| Reference Density | 1000 |
| Density Unit | kg/m3 |
| Exponent | 2 |
| Heat Loss Model | Ignore Heat Loss/Gain |
| User-Defined Fields | |
| Properties on Flowsheet | Hide |

Input Editor

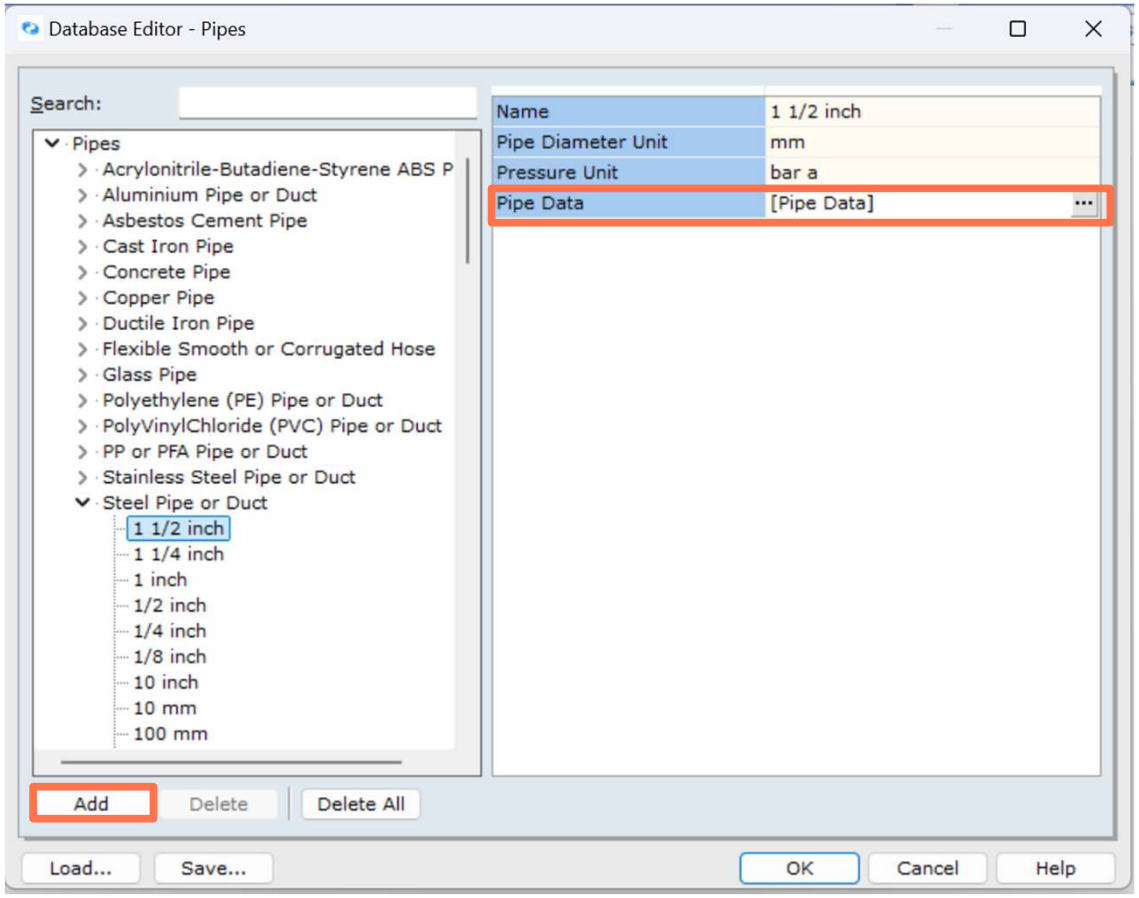
| | |
|---|---|
| Unique Name | |
| Status | On |
| Elevation | 0 |
| Elevation Unit | m |
| Pressure Loss Model | Fixed Value |
| Pressure Loss (Constant) | 1 |
| Heat Loss Model | Ignore Heat Loss/Gain |
| Pressure Loss Unit | Pa |
| User-Defined Fields | |
| Properties on Flowsheet | Hide |

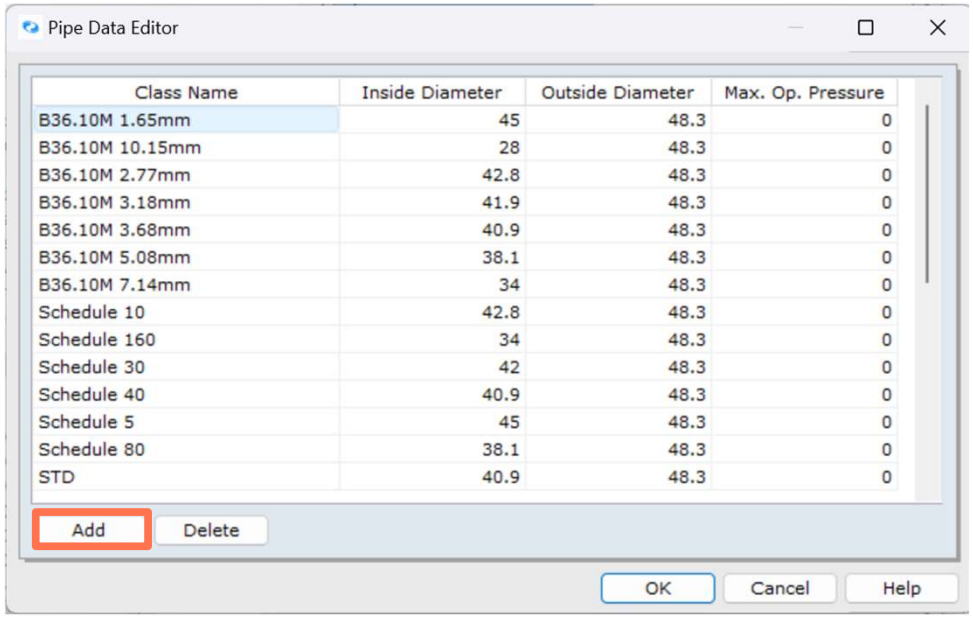
# FLUIDFLOW DATABASE

# FluidFlow Database (Component)

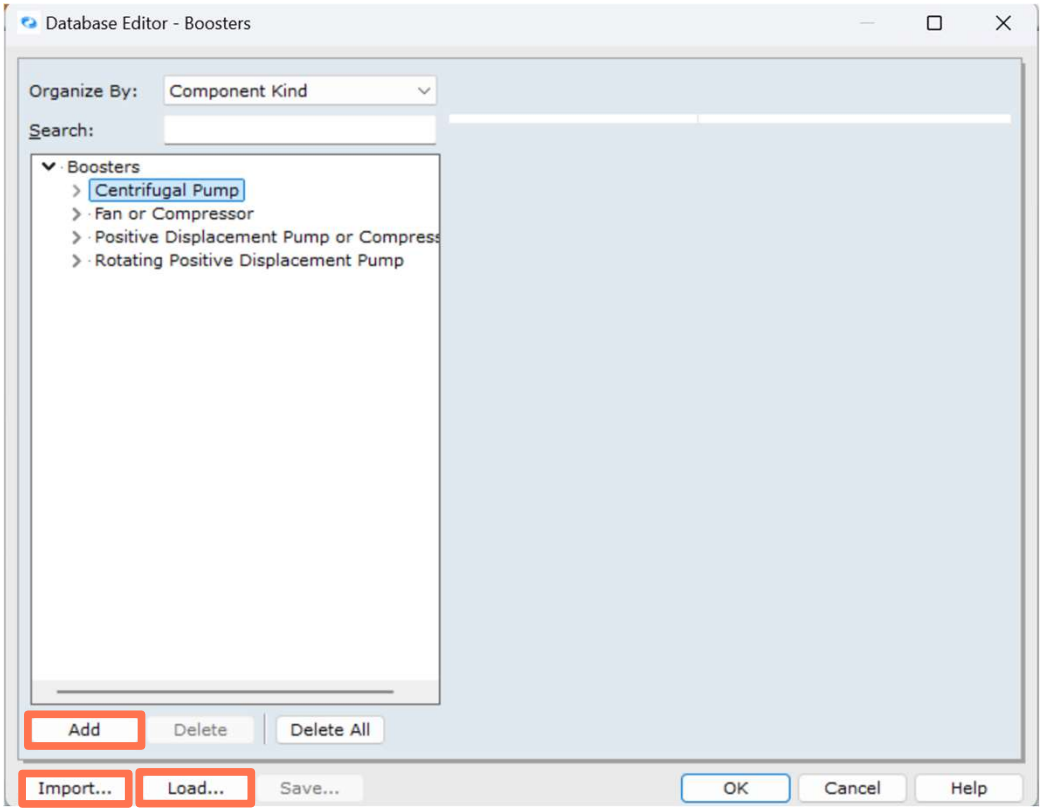


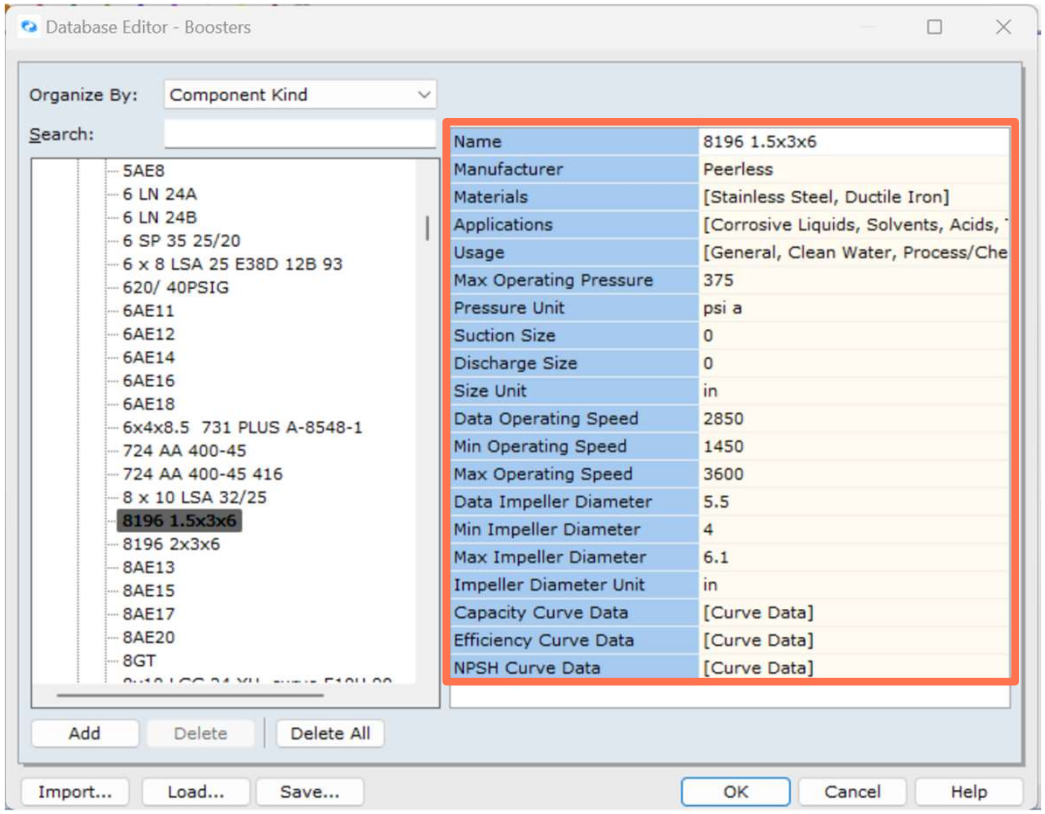
# FluidFlow Database (Pipes)



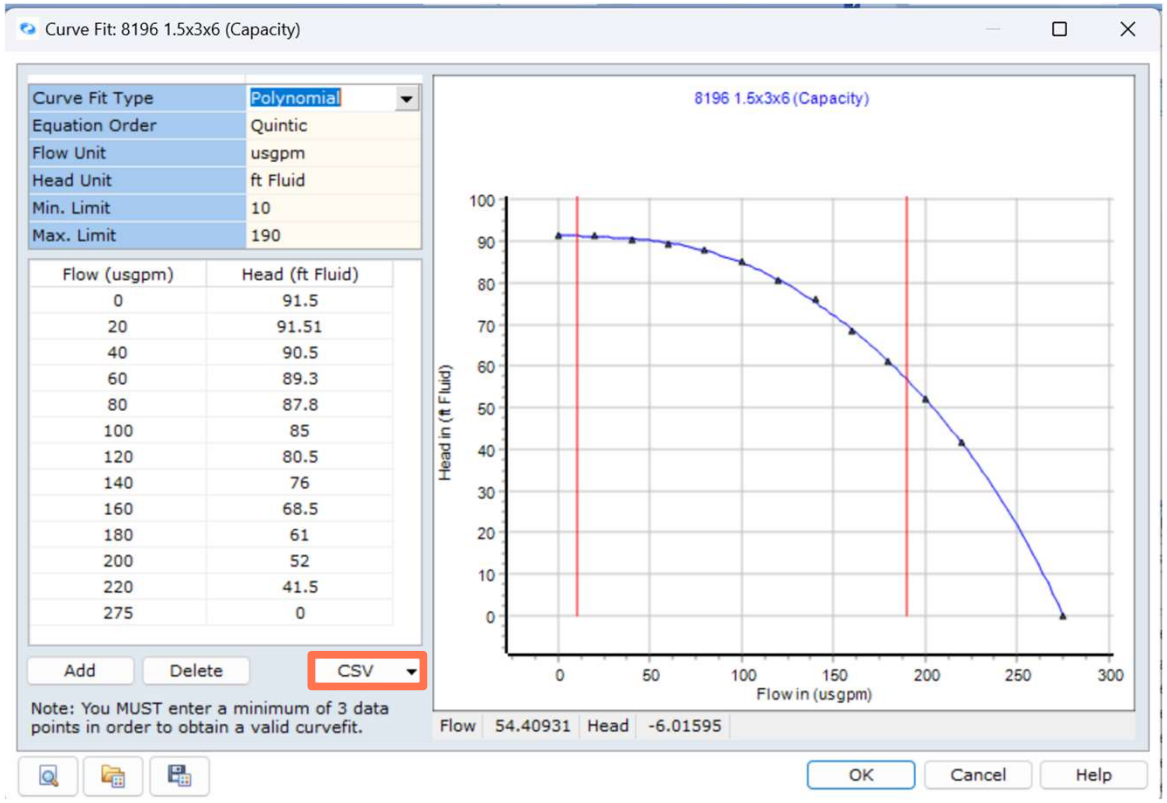
# FluidFlow Database (Boosters)



# FluidFlow Database (Boosters)

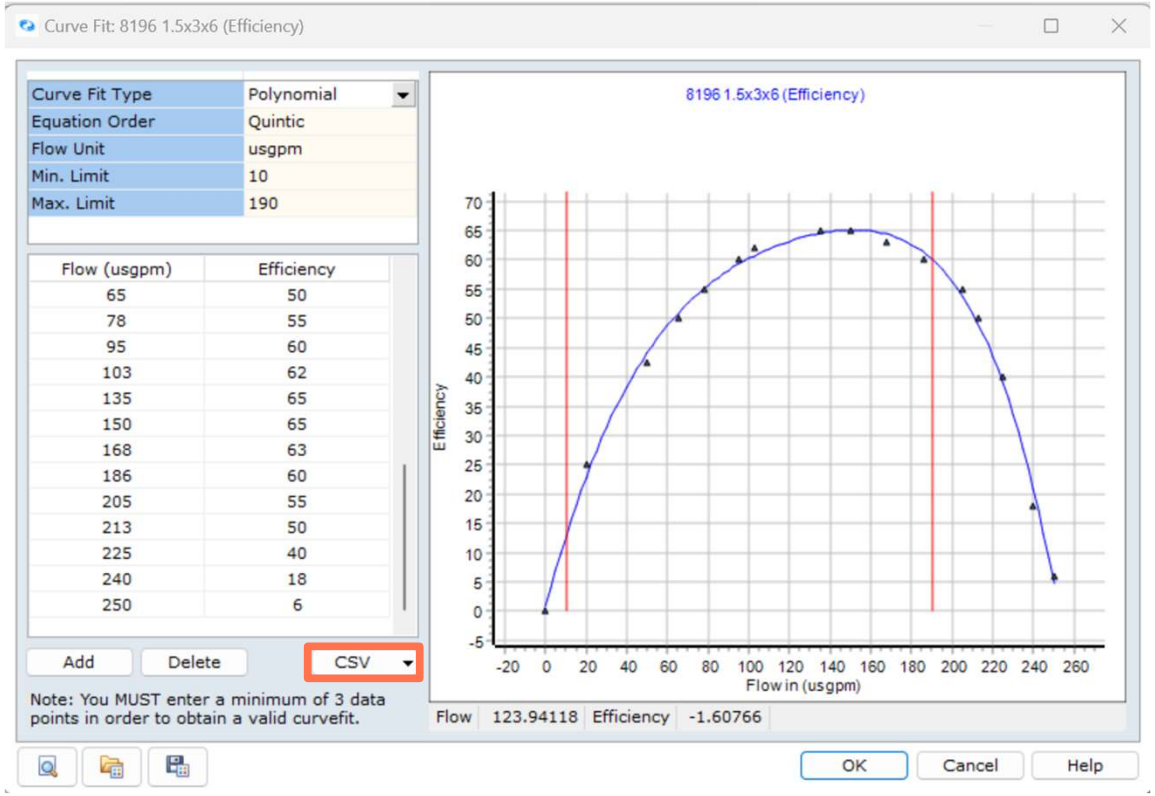
## Pump Head vs. Flow Curve






# FluidFlow Database (Boosters)

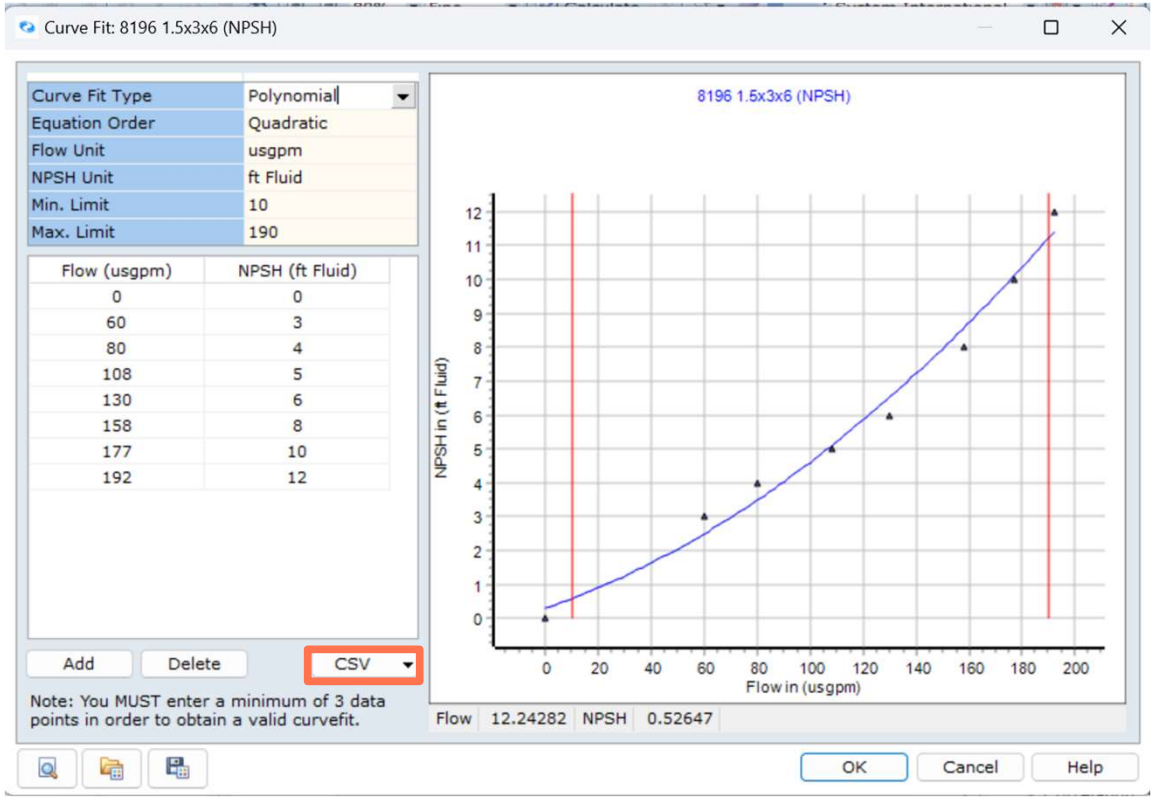
## Pump Efficiency vs. Flow Curve





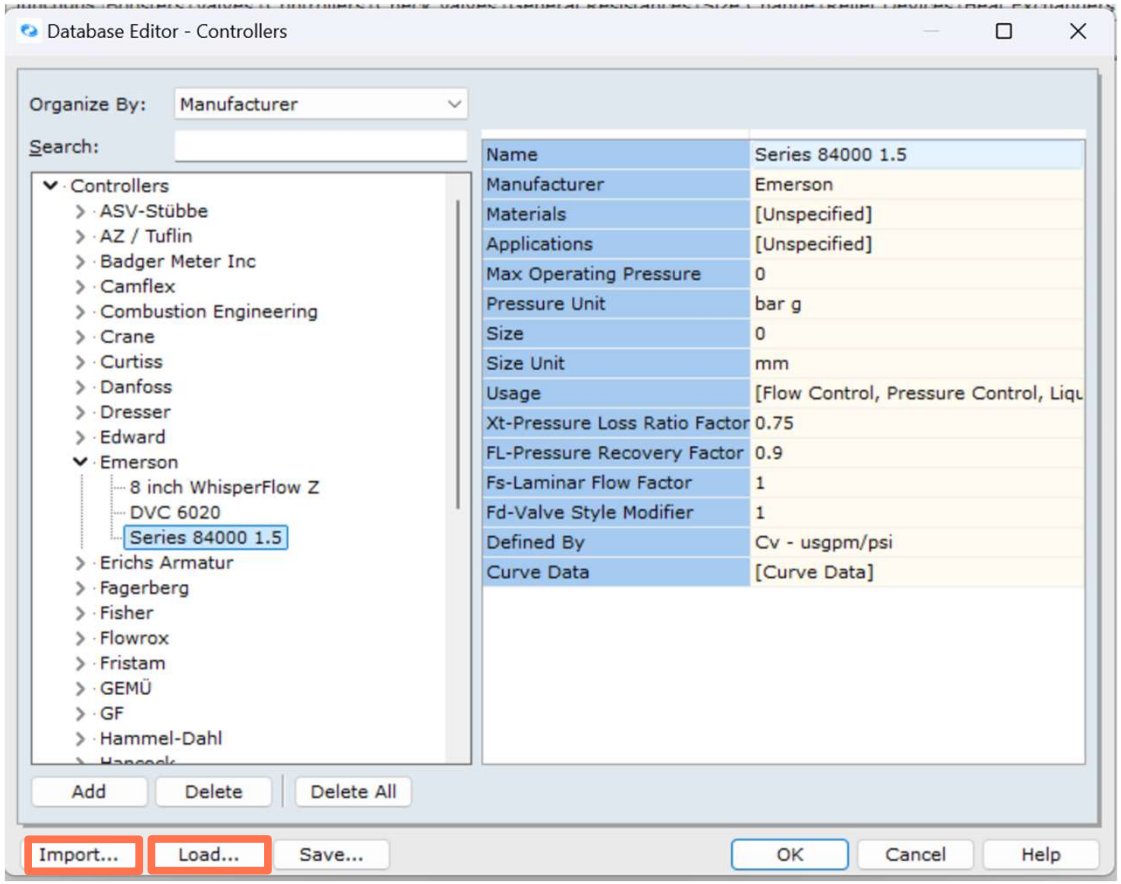

# FluidFlow Database (Boosters)

## Pump NPSHR vs. Flow Curve





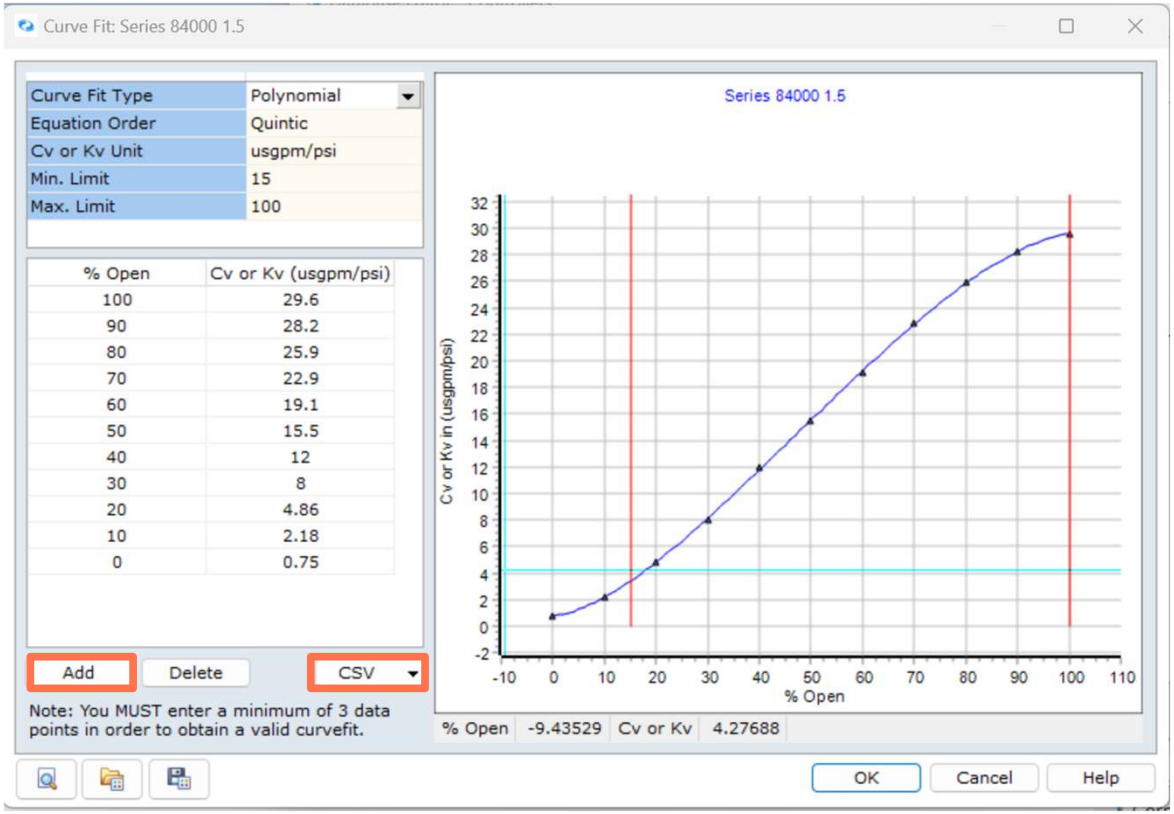

# FluidFlow Database (Control Valves)





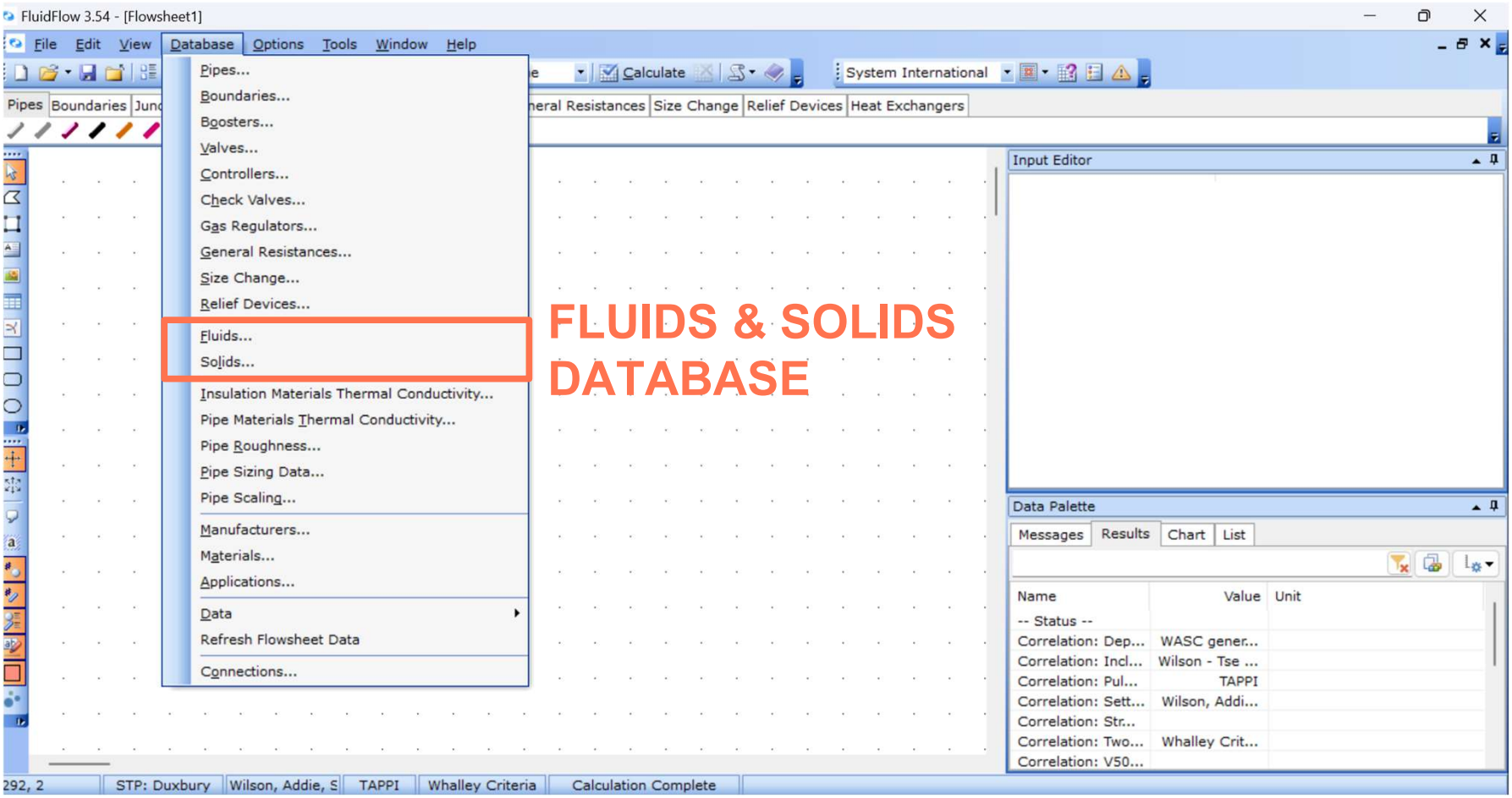

# FluidFlow Database (Control Valves)

## Cv Value vs. % Opening Curve

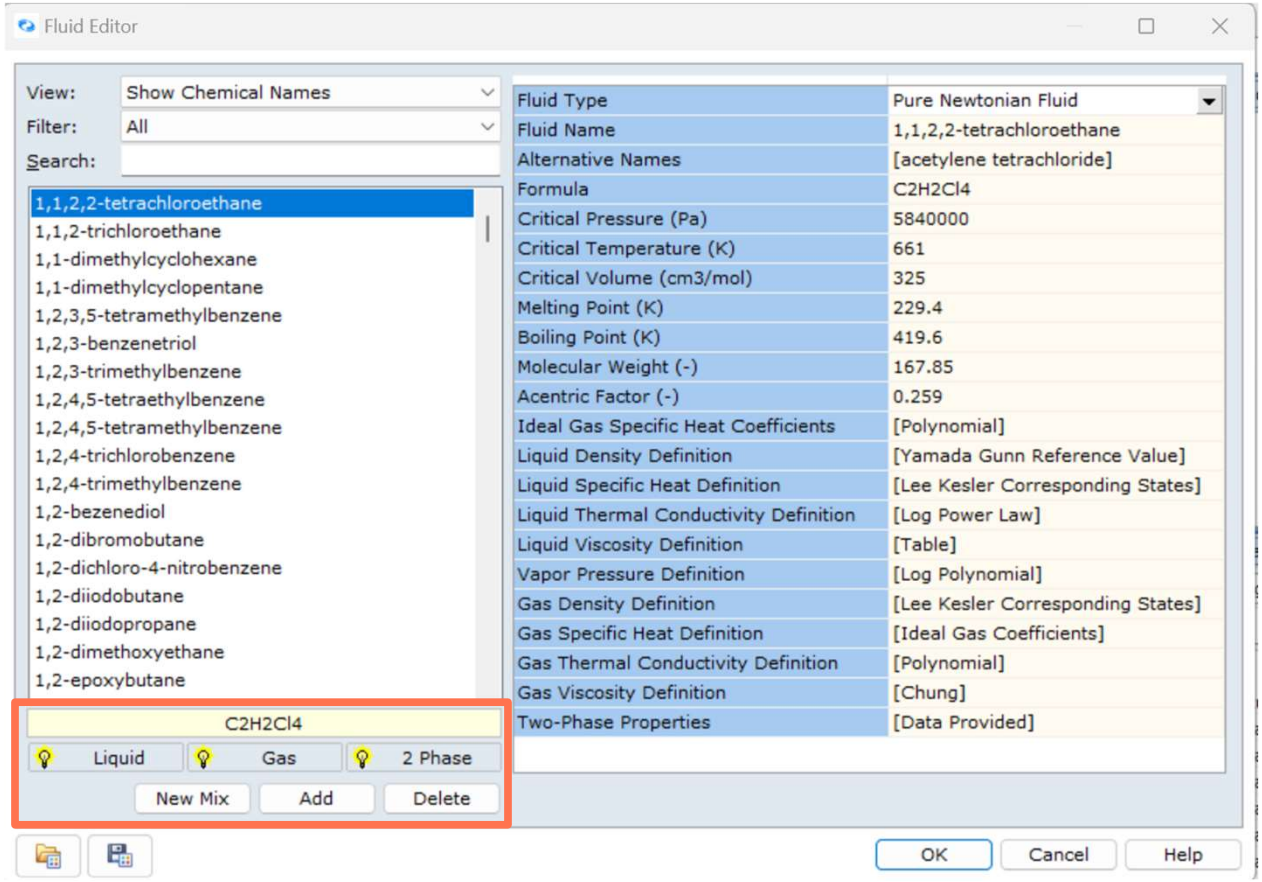





# FluidFlow Database



# FluidFlow Database (Fluids)



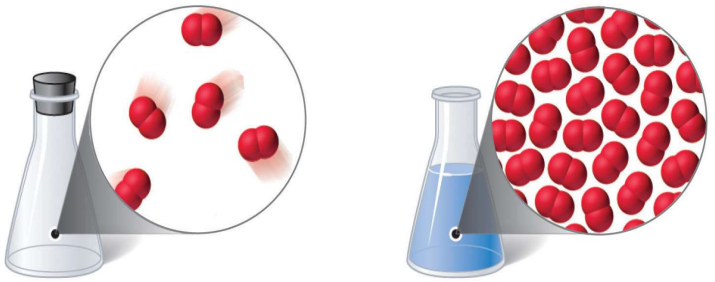
# FluidFlow Database (Fluids)

## Pure Newtonian Fluid (w/ Phase Change)

| Fluid Type | Pure Newtonian Fluid |
|---|---|
| Fluid Name | 1,1,2,2-tetrachloroethane |
| Alternative Names | [acetylene tetrachloride] |
| Formula | C2H2Cl4 |
| Critical Pressure (Pa) | 5840000 |
| Critical Temperature (K) | 661 |
| Critical Volume (cm3/mol) | 325 |
| Melting Point (K) | 229.4 |
| Boiling Point (K) | 419.6 |
| Molecular Weight (-) | 167.85 |
| Acentric Factor (-) | 0.259 |
| Ideal Gas Specific Heat Coefficients | [Polynomial] |
| Liquid Density Definition | [Yamada Gunn Reference Value] |
| Liquid Specific Heat Definition | [Lee Kesler Corresponding States] |
| Liquid Thermal Conductivity Definition | [Log Power Law] |
| Liquid Viscosity Definition | [Table] |
| Vapor Pressure Definition | [Log Polynomial] |
| Gas Density Definition | [Lee Kesler Corresponding States] |
| Gas Specific Heat Definition | [Ideal Gas Coefficients] |
| Gas Thermal Conductivity Definition | [Polynomial] |
| Gas Viscosity Definition | [Chung] |
| Two-Phase Properties | [Data Provided] |

## Simple Newtonian Liquid

| Fluid Type | Simple Newtonian Liquid |
|---|---|
| Fluid Name | Aviation Gasoline |
| Alternative Names | [] |
| Formula | N/A |
| Liquid Density Definition | [Table] |
| Liquid Specific Heat Definition | [Table] |
| Liquid Thermal Conductivity Definition | [Table] |
| Liquid Viscosity Definition | [Table] |
| Vapor Pressure Definition | [Table] |



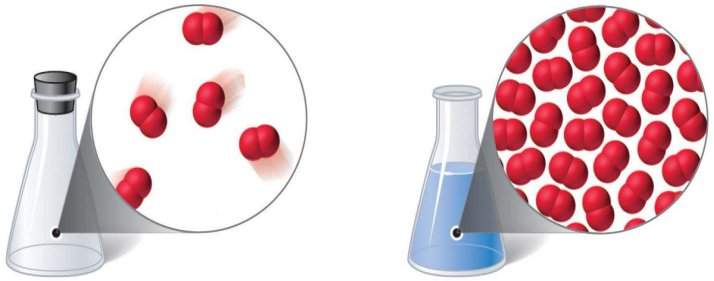
Gas

Liquid

# FluidFlow Database (Fluids)

## Non-Newtonian Liquid

| | |
|---|---|
| Fluid Type | Non Newtonian Liquid |
| Fluid Name | Honey |
| Alternative Names | [] |
| Formula | N/A |
| Liquid Density Definition | [Fixed Value] |
| Liquid Specific Heat Definition | [Fixed Value] |
| Liquid Thermal Conductivity Definition | [Fixed Value] |
| Liquid Viscosity Definition | [Non Newtonian - Power Law] |
| Vapor Pressure Definition | [As Water] |



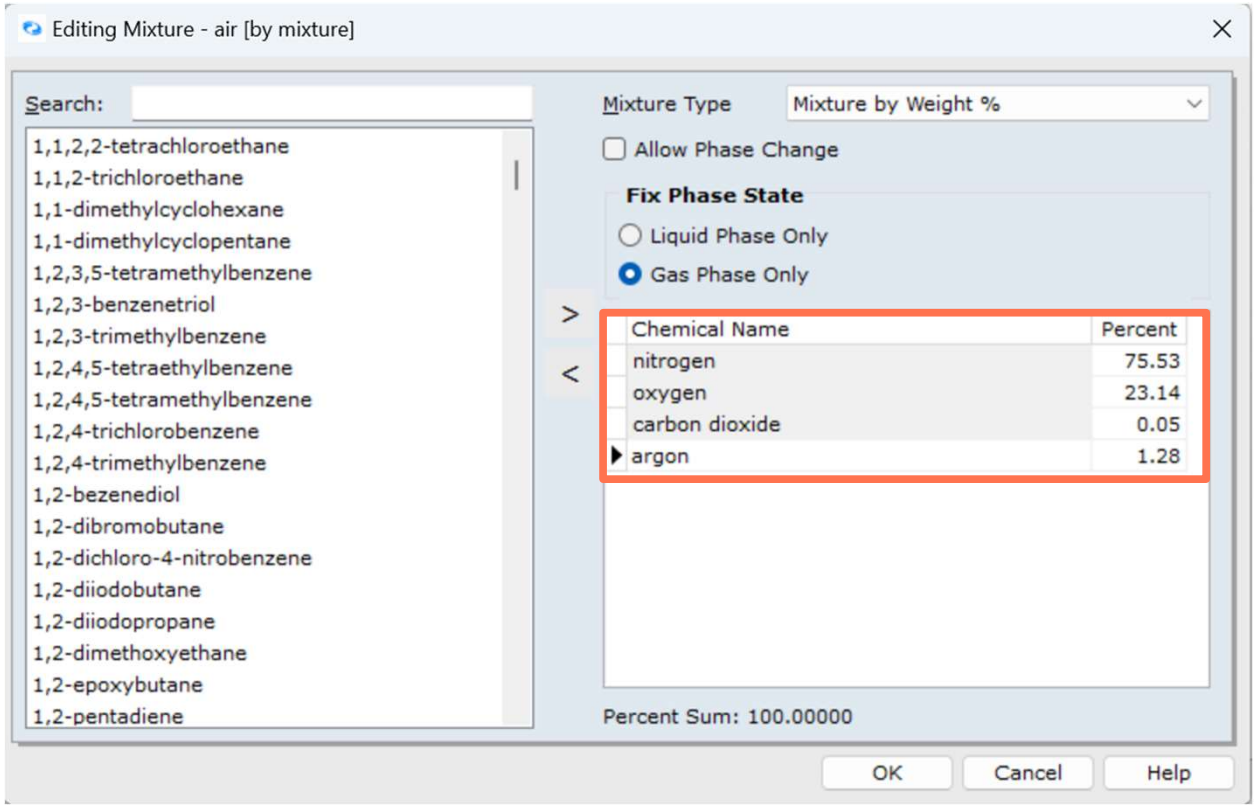
Gas Liquid

## Gas (No Phase Change)

| | |
|---|---|
| Fluid Type | Gas (No Phase Change) |
| Fluid Name | silicon tetrafluoride |
| Alternative Names | [] |
| Formula | SiF4 |
| Critical Pressure (Pa) | 3719000 |
| Critical Temperature (K) | 259 |
| Critical Volume (cm3/mol) | 165 |
| Molecular Weight (-) | 104.079 |
| Acentric Factor (-) | 0.385 |
| Ideal Gas Specific Heat Coefficients | [Polynomial] |
| Gas Density Definition | [BWR HS EOS] |
| Gas Specific Heat Definition | [Ideal Gas Coefficients] |
| Gas Thermal Conductivity Definition | [Polynomial] |
| Gas Viscosity Definition | [Polynomial] |

# FluidFlow Database (Fluids)

## Mixture by Weight % / Mole %



# FluidFlow Database (Fluids)

## Petroleum Fraction or Crude

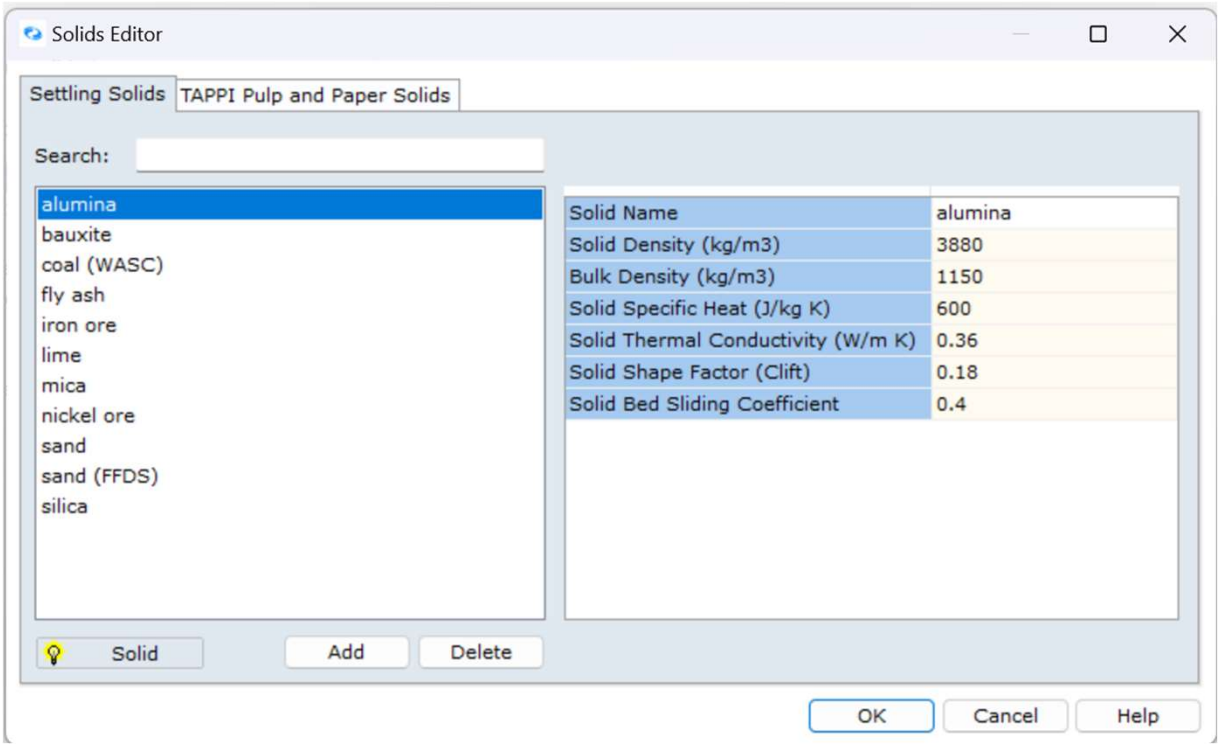
| | |
|---|---|
| Fluid Type | Petroleum Fraction or Crude |
| Fluid Name | kerosene |
| Alternative Names | [] |
| Formula | N/A |
| Specific Gravity of Liquid at 288.65K | 0.82 |
| Boiling Point Curve Definition | [ASTM D86] |
| Critical Pressure (Pa) | [ Estimated Value = 2147316 ] |
| Critical Temperature (K) | [ Estimated Value = 679.6 ] |
| Critical Volume (cm3/mol) | [ Estimated Value = 638.1 ] |
| Boiling Point (K) | [ Estimated Value = 496.86 ] |
| Molecular Weight (-) | [ Estimated Value = 174.608 ] |
| Acentric Factor (-) | [ Estimated Value = 0.5580 ] |
| Watson K Factor (-) | [ Estimated Value = 11.723 ] |
| Liquid Density Definition | [Spencer Danner] |
| Liquid Specific Heat Definition | [Lee Kesler Corresponding States] |
| Liquid Thermal Conductivity Definition | [Sato Riedel] |
| Liquid Viscosity Definition | [Moharam, Al-Mehaideb and Fahim] |
| Vapor Pressure Definition | [Lee Kesler] |
| Gas Density Definition | [Peng Robinson EOS] |
| Gas Specific Heat Definition | [Lee Kesler Corresponding States] |
| Gas Thermal Conductivity Definition | [Chung] |
| Gas Viscosity Definition | [Chung] |





# FluidFlow Database (Solids)

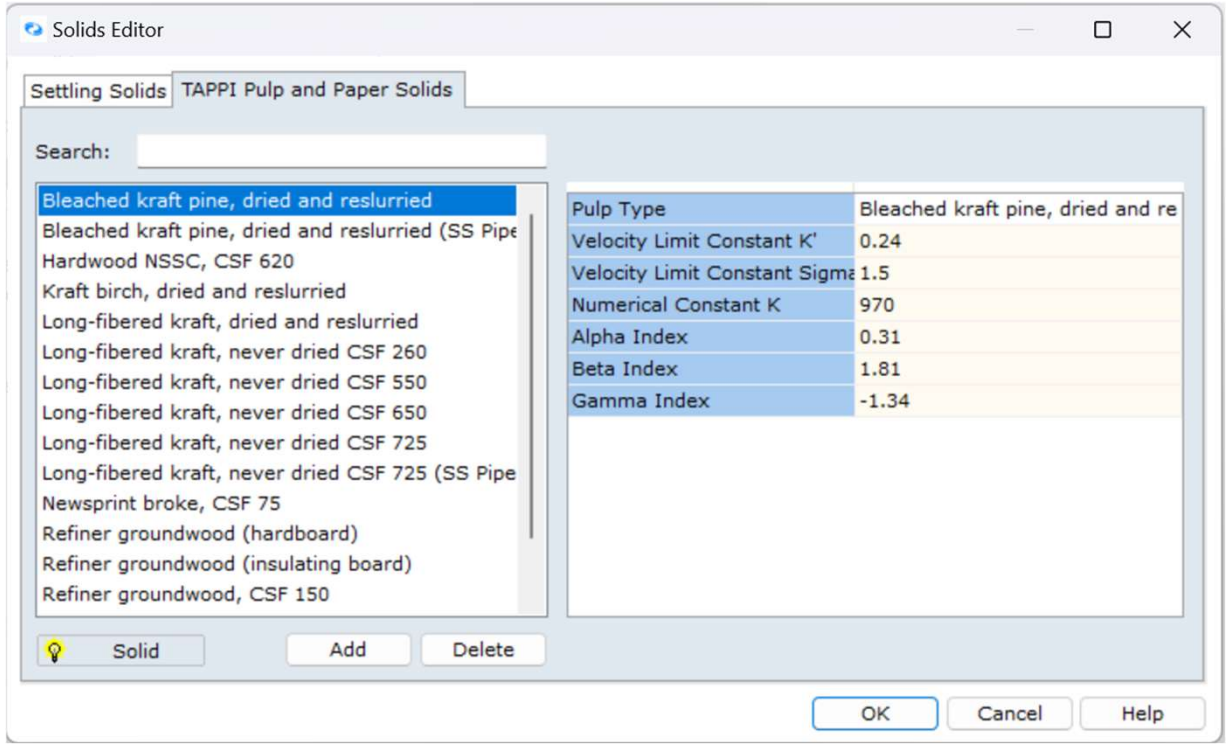
## Settling Solids





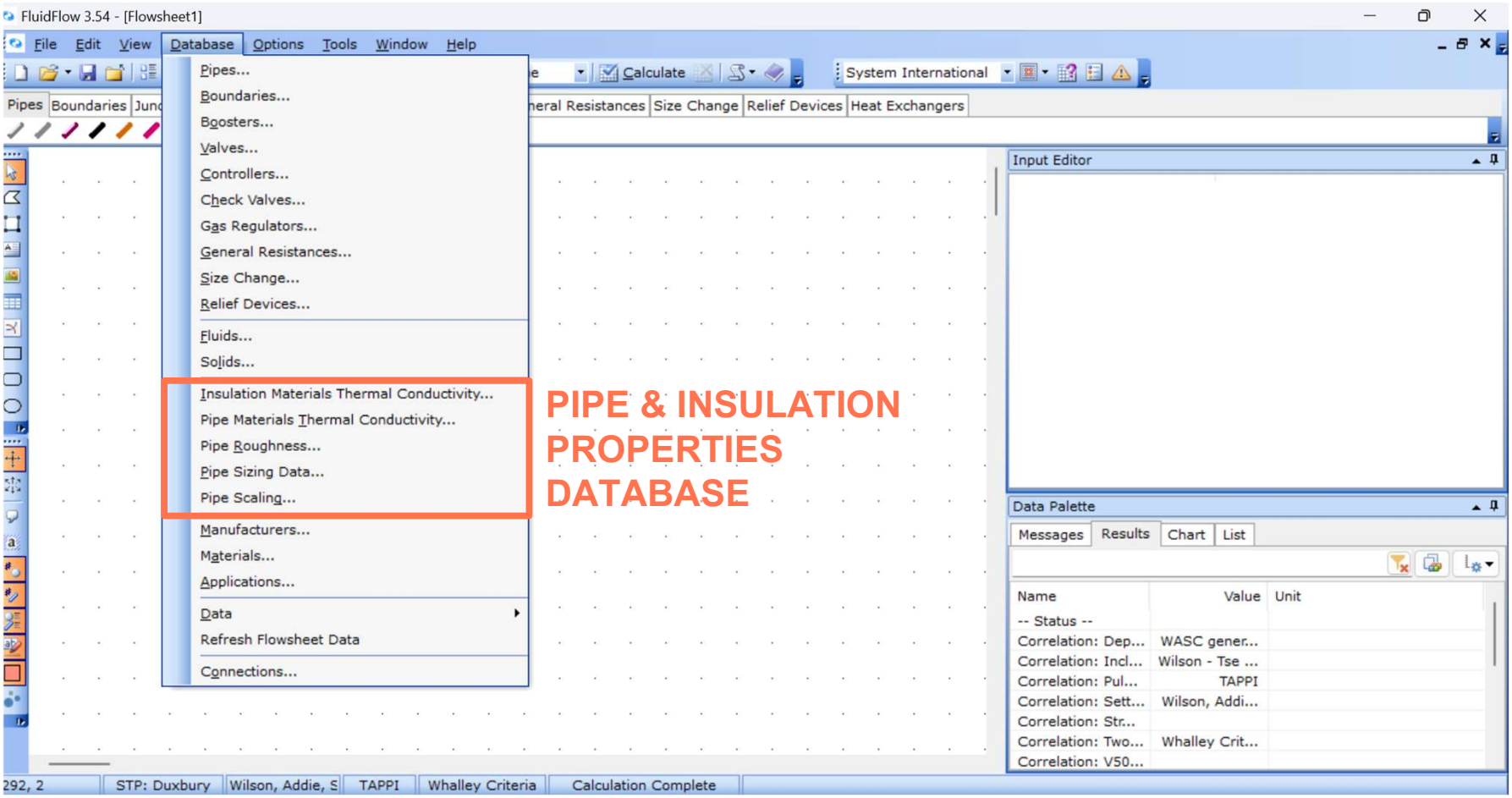

# FluidFlow Database (Solids)

## TAPPI Pulp and Paper Solids



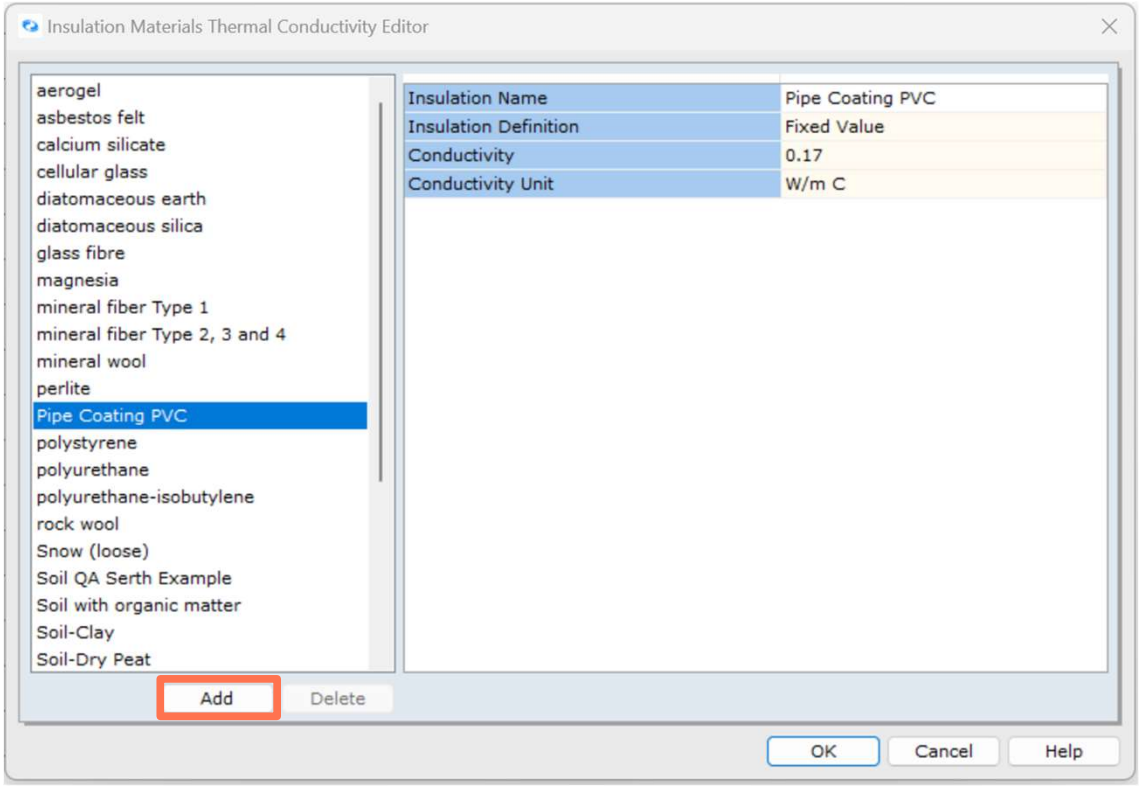



# FluidFlow Database (Pipe & Insulation Properties)



# FluidFlow Database (Pipe & Insulation Properties)

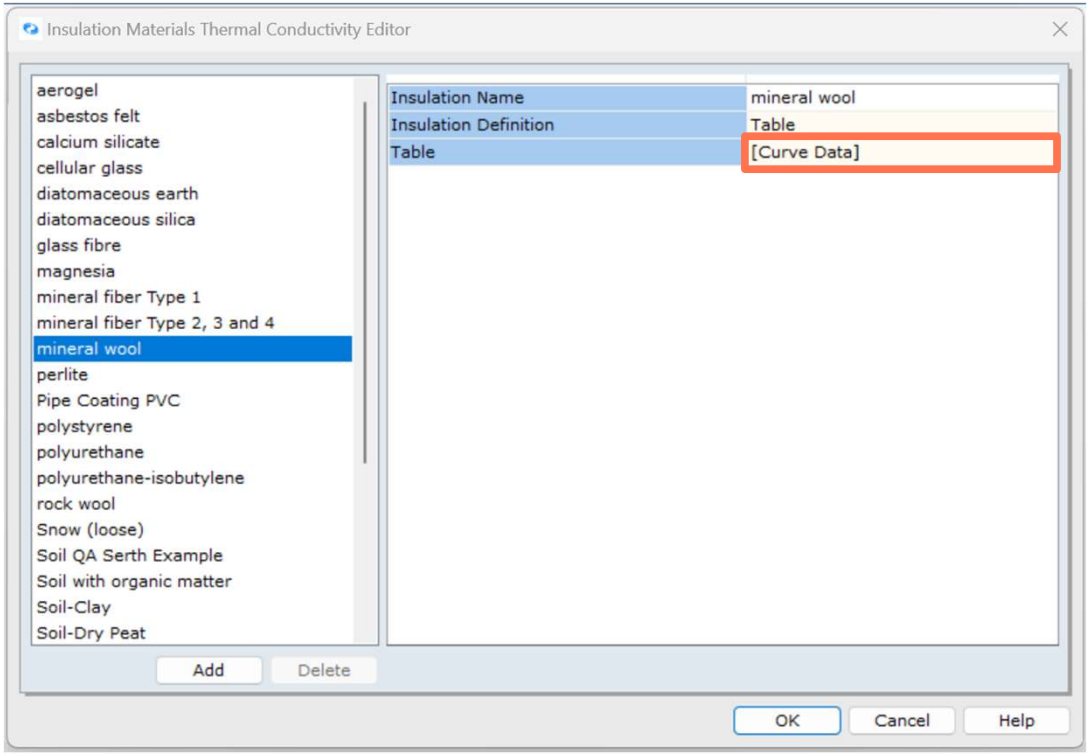
## Insulation Materials Thermal Conductivity

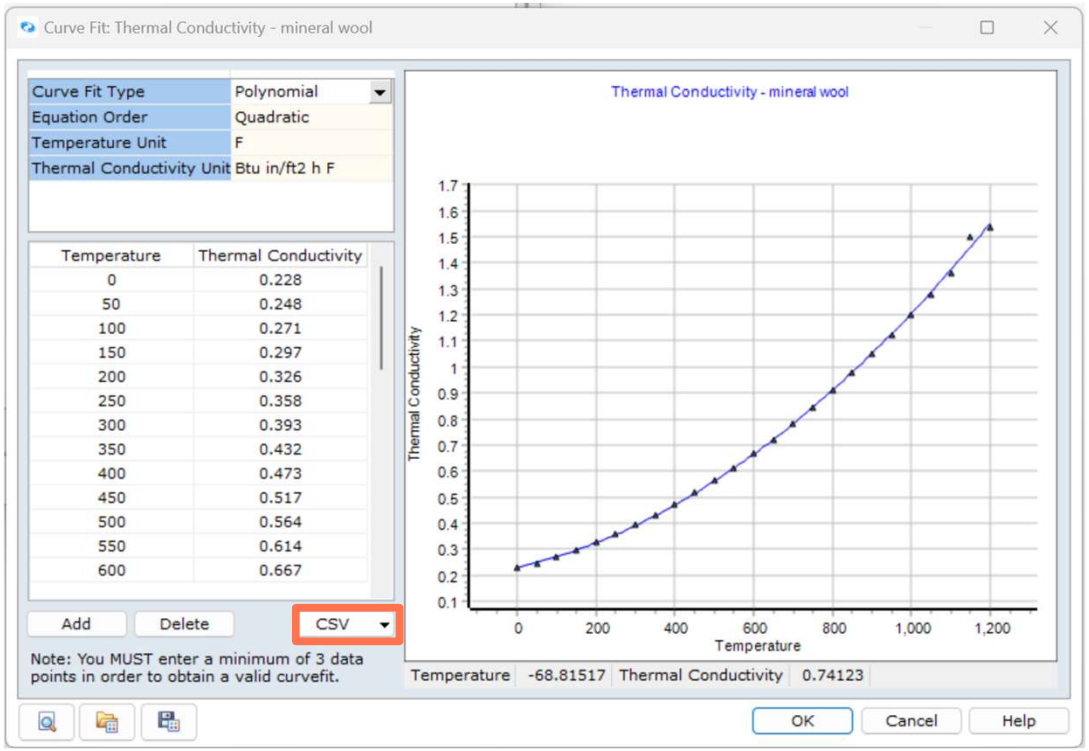





# FluidFlow Database (Pipe & Insulation Properties)

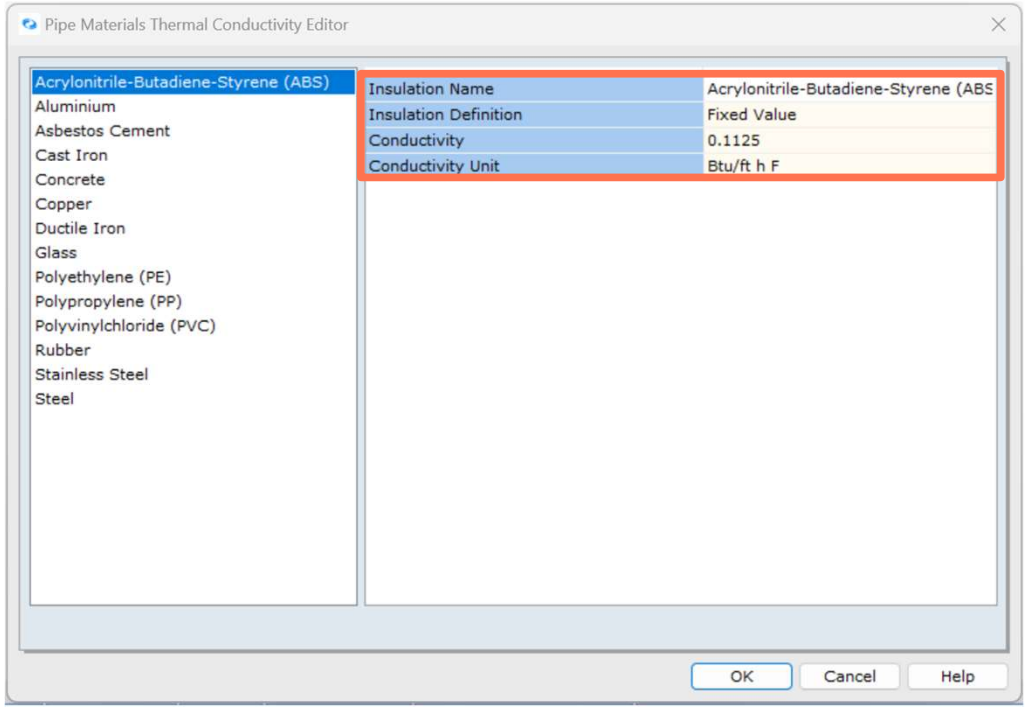
## Insulation Materials Thermal Conductivity



# FluidFlow Database (Pipe & Insulation Properties)

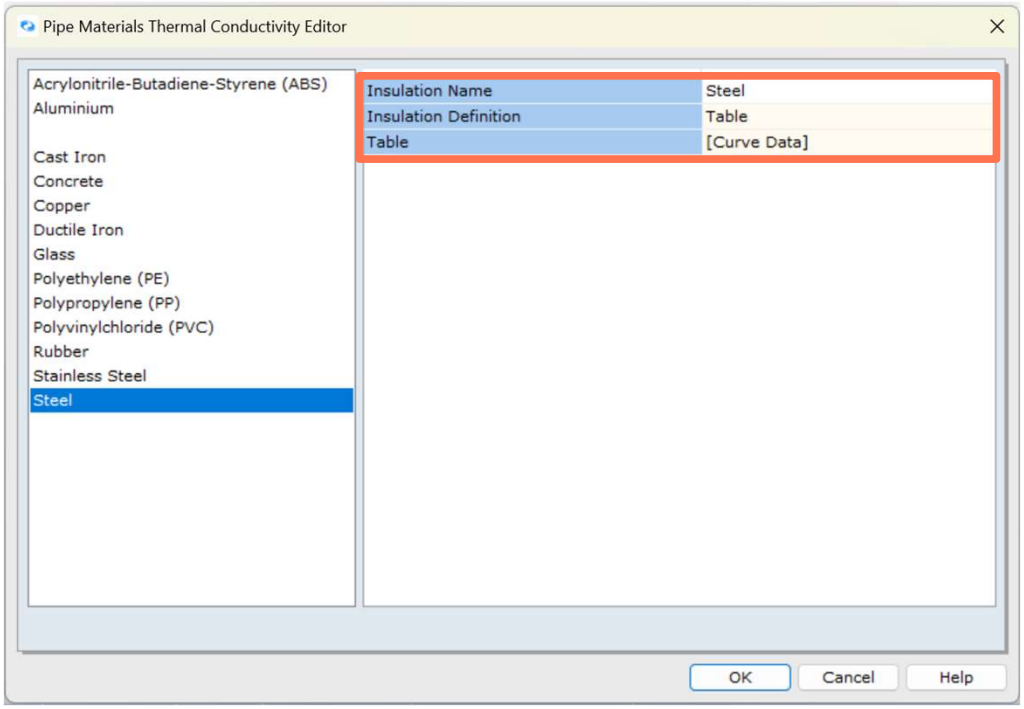
## Pipe Materials Thermal Conductivity (Fixed Value)

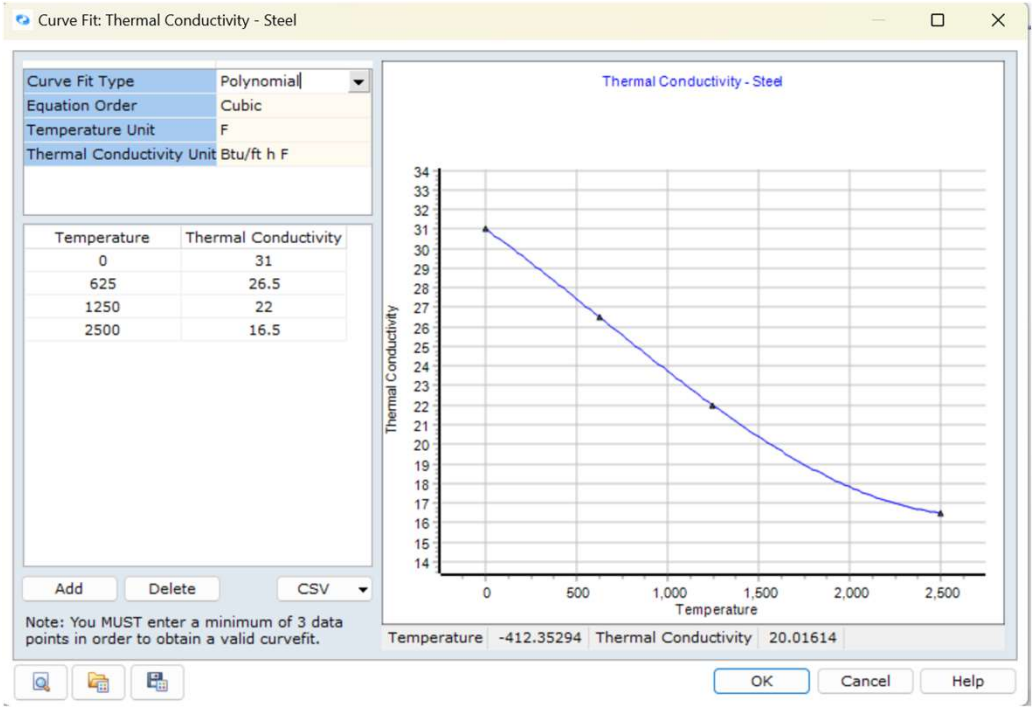





# FluidFlow Database (Pipe & Insulation Properties)

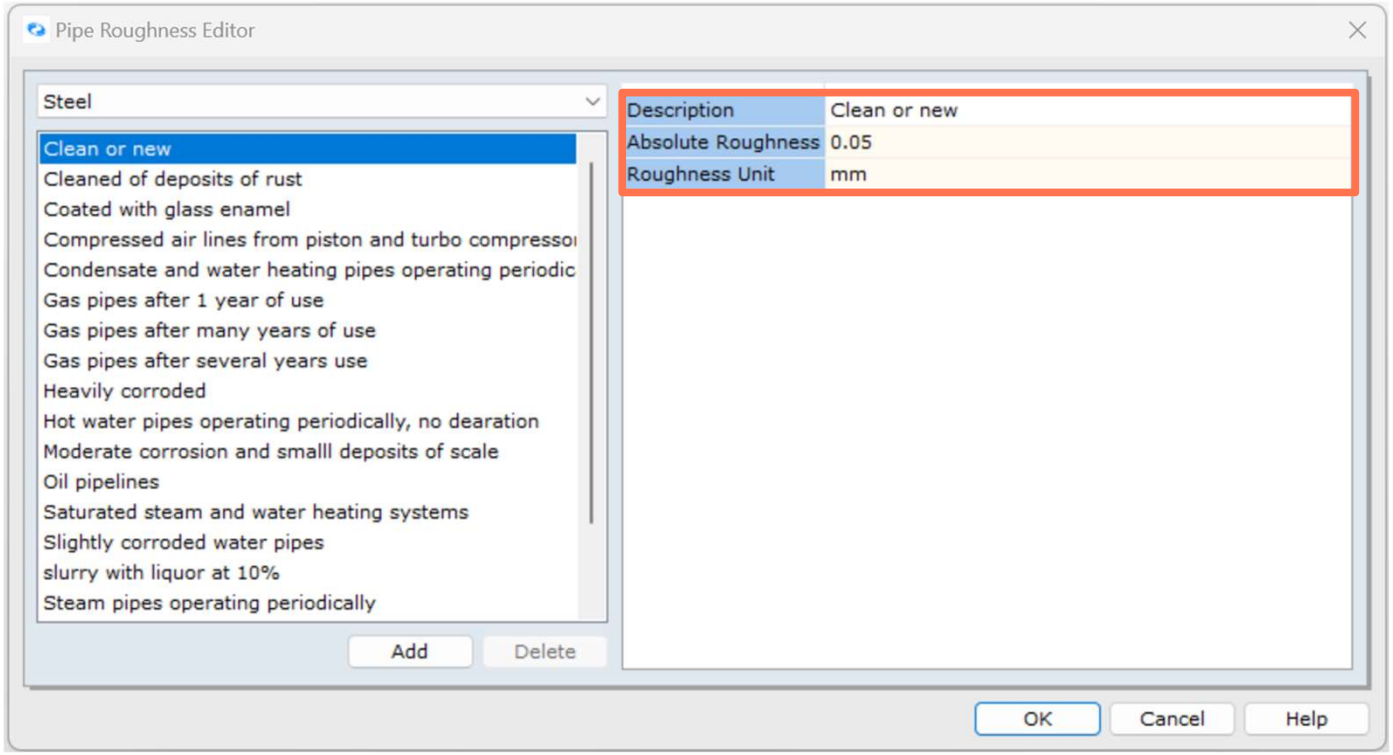
## Pipe Materials Thermal Conductivity (Curve Data)

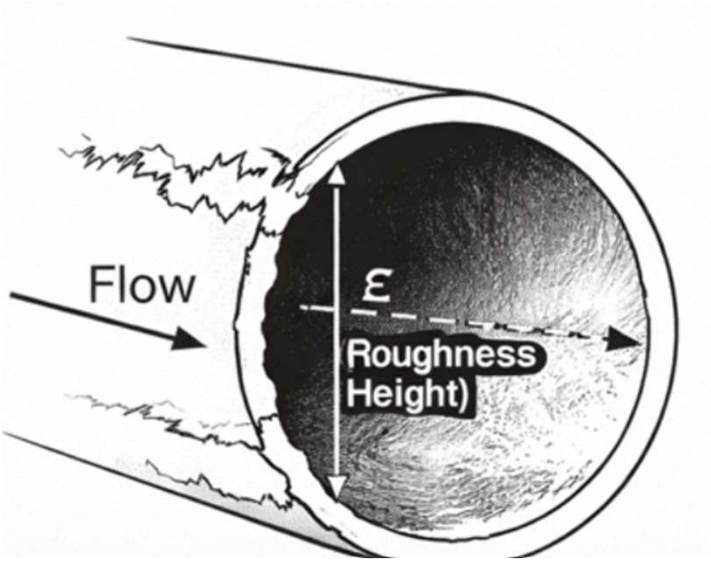


# FluidFlow Database (Pipe & Insulation Properties)

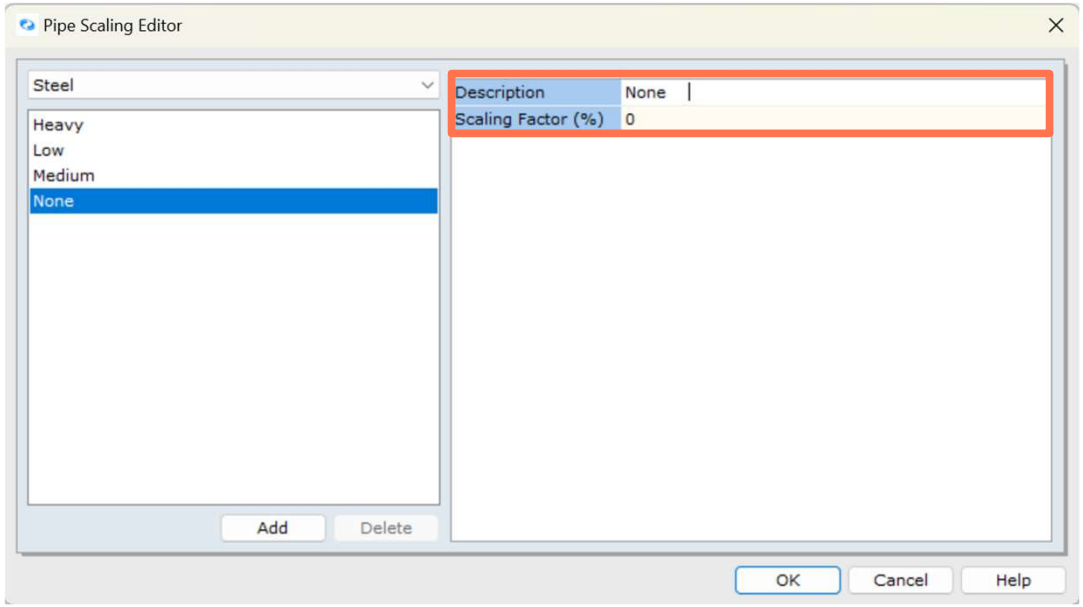
## Pipe Roughness

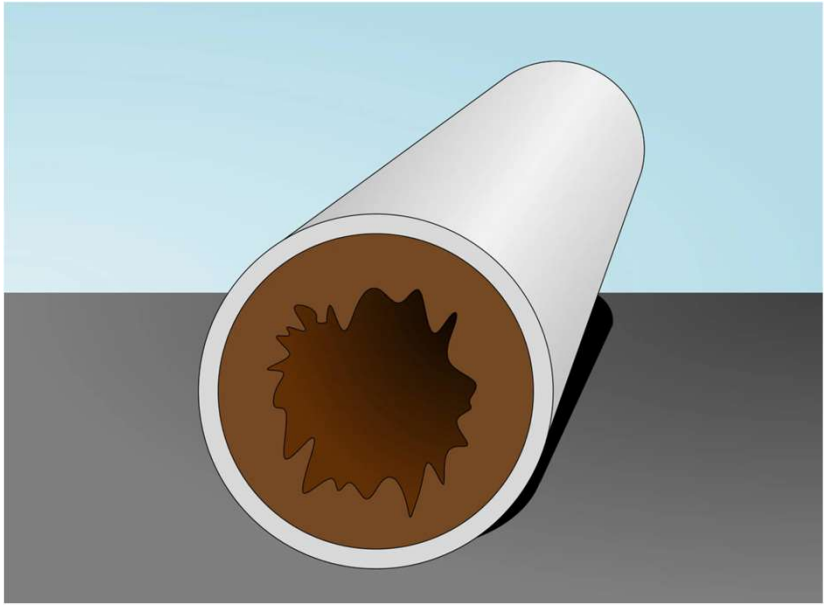


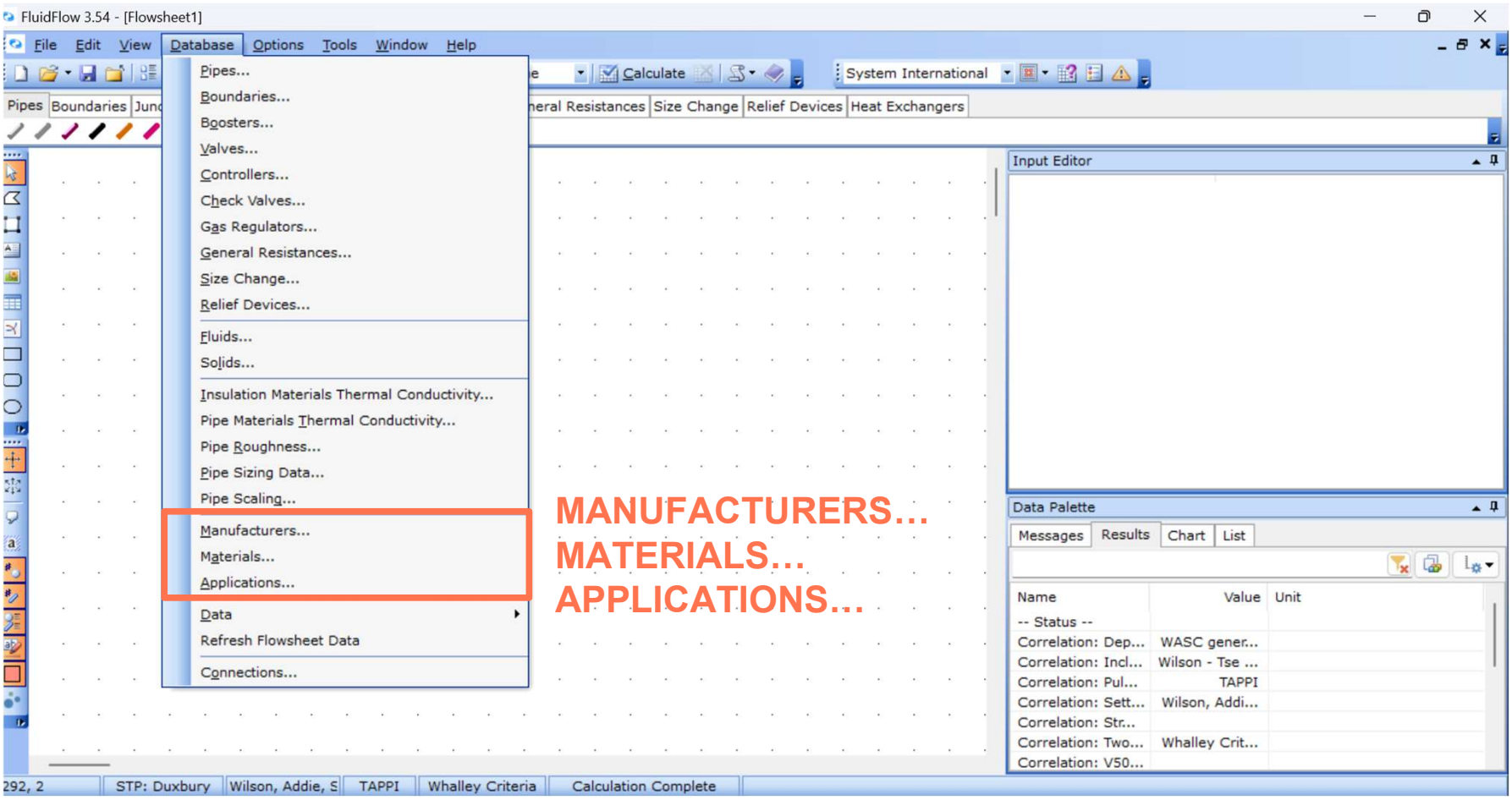
# FluidFlow Database (Pipe & Insulation Properties)

## Pipe Scaling



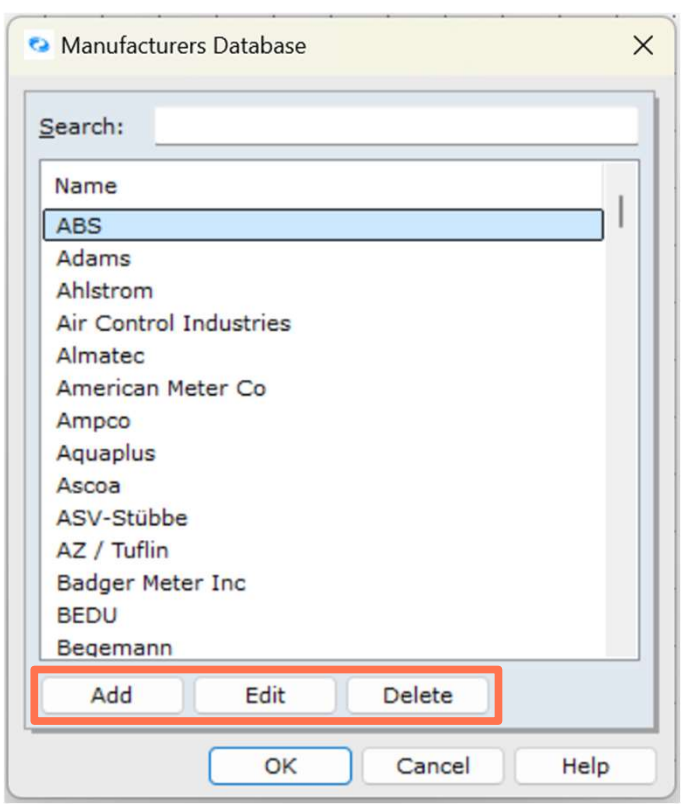



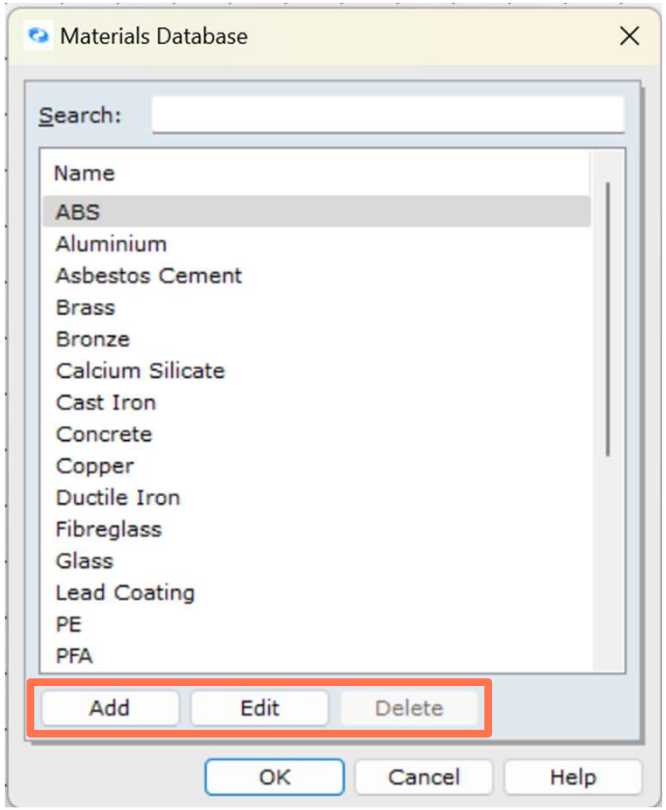
# FluidFlow Database

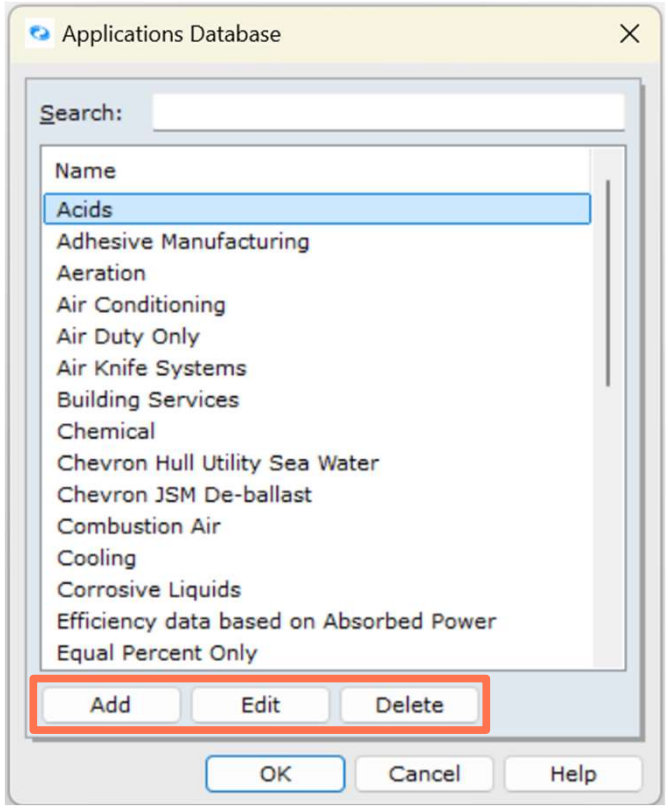


# FluidFlow Database

## Manufacturers, Materials, & Applications Database



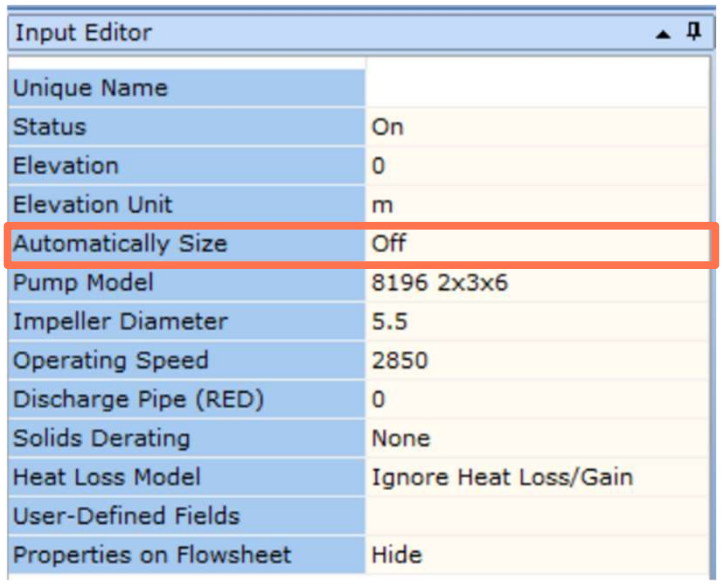



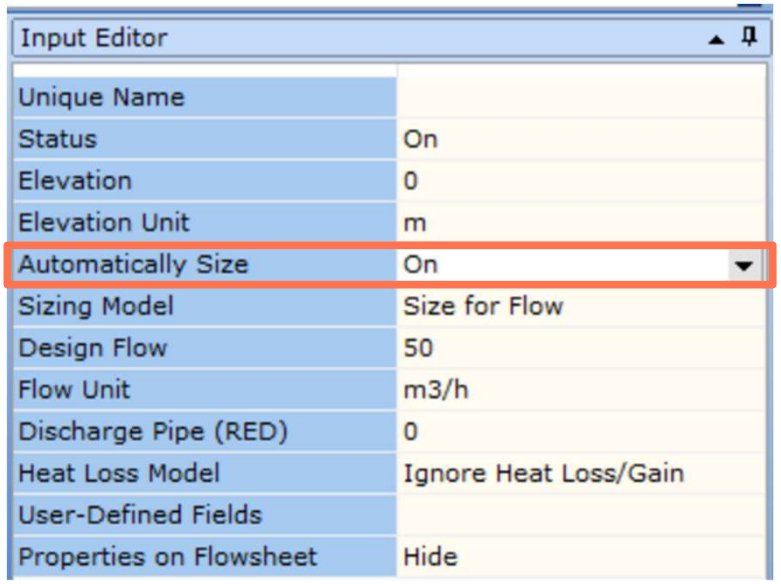
# FLUIDFLOW DESIGN AND RATING CASE MODE

# FluidFlow Design and Rating Case Mode

## Auto Size Feature

- Automatically Size: Set ***Off*** by default. When set to ***On***, **FluidFlow** allows engineers to auto-size the components



# FluidFlow Design and Rating Case Mode

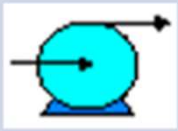
## Auto Size Feature

- **Design (Auto-size On):** a **certain parameter (flow rate, pressure rise, pressure drop, etc.) is specified**, and the necessary **component/equipment is designed** such that the specification is met.

- **Rating (Auto-size Off):** the **component/equipment from vendor data is specified (it may be new or existing)** and the **performance is rated**.

# FluidFlow Design and Rating Case Mode

## Auto Size Feature

| Object | Icon | Sizing Model | Solve For |
|---|---|---|---|
| Centrifugal Pump |  | Size for Flow | Duty Pressure Rise |
| | | Size for Pressure Rise | Duty Flow |
| Rotating Positive Displacement Pump |  | Size for Flow | Duty Pressure Rise |
| Fan or Compressor |  | Size for Flow | Duty Pressure Rise |
| | | Size for Pressure Rise | Duty Flow |
| Positive Displacement Pump or Compressor |  | Size for Flow | Duty Pressure Rise |

# FluidFlow Design and Rating Case Mode

## Auto Size Feature

| Object | Icon |
|---|---|
| Self Acting Pressure Reducer |  |
| Self Acting Pressure Sustainer |  |
| Self Acting Differential Pressure Controller |  |
| Flow Control Valve |  |
| Pressure Control Valve |  |

- ❑ Autosizing Controllers solves for the Control Valve Cv
- ❑ Pressure variable for controllers are at static pressure

# FluidFlow Design and Rating Case Mode

## Auto Size Feature

| Object | Icon | Sizing Model | Solve For |
|---|---|---|---|
| Thin Orifice |  | Size for Flow | Bore Size |
| | | Size for Pressure Loss | |
| Thick Orifice |  | Size for Flow | |
| | | Size for Pressure Loss | |
| Inline Nozzle |  | Size for Flow | Throat Size |
| | | Size for Pressure Loss | |
| Venturi Tube |  | Size for Flow | |
| | | Size for Pressure Loss | |

# FluidFlow Design and Rating Case Mode

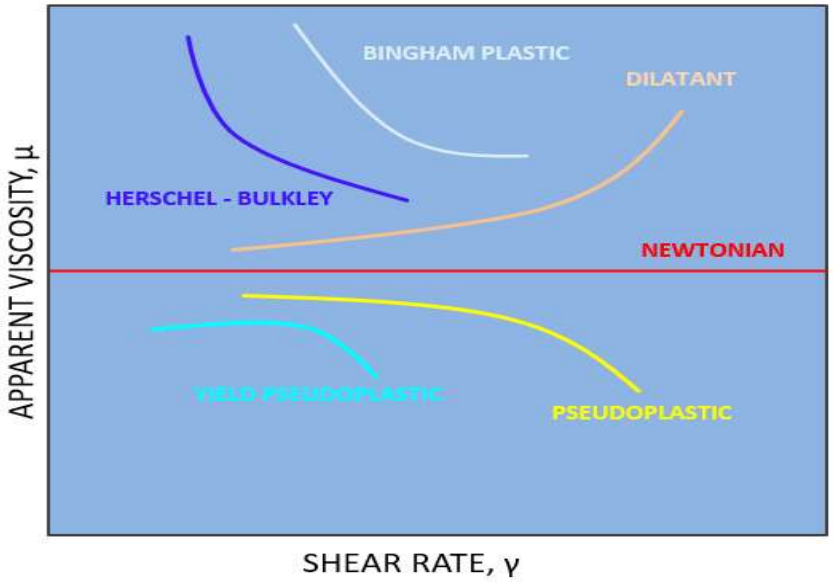
## Auto Size Feature

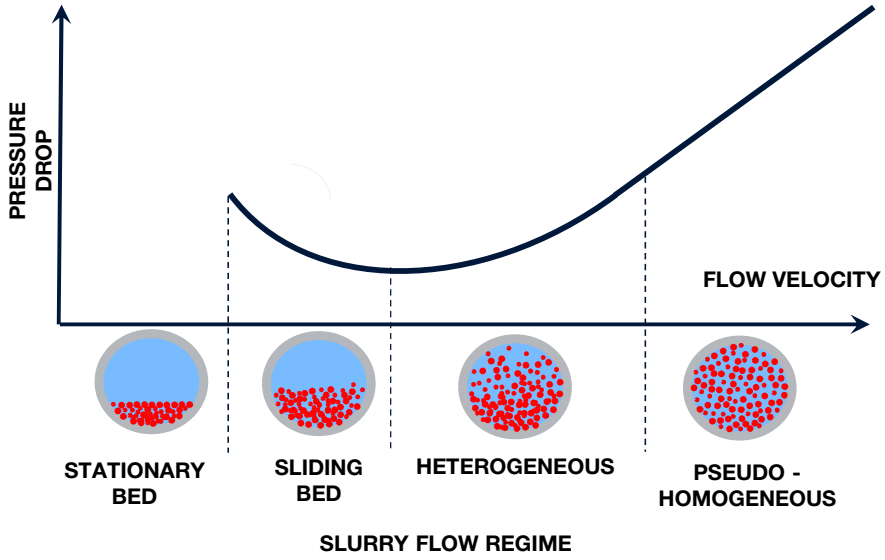
| Object | Icon | Pressure Loss Model | Solve For |
|---|---|---|---|
| Relief Valve |  | API RP520 Part 1 | Orifice Size |
| | | ISO 4126 - 1 | |

# FLUIDFLOW
# SLURRY MODULE

# Why slurry flows are complex?

- Slurry viscosity may increase or decrease as flow is increased, it does not follow Newton's law on viscosity
- Liquid-solid-pipe wall interaction demonstrate non-linear pressure loss profile




- FluidFlow simplifies the sophistication in Modeling and analyzing slurries

# FluidFlow Slurry Module



# Slurry Module

- Enable FluidFlow users to develop hydraulic models dealing with slurries made up of non-Newtonian fluids or liquid-solid settling mixtures
- Model wide range of systems such as:
  - Mine tailings facility
  - Metal concentrate processing plant
  - Hydro-transportation of ores and minerals
  - Dredging and waste systems
  - Fast Moving Consumer Goods process plants
  - Pharmaceutical flow systems
  - Petrochemicals / Polymer process facilities
  - Pulp and paper stock flow systems
- Utilizes the solid database for slurries and pulp and paper stock systems
- Requires simultaneous activation with the liquid module

# Slurry Module Parts

➢ **Homogeneous / Non-settling / Non-Newtonian slurries**




➢ **Heterogeneous / Settling slurries**



# Homogeneous / Non-Settling Slurries



# Homogeneous Slurries

- Occurs across industries such as food processing, petrochemical and polymer plants, fast moving consumer goods process plants, pharmaceuticals, mining and wastewater
- Solid-liquid mixtures behaving as “entirely liquid” due to full suspension of particles
- Behaves as non-Newtonian liquid
- Viscosity varies as the fluid flows and experience shearing across a system
- Challenging to simulate as it requires rheology data and characterization to model fluid behavior



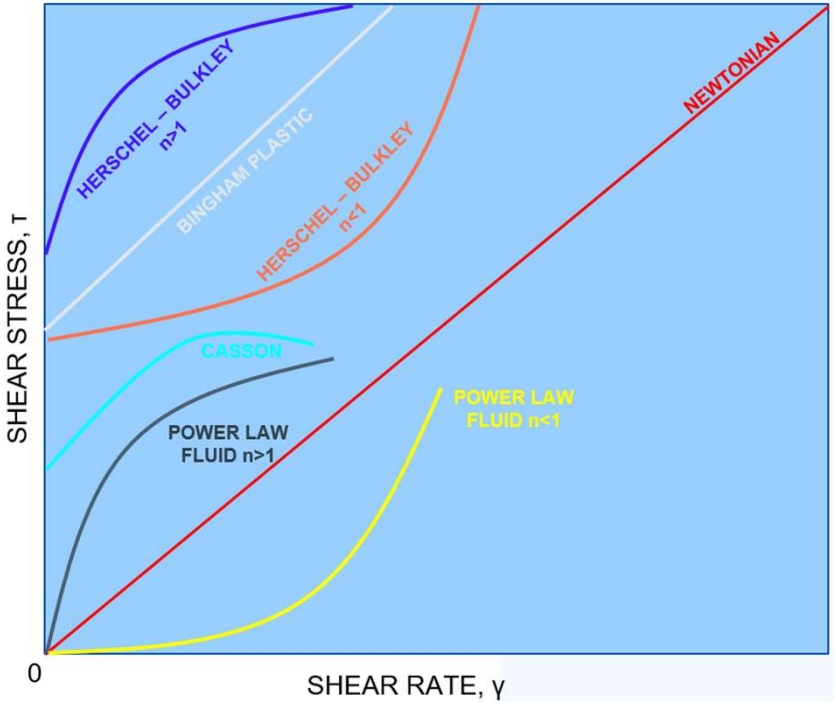
# Homogeneous Slurries

➢ **Rheological data are converted to any of the following rheology models to model flow behavior:**

| | |
|---|---|
| **Herschel – Bulkley** | **Shear Stress ($\tau$) = $\tau_y$ + K $\dot{\gamma}^n$** |
| **Power Law** | **Shear Stress, $\tau$ = K $\dot{\gamma}^n$** |
| **Bingham Plastic** | **Shear Stress, $\tau$ = $\tau_y$ + $\eta_P$ $\dot{\gamma}$** |
| **Casson** | **Shear Stress, $\tau^{0.5}$ = $\tau_{yc}^{0.5}$ + $\eta_c$ $\dot{\gamma}^{0.5}$** |

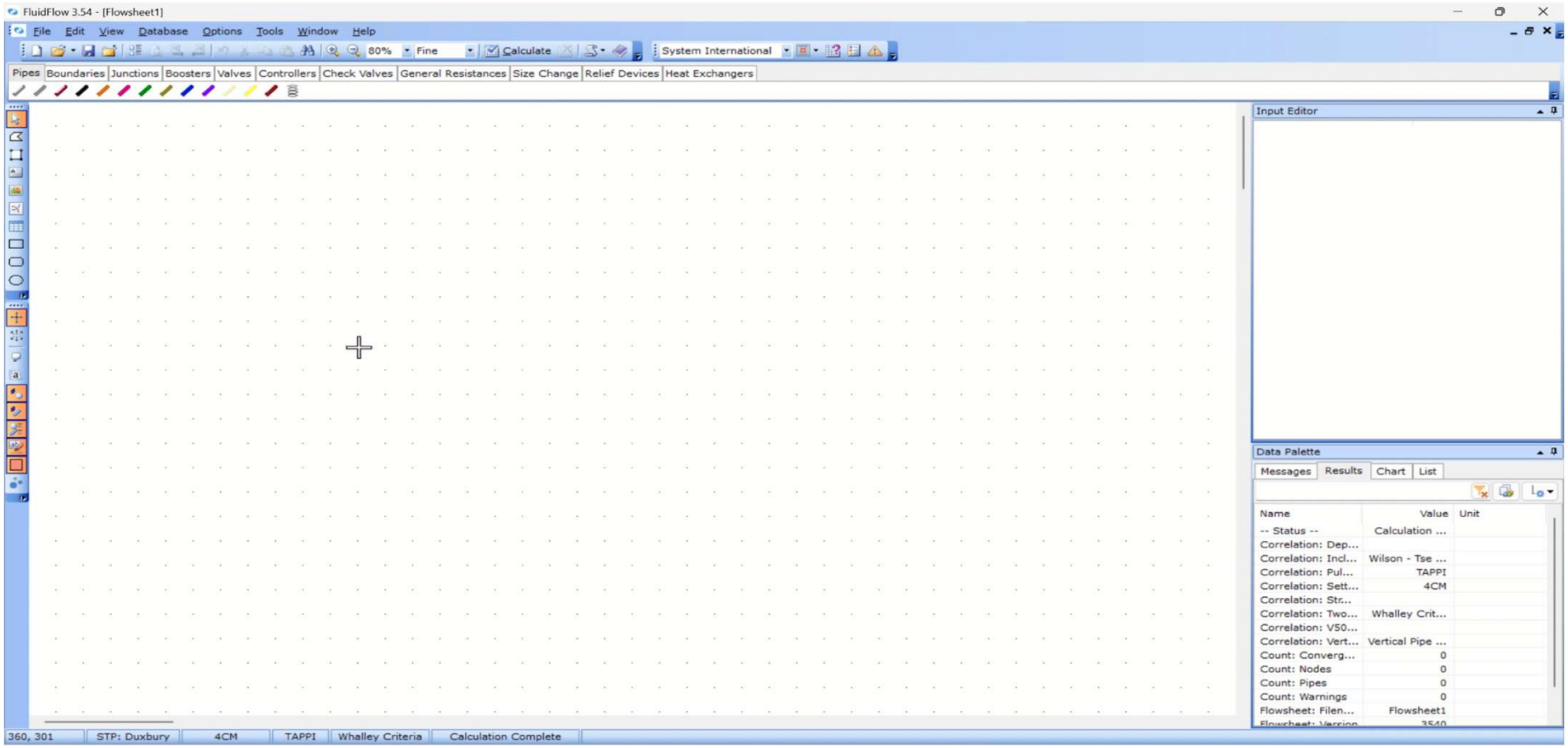
**Where:**

| | |
|---|---|
| $\tau$ | **Shear stress** |
| $\tau_y$ | **Yield stress** |
| **K** | **Consistency coefficient** |
| $\dot{\gamma}$ | **Shear rate, (du/dy)** |
| **n** | **Herschel-Bulkley coefficient or index / Power Law exponent** |
| $\eta_P$ | **Plastic viscosity or coefficient of rigidity** |
| $\eta_c$ | **Casson viscosity** |



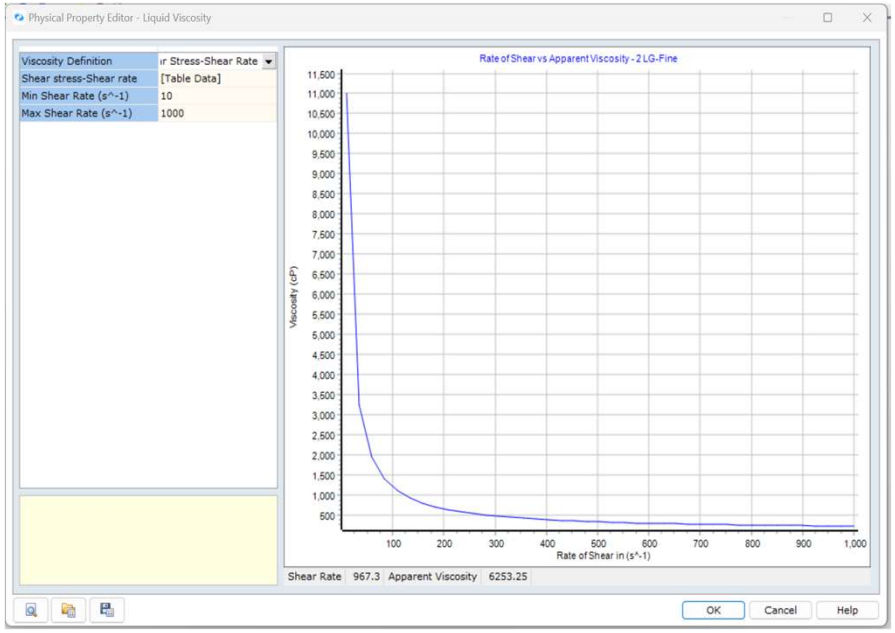

➢ **Each rheology model utilizes distinct pressure loss correlations**

# Homogeneous Slurries

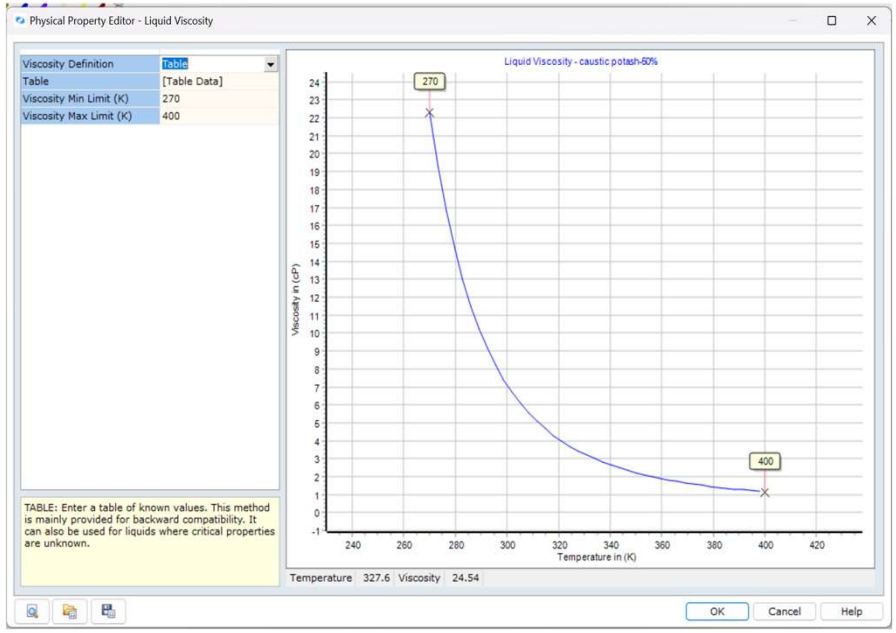


# Homogeneous Slurries

- Fluid editor physical property fields of non-Newtonian and simple Newtonian liquids are similar
- Viscosity representation is not the same:




Non-Newtonian Viscosity

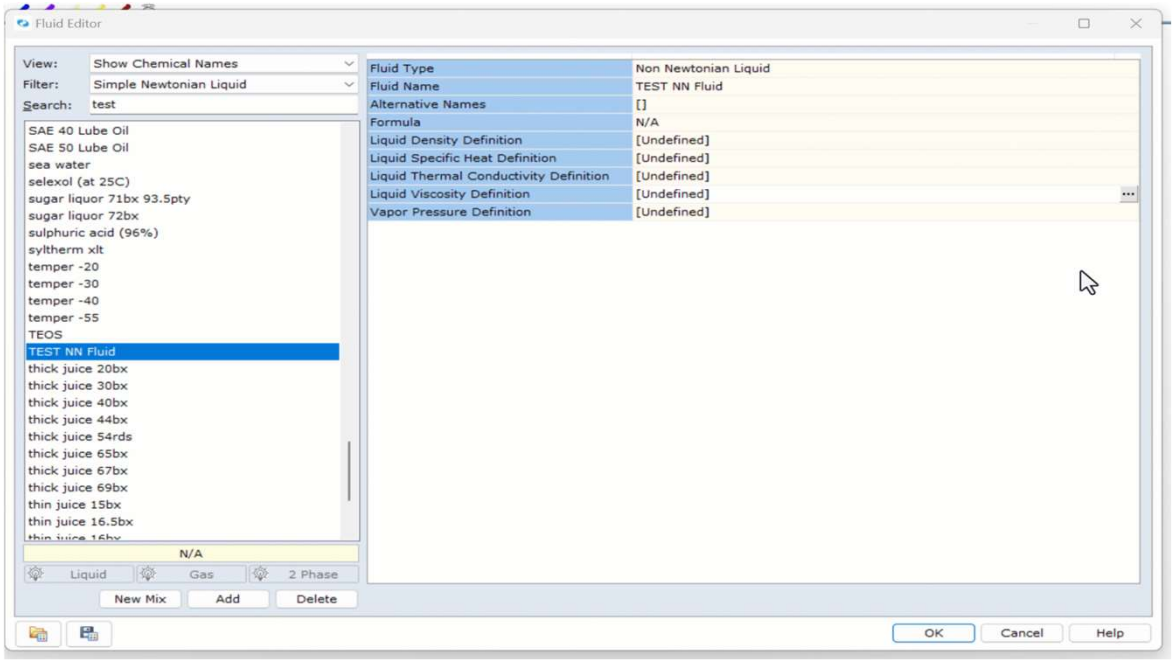



Newtonian Viscosity

# Homogeneous Slurries

➢ **Non-Newtonian viscosity can be defined as:**

- **Directly Defined Constants**
- **Shear Rate vs. Shear Stress Tabulated Data**

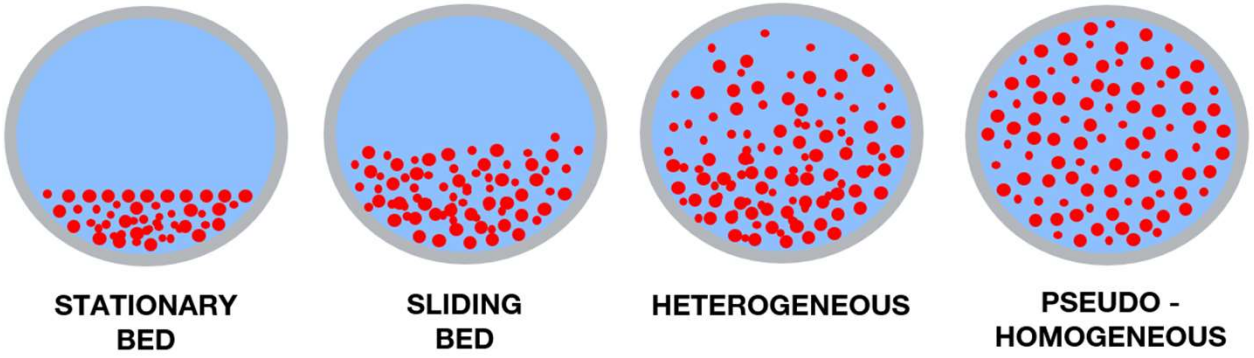


# Heterogeneous / Settling Slurries



# Heterogeneous Slurries

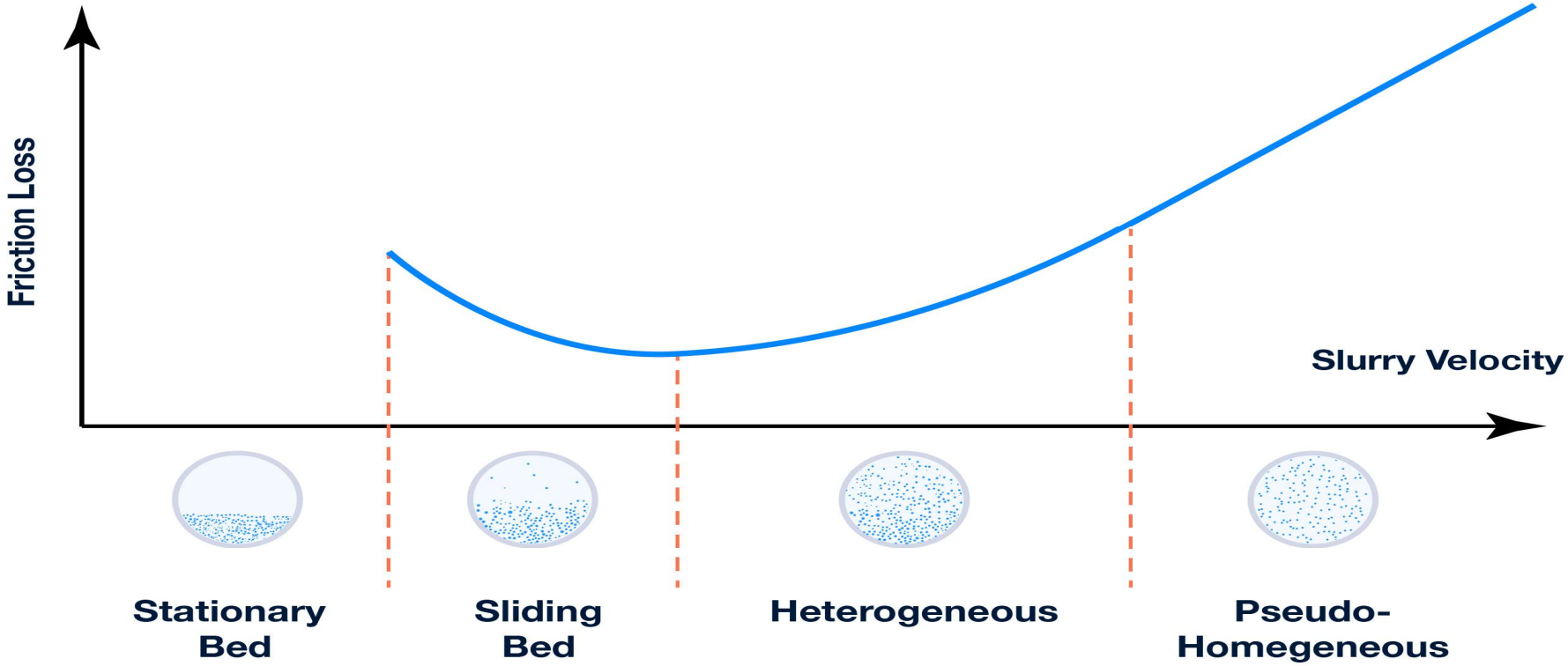
- Streams containing mixture of fine and coarse particles on a Newtonian fluid carrier in full or partial suspension
- Can demonstrate any of these flow regimes across a pipe:




- Flow regime occurrence is influenced by velocity, pipe size, particle size distribution and physical properties
- Each flow regime has different solids-liquid-pipe wall interaction, complicating pressure loss calculations

# Heterogeneous Slurries

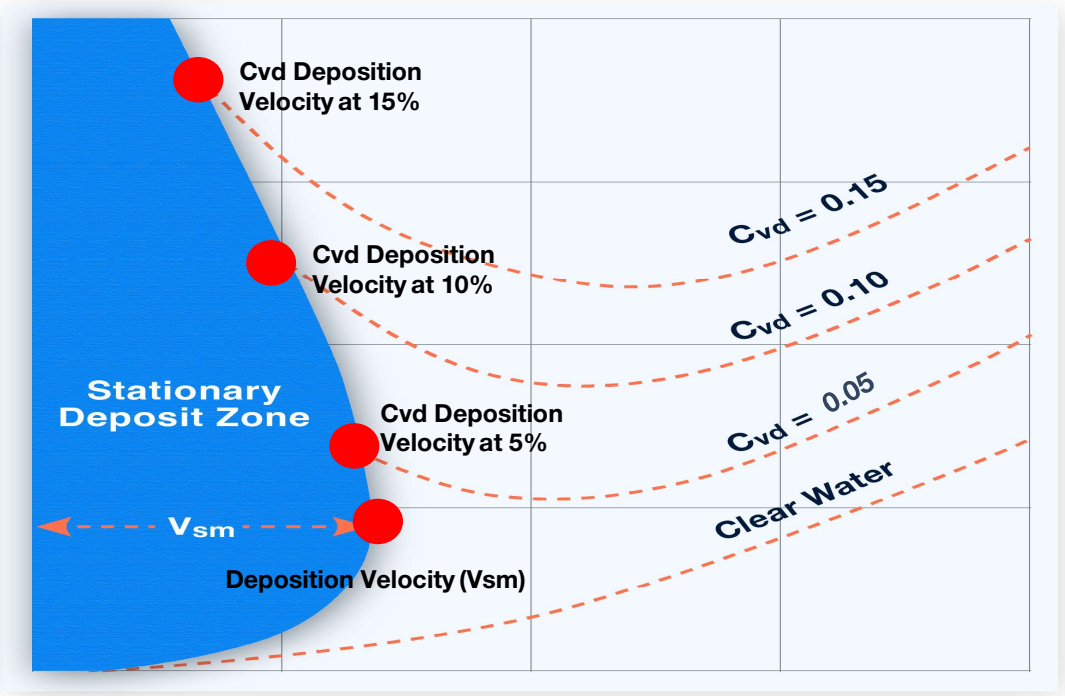
➢ **Slurry pipe curve:**



# Heterogeneous Slurries

➢ Plotting pipe characteristic curve at varying solid concentration generate “Stationary Deposit Zone”

PRESSURE GRADIENT




Slurry Velocity, V

Intersection between the Orange running line and the stationary deposit zone represent individual $C_{vd}$ Deposition Velocity
Peak Velocity for Stationary Deposit Zone represent the Deposition Velocity

# Heterogeneous Slurries

➢ **Slurry Deposition Velocity Correlations:**

- **WASC (Wilson-Addie-Sellgren-Clift) Generalized Relationship**
- **As a function of particle size**
- **GIW VSCALC**

➢ **Slurry Friction Loss Correlations:**

- **Vsm**
- **V50**
- **4CM**
- **Durand**
- **Wasp**
- **WASC (Wilson-Addie-Sellgren-Clift) Method**
- **Sellgren – Wilson Four Component Model**
- **Liu Dezhong**

➢ **Only one of each correlation can be applied in calculation**

➢ **Guide to method selection is discussed in the advanced training courses.**

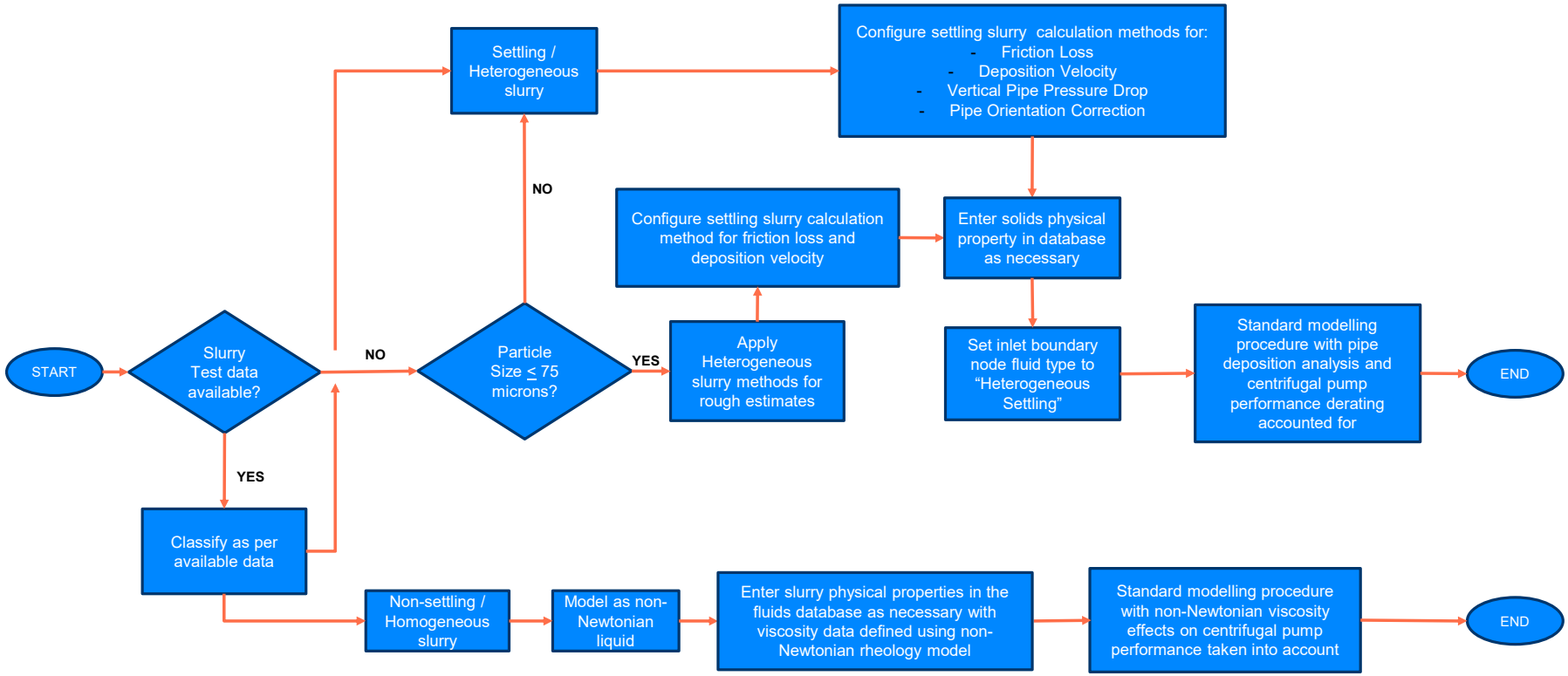
# Heterogeneous Slurries

- Pipe orientation influence solids behavior in slurries
- Actual installations are not always horizontal but can also be inclined or vertical
- Orientation affect frictional losses and solid deposition tendency
- FluidFlow automatically identifies and performs the necessary adjustments for non-horizontal flows
- Inclined pipe correction methods for deposition velocity:
  - Wilson – Tse 1984 Chart
  - Extended Wilson – Tse 1984 Chart
- Vertical Pipe Friction Loss Correlations:
  - Vertical Pipe WASC Loss
  - 4CM
  - Spelay, Gillies, Hashemi and Sanders 2017 Collisional Stress Model
- Only one of each correlation can be applied in calculation
- Guide to method selection is discussed in the advanced training courses.

# Configuring Slurry Hydraulic Models

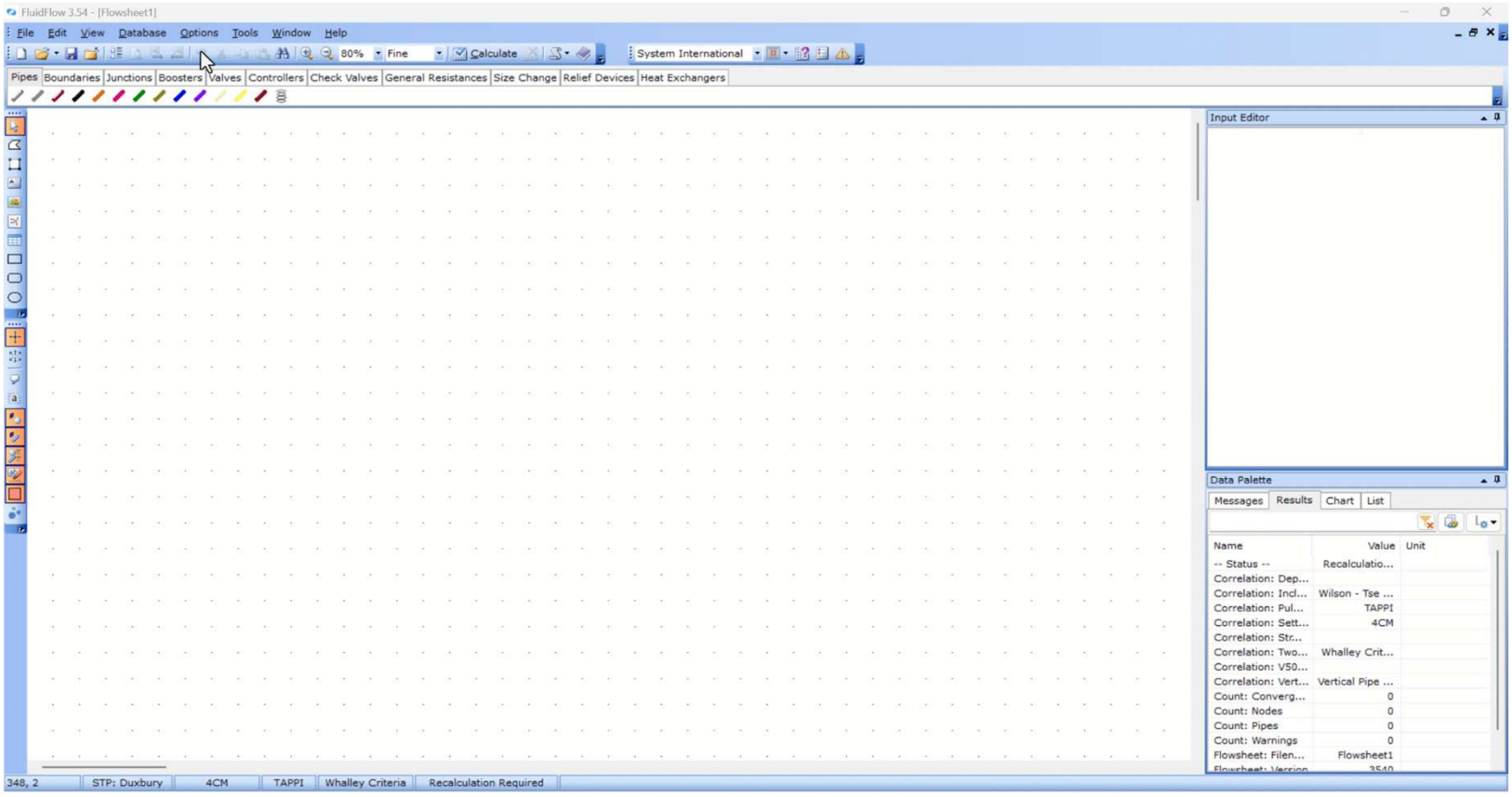


# Typical Slurry Modeling Flowchart



# Method Selection and Application

➢ **Use Calculation Options (Via F2 or Options Menu | Calculation) to configure methods for calculation:**



# Basic Modelling Exercises



# Non-Settling Slurry Exercise

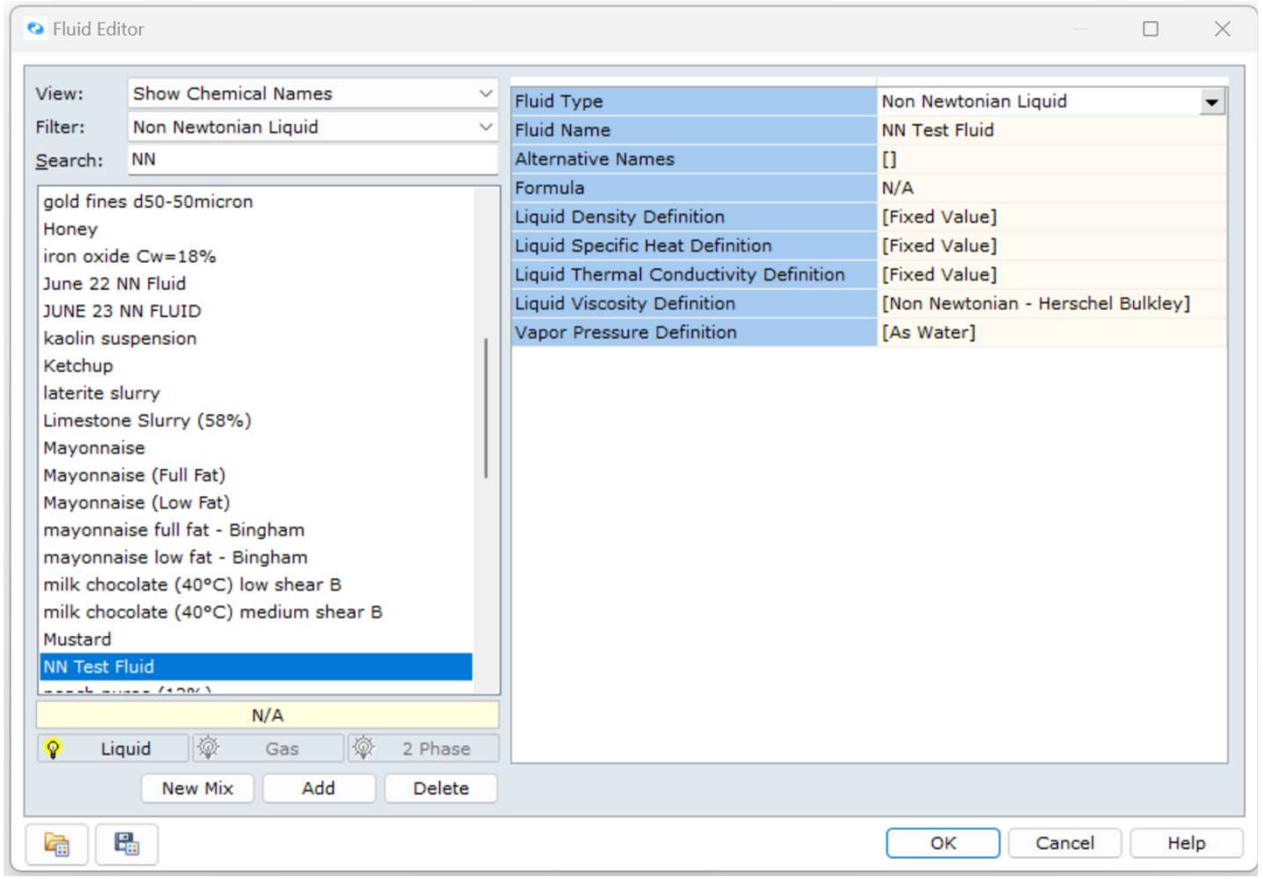
**For a certain mining slurry identified as a Herschel - Bulkley fluid, Calculate the pipe friction loss when 10 cubic meter per hour of flow is discharged to atmospheric pressure through 20 m of 2 inch schedule 40 steel pipe.**

**Further fluid information are given below:**

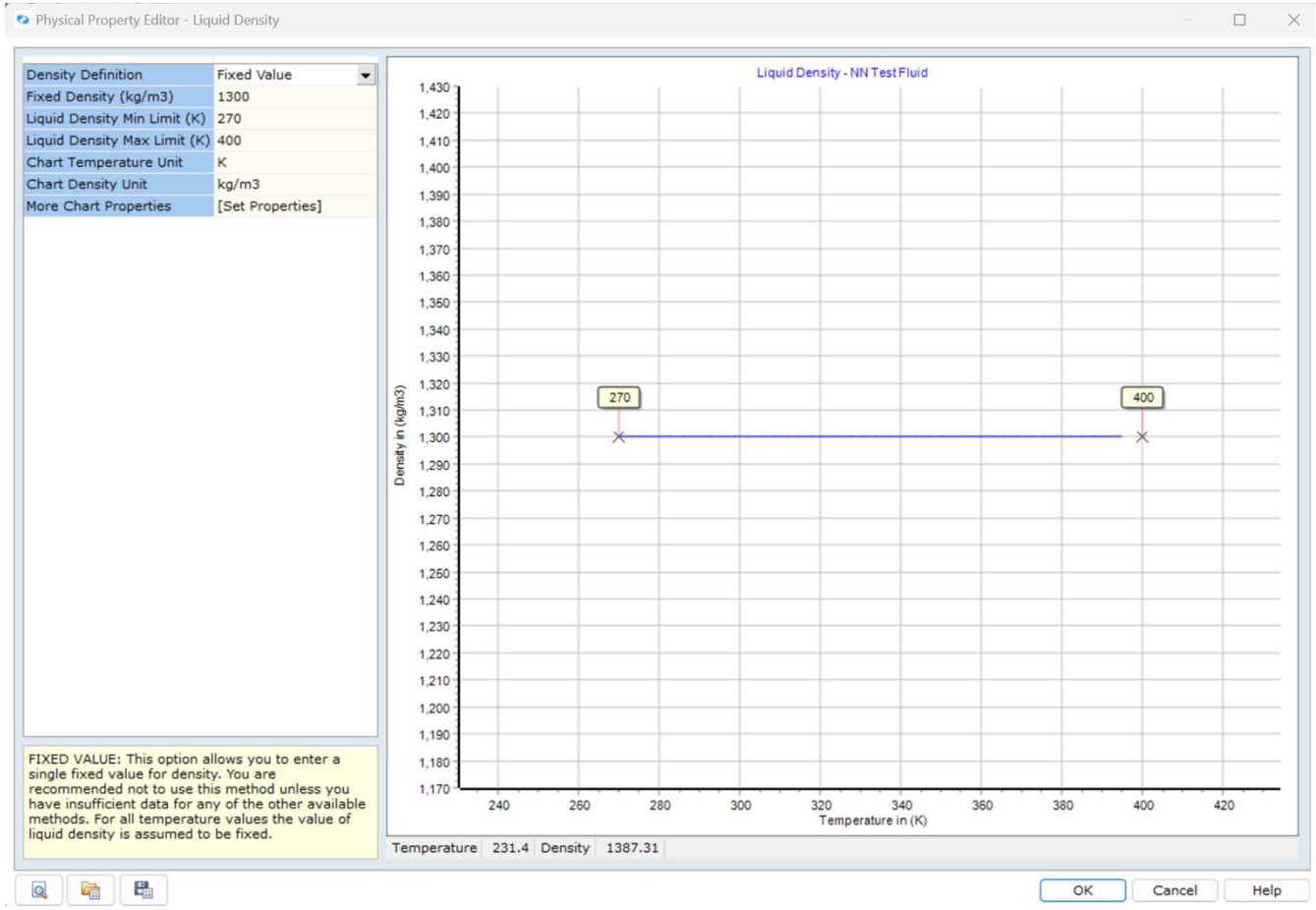
**Slurry Temperature: 25°C**
**Slurry Density: 1300 kg/$m^3$**

**Rheological Data:**
**Yield stress: 10 Pa**
**Consistency Coefficient (K): 1.1 Pa-s**
**Herschel – Bulkley Index: 0.39**

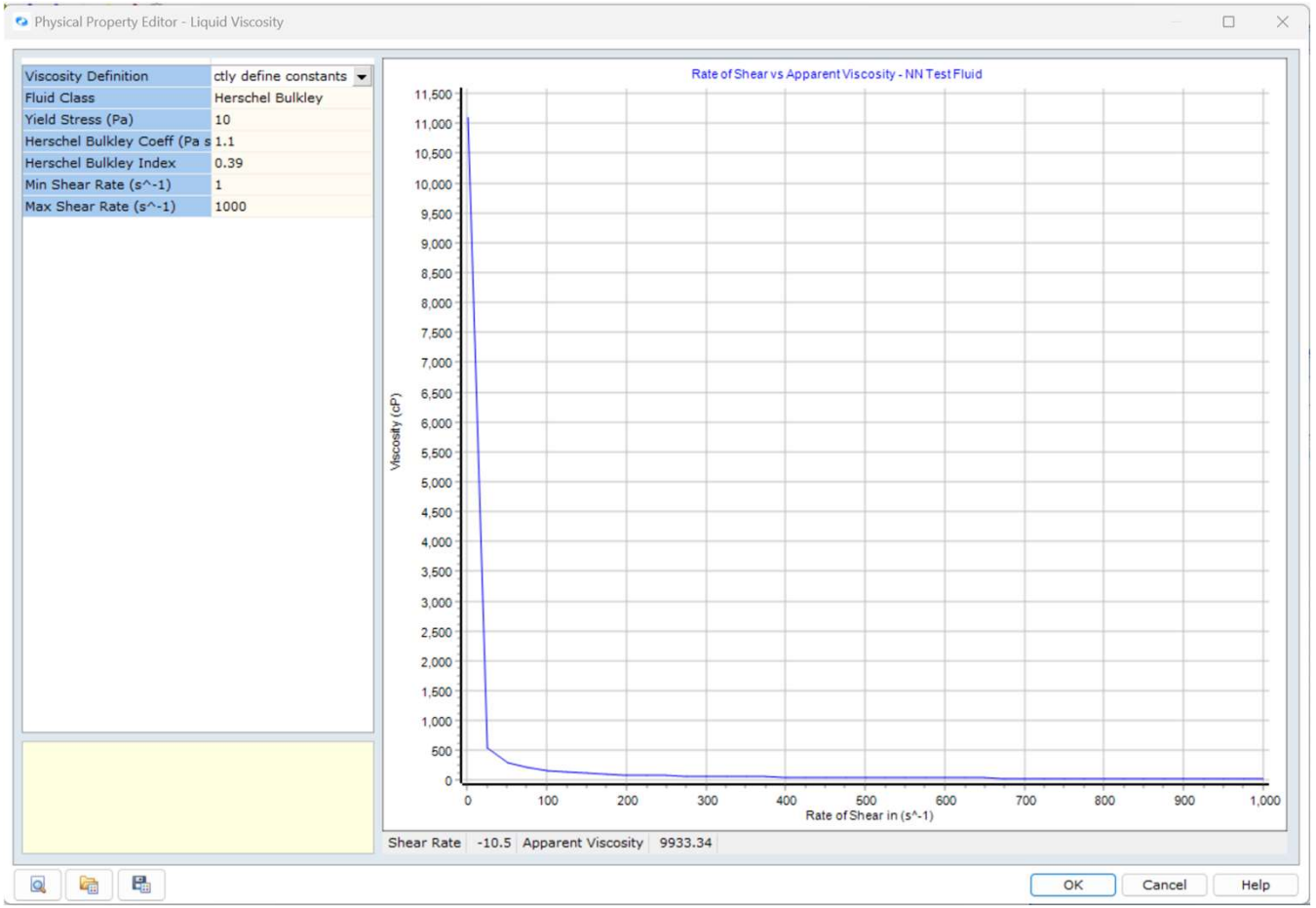
# Non-Settling Slurry Exercise



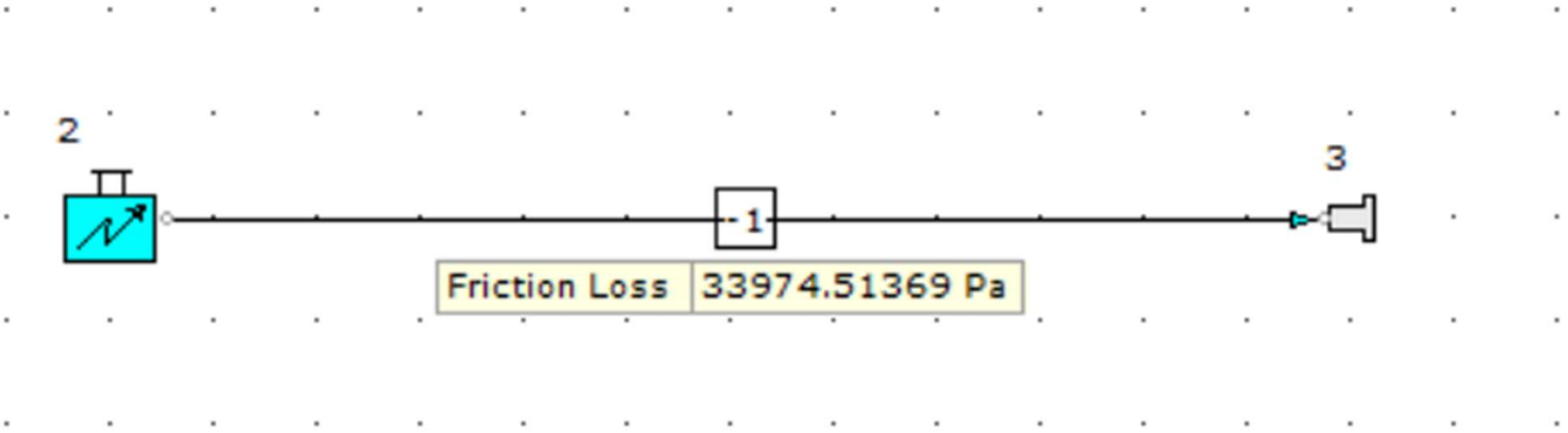
# Non-Settling Slurry Exercise



# Non-Settling Slurry Exercise

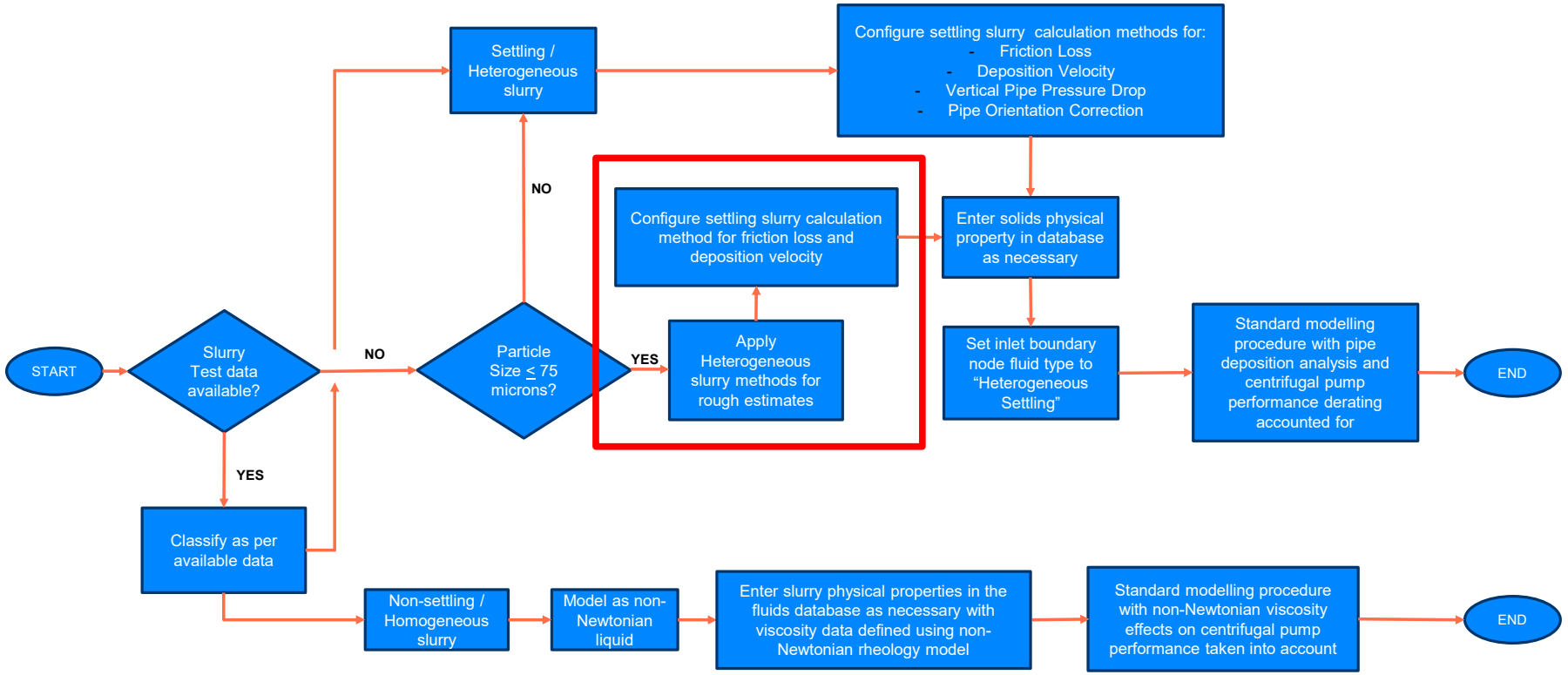


# Non-Settling Slurry Exercise



# Settling Slurry Exercise

**Calculate the pressure drop per meter caused by water-based slurry flowing at 50 m3/hr containing 15% by volume sand across a 2-inch schedule 40 steel pipe.**



# Settling Slurry Exercise

**Calculate the pressure drop per meter caused by water-based slurry flowing at 50 m3/hr containing 15% by volume sand across a 2-inch schedule 40 steel pipe.**

## The Simplified Equation

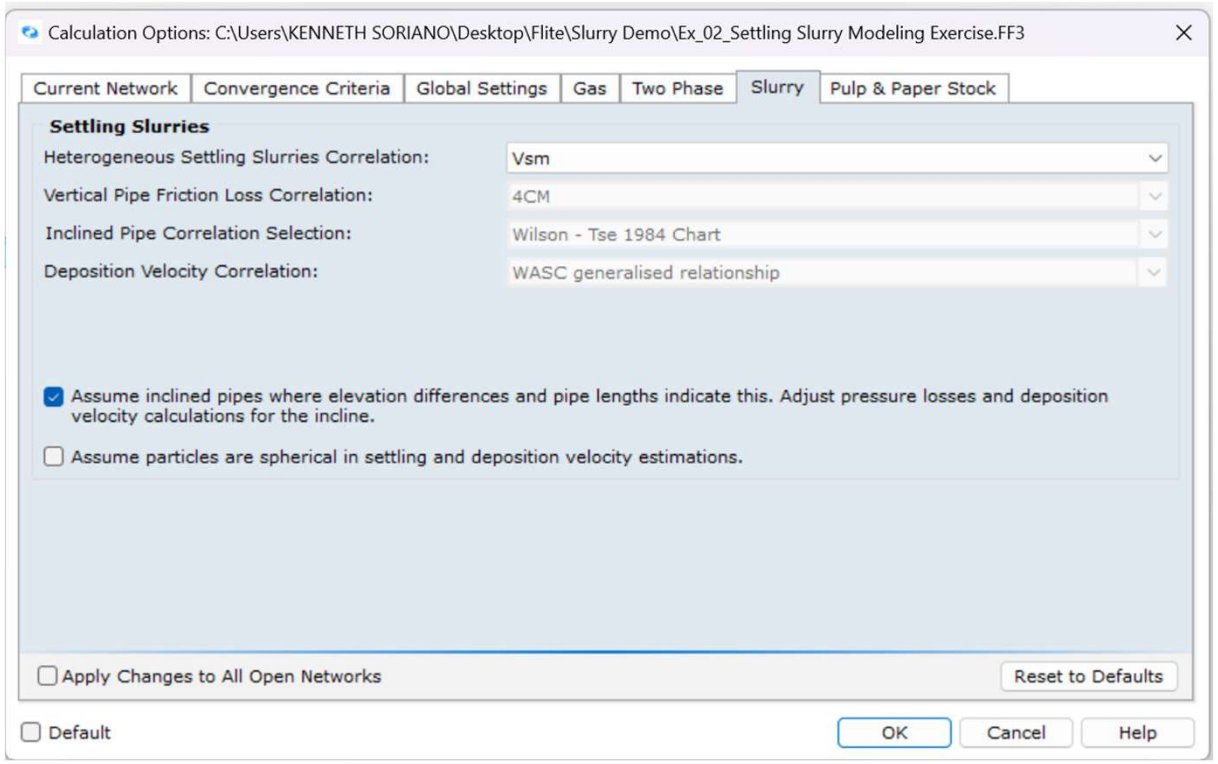
The model is built on a force balance analysis of fully stratified flow and expressed as:

$$\frac{i_m - i_f}{C_{vd}(S_s - S_f)} = 2\mu_s \left(\frac{V_{sm}}{V_m}\right)^M$$

- This model applies a constant value for the stratification ratio exponent “M” which has been validated to occur in fully stratified flow conditions.
- The result gives you a **high-side estimate** of energy loss—great for **conservative design assumptions**.

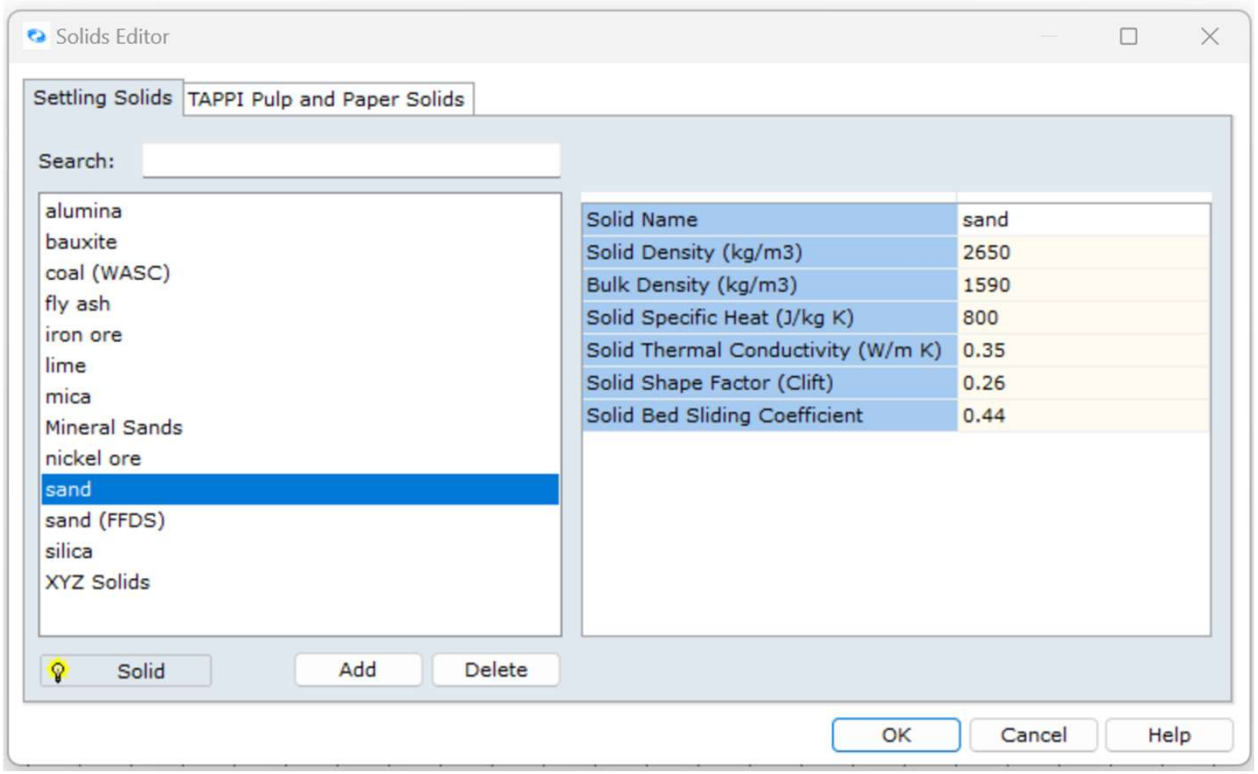
# Settling Slurry Exercise

**Calculate the pressure drop per meter caused by water-based slurry flowing at 50 m3/hr containing 15% by volume sand across a 2-inch schedule 40 steel pipe.**



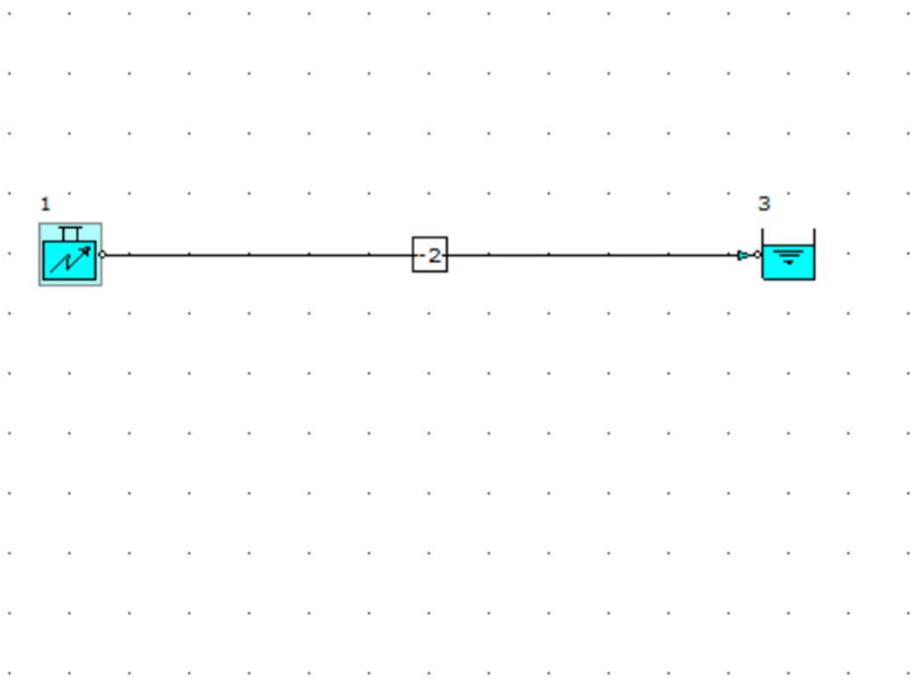
# Settling Slurry Exercise

**Calculate the pressure drop per meter caused by water-based slurry flowing at 50 m3/hr containing 15% by volume sand across a 2-inch schedule 40 steel pipe.**



# Settling Slurry Exercise

**Calculate the pressure drop per meter caused by water-based slurry flowing at 50 m3/hr at 20ºC containing 15% by volume sand across a 2-inch schedule 40 steel pipe.**

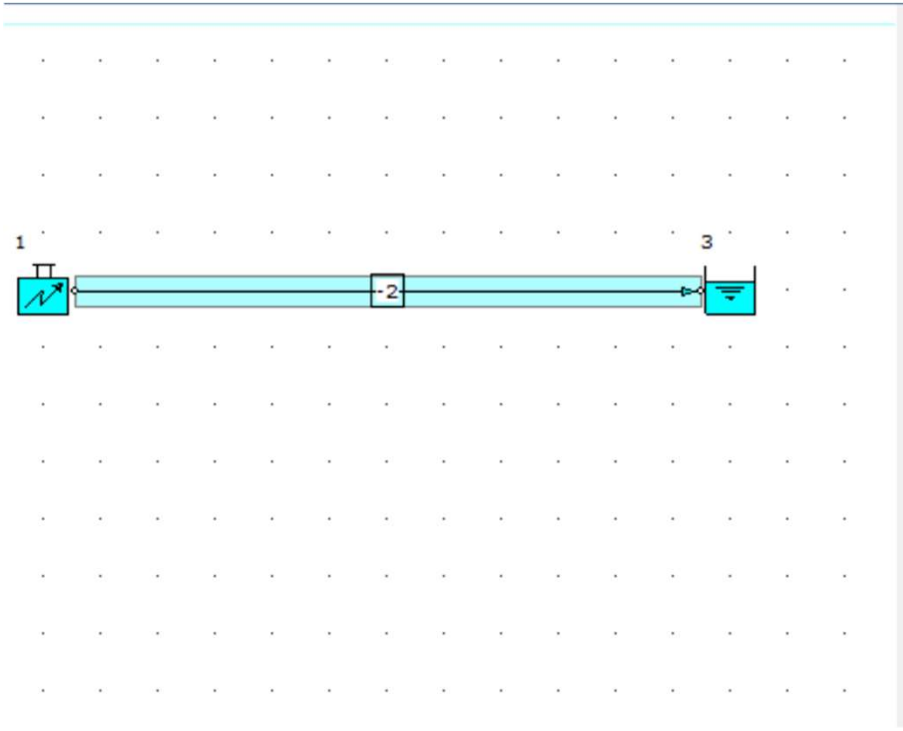



Input Editor

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| Elevation Unit | m |
| Flow Direction | Into Network |
| Flow | 50 |
| Flow Unit | m3/h |
| Temperature | 20 |
| Temperature Unit | C |
| Fluid | water |
| Fluid Type | Heterogeneous Settling |
| User-Defined Fields | |
| Flow Defined By | Total Slurry Flow |
| Solids | sand |
| Concentration defined by | Cv Volume % |
| Solids Concentration % | 15 |
| Properties on Flowsheet | Hide |

# Settling Slurry Exercise

**Calculate the pressure drop per meter caused by water-based slurry flowing at 50 m3/hr containing 15% by volume sand across a 2-inch schedule 40 steel pipe.**

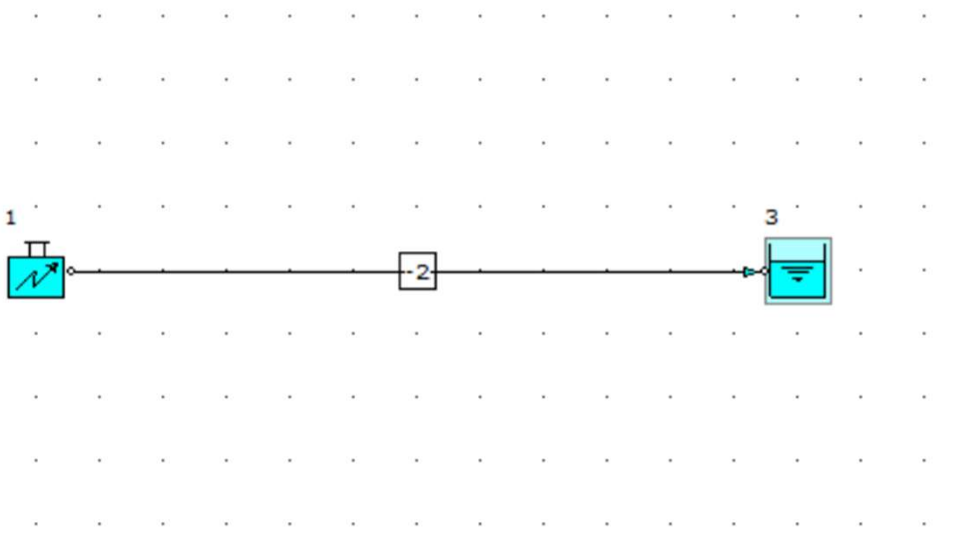



Input Editor

| | |
|---|---|
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| Geometry | Cylindrical |
| Use Database Size | Yes |
| Nominal Size | 2 inch |
| Classification | Schedule 40 |
| Friction Model | Moody |
| Use Database Roughness | Yes |
| Roughness Description | Clean or new |
| Use Database Scaling | No |
| Scaling (0 to 50%) | 0 |
| Sizing Model | Economic Velocity |
| Heat Loss Model | Ignore Heat Loss/Gain |
| User-Defined Fields | |
| Draw Thickness [1..5] | 1 |
| Draw Color | clBlack |

# Settling Slurry Exercise

**Calculate the pressure drop per meter caused by water-based slurry flowing at 50 m3/hr containing 15% by volume sand across a 2-inch schedule 40 steel pipe.**

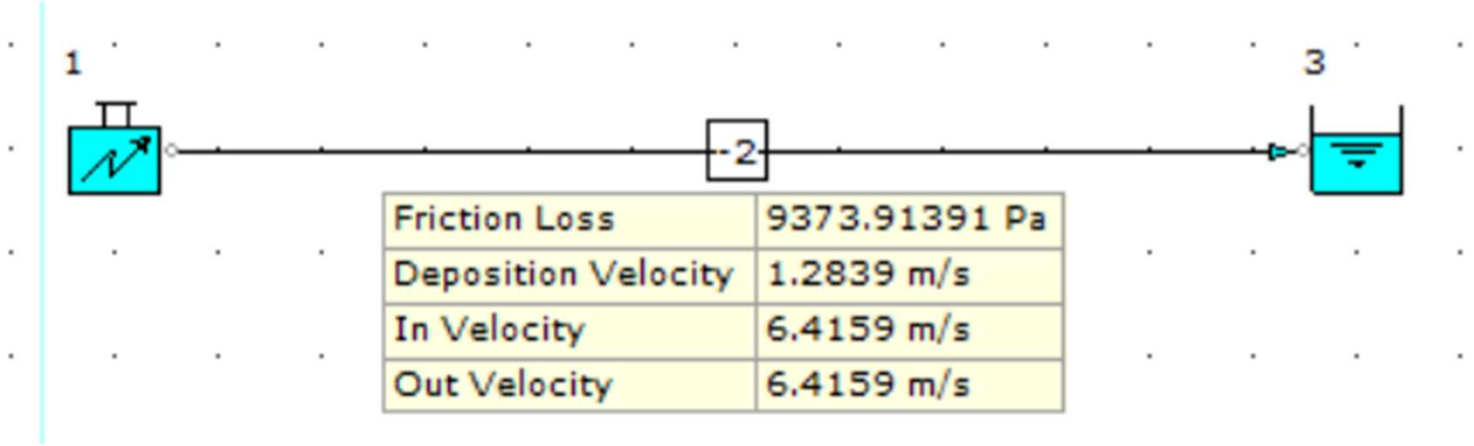



Input Editor

| | |
|---|---|
| Unique Name | |
| Status | On |
| Elevation | 0 |
| Elevation Unit | m |
| Pressure Model | Stagnation Pressure |
| Pressure | 1 |
| Pressure Unit | atm |
| Temperature | 15 |
| Temperature Unit | C |
| Fluid | water |
| Fluid Type | Newtonian/NN-NonSettling |
| User-Defined Fields | |
| Properties on Flowsheet | Hide |

# Settling Slurry Exercise

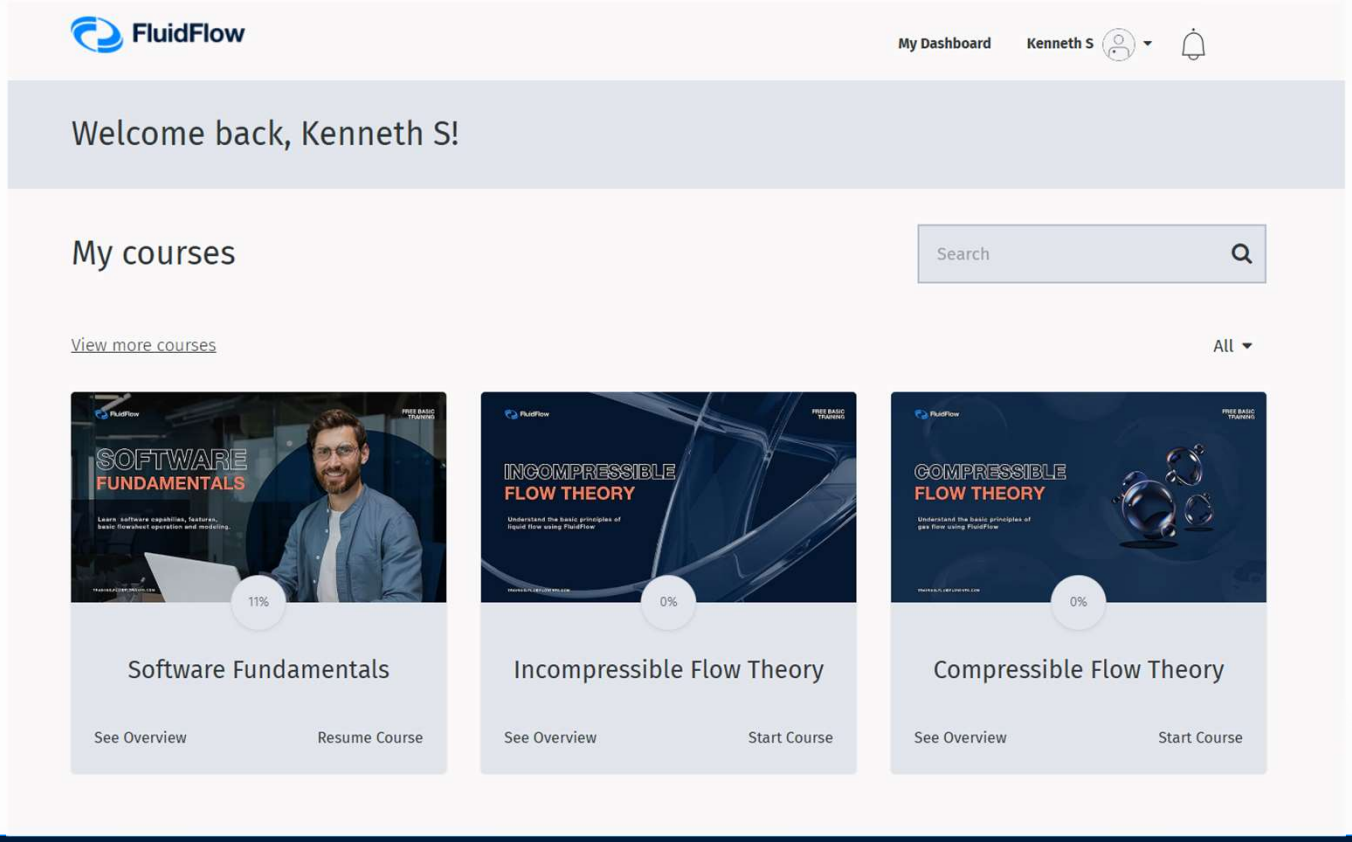
**Calculate the pressure drop per meter caused by water-based slurry flowing at 50 m3/hr containing 15% by volume sand across a 2-inch schedule 40 steel pipe.**



# FLUIDFLOW
# BASIC AND ADVANCED
# TRAINING

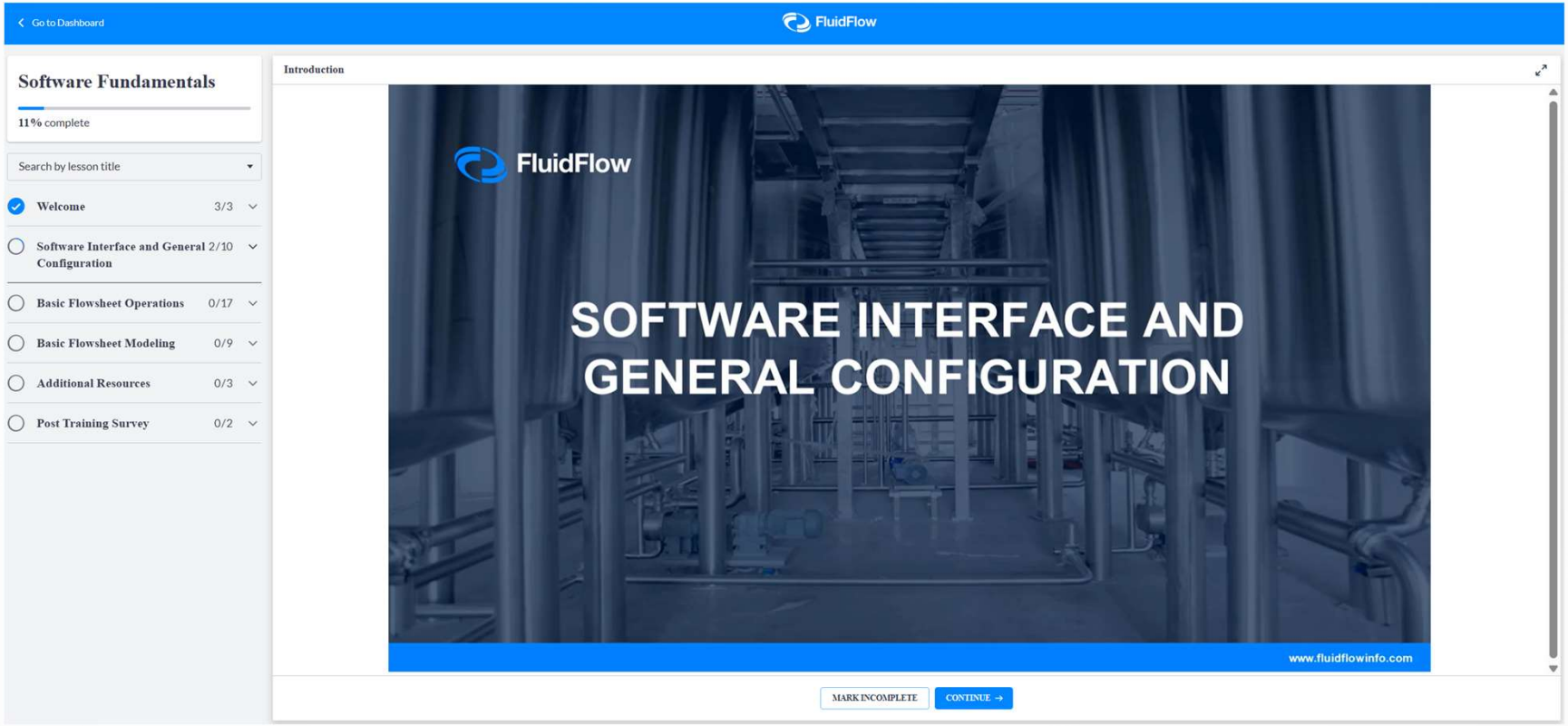
# FluidFlow Basic and Advanced Training

## ❑ Basic Training (FREE)



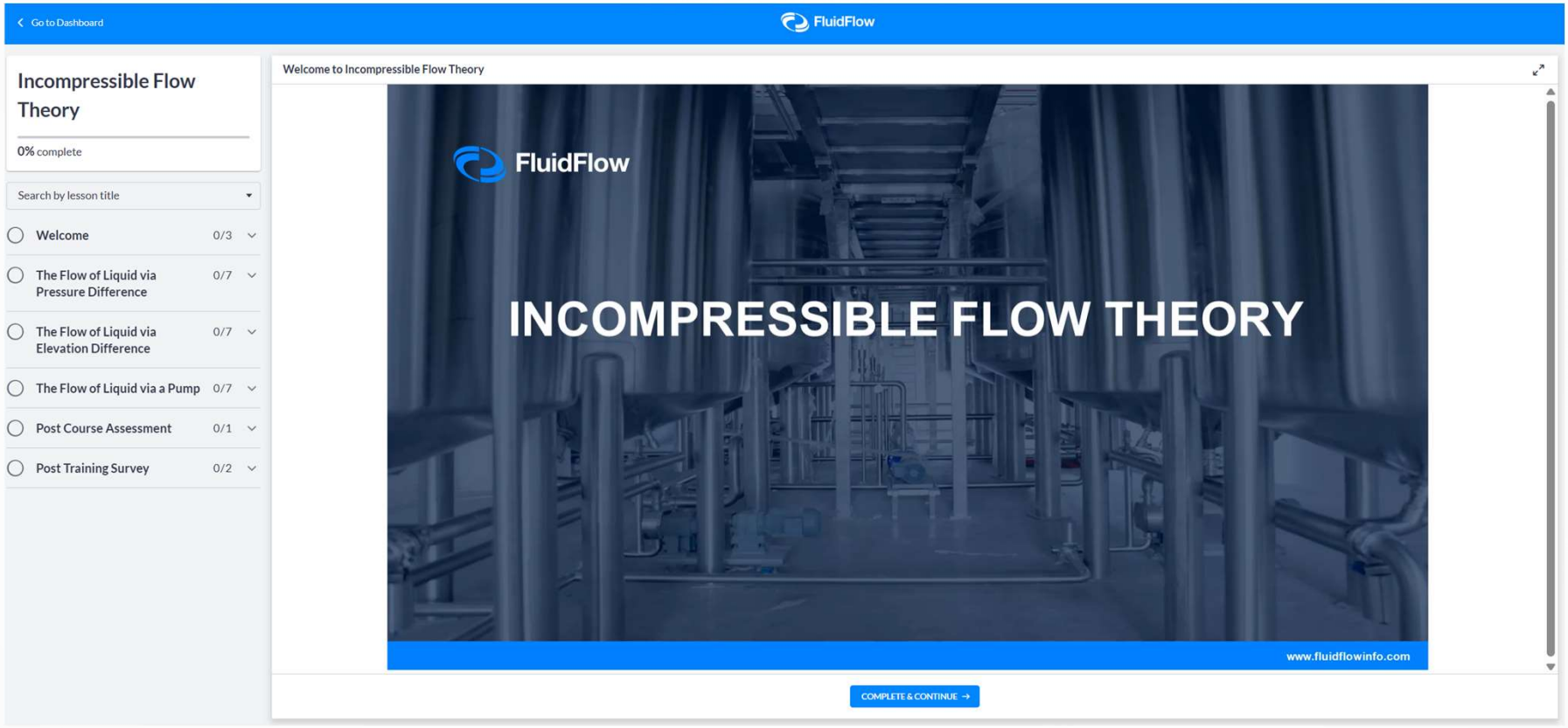
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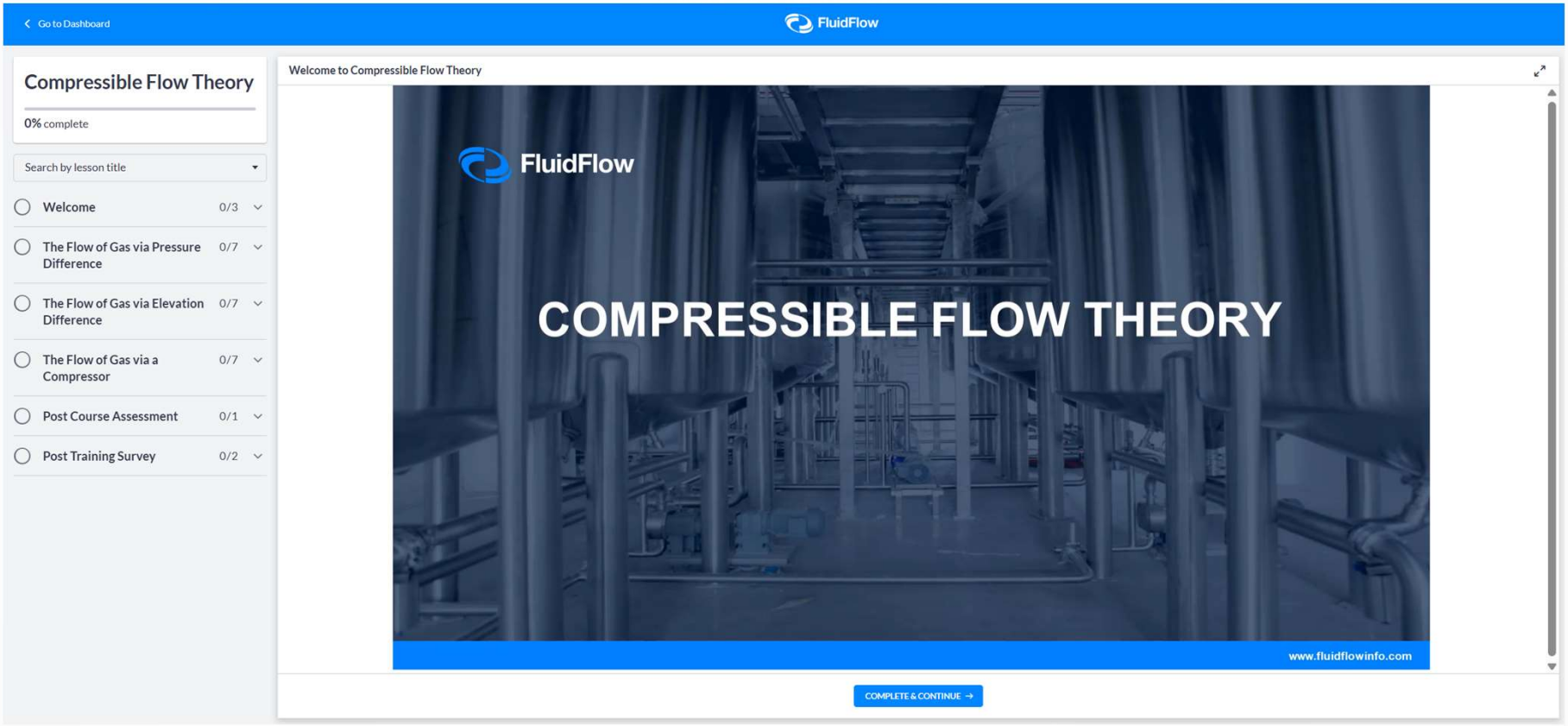
# FluidFlow Basic and Advanced Training

## ❑ Basic Training (FREE)



# FluidFlow Basic and Advanced Training

## ❑ Basic Training (FREE)



# FluidFlow Basic and Advanced Training

❑ Advanced Training

## Explore Our Comprehensive Course Modules

### Detailed Course Content:

**Fundamentals Module:**

- Software Interface and General Configuration
- Basic Flowsheet Operations
- Fundamentals of Fluid Network Modeling
- Database Operations
- Hydraulic Calculation Procedure
- Results Analysis and Interpretation

**Two-Phase Module**

- Two-Phase Flow Theory
- Two-phase flow patterns and modeling approaches
- Flow regime mapping and visualization
- Pressure drop correlations for two-phase systems
- Line Sizing for Two-Phase Flow

# FluidFlow Basic and Advanced Training

## ❑ Advanced Training

### Liquid Module

- Introduction to Pumps
- Pump Sizing Principles
- Developing Pump Process Datasheets
- Centrifugal Pump Performance Modeling
- Centrifugal Pump Curve Viscosity Correction
- Centrifugal Pump Affinity Laws
- Liquid Service Control Valve Sizing
- Analyzing Pump Performance in FluidFlow

### Gas Module

- Compressible Flow Principles and Calculations
- Pressure Drop in Gas Networks
- Gas Property Modeling and Equations of State
- Control Valve Basics, Sizing & Selection
- Line Sizing for Gas/Vapor
- Choked Flow Analysis
- Heat Transfer in Gas Systems
- Fan and Compressor Selection

### Slurry Module

- Introduction to Slurries
- Slurry Pipe Characteristic Curve
- Settling Slurry Model Input Data
- Settling Slurry Friction Loss
- Slurry Flow Characteristic Velocities
- Specific Energy Consumption
- Non-Horizontal Settling Slurry Flows
- Centrifugal Slurry Pump Performance
- Introduction to Non-Newtonian Liquids
- Newtonian vs. Non-Newtonian Hydraulic Modeling
- Non-Newtonian Viscosity Models
- Defining Non-Newtonian Viscosity
- Non-Newtonian Friction Loss Calculations
- Non-Newtonian Centrifugal Pump Viscosity Correction

# Got Questions? Send us an email!

**Technical Product Support**
**(support@fluidflowinfo.com)**

**Customer Success**
**(success@fluidflowinfo.com)**

