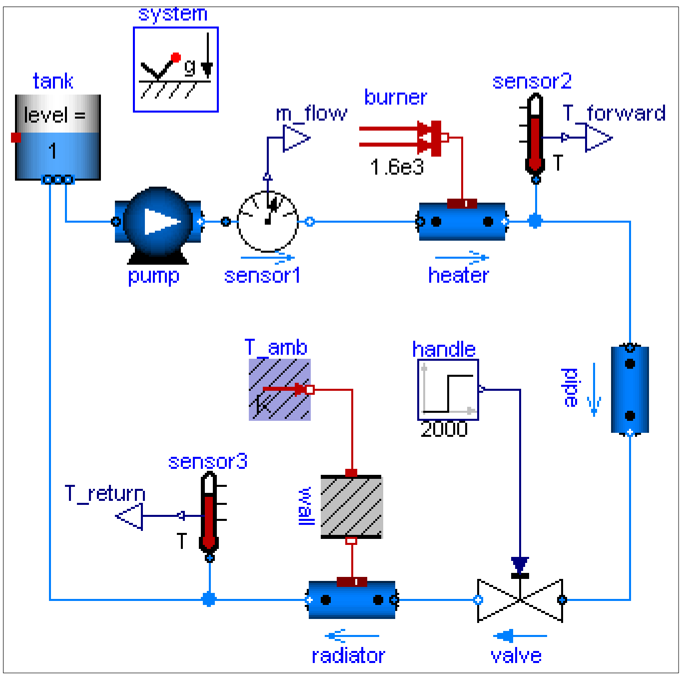
# Modelica_Fluid Library

Version 1.0

January 2009

Users Guide and Reference




Modelica Association
http://www.Modelica.org

# Contents

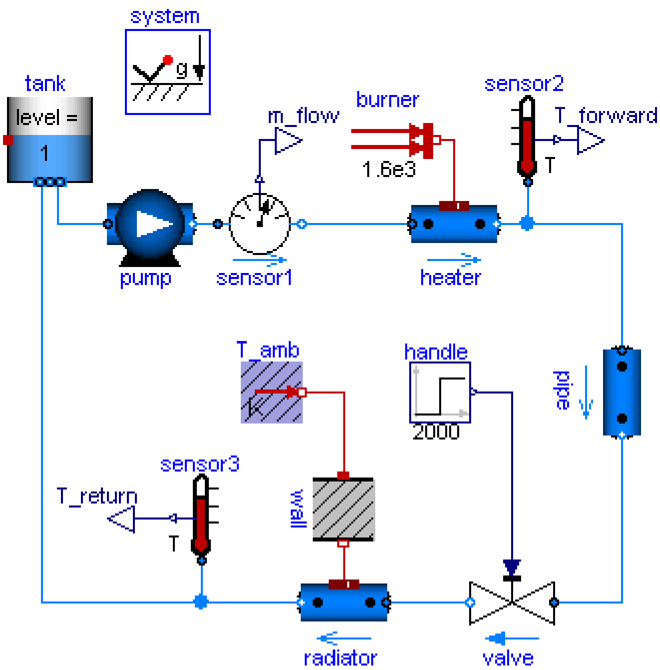
## Modelica_Fluid

**Modelica_Fluid, 1.0: One-dimensional thermo-fluid flow models using the Modelica.Media media description (requires package Modelica 3.0 or later, and stream connector support in the Modelica tool)**

### Information

The **Modelica_Fluid** library is a **free** Modelica package provided under the Modelica License 2. The library contains components describing **1-dimensional thermo-fluid flow** in networks of vessels, pipes, fluid machines, valves and fittings. A unique feature is that the component equations and the media models as well as pressure loss and heat transfer correlations are decoupled from each other. All components are implemented such that they can be used for media from the Modelica.Media library. This means especially that an incompressible or compressible medium, a single or a multiple substance medium with one or more phases might be used. The goal is to include the Modelica_Fluid library in the Modelica standard library as Modelica.Fluid.

In the next figure, several features of the library are demonstrated with a simple heating system with a closed flow cycle. By just changing one configuration parameter in the system object the equations are changed between steady-state and dynamic simulation with fixed or steady-state initial conditions.




With respect to previous versions, the design of the connectors has been changed in a non-backward compatible way, using the recently developed concept of stream connectors that results in much more reliable simulations (see an overview and a rationale here). This extension will be included in Modelica 3.1. As of Jan. 2009, the stream concept is supported in Dymola 7.1. It is recommended to use Dymola 7.2 (announced for Feb. 2009), or a later Dymola version, since this version supports a new annotation to connect very conveniently to vectors of connectors. Other tool vendors will support the stream concept as well.

The following parts are useful, when newly starting with this library:

- UsersGuide.
- UsersGuide.ReleaseNotes summarizes the changes of the library releases.
- Examples contains examples that demonstrate the usage of this library.



Extends from Modelica.Icons.Library (Icon for library).

### Package Content

| Name | Description |
|---|---|
| UsersGuide | Users Guide |
| Examples | Demonstration of the usage of the library |
| System | System properties and default values (ambient, flow direction, initialization) |
| Vessels | Devices for storing fluid |
| Pipes | Devices for conveying fluid |
| Machines | Devices for converting between energy held in a fluid and mechanical energy |
| Valves | Components for the regulation and control of fluid flow |
| Fittings | Adaptors for connections of fluid components and the regulation of fluid flow |
| Sources | Define fixed or prescribed boundary conditions |
| Sensors | Ideal sensor components to extract signals from a fluid connector |
| Interfaces | Interfaces for steady state and unsteady, mixed-phase, multi-substance, incompressible and compressible flow |
| Types | Common types for fluid models |
| Utilities | Utility models to construct fluid components (should not be used directly) |
| Icons | Library of resuable icons |

## Modelica_Fluid.UsersGuide

**Users Guide**

The library **Modelica_Fluid** is a **free** Modelica package provided under the Modelica License 2. The library contains components describing **1-dimensional thermo-fluid flow** in networks of pipes. A unique feature is that the component equations and the media models as well as pressure loss and heat transfer correlations are decoupled from each other. All components are implemented such that they can be used for media from the Modelica.Media library. This means especially that an incompressible or compressible medium, a single or a multiple substance medium with one or more phases might be used. The goal is to include the Modelica_Fluid library in the Modelica standard library as Modelica.Fluid.

### Package Content

| Name | Description |
|---|---|
| Overview | Overview |
| GettingStarted | Getting started |
| ComponentDefinition | Component definition |
| BuildingSystemModels | Building system models |
| ReleaseNotes | Release notes |
| ModelicaLicense2 | Modelica License 2 |
| Contact | Contact |

## UsersGuide.Overview

### Overview

The Modelica_Fluid library provides basic interfaces and components to model 1-dimensional thermo-fluid flow in networks of pipes. It is not the intention that this library covers all application cases because the fluid flow area is too large and because for special applications it is possible to implement libraries with simpler component interfaces. Instead, the goal is that the Modelica_Fluid library provides a **reasonable set of components** and that it **demonstrates** how to implement components of a fluid flow library in Modelica, in particular to cope with difficult issues such as connector design, reversing flow and initialization. It is planned to include more components in the future. User proposals are welcome.

This library has the following main features:

- The connectors Modelica_Fluid.Interfaces.FluidPort_a/_b are designed for one-dimensional flow of a **single substance** or of a **mixture of substances** with optional **multiple phases**. All media models from Modelica.Media can be utilized when connecting components. For one substance media, the additional arrays for multiple substance media have zero dimension and are therefore removed from the code during translation. The general connector definition therefore does not introduce an overhead for special cases.

- All the components of the Modelica_Fluid library are designed that they can be utilized for all media models from Modelica.Media if this is posssible. For example, all media can be utilized for the Modelica_Fluid.Sensors/Sources components. For some components only special media are possible, since additional functionality is required. For example, Modelica_Fluid.Components.Evaporator requires a two phase medium (extending from Modelica.Media.Interfaces.PartialTwoPhaseMedium).

- In order to simplify the initialization in the components, there is the restriction that only media models are supported that have T, (p,T), (p,h), (T,X), (p,T,X) or (p,h,X) as independent variables. Other media models would be possible, e.g., with (T,d) as independent variables. However, this requires to rewrite the code for the component initialization. (Note, T is temperature, p is pressure, d is density, h is specific enthalpy, and X is a mass fraction vector).

- All components work for **incompressible** and **compressible** media. This is implemented by a small change in the initialization of a component, if the medium is incompressible. Otherwise, the equations of the components are not influenced by this property.

- All components allow fluid flow in both directions, i.e., **reversing flow** is supported. However, it is possible to declare that the flow through a component only has the design direction, in order to obtain faster simulation code.

- Two or more components can be connected together. This means that the pressures of all connected ports are equal and the mass flow rates sum up to zero. Specific enthalpy, mass fractions and trace substances are mixed according to the mass flow rates.

- The **momentum balance** and the **energy balance** are only fulfilled exactly if **two ports of equal diameter** are connected. In all other cases, the balances are approximated, because kinetic and friction effect are neglected. An explicit fitting or junction should be used if these are important for the specific problem at hand. In all circuits where friction dominates, or components such as pumps determine the flow rate, kinetic pressure is typically irrelevant. You can consider the Modelica_Fluid.Examples.Explanatory.MomentumBalanceFittings model (and its documentation) to see one case where the momentum balance essentially depends on kinetic pressure, so it is necessary to use explicit fittings in order to obtain correct results.

- Given the above-mentioned limitations, there is no restriction how components can be connected together. The resulting simulation performance however often strongly depends on the model structure and modeling assumptions made. In particular the direct connection of fluid volumes generally results in high-index DAEs for the pressures. The direct connection of flow models generally results in systems of implicit nonlinear algebraic equations.

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## UsersGuide.GettingStarted

### Getting started

Please explore the Examples, which provide simple models for a broad variety of applications.

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## UsersGuide.ComponentDefinition

### Component definition

In this section it is described how the components of the Modelica_Fluid library are implemented. If you would like to introduce new components either in Modelica_Fluid or your own library, you should be aware of the issues discussed in this section.

This section is partly based on the following paper:

Elmqvist H., Tummescheit H., and Otter M.:

**Object-Oriented Modeling of Thermo-Fluid Systems**. Modelica 2003 Conference, Linköping, Sweden, pp. 269-286, Nov. 3-4, 2003. Download from: http://www.modelica.org/Conference2003/papers/h40_Elmqvist_fluid.pdf

Please note that the design of the connectors has been changed with respect to the design presented in that paper.

### Package Content

| Name | Description |
|---|---|
| FluidConnectors | Fluid connectors |
| BalanceEquations | Balance equations |
| UpstreamDiscretization | Upstream discretization |
| RegularizingCharacteristics | Regularizing characteristics |
| WallFriction | Wall friction |
| ValveCharacteristics | Valve characteristics |

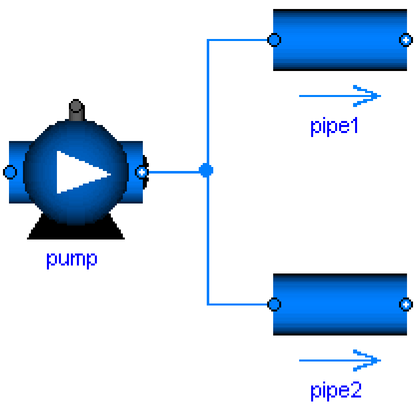
## UsersGuide.ComponentDefinition.FluidConnectors

**Fluid connectors**

In this section the design of the fluid connectors is explained.

Fluid connectors represent the points in a device (e.g. the flanges) through which a fluid can flow into or out of the component, carrying its thermodynamic properties; these flanges are assumed to be fixed in space.

A major design goal is that components can be arbitrarily connected and that the important balance equations are automatically fulfilled when 2 or more components are connected together at one point as shown in the next figure:




In such a case the balance equations define **ideal mixing**, i.e., the upstream discretization scheme of each component uses values that result from ideal mixing in an infinitely small time period. If more realistic modelling is desired that takes into account mixing losses, an explicit model has to be used in the connection point.

### Single substance media

For a single substance medium, the connector definition in Modelica_Fluid.Interfaces.FluidPort reduces to

```
connector FluidPort
   replaceable package Medium = Modelica.Media.Interfaces.PartialMedium
            "Medium model of the fluid";
   flow Medium.MassFlowRate m_flow;
            "Mass flow rate from the connection point into the component";
   Medium.AbsolutePressure p
            "Thermodynamic pressure in the connection point";
   stream Medium.SpecificEnthalpy h_outflow
             "Specific thermodynamic enthalpy close to the connection point if m_flow <
0";
end FluidPort;
```

The first statement defines the Medium flowing through the connector. In a medium, medium specific types such as "Medium.AbsolutePressure" are defined that contain medium specific values for the min, max and nominal attributes. Furthermore, Medium.MassFlowRate is defined as:

```
type MassFlowRate =
   Modelica.SIunits.MassFlowRate(quantity="MassFlowRate." + mediumName);
```

With the current library design, it is necessary to explictly select the medium model for each component in a circuit. This model is then propagated to the ports, and a Modelica translator will check that the quantity and unit attributes of connected interfaces are identical. Therefore, an error occurs, if connected FluidPorts do not have a medium with the same medium name. In the future, automatic propagation of fluid models through the ports will be introduced, but this still not possible with Modelica 3.0.

The thermodynamic pressure is an *effort* variable, which means that the connection of two or more ports states that the port pressures are the same.

The mass flow rate is a *flow* variable, which means that the connection of two or more ports states that the sum of all flow rates is zero.

The last variable is a *stream* variable, i.e., a specific quantity carried by the flow variable. The quantity on the connector always corresponds to the value close to the connection point, assuming that the fluid is flowing out of the connector, regardless of the actual direction of the flow. This helps avoiding singularities when the mass flow goes through zero. The stream properties for the other flow direction can be inquired with the built-in operator inStream(..), while the value of the stream variable corresponding to the actual flow direction can be inquired through the built-in operator actualStream(..).

The actual equations corresponding to these operators are introduced and solved automatically by the tool. In principle, they correspond to the balance equation sum(flow_variable) = 0 and sum(flow_variable*stream_variable_at_connection) = 0 applied to the set of connected ports. In this case the first equation is the mass balance sum(m_flow) = 0, and the second is the energy balance at the connection point sum(m_flow*h_connection) = 0.

In the simpler case of a one-to-one connections between port_a and port_b, inStream(port_a.h_outflow) just returns port_b.h_outflow. For multiple-way connections, mixing equations are generated, and special care is taken in order to avoid discontinuities around zero flow rates. For more details, see this presentation which illustrates the stream concept rationale and the underlying technicalities.

A connector should have only the minimal number of variables to describe the interface, otherwise there will be connection restrictions in certain cases. Therefore, in the connector no redundant variables are present, e.g., the temperature T is not present because it can be computed from the connector variables pressure p and specific enthalpy h.

Here are two simple examples to illustrate modeling with stream connectors. The first one is a rigid adiabatic volume mixing two flows, where the kinetic and gravitational terms in the energy balance are neglected for simplicity.

```
model MixingVolume "Volume that mixes two flows"
  replaceable package Medium = Modelica.Media.Interfaces.PartialPureSubstance;
  FluidPort port_a, port_b;
  parameter Modelica.SIunits.Volume V "Volume of device";
  Modelica.SIunits.Mass             m "Mass in device";
  Modelica.SIunits.Energy           U "Inner energy in device";
  Medium.BaseProperties medium(preferredMediumStates=true) "Medium in the device";
equation
  // Definition of port variables
  port_a.p         = medium.p;
  port_b.p         = medium.p;
  port_a.h_outflow = medium.h;  // The stream variable always corresponds to the
  port_b.h_outflow = medium.h;  // properties of the fluid holdup (outgoing flow)

  // Total quantities
  m = V*medium.d;
  U = m*medium.u;
   // Mass and energy balance (actualStream(..) is a built-in operator for streams to
  // compute the right h, depending on the flow direction)
  der(m) = port_a.m_flow + port_b.m_flow;
  der(U) = port_a.m_flow*actualStream(port_a.h_outflow) +
           port_b.m_flow*actualStream(port_b.h_outflow);
end MixingVolume;
```

The second example is the model of a component describing a lumped pressure loss between two ports, with no energy storage and no heat transfer. An isenthalpic transformation is assumed (changes in kinetic and potential energy between inlet and outlet are neglected)

```
model PressureLoss "Pressure loss component"
  replaceable package Medium=Modelica.Media.Interfaces.PartialPureSubstance;
  FluidPort port_a, port_b:
  Medium.ThermodynamicState port_a_state_inflow "State at port_a if inflowing";
  Medium.ThermodynamicState port_b_state_inflow "State at port_b if inflowing";
  Medium density d_a, d_b "Density at ports a and b if inflowing";
  replaceable function f "Function to compute the mass flow rate";
equation
  // Medium states for inflowing fluid
  port_a_state_inflow = Medium.setState_phX(port_a.p, inStream(port_a.h_outflow));
  port_b_state_inflow = Medium.setState_phX(port_b.p, inStream(port_b.h_outflow));
  // Mass balance
  0 = port_a.m_flow + port_b.m_flow;
  // Instantaneous propagation of enthalpy flow between the ports with
  // isenthalpic state transformation (no storage and no loss of energy)
  port_a.h_outflow = inStream(port_b.h_outflow);
  port_b.h_outflow = inStream(port_a.h_outflow);
  // (Regularized) Momentum balance
  port_a.m_flow = f(port_a.p, port_b.p, d_a, d_b);
end PressureLoss;
```

If many such components are connected in series between two models with storage, the specific enthalpies are propagated in both directions and available to all pressure loss components, without problems when the mass flow goes through zero. The function f then uses either d_a or d_b depending on the sign of port_a.p-port_b.p, with a suitable regularization around zero to avoid discontinuities.

Please note that these models are highly idealized in order to explain the stream connector concept. Device models in the library are much more complete, handling issues such as initialization, steady vs. dynamic modelling, heat transfer from the outside, etc.

#### Multiple-substance media

Modelica_Fluid can handle models where the fluid contains multiple substances, so that its composition can be characterized by mass fraction vectors.

```
connector FluidPort
   replaceable package Medium = Modelica.Media.Interfaces.PartialMedium
      "Medium model of the fluid";
   flow Medium.MassFlowRate m_flow;
      "Mass flow rate from the connection point into the component"
   Medium.AbsolutePressure p
      "Thermodynamic pressure in the connection point";
   stream Medium.SpecificEnthalpy h_outflow
       "Specific thermodynamic enthalpy close to the connection point if m_flow < 0";
   stream Medium.MassFraction Xi_outflow[Medium.nXi]
       "Independent mixture mass fractions m_i/m close to the connection point if m_flow
< 0";
   stream Medium.ExtraProperty C_outflow[Medium.nC]
       "Properties c_i/m close to the connection point if m_flow < 0";
  end FluidPort;
```

The mass fraction vectors Xi and C are also stream quantities, as they are carried by the mass flow rate. The corresponding connection equations are sum(m_flow*Xi) and sum(m_flow*C), which correspond to mass balances for the single substances. The vector Xi contains the mass fractions of the main components of the fluid, and is used together with p and h to determine the thermodynamic state of the fluid. The vector C contains the mass fraction of the trace components, which are accounted for in mass balances, but is ignored when computing the fluid properties. This allows to easily declare and use medium models with trace components starting from existing medium models (e.g. adding $CO_2$ traces to Moist Air for air conditioning models).

### Approximations in balance equations at connection point

Summing up, when two or more ports of the type FluidPort are connected, the following equations are generated by the tool:

```
sum(port_j.m_flow) = 0;               // Total Mass balance
port_j = port_k;                      // Momentum balance
sum(port_j.m_flow*h_connection) = 0;  // Energy balance
sum(port_j.m_flow*Xi_connection) = 0; // Single component mass balances
sum(port_j.m_flow*C_connection) = 0;  // Trace components mass balances
```

It is **very important** to bear in mind that

- the mass balances are always exact;
- the momentum and energy balance are only exact when two port with the same diameter are connected, because there is no friction and no change in fluid velocity.

In all other cases, i.e., different port diameters and/or multple port connections:

- The momentum balance does not consider friction effects and changes of pressure due to changes in velocity.
- There might thus be errors in the momentum balance of the order of magnitude of the dynamic pressure $\rho v^2/2$.
- The energy balance does not consider the kinetic terms (gravity terms cancel out due to the infinitesimal size of the connection volume). There might thus be errors in the

  momentum balance of the order of magnitude of the kinetic energy v^2/2.

In many applications, where fluid speeds are low and thermal phenomena are mainly of interest, these approximations are commonly made and lead to acceptable results. In all other cases, explicit fitting and junction models should be used, that model explicitly all the kinetic phenomena with the appropriate level of detail.

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### UsersGuide.ComponentDefinition.BalanceEquations

**Balance equations**

For one-dimensional flow along the coordinate "x", the following partial differential equations hold

| | |
|---|---|
| Mass balance | $\frac{\partial(\rho A)}{\partial t} + \frac{\partial(\rho A v)}{\partial x} = 0$ |
| Momentum balance | $\frac{\partial(\rho v A)}{\partial t} + \frac{\partial(\rho v^2 A)}{\partial x} = -A\frac{\partial p}{\partial x} - F_F - A\rho g\frac{\partial z}{\partial x}$ |
| Energy balance 1 | $\frac{\partial(\rho(u + \frac{v^2}{2})A)}{\partial t} + \frac{\partial(\rho v(u + \frac{p}{\rho} + \frac{v^2}{2})A)}{\partial x} = -A\rho v g\frac{\partial z}{\partial x} + \frac{\partial}{\partial x}(kA\frac{\partial T}{\partial x}) + \dot{Q}_e$ |
| Pipe friction | $F_F = \frac{1}{2}\rho v\|v\| f S$ |

| | |
|---|---|
| | x: independent spatial coordinate (flow is along coordinate x)<br>t: time<br>v(x,t): mean velocity<br>p(x,t): mean pressure<br>T(x,t): mean temperature<br>ρ(x,t): mean density<br>u(x,t): specific internal energy<br>z(x): height over ground<br>A(x): area perpendicular to direction x<br>g: gravity constant<br>f: Fanning friction factor<br>S: circumference |

An alternative energy balance can be derived by multiplying the momentum balance with "v" and substracting it from the energy balance 1 above. This results in the "energy balance 2":

| | |
|---|---|
| Energy balance 2 | $$\frac{\partial(\rho u A)}{\partial t} + \frac{\partial(\rho v (u + \frac{p}{\rho}) A)}{\partial x} = vA\frac{\partial p}{\partial x} + vF_F + \frac{\partial}{\partial x}(kA\frac{\partial T}{\partial x}) + \dot{Q}_e$$ |

This formulation separates the internal energy of the fluid from the kinetic energy of fluid flow. The internal energy is treated by the energy balance 2, the kinetic energy is treated by the momentum balance equally well. The evaluation of medium properties, which are independent of the kinetic energy, and the formulation of many fluid models is simplified with the energy balance 2. The overall conservation of energy is achieved by considering the mutual dependencies of energy and momentum balance.

Some components in the library, like DynamicPipe, provide a rigorous implementation of mass, momentum and energy balance, using the energy balance 2 equation. Other components, like Valves and Fittings, neglect the impact of changes of the kinetic energy and potential energy on the energy balance, because they are usually irrelevant compared to changes due to heat flows. The StaticPipe component neglects the effect of kinetic energy, but includes the potential energy in the balance, which might be substantial.

All modelling assumptions and simplifications are stated in the component documentation; please note that some of the assumptions might be stated in the base classes the component inherits from.

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## UsersGuide.ComponentDefinition.UpstreamDiscretization

### Upstream discretization

When implementing a Fluid component, the difficult arises that the value of intensive quantities (such as p, T, ρ) shall be accessed from the **upstream** volume. For example, if the fluid flows from volume A to volume B, then the intensive quantities of volume B have no influence on the fluid between the two volumes. On the other hand, if the flow direction is reversed, the intensive quantities of volume A have no influence on the fluid between the two volumes.

In the Modelica_Fluid library, such a situation is handeled with the following code fragment (from Interfaces.PartialTwoPortTransport):

```
replaceable package Medium =
                Modelica.Media.Interfaces.PartialMedium
```

```
                  annotation(choicesAllMatching = true);

    Interfaces.FluidPort_a port_a(redeclare package Medium = Medium);
    Interfaces.FluidPort_b port_b(redeclare package Medium = Medium);

    Medium.ThermodynamicState port_a_state_inflow
                  "Medium state close to port_a for inflowing mass flow";
    Medium.ThermodynamicState port_b_state_inflow
                  "Medium state close to port_b for inflowing mass flow";

  equation
    // Isenthalpic state transformation (no storage and no loss of energy)
    port_a.h_outflow  = inStream(port_b.h_outflow);
    port_b.h_outflow  = inStream(port_a.h_outflow);

    port_a.Xi_outflow = inStream(port_b.Xi_outflow);
    port_b.Xi_outflow = inStream(port_a.Xi_outflow);

    // Mass balance
    port_a.m_flow + port_b.m_flow = 0;

    // Medium states for inflowing medium
    port_a_state_inflow = Medium.setState_phX(port_a.p, port_b.h_outflow,
port_b.Xi_outflow);
    port_b_state_inflow = Medium.setState_phX(port_b.p, port_a.h_outflow,
port_a.Xi_outflow);

    // Densities close to the parts when mass flows in to the respective port
    port_a_rho_inflow = Medium.density(port_a_state_inflow);
    port_b_rho_inflow = Medium.density(port_b_state_inflow);

    // Pressure drop correlation (k_ab, k_ba are the loss factors for the two flow
    // directions; e.g. for a circular device: k = 8*zeta/(pi*diameter)^2)^2)
    m_flow = Utilities.regRoot2(port_a.p - port_b.p, dp_small,
                                port_a_rho_inflow/k1, port_b_rho_inflow/k2);
```

The medium states for inflowing media can be used to compute density and dynamic viscosity which in turn can be use to formulate the pressure drop equation. The standard pressure drop equation

```
   dp = port_a - port_b;
   m_flow = sqrt(2/(zeta*diameter))*if dp >= 0 then  sqrt(dp)
                                               else -sqrt(-dp)
```

cannot be used, since the function has an infinite derivative at dp=0. Instead the region around zero mass flow rate must be regularized using one of the regularization functions of Modelica_Fluid.Utilities. This requires to have density and/or other medium properties for both flow directions at the same time. These media properties can be computed from the medium states of the inflowing fluid at the two ports.

If the above component is connected between two volumes, i.e., the independent medium variables in port_a and port_b are usually states, then port_a.h and port_b.h are either states (i.e., known quantities in the model) or are computed from states. In either case they are "known". In such a situation, all equations can be directly evaluated without any problems. Zero or reversed mass flow rate does not pose any problems because the medium properties are always computed for both flow directions and are then used in the regularization function.

If 3 or more components are connected together, it can be shown that a system of non-linear algebraic equations appear. The equations are written by purpose in such a form, that a tool can select mass flow rates and pressures as iteration variables of this system. The advantage is that these iteration variables are continuous and even often differentiable. The alternative to use the medium states as iteration variables is not good, because T,h,d are discontinuous for reversing flow direction.

UsersGuide.ComponentDefinition.RegularizingCharacteristics

### Regularizing characteristics

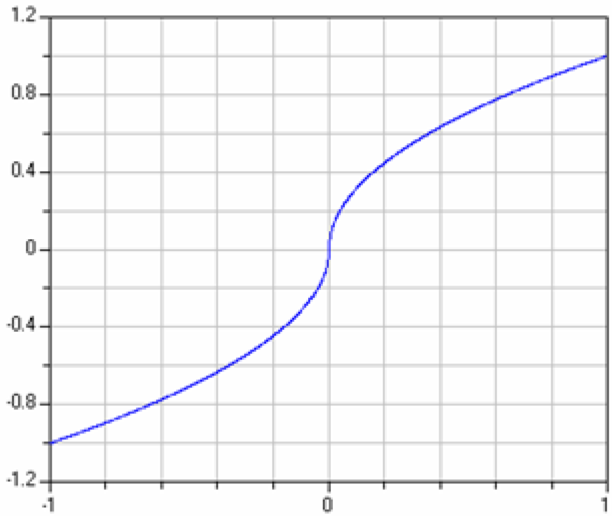
Pressure drop equations and other fluid characteristics are usually computed by **semi-empirical** equations. Unfortunately, the developers of semi-empirical equations nearly never take into account that the equation might be used in a simulation program. As a consequence, these semi-empirical equations can nearly never be used blindly but must be slightly modified or adapted in order that obvious simulation problems are avoided. Below, examples are given to demonstrate what problems occur and how to regularize the characteristics:

### Square root function

In several empirical formulae, expressions of the following form are present, e.g., for turbulent flow in a pipe:

```
y = if x < 0 then -sqrt( abs(x) ) else sqrt(x)
```

A plot of this characteristic is shown in the next figure:




The difficulty with this function is that the derivative at x=0 is infinity. In reality, such a function does not exist. E.g., for pipe flow, the flow becomes laminar for small velocities and therefore around zero the sqrt() function is replaced by a linear function. Since the laminar region is usually of not much practical interest, the above approximation is used.

The direct implementation above does not work in Modelica, because an event is generated when x < 0 changes sign. In order to detect this event, an event iteration takes place. During the event iteration, the active if-branch is not changed. For example, assume that x is positive (= "else" branch) and shall become negative. During the event iteration x is slightly negative and the else branch, i.e., sqrt(x), is evaluated. Since this results in an imaginary number, an error occurs. It would be possible to fix this, by using the **noEvent**() operator to explicitly switch of an event:

```
y = if noEvent(x < 0) then -sqrt( abs(x) ) else sqrt(x)
```

Still, it is highly likely that good integrators will not work well around x=0, because they will recognize that the derivative changes very sharply and will reduce the step size drastically.

There are several solutions around this problem: Around x=0, the sqrt() function can be replaced by a polynomial of 3rd order which is determined in such a way that it smoothly touches the sqrt() function, i.e., the whole function is continuous and continuously differentiable. In the Modelica_Fluid library, implementations of such critical functions are provided in sublibrary Modelica_Fluid.Utilities. The above sqrt() type function is computed by function **Utilities.regRoot**(). This function is defined as:

```
y := x/(x*x+delta*delta)^0.25;
```

where "delta" is the size of the small region around zero where the sqrt() function is approximated by another function. The plot of the function above is practically identical to the one of the original function. However, it has a finite derivative at x=0 and is differentiable upto any order. With the default value of delta=0.01, the difference between the function above and regRoot(x) is 16% around x=0.01, 0.25% around x=0.1 and 0.0025% around x=1.

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## UsersGuide.ComponentDefinition.WallFriction

### Wall friction

One important special case for a pressure loss is the friction at the wall of a pipe under the assumption of quasi steady state flow (i.e., the mass flow rate varies only slowly). In this section it is explained how this case is handeled in the Modelica_Fluid library for pipes with **nonuniform roughness**, including the smooth pipe as a special case (see Pipes.BaseClasses.WallFriction. The treatment is non-standard in order to get a numerically well-posed description.

For pipes with circular cross section the pressure drop is computed as:

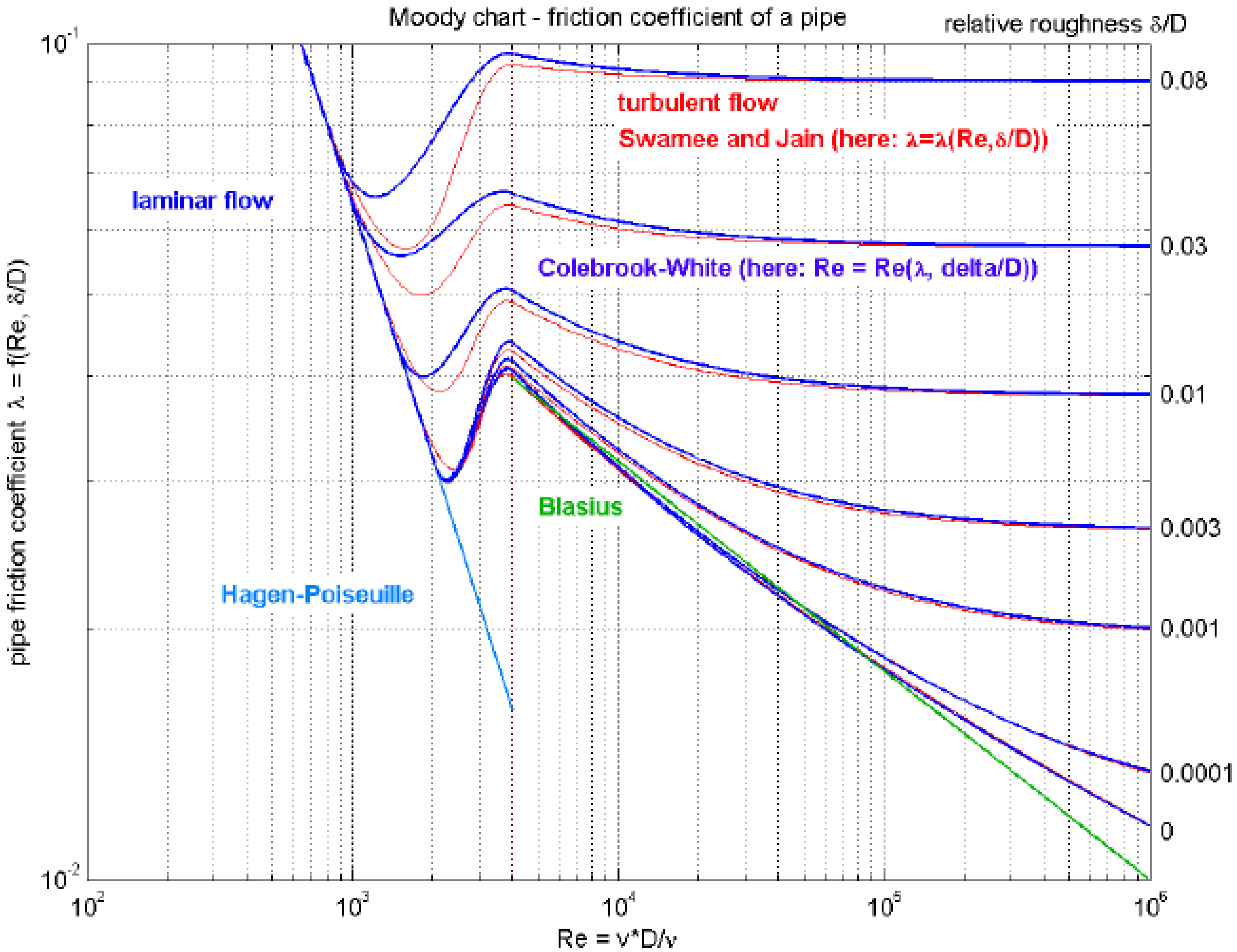
```
   dp = λ(Re,Δ)*(L/D)*ρ*v*|v|/2
      = λ(Re,Δ)*8*L/(π^2*D^5*ρ)*m_flow*|m_flow|
      = λ2(Re,Δ)*k2*sign(m_flow);

with
   Re     = |v|*D*ρ/μ
          = |m_flow|*4/(π*D*μ)
   m_flow = A*v*ρ
   A      = π*(D/2)^2
   λ2     = λ*Re^2
   k2     = L*μ^2/(2*D^3*ρ)
```

where

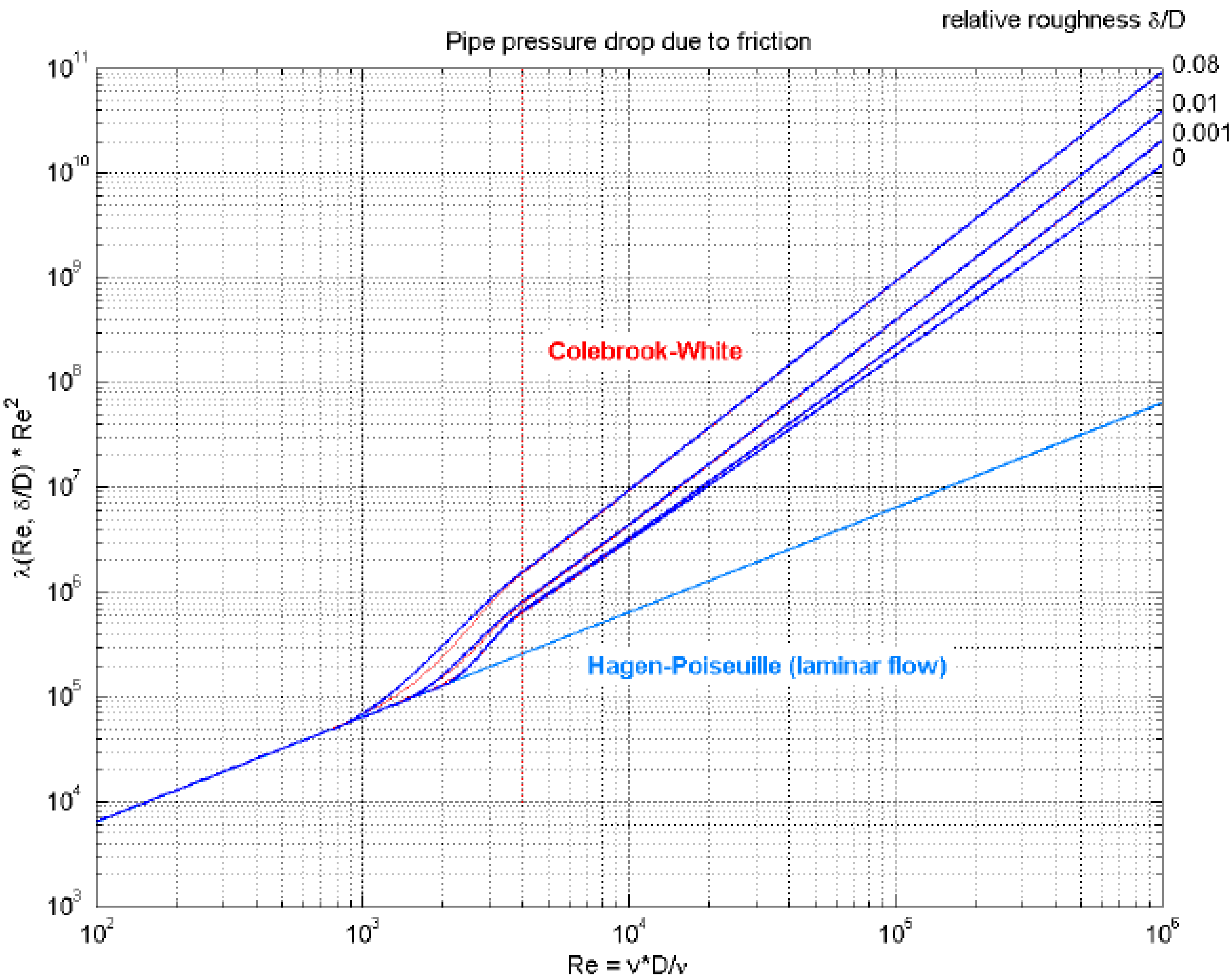
- L is the length of the pipe.
- D is the diameter of the pipe. If the pipe has not a circular cross section, D = 4*A/P, where A is the cross section area and P is the wetted perimeter.
- λ = λ(Re,Δ) is the "usual" wall friction coefficient.
- λ2 = λ*Re^2 is the used friction coefficient to get a numerically well-posed formulation.
- Re = |v|*D*ρ/μ is the Reynolds number.
- Δ = δ/D is the relative roughness where "δ" is the absolute "roughness", i.e., the averaged height of asperities in the pipe (δ may change over time due to growth of surface asperities during service, see *[Idelchick 1994, p. 85, Tables 2-1, 2-2]*).

- ρ is the upstream density.
- μ is the upstream dynamic viscosity.
- v is the mean velocity.

The first form with λ is used and presented in textbooks, see "blue" curve in the next figure:




This form is not suited for a simulation program since λ = 64/Re if Re < 2000, i.e., a division by zero occurs for zero mass flow rate because Re = 0 in this case. More useful for a simulation model is the friction coefficient λ2 = λ*Re^2, because λ2 = 64*Re if Re < 2000 and therefore no problems for zero mass flow rate occur. The characteristic of λ2 is shown in the next figure and is used in Modelica_Fluid:




The pressure loss characteristic is divided into three regions:

- **Region 1**: For **Re ≤ 2000**, the flow is **laminar** and the exact solution of the 3-dim. Navier-Stokes equations (momentum and mass balance) is used under the assumptions of steady flow, constant pressure gradient and constant density and viscosity (= Hagen-Poiseuille flow) leading to λ2 = 64*Re. Therefore:

```
dp = 128*μ*L/(π*D^4*ρ)*m_flow
```

- **Region 3**: For **Re ≥ 4000**, the flow is **turbulent**. Depending on the calculation direction (see "inverse formulation" below) either of two explicite equations are used. If the pressure drop dp is assumed to be known, λ2 = |dp|/k2. The Colebrook-White equation *[Colebrook 1939; Idelchik 1994, p. 83, eq. (2-9)]*:

```
1/sqrt(λ) = -2*lg( 2.51/(Re*sqrt(λ)) + 0.27*Δ)
```

  gives an implicit relationship between Re and λ. Inserting λ2 = λ*Re^2 allows to solve this equation analytically for Re:

```
Re = -2*sqrt(λ2)*lg(2.51/sqrt(λ2) + 0.27*Δ)
```

  Finally, the mass flow rate m_flow is computed from Re via m_flow = Re*π*D*μ/4*sign(dp). These are the **red** curves in the diagrams above.
  If the mass flow rate is assumed known (and therefore implicitly also the Reynolds number), then λ2 is computed by an approximation of the inverse of the Colebrook-White equation *[Swamee and Jain 1976; Miller 1990, p. 191, eq.(8.4)]* adapted to λ2:

```
λ2 = 0.25*(Re/lg(Δ/3.7 + 5.74/Re^0.9))^2
```

The pressure drop is then computed as dp = k2*λ2*sign(m_flow). These are the **blue** curves in the diagrams above.

- **Region 2**: For **2000 ≤ Re ≤ 4000** there is a transition region between laminar and turbulent flow. The value of λ2 depends on more factors as just the Reynolds number and the relative roughness, therefore only crude approximations are possible in this area.
  The deviation from the laminar region depends on the relative roughness. A laminar flow at Re=2000 is only reached for smooth pipes. The deviation Reynolds number Re1 is computed according to *[Samoilenko 1968; Idelchik 1994, p. 81, sect. 2.1.21]* as:

  ```
  Re1 = 745*e^(if Δ ≤ 0.0065 then 1 else 0.0065/Δ)
  ```

  These are the **blue** curves in the diagrams above.
  Between Re1=Re1(δ/D) and Re2=4000, λ2 is approximated by a cubic polynomial in the "lg(λ2) - lg(Re)" chart (see figures above) such that the first derivative is continuous at these two points. In order to avoid the solution of non-linear equations, two different cubic polynomials are used for the direct and the inverse formulation. This leads to some discrepancies in λ2 (= differences between the red and the blue curves). This is acceptable, because the transition region is anyway not precisely known since the actual friction coefficient depends on additional factors and since the operating points are usually not in this region.

The absolute roughness δ has usually to be estimated. In *[Idelchik 1994, pp. 105-109, Table 2-5; Miller 1990, p. 190, Table 8-1]* many examples are given. As a short summary:

| | | |
|---|---|---|
| **Smooth pipes** | Drawn brass, coper, aluminium, glass, etc. | δ = 0.0025 mm |
| **Steel pipes** | New smooth pipes | δ = 0.025 mm |
| | Mortar lined, average finish | δ = 0.1 mm |
| | Heavy rust | δ = 1 mm |
| **Concrete pipes** | Steel forms, first class workmanship | δ = 0.025 mm |
| | Steel forms, average workmanship | δ = 0.1 mm |
| | Block linings | δ = 1 mm |

The equations above are valid for incompressible flow. They can also be applied for **compressible** flow up to about **Ma = 0.6** (Ma is the Mach number) with a maximum error in λ of about 3 %. The effect of gas compressibility in a wide region can be taken into account by the following formula derived by Voronin *[Voronin 1959; Idelchick 1994, p. 97, sect. 2.1.81]*:

```
λ_comp = λ*(1 + (κ-1)/2 * Ma^2)^(-0.47)
```

where κ is the isentropic coefficient (for ideal gases, κ is the ratio of specific heat capacities cp/cv). An appreciable decrease in the coefficent "λ_comp" is observed only in a narrow transonic region and also at supersonic flow velocities by about 15% *[Idelchick 1994, p. 97, sect. 2.1.81]*. This effect is not yet included in Modelica_Fluid. Another restriction is that the pressure drop model is valid only for steady state or slowly changing mass flow rate. For large fluid acceleration, the pressure drop depends additionally on the frequency of the changing mass flow rate.

### Inverse formulation

In the "Advanced menu" it is possible via parameter "from_dp" to define in which form the pressure drop equation is actually evaluated (**default** is from_dp = **true**):

```
from_dp = true:   m_flow = f1(dp)
        = false:  dp     = f2(m_flow)
```

"from_dp" can be useful to avoid nonlinear systems of equations in cases where the inverse pressure loss function is needed.

**Summary**

A detailed pressure drop model for pipe wall friction is provided in the form m_flow = f1(dp, Δ) or dp = f2(m_flow, Δ). These functions are continuous and differentiable, are provided in an explicit form without solving non-linear equations, and do behave well also at small mass flow rates. This pressure drop model can be used stand-alone in a static momentum balance and in a dynamic momentum balance as the friction pressure drop term. It is valid for incompressible and compressible flow up to a Mach number of 0.6.

**References**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Samoilenko L.A. (1968):
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Swamee P.K. and Jain A.K. (1976):
: **Explicit equations for pipe-flow problems**. Proc. ASCE, J.Hydraul. Div., 102 (HY5), pp. 657-664.

Voronin F.S. (1959):
: **Effect of contraction on the friction coefficient in a turbulent gas flow**. Inzh. Fiz. Zh., vol. 2, no. 11, pp. 81-85.


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## UsersGuide.ComponentDefinition.ValveCharacteristics

### Valve characteristics

The control valves in Valves have the parameters **Kv** and **Cv**. They are defined as unit-less variables, but in the description text a unit is given. The reason for this definition is the following:

The basic equation for valves is:

```
q = Av*sqrt(dp/rho)
```

In SI units, [q] is m3/s, [dp] is Pascal, [rho] is [kg/m3], and Av is an area, thus [Av] = m2. Basically, the equation stems from Bernoulli's law. Av is roughly 1.4 times the area of the valve throat. Now, usually valves aren't so big that their throat area is of the order of magnitude of square meters - depending on the applications it is from a few square millimeters to a few square centimeters. Therefore, in the common engineering practice, the following equations are used:

Europe:

```
q = Kv sqrt(dp/(rho/rho0)) , with [q] = m3/h, [dp] = bar
```

US:

```
q = Cv sqrt(dp/(rho/rho0)) , with [q] = USG/min, [dp] = psi
```

In both cases rho0 is the density of cold water at 4 °C, 999 kg/m3. Note that these equations use relative, not absolute densities.

It turns out that Kv = 1e6/27.7*Av and Cv = 1e6/24*Av, so both US and EU engineers get more or less the same numbers (just by sheer luck), with a range between a few units and a few hundred units for typical industrial applications, and everybody is happy.

Now, we've got two problems here. First, depending on the unit, we change the equation: with SI units, we use the density, with non-SI units, we use the relative density. So the quantities (not only the units!) of Av and Cv/Kv are different.

Second, the units of Kv and Cv are usually labelled "m3/h" and "USG/min", but as a matter of fact they are different, as can be seen from the equations above: they are actually m3/(h*sqrt(bar)) and USG/(min*sqrt(psi)). If I have a valve with Kv = 10 m3/h, it means I get 10 m3/h "for a pressure drop of 1 bar". Unfortunately, this is not correct from the point of view of strict dimensional analysis, but nobody uses sqrt(Pa) or sqrt(bar).

You might think this is crazy (it is, expecially when you try to explain it), but as a matter of fact the valve coefficient is **never** given in square meters in any catalog or datasheet; Cv is still the most used (even in Europe), followed by Kv. So, it will be very inconvenient for users to type in Av in square meters.

The pragmatic approach used in Modelica_Fluid.ControlValves is to accept the fact that m3/h and USG/min are not the real units of Cv and Kv, so we can't use the general unit conversion mechanism, put them just as mnemonic labels in the comment, use non-dimensional coefficients in the interface, and then define properly dimensioned unit conversion within the model

---

## UsersGuide.BuildingSystemModels

**Building system models**

This section is a quick primer explaining how to build a system model using Modelica_Fluid. It covers some key issues, such as the System component, the definition of medium models in the system, and the typical customizations available in the Modelica_Fluid models.

### Package Content

| Name | Description |
|---|---|
| SystemComponent | System component |
| MediumDefinition | Definition of the medium models |
| CustomizingModel | Customizing a system model |

---

## UsersGuide.BuildingSystemModels.SystemComponent

**System component**

The Modelica_Fluid library is designed so that each model of a system must include an instance `system` of the `System` component at the top level, in the same way as the `World` model of the MultiBody Library. The System component contains the parameters that describe the environment surrounding the components (ambient pressure and temperature, gravity acceleration), and also provides default settings for many parameters which are used consistently by the models in the library. These parameters are then propagated to the individual components using the inner/outer variable mechanism. In case the system model is structured hieararchically, it is possible to either put a single System component at the top level, or possibly to put many of them at different levels, which will only influence the system components from that level down.

All the parameters defined in the System model are used as default values for the parameters of the individual components of the system model. Note that it is always possible to ovverride these defaults locally by changing the value of the parameters in the specific component instance.

- The *General* tab of the System model allows to set the default enviroment variables (pressure, temperature and gravity) used by all the components.
- The *Assumptions* tab allows to change the default modelling assumptions used by all the components (see the section *Customizing a system model later*)
- The *Initialization* tab allows to define default start values for mass flow rates, pressures and temperatures in the model; this can be useful to help nonlinear solver converge to the solution of any nonlinear system of equations that involves such variables, by providing meaningful guess values.
- The *Advanced* tab contains default values for parameters used in the advanced settings of some components.

Remember to **always add a System component** at the top level of your system model, otherwise you will get errors when compiling the model. The tool will automatically name it `system`, so that it is recognised by all other components.

---

## UsersGuide.BuildingSystemModels.MediumDefinition

### Definition of the medium models

All the models in Modelica_Fluid compute fluid properties by using medium models defined by Modelica.Media packages. Custom fluid models can also be used, provided they extend the interfaces defined in Modelica.Media.Interfaces.

All the components in Modelica_Fluid use a *replaceable* medium package, called `Medium`: the model is written for a generic fluid, and a specific fluid model can then be specified when building a system model by redeclaring the package. This can be done in different ways:

- If several components use the same medium, it is possible to select all of them within a GUI, and set them simultaneously (as they are all named Medium).
- It is also possible to declare one or more (possibly replaceable) medium packages in the model, and then use them to set up the individual components

.

---

## UsersGuide.BuildingSystemModels.CustomizingModel

### Customizing a system model

Once a system model has been built, it is possible to obtain different approximations by appropriately setting the defaults in the System component (and/or the settings of specific components.

The Assumptions | allowFlowReversal parameter determines whether reversing flow conditions (i.e. flow direction opposite to design direction) are modelled or not. By default, reversing flow conditions are considered by the models, but this causes a significant increase of complexity in the equations, due to the conditional equations depending on the flow direction. If you know in advance that the flow in a certain component (or in the whole system) will always be in the design direction, then setting this parameter to false will produce a much faster and possibly more robust simulation code.

The flags in the Assumptions | Dynamics tab allow different degrees of approximation on the mass, energy, and momentum equations of the components.

- DynamicFreeInitial: dynamic equations are considered (nonzero storage), no initial equations are provided, and the start values are used as guess values.
- FixedInitial: dynamic equations are considered (nonzero storage) and initial equations are included, fixing the states to the start values provided by the component parameters.
- SteadyStateInitial: dynamic equations are considered (nonzero storage), initial equations are included, declaring that the state derivatives are zero (steady-state initialization) and the start values are used as guess values for the nonlinear solver.
- SteadyState: algebraic (or static) balance equations are considered (no storage) and the start values are used as guess values for the nonlinear solver.

It is then possible to neglect the storage of mass, momentum, and energy in the whole system (or just in parts of it) just by a few mouse clicks in a GUI, and also to change the type of initialization when considering dynamic models. Please note that some combinations of the options might be contradictory, and will therefore trigger compilation errors.

---

## UsersGuide.ReleaseNotes

### Release notes

#### Version 1.0, 2009-01-28

Modelica_Fluid was refactored and finalized for the release:

- Refactoring of the code
  This became necessary as the previous release Modelica_Fluid Streams Beta3 still reflected the long development history, while the basic concepts had been crystalized. Please consult the subversion control (SVN) logs for individual changes.
- Device oriented package names
  The former sub-packages Junctions and PressureLosses have been combined into the new subpackage Fittings. The former Pumps and Volumes.SweptVolume have become the initial version of fluid Machines. The former Volumes package is now called Vessels.
- Complete implementation of one-dimenstional fluid flow
  The balance equations as documented in UsersGuide.ComponentDefinition.BalanceEquations are

now completely implemented. The implementations with generic boundary flow and source terms find in:

- Interfaces.PartialDistributedVolume, Interfaces.PartialLumpedVolume: Energy, Mass and Substance balances
- Interfaces.PartialDistributedFlow, Interfaces.PartialLumpedFlow: Momentum balance

Specific models combine the balances and define the boundary flow and source terms as appropriate. For instance

- Vessels.OpenTank extends from Interfaces.PartialLumpedVolume,
- Fittings.SimpleGenericOrifice extends from Interfaces.PartialLumpedFlow, besides Interfaces.PartialTwoPortTransport,
- Pipes.DynamicPipe is based on Interfaces.PartialDistributedVolume and Interfaces.PartialDistributedFlow, besides Interfaces.PartialTwoPort.

All non-trivial mass and energy balances of Vessels, Machines and Fittings have been replaced with PartialLumpedVolume. The mass and energy balances of Pipes are based on PartialDistributedVolume.
See Examples.BranchingDynamicPipes for an example utilizing the complete balance equations.

- New approach for the connection of distributed flow models
  The staggered grid approach offers different choices for the connection approach. So far the preferred modeling was to put full mass balances into the pipes and expose half momentum balances through the ports (ModelStructure a_v_b). This resulted in nonlinear equation systems for pressure/flow correlations in connection sets. A new default ModelStructure av_vb has been introduced putting full momentum balances into the models and exposing half mass balances through the ports (av_vb replaces the former avb). This way the nonlinear equation systems are avoided. High-index DAEs need to be treated instead in connection sets. Alternatively a Fitting like SuddenExpansion can be introduced to account for different cross flow areas of connected flow models.

- New Vessels.BaseClasses.PartialLumpedVessel treating the ports, including hydraulic resistances, for ClosedVolume, SimpleTank and SweptVolume.

- Clarification of modeling assumptions
  The documentation has been extended to better explain the modeling assumptions made. In particular the section UsersGuide.ComponentDefinition.FluidConnectors now makes clear that the ports represent the thermodynamic enthalpy, as opposed to stagnation enthalpy, and thermodynamic or static pressure, as opposed to total pressure. An new package Explanatory has been added to the examples to show the difference beteen static pressure and total pressure and possible implications.
  See Examples.Explanatory.MomentumBalanceFittings.

- System (former Ambient)
  The use of the global System object has been extended towards common default values for modeling assumptions, initialization, and advanced settings that are different for each application of the library but should nevertheless provide default values for reasons of convenience. In particular steady-state initialization and complete steady-state simulation can now be specified system-wide. A new Types.Init.Dynamics has been introduced, combining steady-state and initial conditions. The former Types.Init has become obsolete.
  See Examples.HeatingSystem

  .

- Extension of pumps for better consideration of zero flow and heat transfer with environment
  The simplified mass and energy balances have been replaced with a rigorous formulation. Moreover an optional heat transfer model can be configured for heat exchanged with the environment or the housing.
  See Machines.BaseClasses.PartialPump

- Refinement of valves for flow reversal
  All valves now use upstream discretization for reverting flow conditions.

- Finalization of trace substances
  Modelica_Fluid now provides a sound implementation for trace substances, which can easily be added to existing Media models, in order to study their evolution in a fluid system.

  See Examples.TraceSubstances.RoomCO2WithControls
  .

- Vectorized ports for volumes
  The ports of models that typically have large volumes, like Vessels and Sources, have been vectorized. Formerly the connection of multiple flow models to the same port of such volume models resulted in unintended mixing equations for stream variables in connection sets outside the volumes. The mixing takes place inside the volumes when using multiple ports. Moreover a Fittings.MultiPort has been introduced. It can be attached to components like pipes, which don't have vectorized ports on their own.

- Inverse parameterization of flow models with nominal operational conditions
  Flow models have been added or extended to support the parameterization with nominal values (Machines.ControlledPump, Orifices.SimpleGenericOrifice, Pipes.BaseClasses.FlowModels.NominalTurbulentFlow). They are intended for early phases of system modeling, if geometries and flow characteristics are of secondary interest. As these models use the same interfaces, base classes and naming conventions, they can easily be replaced with more detailed models as more information shall be taken into account later on.
  See Examples.InverseParameterization

  .

- Replaceable HeatTransfer models
  The Vessels and the Machines now have replaceable HeatTransfer models, besides the Pipes. All HeatTransfer models are optional. The heat transfer models are parameterized with the Medium and the ThermodynamicState of involved flow segments.
  See Interfaces.PartialHeatTransfer.

- All examples are working now (using Dymola 7.1).
  The number of examples has been extended with the former critical test cases HeatingSystem and IncompressibleFluidNetwork. Moreover the HeatExchangers have been moved into Examples.

**Version 1.0 Streams Beta 3, 2008-10-12**

Modelica_Fluid was further improved:

- Volumes, tanks, junctions
  Added asserts to require that ports are connected at most once. If a user would perform more than one connection, ideal mixing takes place for the connected components and this is nearly never what the user would like to have

- Ambient
  Renamed Ambient to System, including adaptation of models.
  Introduced default values system.flowDirection and as a comment system.initType.
  system.flowDirection is used in two port components as default.

- GenericJunction
  Corrected specification of flowDirection.
  Added a HeatPort.

- PartialDistributedFlow models
  Adapted determination of velocities to usage of upstream properties at ports.
  Corrected and unified initialization of p_start[*] values.

- DistributedPipe models
  Changed treatment of port densities and viscosities to the treatment of the lumped pipe model. This way events are avoided if the mass flow rate crosses or approaches zero.
  Correct determination of Reynolds numbers.
  Added test model DistributedPipeClosingValve.

- ControlValves
  Changed flowCharacteristic into valveCharacteristic
  Removed parameter Kv and added dp_nom, m_flow_nom from linear and discrete valve interfaces.
  Added test cases.
  Adapted Examples to new LinearValve and DiscreteValve, using nominal values instead of Kv.
  Changed default flow coefficient selection to OpPoint

- Fixed units for Kv and Cv in control valve models.

- Updated tests for valves.

- Bug in Modelica_Fluid.Test.TestComponents.Pumps.TestWaterPump2 corrected (complicated redeclaration issue).

- Adapted AST_BatchPlant so that "Check" is sucessful. Simulation fails after 600 s.

- Introduced density_pTX(Medium.p_default, Medium.T_default, Medium.X_default) as default value for nominal densities (previously it was a literal such as 1000).

- Pumps
  Updated energy balance equations for pumps (no division by zero anymore, fixed several bugs related to Np).
  Added two more test cases for pumps.
  Fixed pump initialization options.

- PartialPump
  Explanation for the energy balanced added as comment
  "h=0" replaced by "h=Medium.h_default" since otherwise an assert is triggered if "h=0" is not in the medium range.
  Fluid ports positioned in the middle line and using the same size as for all other components.

- Pumps.Pump
  Resized input connector, so that it has the same size as the standard input connectors.
  Changed icon text to input connector to "N_in [rpm]".
  Added unit 1/min to the external and internal input connector.

- PartialValve
  fillcolor=white added to icon
  made line Thickness = Single, since icon does not look nice sometimes

- All components
  Changed %name color from black to blue (is a conversion bug, since Modelica 2 has blue as default color whereas Modelica 3 has black and Dymola is not taking care off this).

- Sources
  Made icon elements unvisible, if corresponding input is disabled.

- Valves, Pipes, PressureLosses, HeatExchangers, two port senors
  Added an arrow in the icon for the "design flow direction" from port_a to port_b.

- Moved default initialization in "System" in to a comment, since no effect yet
- Added the explanation from Francesco for Kv, Cv for valves in the users guide and added links in the corresponding valves to this description

"Check" for the library is successful. "Check with Simulation" (i.e., simulating all test models in the library) is successful with the exceptions:

- Examples.AST_BatchPlant.BatchPlant_StandardWater
  Need to be fixed in a later release (requires quite a lot of work).
- Test.TestOverdeterminedSteadyStateInit.Test5
  Test.TestOverdeterminedSteadyStateInit.Test6
  These are test cases where too much initial conditions are given. The goal is to work on methods how this can be handled. So, this is a principal problem that these models do not simulate.

**Version 1.0 Streams Beta 2, 2008-10-08**

Modelica_Fluid was transformed to Modelica 3 and to Modelica Standard library 3.0 (by automatic conversion). Further changes:

- Emulated enumerations changed to real enumerations.
- Improved ControlValves code
- Introduced stream connectors with stream keyword (was previously an annotation)
- Introduced inStream() instead of inflow()
- Introduced m_flow*actualStream(h_outflow) instead of streamFlow() or semiLinear(m_flow, inStream(h_outflow), medium.h)
- Removed Modelica_Fluid.Media and all references to it (since now available in Modelica.Media of MSL3.0).
- Fixed PartialLumpedVolume for media with multiple substances
- New function "Utilities.RegFun3" for regularization with static head
- Fix density in static head models with the new RegFun3 functions (ticket 7)
- Minor bug in MixingVolume corrected:
  V_lumped and Wb_flow have been set as modifiers when extending from PartialLumpedVolume, although they are not declared as input. This is not allowed in Modelica 3. Fixed by replacing the modifiers by equations.
- Modelica_Fluid.Sources.FixedBoundary
  Introduced p_default, T_default, h_default as default values, since otherwise warnings will always be printed because parameter value is missing.
- Modelica_Fluid.Sources.Boundary_pT
  Modelica_Fluid.Sources.Boundary_ph
  Modelica_Fluid.Sources.MassFlowSource_T
  Changed default values of parameters reference_p, reference_T to p_default, T_default (some have been xx_default, some reference_xx, it seems best to always use the same approach)
- Modelica_Fluid.Pipes.BaseClasses.PartialDistributedFlow
  Added default value for parameter "rho_nominal" = Medium.density_pTX(Medium.p_default,

Medium.T_default, Medium.X_default) in order to avoid unnecessary warning messages. Should be replaced by "Medium.rho_default", once available.

- Modelica_Fluid.Pipes.DistributedPipe
  Modelica_Fluid.Pipes.DistributedPipeSb
  Modelica_Fluid.Pipes.DistributedPipeSa
  Added default value for parameter "mu_nominal" (computed with default values of p,T,X from dynamicViscosity(..))

- Modelica_Fluid.Pipes.BaseClasses.PartialDistributedFlowLumpedPressure
  Replaced default value "rho_nominal=0.01" by Medium.density_pTX(Medium.p_default, Medium.T_default, Medium.X_default)

- Modelica_Fluid.Volumes.OpenTank
  Modelica_Fluid.Volumes.Tank
  Corrected icons of ports (wrongly sized by automatic conversion from Modelica 2 to Modelica 3).

- Examples.BranchingDistributedPipes
  Modelica_Fluid.Test.TestComponents.Junctions.TestGenericJunction
  Modelica_Fluid.Test.TestComponents.Pipes.TestDistributedPipe01
  Parameters dp_nom, m_flow_nom are not defined in junction components. Values provided.

- PressureLosses.BaseClasses.QuadraticTurbulent.BaseModel
  No default or start values for "parameter LossFactorData data" Changed the model to "partial model" to avoid warning messages

**Version 1.0 Streams Beta 1, 2008-05-02**

Changed connectors to stream connectors and adapted the following sublibraries:

- Volumes
- PressureLosses
- Sensors
- Sources
- ControlValves
- HeatExchangers
- Junctions
- Pipes
- Pumps
- Test and Exampleas (most of the examples and tests are simulating)

Other changes:

- Introduced HeatPorts with vectorized icon in Modelica_Fluid.Interfaces
- Deleted Modelica_Fluid.WorkInProgress since it seems to be too much work to convert it to stream connectors
- Added Modelica_Fluid.Media (contains ConstantLiquidWater medium because functions are missing in Modelica.Media),

- 

- Added two additional test cases with LumpedPipes (to identify problems with hierarchically connected stream connectors).
- Deleted TestPortVolumes since PortVolumes can no longer be implemented with stream connectors
- Leakage flow introduced for valves
- Drumboiler Example corrected
- Regularization for sensors (T,h,...), in order that no discontinuity for bi-directional flow
- Density computation in static head corrected
- New functions Utilities.regUnitStep, regStep
- New components (TestComponents.Sensors.TestOnePortSensors1/.TestOnePortSensors2l, TestRegStep)
- PartialTwoPortTransport
    - Introduced port_a.T, port_b.T (for plotting)
    - Removed initialization menu
    - Introduced dp_start, m_flow_start
    - Removed previous start values of PartialTwoPortTransport in all models
- PartialPump: Removed p_nom, since no longer needed (only dp_nom)
- Made "%name" in the icons of all components unified (and better looking)
- Changed default value of leackage flow of valves to zero.
- Fixed Modelica_Fluid.Junctions.MassFlowRatio so that it compiles (inflow(..) currently only supported for scalars, not for vectors)
- Added script libraryinfo.mos, in order that Modelica_Fluid appears in the Dymola library window automatically (provided library is in MODELICAPATH)
- Replaced semiLinear(..) by streamFlow(..) (not yet at all places)
- Introduced check-boxes in parameter menu of Sources (is more convenient to use)
- TwoPortTransport
  Computation of V_flow and optionally port_a_T, port_b_T. Error in temperature calculation corrected
- Tank:
  Default of bottom pipe diameter changed from 0 to 0.1, since otherwise a division by zero (if not connected and not changed).
- Modelica_Fluid.ControlValves.ValveVaporizing:
  Due to changes in PartialTwoPortTransport, port_a_T_inflow does no longer exist and the usage to it is removed.
- Modelica_Fluid.Test.TestComponents.Sensors.TestTemperatureSensor:
  Due to changes in PartialTwoPortTransport, p_start does no longer exist and the usage to it is removed.

- VersionBuild introduced, as well as automatic update of VersionBuild/VersionDate

**Version 1.0 Beta 4, 2008-04-26**

Changes according to the Modelica Design Meetings since the last beta version. This version is used to "freeze" the current development, in order to change to a version with a new connector design using stream variables.

**Version 1.0 Beta 3, 2007-06-05**

Changes according to the Modelica Design Meetings since the Modelica'2006 conference, especially, improved initialization, changed Source components (input connectors must be enabled), improved tank component, moved test models from Examples to new package Test, many more test models, etc. This version is slightly non-backward compatible to version 1.0 Beta 2.

**Version 1.0 Beta 2, 2006-08-28**

Package considerably restructured and some new components added. New examples (ControlledTankSystem, AST_BatchPlant).

**Version 0.96, 2006-01-08**

- New package Modelica_Fluid.PressureLosses.
- New package Modelica_Fluid.WorkInProgress.
- New components in Modelica_Fluid.Components:
  ShortPipe, OpenTank, ValveDiscrete, StaticHead.
- New components in Modelica_Fluid.Examples.
- Improved users guide.

**Version 0.910, 2005-10-25**

- Changes as decided on 41th-45th Modelica Design Meetings (details, see minutes).

**Version 0.900, 2004-10-18**

- Changes as decided on 40th Modelica Design Meeting in Dresden (see also minutes)

**Version 0.794, 2004-05-31**

- Sensors.mo, Examples/DrumBoiler.mo: extend sensors with user choice for measurement unit.
- Components.mo, Types.mo: moved components and types to package Examples.
- Moved Examples from **file** Modelica_Fluid/package.mo to Modelica.Media/Examples **subdirectory** and created separate file per sub-package. This shall simplify the maintenance of examples by different authors
- Moved Interfaces from file Modelica_Fluid/package.mo to Modelica_Fluid/Interfaces.mo

**Version 0.793, 2004-05-18**

- Removed "semiLinear" function since available as Modelica 2.1 built-in operator in Dymola.
- Minor bug in "Components.ShortPipe" corrected.
- Bug in "Components.Orifice" corrected (dp was previously calculated in Interfaces.PartialTwoPortTransport, but this was removed and not updated in Orifice).

**Version 0.792, 2003-11-07**

This is the first consolidated version made up from several changes for Modelica'2003. Modelica_Fluid is still quite far away from a library that could be included in the Modelica standard library.

**Previous Releases**

- *Oct., 2003*
  by Martin Otter: Adapted to latest design of the Modelica.Media library.
  by Ruediger Franke: Included sensor components and Modelica_Fluid.Examples.DrumBoiler example.
- *Sept., 2003*
  by Martin Otter: Changes according to the decisions of the Modelica design meeting in Dearborn, Sept. 2-4, 2003. Fluid library splitt in to two packages: Modelica.Media that contains the media models and Modelica_Fluid that contains fluid flow components. Modelica.Media is independent of Modelica_Fluid and my be used also from other packages that may have a different design as Modelica_Fluid.
- *Aug., 2003*
  by Martin Otter: Improved documentation, PortVicinity (now called semiLinear) manually expanded, two different volume types, replaced number of massFractions from n to n-1 in order that usage of model for single substances is easier and in order that no special cases have to be treated in the equations (previously the massFraction equations had to be removed for single substance flow; now they are removed automatically, since the dimensions are zero, and not one as previously), included asserts to check the validity of the medium models, included the dynamic viscosity in the medium models, adapted the examples and medium models to the changes in Interfaces, improved menus according to the new features in Dymola 5.1. Added "Components.ShortPipe" that contains a detailed model of the frictional losses in pipes over a very wide range.
- *Feb., 2003*
  by Martin Otter: Included several elementary components and a model for moisted air. Some elementary components, such as FixedAmbient, are adapted versions from the SimpleFlow fluid library of Anton Haumer.
- *Dec., 2002*
  by Hubertus Tummescheit: Improved version of the high precision water model (Copy from ThermoFluid library, code reorganization, enhanced documentation, additional functions).
- *Nov. 30, 2002*
  by Martin Otter: Improved the design from the design meeting: Adapted to Modelica standard library 1.5, added "choicesAllMatching=true" annotation, added short documentation to "Interfaces", added packages "Examples" and "Media" (previously called "Properties") from previous versions and adapted them to the updated "Interfaces" package.

- *Nov. 20-21, 2002*
  by Hilding Elmqvist, Mike Tiller, Allan Watson, John Batteh, Chuck Newman, Jonas Eborn: Improved at the 32nd Modelica Design Meeting.

- *Nov. 11, 2002*
  by Hilding Elmqvist, Martin Otter: improved version.

- *Nov. 6, 2002*
  by Hilding Elmqvist: first version of the basic design.

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## UsersGuide.ModelicaLicense2

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## Acknowledgements:

The development of this library has been a collaborative effort and many have contributed.

- The previous design of this library (until beginning of 2008) was based on the paper Elmqvist H., Tummescheit H., and Otter M.: Object-Oriented Modeling of Thermo-Fluid Systems. Modelica 2003 Conference, Linköping, Sweden, pp. 269-286, Nov. 3-4, 2003.
  This design has been partly changed, especially by the introduction of the streams concept.
- The Fluid library development was organized in 2002-2004 by Martin Otter, since 2004 it is organized by Francesco Casella, and since 2008 it is organized jointly by Francesco Casella and Rüdiger Franke.
- Francesco Casella included several components of his ThermoPower library with some rewriting. The stream connector concept used in Modelica_Fluid is based on a similar concept developed by him for the ThermoPower library.
- Rüdiger Franke initiated the stream connector concept as an extension and improved version of the ThermoPower concept. In Nov. 2008 - Jan. 2009 he greatly restructured and improved the library.
- 
- Michael Wetter introduced trace constituents in Modelica_Fluid consistently and provided corresponding examples under Examples.TraceSubstances.
- The following people contributed to the fluid component models, examples, and the further design of the library (alphabetical list):
  John Batteh, Francesco Casella, Jonas Eborn, Hilding Elmqvist, Rüdiger Franke, Manuel Gräber, Henning Knigge, Sven Erik Mattsson, Chuck Newman, Hans Olsson, Martin Otter, Katrin Prölß, Christoph Richter, Michael Sielemann, Mike Tiller, Hubertus Tummescheit, Allan Watson, Michael Wetter.

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## Modelica_Fluid.Examples

**Demonstration of the usage of the library**

### Information

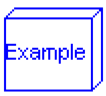
Extends from Modelica.Icons.Library (Icon for library).

### Package Content

| Name | Description |
|---|---|
| PumpingSystem | Model of a pumping system for drinking water |
| HeatingSystem | Simple model of a heating system |
| DrumBoiler | Drum boiler example, see Franke, Rode, Krueger: On-line Optimization of Drum Boiler Startup, 3rd International Modelica Conference, Linkoping, 2003 |
| Tanks | Library demonstrating the usage of the tank model |
| ControlledTankSystem | Tank system with controller, start/stop/shut operation and diagram animation |
| AST_BatchPlant | Model of the experimental batch plant at Process Control Laboratory at University of Dortmund (Prof. Engell) |
| IncompressibleFluidNetwork | Multi-way connections of pipes and incompressible medium model |
| BranchingDynamicPipes | Multi-way connections of pipes with dynamic momentum balance, pressure wave and flow reversal |
| HeatExchanger | Demo of a heat exchanger model |
| TraceSubstances | Library demonstrating the usage of trace substances |
| InverseParameterization | Demonstrates the parameterization of a pump and a pipe for given nominal values |
| Explanatory | A set of examples illustrating when special attention has to be paid |

## Examples.PumpingSystem

**Model of a pumping system for drinking water**



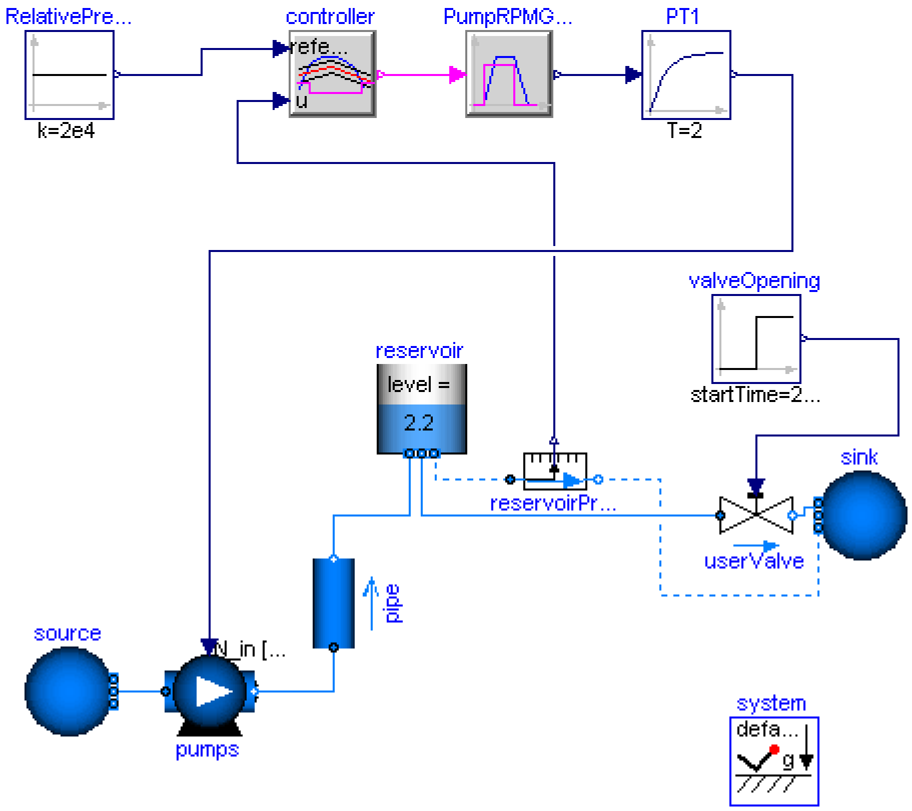

### Information

Water is pumped from a source by a pump (fitted with check valves), through a pipe whose outlet is 50 m higher than the source, into a reservoir. The users are represented by an equivalent valve, connected to the reservoir.

The water controller is a simple on-off controller, regulating on the gauge pressure measured at the base of the tower; the output of the controller is the rotational speed of the pump, which is represented by the output of a first-order system. A small but nonzero rotational speed is used to represent the standby state of the pumps, in order to avoid singularities in the flow characteristic.

Simulate for 2000 s. When the valve is opened at time t=200, the pump starts turning on and off to keep the reservoir level around 2 meters, which roughly corresponds to a gauge pressure of 200 mbar

If using Dymola, turn off "Equidistant time grid" to avoid numerical errors.

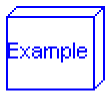



Extends from Modelica.Icons.Example (Icon for an example model).

---

### Examples.HeatingSystem

**Simple model of a heating system**




#### Information

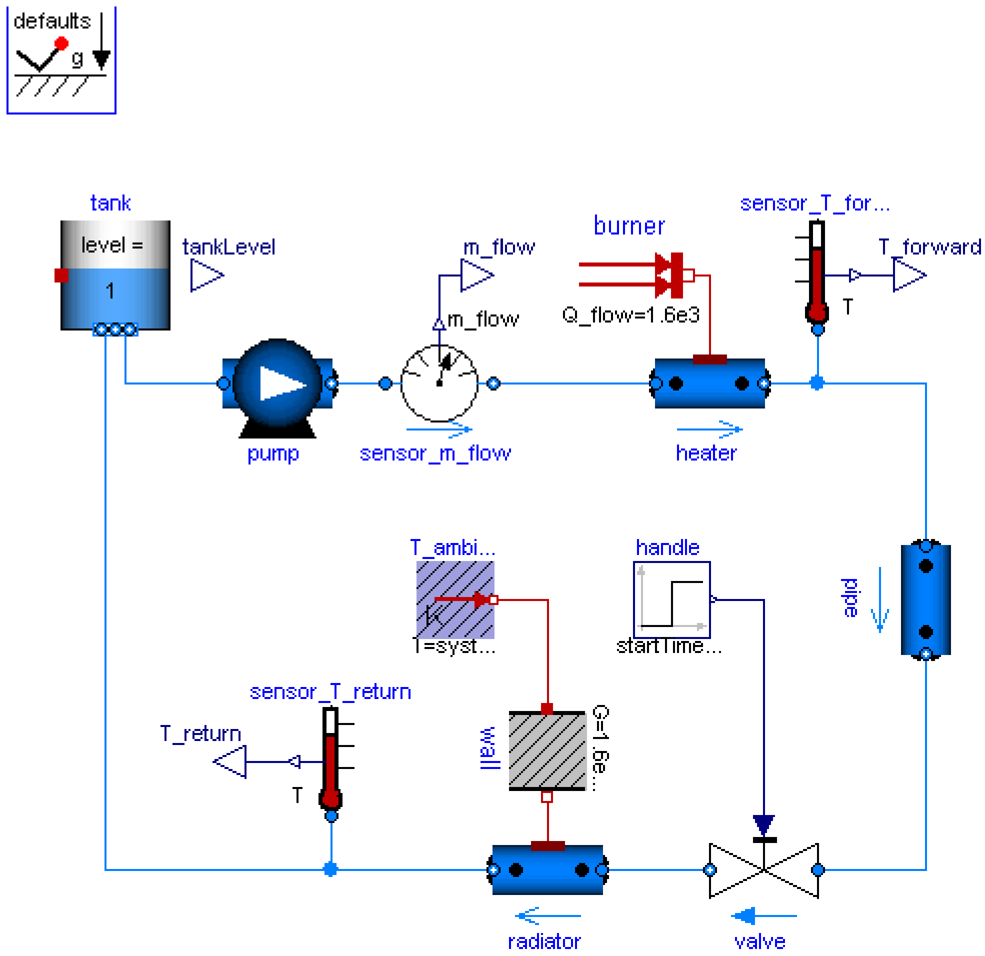
Simple heating system with a closed flow cycle. It is set up for steady-state initial values. After 2000s of simulation time the valve fully opens. A simple idealized control is embedded into the respective components, so that the heating system can be regulated with the valve: the pump controls the pressure, the burner controls the temperature.

One can investigate the temperatures and flows for different settings of `system.energyDynamics` (see Assumptions tab of the system object). With `system.energyDynamics==Types.Dynamics.SteadyState` all but one dynamic states are eliminated. The left state `tank.m` is to account for the closed flow cycle. It is constant as outflow and inflow are equal in a steady-state simulation.

Note that a closed flow cycle generally causes circular equalities for the mass flow rates and leaves the pressure undefined. This is why the tank.massDynamics, i.e. the tank level determining the port pressure, is modified locally to Types.Dynamics.FixedInitial.

Also note that the tank is thermally isolated againts its ambient. This way the temperature of the tank is also well defined for zero flow rate in the heating system, e.g. for valveOpening.offset=0 at the beginning of a simulation. The pipe however is assumed to be perfectly isolated. If steady-state values shall be obtained with the valve fully closed, then a thermal coupling between the pipe and its ambient should be defined as well.

Moreover it is worth noting that the idealized direct connection between the heater and the pipe, resulting in equal port pressures, is treated as high-index DAE, as opposed to a nonlinear equation system for connected pressure loss correlations. A pressure loss correlation could be additionally introduced to model the fitting between the heater and the pipe, e.g. to adapt different diameters.




Extends from Modelica.Icons.Example (Icon for an example model).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | |

### Connectors

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | |

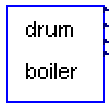
## Examples.DrumBoiler

**Drum boiler example, see Franke, Rode, Krueger: On-line Optimization of Drum Boiler Startup, 3rd International Modelica Conference, Linkoping, 2003**

### Package Content

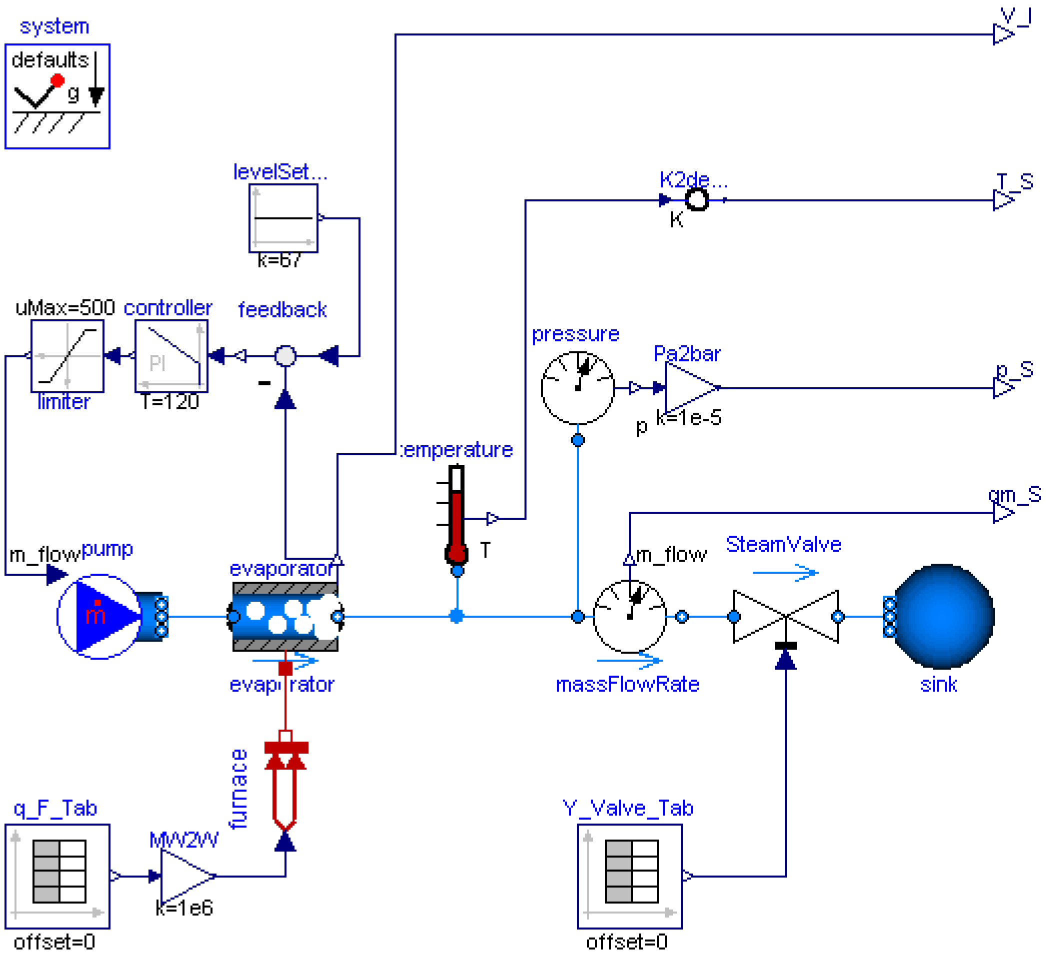
| Name | Description |
|---|---|
| DrumBoiler | Complete drum boiler model, including evaporator and supplementary components |
| BaseClasses | Additional components for drum boiler example |

## Examples.DrumBoiler.DrumBoiler




**Complete drum boiler model, including evaporator and supplementary components**

### Information




Extends from Modelica.Icons.Example (Icon for an example model).

### Connectors

| Type | Name | Description |
|---|---|---|
| output RealOutput | T_S | |
| output RealOutput | p_S | |

| | | |
|---|---|---|
| output RealOutput | qm_S | |
| output RealOutput | V_l | |

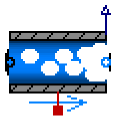
## Examples.DrumBoiler.BaseClasses

**Additional components for drum boiler example**

### Package Content

| Name | Description |
|---|---|
|  EquilibriumDrumBoiler | Simple Evaporator with two states, see Astroem, Bell: Drum-boiler dynamics, Automatica 36, 2000, pp.363-378 |

## Examples.DrumBoiler.BaseClasses.EquilibriumDrumBoiler



**Simple Evaporator with two states, see Astroem, Bell: Drum-boiler dynamics, Automatica 36, 2000, pp.363-378**

### Information

Model of a simple evaporator with two states. The model assumes two-phase equilibrium inside the component; saturated steam goes out of the steam outlet.

References: Astroem, Bell: Drum-boiler dynamics, Automatica 36, 2000, pp.363-378

Extends from Interfaces.PartialTwoPort (Partial component with two ports).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Mass | m_D | mass of surrounding drum metal [kg] |
| SpecificHeatCapacity | cp_D | specific heat capacity of drum metal [J/(kg.K)] |
| Volume | V_t | total volume inside drum [m3] |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| **Initialization** | | |
| AbsolutePressure | p_start | Start value of pressure [Pa] |
| Volume | V_l_start | Start value of liquid volumeStart value of volume [m3] |

### Connectors

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| HeatPort_a | heatPort | |

| | | |
|---|---|---|
| output RealOutput | V | liquid volume |

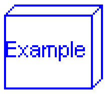
## Examples.Tanks

**Library demonstrating the usage of the tank model**

### Package Content

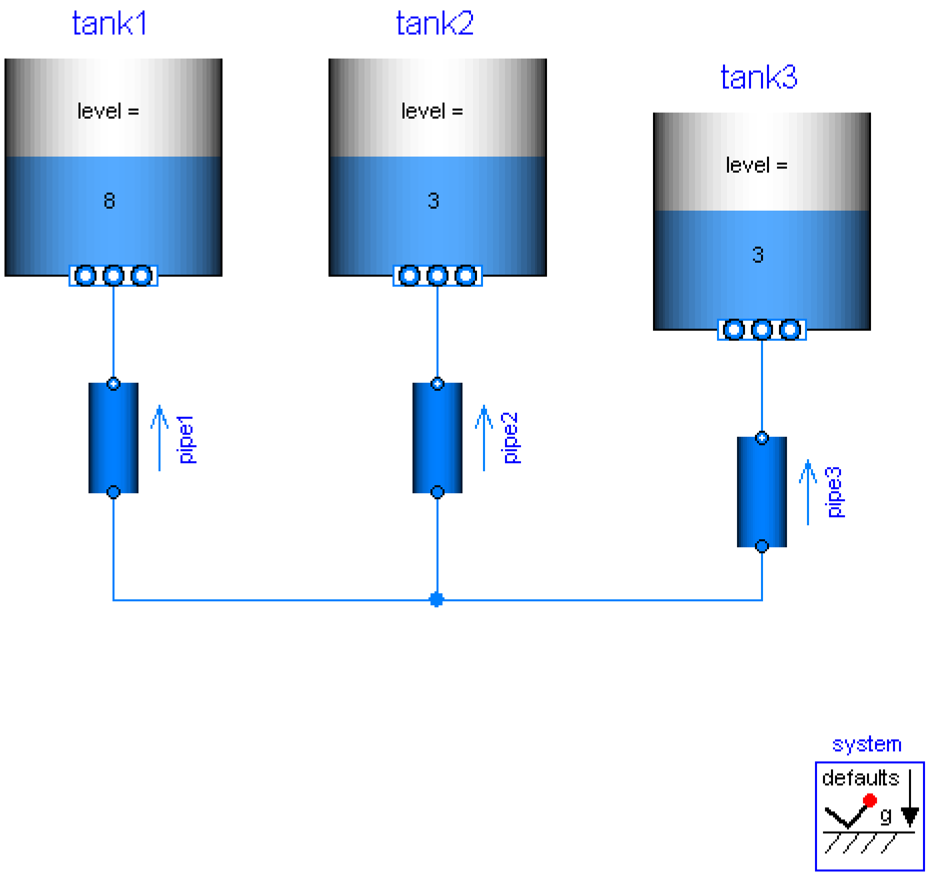
| Name | Description |
|---|---|
| ThreeTanks | Demonstrating the usage of SimpleTank |
| TanksWithOverflow | Two tanks connected with pipes at different heights |
| EmptyTanks | Show the treatment of empty tanks |

## Examples.Tanks.ThreeTanks



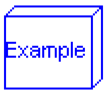

**Demonstrating the usage of SimpleTank**

### Information




Extends from Modelica.Icons.Example (Icon for an example model).

## Examples.Tanks.TanksWithOverflow



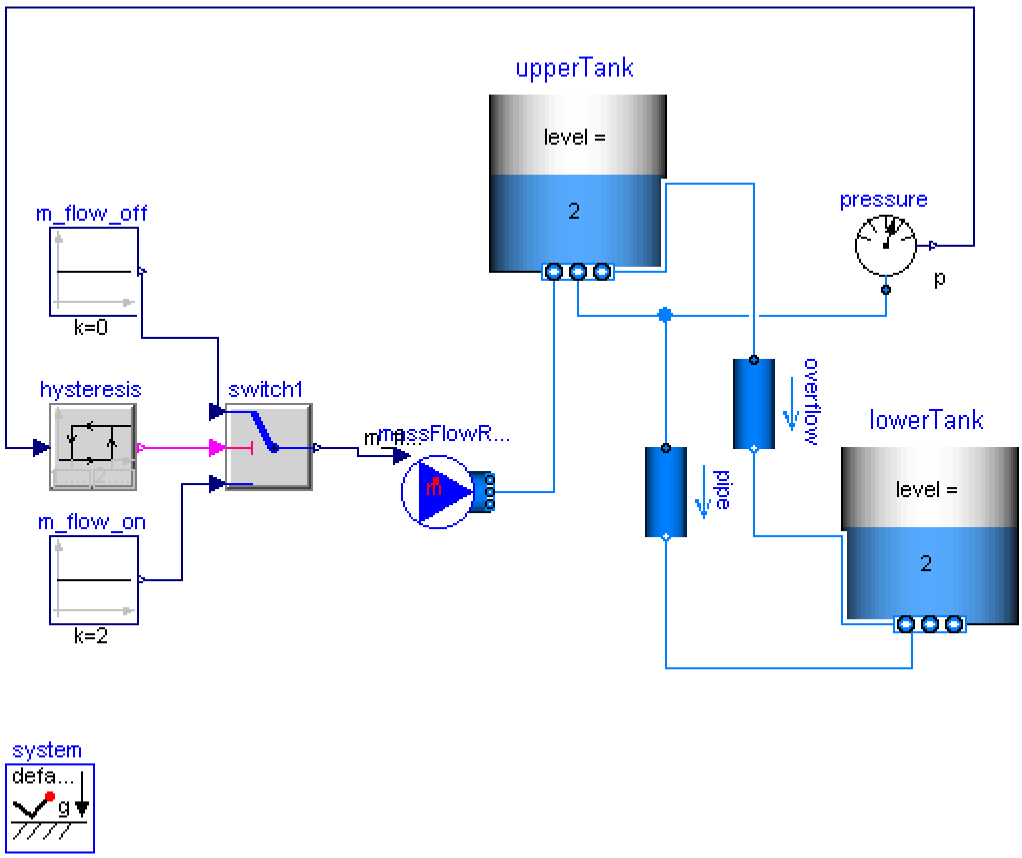
**Two tanks connected with pipes at different heights**

## Information

The mass flow rate to the upper tank is controlled by the static pressure at its bottom. The fluid flows through a pipe and forced by different heights from the upper tank to the lower tank.

Additional fluid flows through an overflow pipe if the level of the upper tank exceeds 10m. Initially the overflow enters the lower tank above its fluid level; later on the fluid level exceeds the overflow port.

Note that the number of solver intervals has been increased, accounting for the long simulation time horizon. Otherwise the simulation may fail due to too large steps subject to events. Alternatively the simulation accuracy could be increased in order to avoid errors.

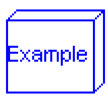



Extends from Modelica.Icons.Example (Icon for an example model).

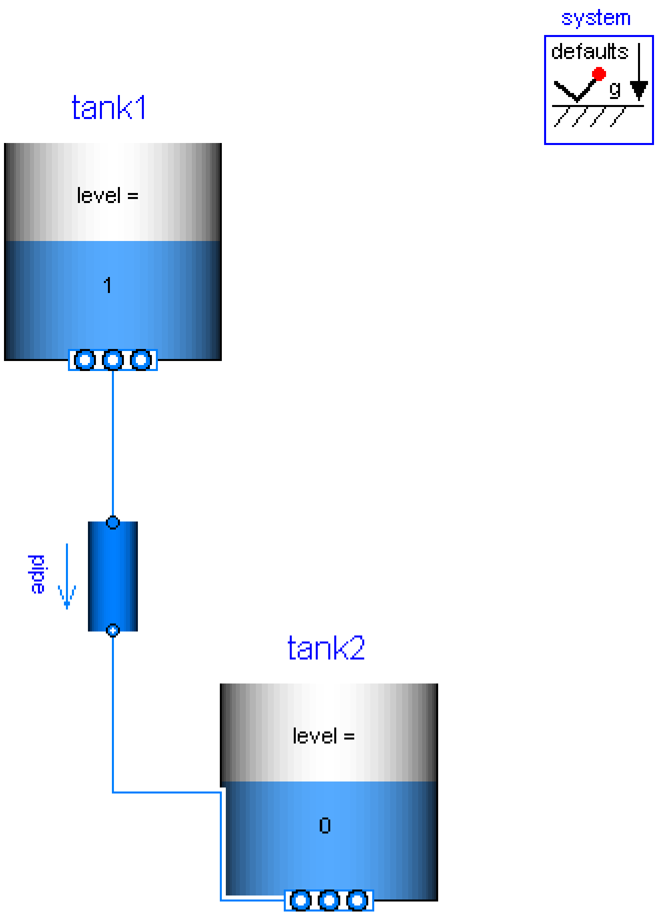
---

## Examples.Tanks.EmptyTanks

**Show the treatment of empty tanks**



### Information




Extends from Modelica.Icons.Example (Icon for an example model).

---

## Examples.ControlledTankSystem

**Tank system with controller, start/stop/shut operation and diagram animation**

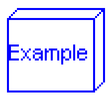
### Package Content

| Name | Description |
|---|---|
| ControlledTanks | Demonstrating the controller of a tank filling/emptying system |
| Utilities | |

---

## Examples.ControlledTankSystem.ControlledTanks

**Demonstrating the controller of a tank filling/emptying system**




### Information

With this example, the controller of a tank filling/emptying system is demonstrated.

The basic operation is to fill and empty the two tanks:

1. Valve 1 is opened and tank 1 is filled.
2. When tank 1 reaches its fill level limit, valve 1 is closed.
3. After a waiting time, valve 2 is opened and the fluid flows from tank 1 into tank 2.
4. When tank 1 reaches its minimum level, valve 2 is closed.
5. After a waiting time, valve 3 is opened and the fluid flows out of tank 2
6. When tank 2 reaches its minimum level, valve 3 is closed

The above "normal" process can be influenced by three buttons:

- Button **start** starts the above process. When this button is pressed after a "stop" or "shut" operation, the process operation continues.

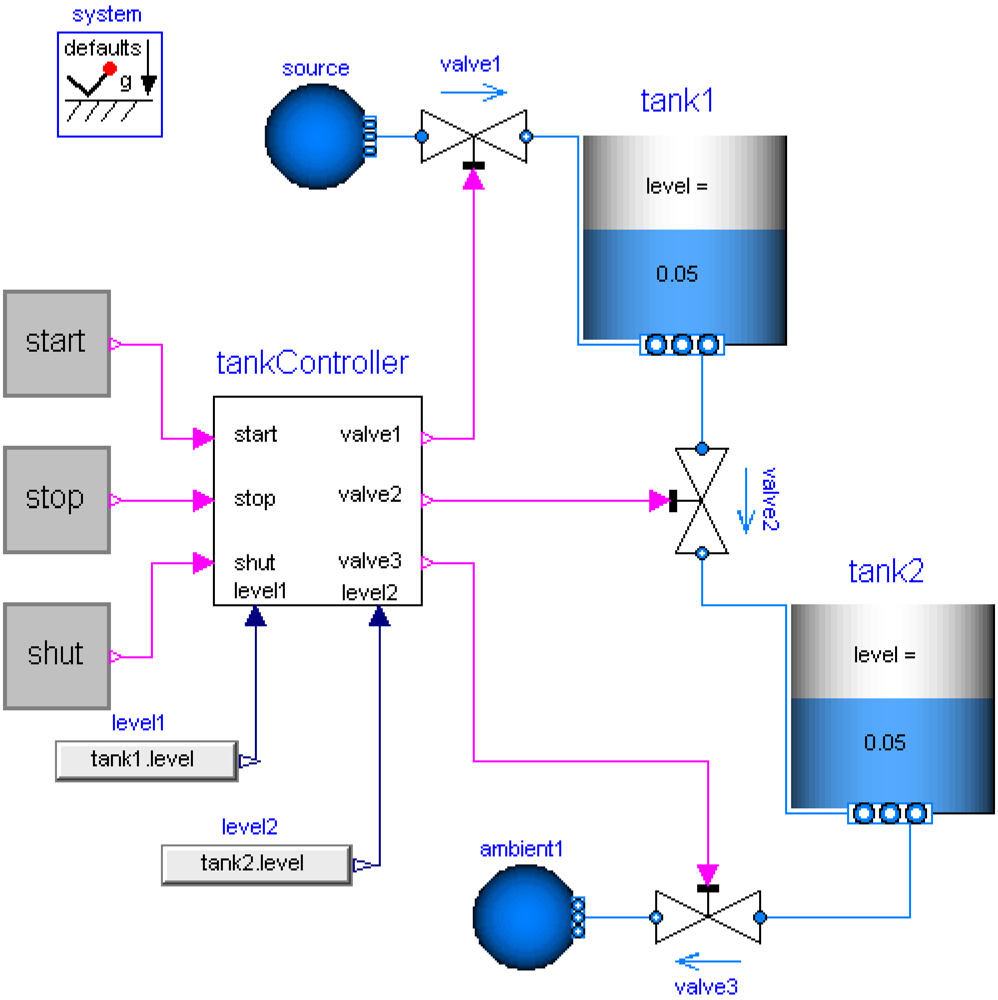
  .
- Button **stop** stops the above process by closing all valves. Then, the controller waits for further input (either "start" or "shut" operation).
- Button **shut** is used to shutdown the process, by emptying at once both tanks by opening valve 2 and valve 3. When this is achieved, the process goes back to its start configuration where all 3 valves are closed. Clicking on "start", restarts the process.

The demo-run uses the following button presses:

- Button **start** pressed at 20 s.
- Button **stop** pressed at 220 s
- Button **start** pressed at 280 s
- Button **stop** pressed at 650 s
- Button **shut** pressed at 700 s
- Simulate for 900 s

This example is based on

Dressler I. (2004):
**Code Generation From JGrafchart to Modelica**. Master thesis, supervisor: Karl-Erik Arzen, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden, March 30, 2004




Extends from Modelica.Icons.Example (Icon for an example model).

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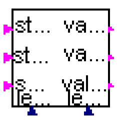
## [Examples.ControlledTankSystem](#).Utilities

### Package Content

| Name | Description |
|---|---|
| [TankController](#) | Controller for tank system |
| [NormalOperation](#) | Normal operation of tank system (button start pressed) |
| [RadioButton](#) | Button that sets its output to true when pressed and is reset when an element of 'reset' becomes true |

---

## [Examples.ControlledTankSystem.Utilities](#).TankController



**Controller for tank system**

### Parameters

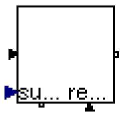
| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| Height | maxLevel | Fill level of tank 1 [m] |
| Height | minLevel | Lowest level of tank 1 and 2 [m] |
| Time | waitTime | Wait time, between operations [s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| input BooleanInput | start | |
| input BooleanInput | stop | |
| input BooleanInput | shut | |
| input RealInput | level1 | |
| input RealInput | level2 | |
| output BooleanOutput | valve1 | |
| output BooleanOutput | valve2 | |
| output BooleanOutput | valve3 | |

## Examples.ControlledTankSystem.Utilities.NormalOperation




**Normal operation of tank system (button start pressed)**

### Information

Extends from Modelica.StateGraph.PartialCompositeStep (Superclass of a subgraph, i.e., a composite step that has internally a StateGraph).

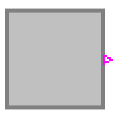
### Parameters

| Type | Name | Description |
|---|---|---|
| Height | maxLevel | Fill level of tank 1 [m] |
| Height | minLevel | Lowest level of tank 1 and 2 [m] |
| Time | waitTime | Wait time between operations [s] |
| Exception connections | | |
| Integer | nSuspend | Number of suspend ports |
| Integer | nResume | Number of resume ports |

### Connectors

| Type | Name | Description |
|---|---|---|
| Step_in | inPort | |
| Step_out | outPort | |
| CompositeStep_suspend | suspend[nSuspend] | |
| CompositeStep_resume | resume[nResume] | |
| input RealInput | level1 | |

## Examples.ControlledTankSystem.Utilities.RadioButton



**Button that sets its output to true when pressed and is reset when an element of 'reset' becomes true**

### Information

### Parameters

| Type | Name | Description |
|---|---|---|
| Time | buttonTimeTable[:] | Time instants where button is pressend [s] |
| Time varying expressions | | |
| Boolean | reset[:] | Reset button to false, if an element of reset becomes true |

### Connectors

| Type | Name | Description |
|---|---|---|
| output BooleanOutput | on | |

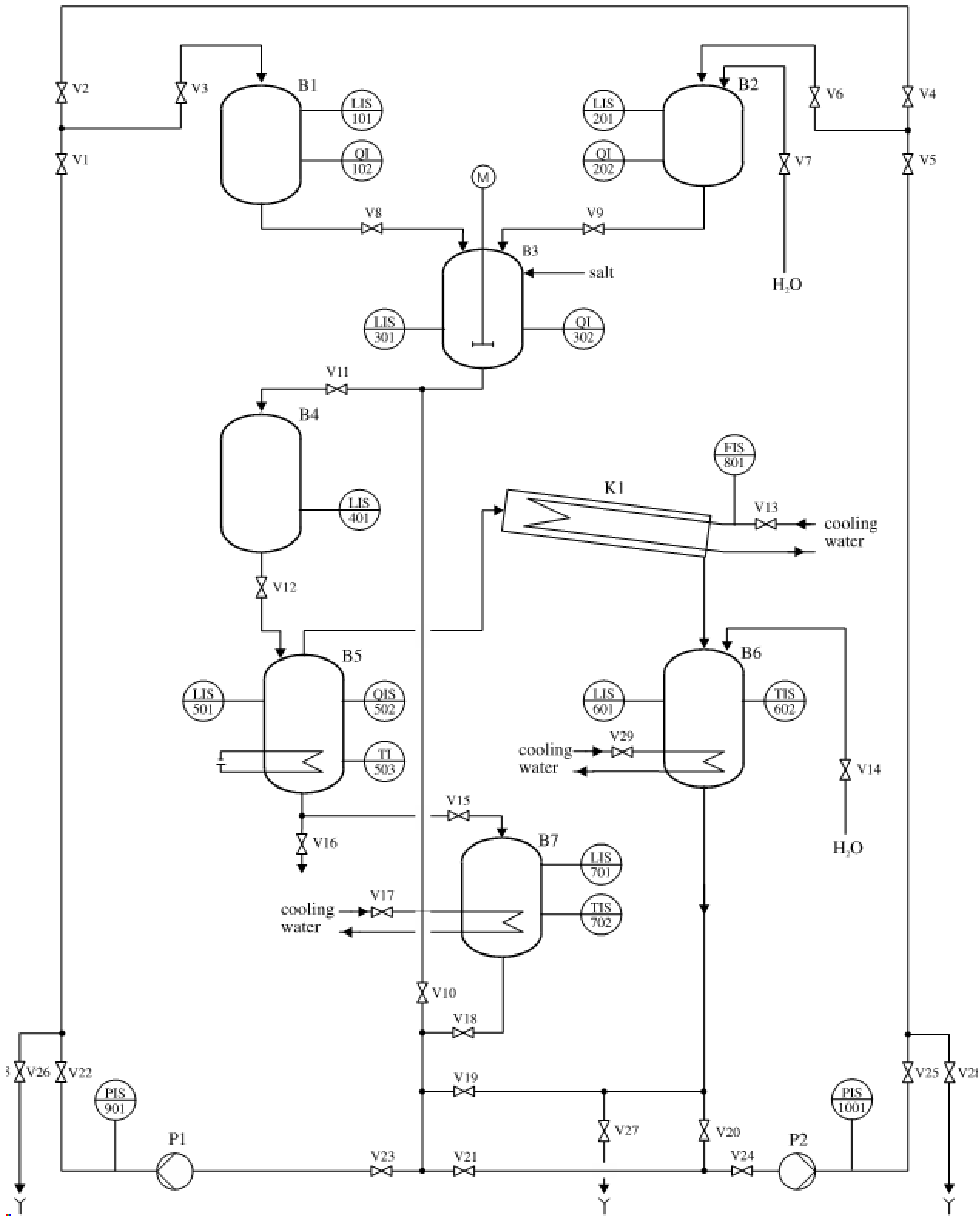
## Examples.AST_BatchPlant

**Model of the experimental batch plant at Process Control Laboratory at University of Dortmund (Prof. Engell)**

### Information

The process under consideration is an evaporation plant for a student lab at the Process Control Laboratory (AST) of the University of Dortmund that evaporates a water sodium chloride mixture so that a higher concentrated solution is produced. The task of the students is to learn how to program the process control system. A picture of the batch plant is shown in the figure below.

The flow sheet diagram is shown in the next figure.

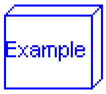



Pure water from tank B1 and concentrated sodium chloride solution from tank B2 are mixed in a mixing tank B3. After buffering in tank B4 the mixture flows to the evaporator B5. Here the water sodium chloride mixture is evaporated until the desired con-centration is reached. The steam is condensed in the condenser K1 and cooled afterwards in the cooling tank B6. The concentrated solution is also led to a cooling tank B7. The cooled fluids are pumped back to the charging vessels by the pumps P1 and P2. Be-tween the tanks several valves are present that are regulated by a central control system.

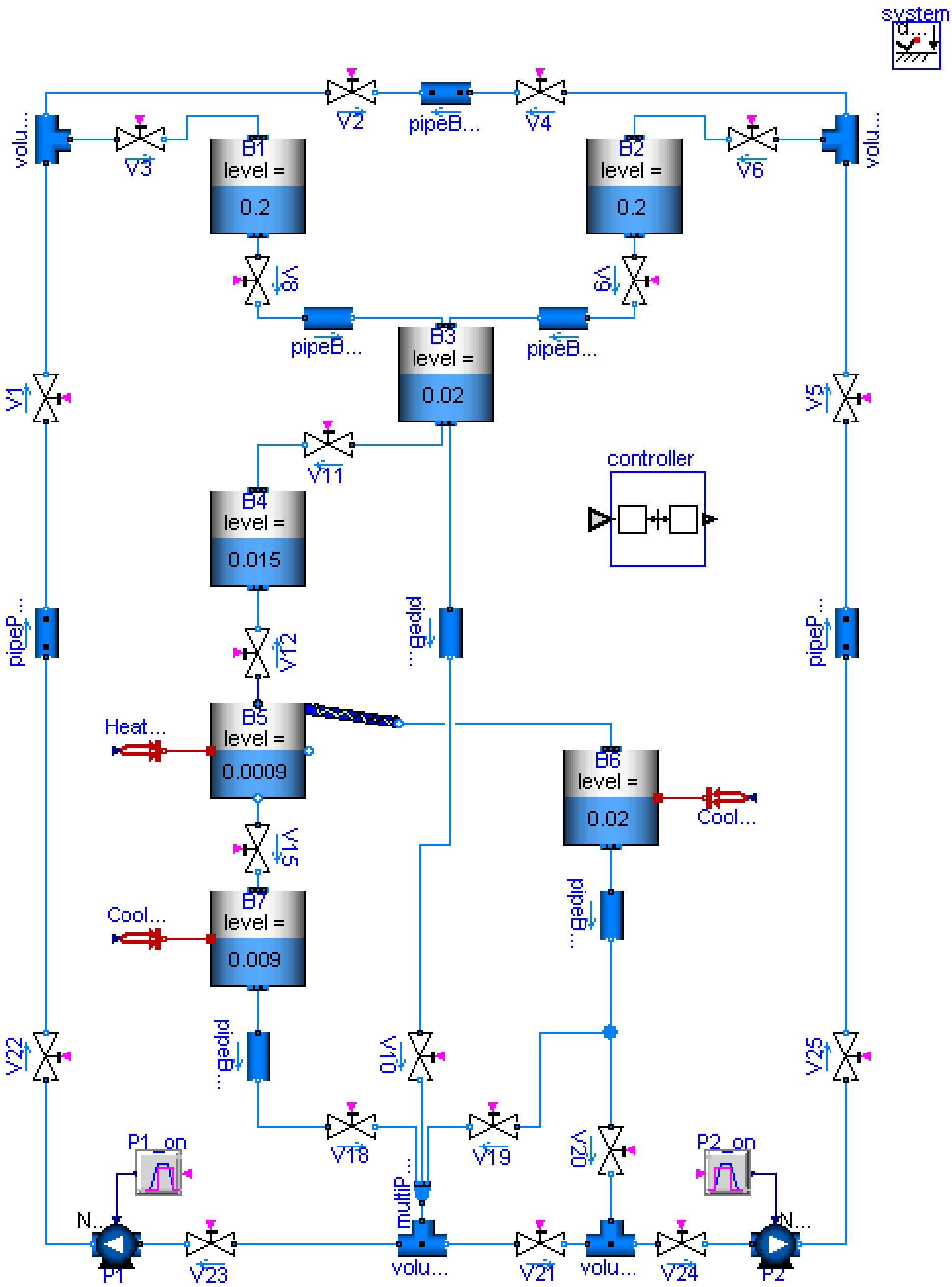
### Package Content

| Name | Description |
|---|---|
| BatchPlant_StandardWater | |
| BaseClasses | |
| Test | Test of used tank models |

## Examples.AST_BatchPlant.BatchPlant_StandardWater




### Information




Extends from Modelica.Icons.Example (Icon for an example model).

## Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package BatchMedium | | Component media |
| Length | pipeDiameter | [m] |

## Connectors

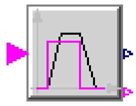
| Type | Name | Description |
|---|---|---|
| replaceable package BatchMedium | | Component media |

## Examples.AST_BatchPlant.BaseClasses

### Package Content

| Name | Description |
|---|---|
| TriggeredTrapezoid | Triggered trapezoid generator |
| setReal | Set output signal to a time varying Real expression |
| TankWith3InletOutletArraysWithEvaporatorCondensor | Tank with Heating and Evaporation |
| InnerTank | |
| Controller | |
| ControllerUtilities | |
| Init | Enumeration to define initialization options |
| TankWithTopPorts | Tank with inlet/outlet ports and with inlet ports at the top |

## Examples.AST_BatchPlant.BaseClasses.TriggeredTrapezoid



**Triggered trapezoid generator**

### Information

The block TriggeredTrapezoid has a boolean input and a real output signal and requires the parameters *amplitude*, *rising*, *falling* and *offset*. The output signal **y** represents a trapezoidal signal dependent on the input signal **u**.

The behaviour is as follows: Assume the initial input to be false. In this case, the output will be *offset*. After a rising edge (i.e. the input changes from false to true), the output is rising during *rising* to the sum of *offset* and *amplitude*. In contrast, after a falling edge (i.e. the input changes from true to false), the output is falling during *falling* to a value of *offset*.

Note, that the case of edges before expiration of rising or falling is handled properly.

Extends from Modelica.Blocks.Interfaces.partialBooleanBlockIcon (Basic graphical layout of logical block).

### Parameters

| Type | Name | Description |
|---|---|---|
| Real | amplitude | Amplitude of trapezoid |
| Time | rising | Rising duration of trapezoid [s] |
| Time | falling | Falling duration of trapezoid [s] |
| Real | offset | Offset of output signal |

### Connectors

| Type | Name | Description |
|---|---|---|
| input BooleanInput | u | Connector of Boolean input signal |

| | | |
|---|---|---|
| output RealOutput | y | Connector of Real output signal |
| output BooleanOutput | y_high | |

## Examples.AST_BatchPlant.BaseClasses.setReal

**Set output signal to a time varying Real expression**

### Information

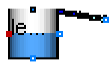
### Parameters

| Type | Name | Description |
|---|---|---|
| Time varying input signal | | |
| RealInput | u | Set value of Real input |

### Connectors

| Type | Name | Description |
|---|---|---|
| Time varying input signal | | |
| input RealInput | u | Set value of Real input |

## Examples.AST_BatchPlant.BaseClasses.TankWith3InletOutletArraysWithEvaporatorCondensor



**Tank with Heating and Evaporation**

### Information

This tank has the same geometric variables as TankWith3InletOutletArrays plus the feature of a HeatPort and the possibility of evaporation. (Assumption: The gas is condensed emidiatly afterwards so that a liquid boiling fluid is created.)

The tank can be initialized with the following options:

- GuessValues: no explicit initial conditions
- InitialValues: initial values of temperature (or specific enthalpy), composition and level are specified
- SteadyStateHydraulic: initial values of temperature (or specific enthalpy) and composition are specified; the initial level is determined so that levels and pressure are at steady state.

Full steady state initialization is not supported, because the corresponding intial equations for temperature/enthalpy are undetermined (the flow rate through the port at steady state is zero).

### Parameters

| Type | Name | Description |
|---|---|---|
| Area | crossArea | Tank area [m2] |
| Area | top_pipeArea[n_TopPorts] | Area of outlet pipe [m2] |
| Area | side_pipeArea[n_SidePorts] | Area of outlet pipe [m2] |
| Area | bottom_pipeArea[n_BottomPorts] | Area of outlet pipe [m2] |
| Height | height | Height of Tank [m] |

| | | |
|---|---|---|
| Volume | V0 | Volume of the liquid when the level is zero [m3] |
| Real | side_heights[n_SidePorts] | |
| Real | bottom_heights[n_BottomPorts] | |
| Real | top_heights[n_TopPorts] | |
| AbsolutePressure | p_ambient | Tank surface pressure [Pa] |
| Temperature | T_ambient | Tank surface Temperature [K] |
| Integer | n_TopPorts | number of Top connectors |
| Integer | n_SidePorts | number of side connectors |
| Integer | n_BottomPorts | number of bootom connectors |
| Real | min_level_for_heating | |
| **Initialization** | | |
| Height | level_start | Initial tank level [m] |
| Init | initType | Initialization option |
| Boolean | use_T_start | Use T_start if true, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_b | BottomFluidPort[n_BottomPorts] | |
| FluidPort_a | TopFluidPort[n_TopPorts] | |
| FluidPort_b | SideFluidPort[n_SidePorts] | |
| FluidPort_b | Condensed | |
| HeatPort_a | heatPort | |

## Examples.AST_BatchPlant.BaseClasses.InnerTank

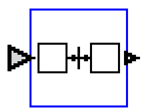
### Parameters

| Type | Name | Description |
|---|---|---|
| MassFraction | Xi[Medium.nXi] | Actual mass fractions of fluid in tank [kg/kg] |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port | |

## Examples.AST_BatchPlant.BaseClasses.Controller



### Parameters

| Type | Name | Description |
|---|---|---|
| Real | w_dilution | |
| Real | w_concentrate | |

| | | |
|---|---|---|
| Real | startTime | |
| Real | T5_batch_level | |

### Connectors

| Type | Name | Description |
|---|---|---|
| Port_Sensors | sensors | |
| Port_Actuators | actuators | |

## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities

### Package Content

| Name | Description |
|---|---|
| Adapter_Inference | |
| Adapter_Superposition | |
| Block_Recipe_TBD | |
| BlockMain | |
| Buffer_Recipe_TBD | |
| BufferMain | |
| Port_Actuators | |
| Port_IdleTanks | |
| Port_Sensors | |

## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities.Adapter_Inference

## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities.Adapter_Superposition

## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities.Block_Recipe_TBD

### Parameters

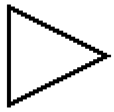
| Type | Name | Description |
|---|---|---|
| Real | startTime | |
| Real | w_dilution | |
| Real | w_concentrat | |
| Real | T3_batch_level | |
| Real | T5_batch_level | |

## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities.BlockMain

## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities.Buffer_Recipe_TBD

## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities.BufferMain

## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities.Port_Actuators



### Contents

| Type | Name | Description |
|---|---|---|
| Boolean | P1 | |
| Boolean | P2 | |
| Boolean | T5_Heater | |
| Boolean | T7_Cooling | |
| Boolean | T6_Cooling | |
| Boolean | V1 | |
| Boolean | V2 | |
| Boolean | V3 | |
| Boolean | V4 | |
| Boolean | V5 | |
| Boolean | V6 | |
| Boolean | V8 | |
| Boolean | V9 | |
| Boolean | V10 | |
| Boolean | V11 | |
| Boolean | V12 | |
| Boolean | V15 | |
| Boolean | V18 | |
| Boolean | V19 | |
| Boolean | V20 | |
| Boolean | V21 | |
| Boolean | V22 | |
| Boolean | V23 | |
| Boolean | V24 | |
| Boolean | V25 | |

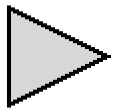
## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities.Port_IdleTanks

### Contents

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| Boolean | T5_idle | |
| Boolean | T7_idle | |

## Examples.AST_BatchPlant.BaseClasses.ControllerUtilities.Port_Sensors



### Contents

| Type | Name | Description |
|---|---|---|
| Real | LIS_301 | |
| Real | QI_302 | |
| Real | LIS_501 | |
| Real | QIS_502 | |
| Real | TI_503 | |
| Real | LIS_601 | |
| Real | TIS_602 | |
| Real | LIS_701 | |
| Real | TIS_702 | |

## Examples.AST_BatchPlant.BaseClasses.Init

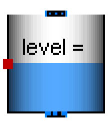
**Enumeration to define initialization options**

### Information

Integer type that can have the following values (to be selected via choices menu):

| Types.Init. | Meaning |
|---|---|
| GuessValues | GuessValues -- Guess values (not fixed) for p, T or h, X, C |
| InitialValues | Initial values for p, T or h, X, C |
| SteadyStateMomentum | Steady state momentum |
| SteadyStateHydraulic | Hydraulic steady state (der(p)=0), guess value for p, initial values for T or h, X, C |
| SteadyState | Steady state (guess values for p, T or h, X, C) |

## Examples.AST_BatchPlant.BaseClasses.TankWithTopPorts




**Tank with inlet/outlet ports and with inlet ports at the top**

### Information

Model of a tank that is open to the environment at the fixed pressure `p_ambient`. The tank is filled with a single or multiple-substance liquid, assumed to have uniform temperature and mass fractions.

At the top of the tank over the maximal fill level **height** a vector of FluidPorts, called **topPorts**, is present. The assumption is made that fluid flows always in to the tank via these ports (and never back in to the connector).

The vector of connectors **ports** are fluid ports at the bottom and side of the tank at a defineable height. Fluid can flow either out of or in to this port. The fluid level of the tank may be below one of these ports. This case is approximated by introducing a large pressure flow coefficient so that the mass flow rate through this port is very small in this case.

If the tank starts to over flow (i.e., level > height), an assertion is triggered.

When the diagram layer is open in the plot environment, the level of the tank is dynamically visualized. Note, the speed of the diagram animation in Dymola can be set via command **animationSpeed**(), e.g., animationSpeed(speed = 10)

Extends from Interfaces.PartialLumpedVolume (Lumped volume with mass and energy balance).

### Parameters

| Type | Name | Description |
|---|---|---|
| Height | height | Maximum level of tank before it overflows [m] |
| Area | crossArea | Area of tank [m2] |
| Volume | V0 | Volume of the liquid when level = 0 [m3] |
| replaceable package Medium | | Medium in the component |
| Volume | fluidVolume | Volume [m3] |
| VesselPortsData | portsData[nPorts] | Data of inlet/outlet ports at side and bottom of tank |
| **Assumptions** | | |
| Ambient | | |
| AbsolutePressure | p_ambient | Tank surface pressure [Pa] |
| Temperature | T_ambient | Tank surface Temperature [K] |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use the HeatTransfer model |
| **Initialization** | | |
| Height | level_start | Start value of tank level [m] |
| AbsolutePressure | p_start | Start value of pressure [Pa] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| **Advanced** | | |
| Port properties | | |
| Real | hysteresisFactor | Hysteresis for empty pipe = diameter*hysteresisFactor |
| Boolean | stiffCharacteristicForEmptyPort | =true, if steep pressure loss characteristic for empty pipe port |
| Real | zetaLarge | Large pressure loss factor if mass flows out of empty pipe port |
| MassFlowRate | m_flow_small | Regularization range at zero mass flow rate [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| VesselFluidPorts_a | topPorts[nTopPorts] | Inlet ports over height at top of tank (fluid flows only from the port in to the tank) |
| VesselFluidPorts_b | ports[nPorts] | inlet/outlet ports at bottom or side of tank (fluid flows in to or out of port; a port might be above the fluid level) |
| HeatPort_a | heatPort | |

## Examples.AST_BatchPlant.Test

**Test of used tank models**

### Package Content

| Name | Description |
|---|---|
| OneTank | Tank with one time-varying top inlet mass flow rate and a bottom outlet into the ambient |
| TwoTanks | |
| TankWithEmptyingPipe1 | Demonstrates a tank with one constant top inlet mass flow rate and a bottom outlet into the ambient |
| TankWithEmptyingPipe2 | Demonstrates a tank with one constant top inlet mass flow rate and a bottom outlet into the ambient |
| TanksWithEmptyingPipe1 | Demonstrates a tank with one constant top inlet mass flow rate and a bottom outlet into the ambient |
| TanksWithEmptyingPipe2 | Demonstrates a tank with one constant top inlet mass flow rate and a bottom outlet into the ambient |

## Examples.AST_BatchPlant.Test.OneTank

**Tank with one time-varying top inlet mass flow rate and a bottom outlet into the ambient**

Example

## Examples.AST_BatchPlant.Test.TwoTanks

Example

### Parameters

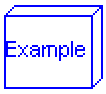
| Type | Name | Description |
|---|---|---|
| Boolean | stiffCharacteristicForEmptyPort | |

## Examples.AST_BatchPlant.Test.TankWithEmptyingPipe1

**Demonstrates a tank with one constant top inlet mass flow rate and a bottom outlet into the ambient**

Example

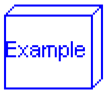
### Examples.AST_BatchPlant.Test.TankWithEmptyingPipe2




**Demonstrates a tank with one constant top inlet mass flow rate and a bottom outlet into the ambient**

---

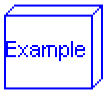
### Examples.AST_BatchPlant.Test.TanksWithEmptyingPipe1




**Demonstrates a tank with one constant top inlet mass flow rate and a bottom outlet into the ambient**

---

### Examples.AST_BatchPlant.Test.TanksWithEmptyingPipe2



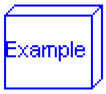

**Demonstrates a tank with one constant top inlet mass flow rate and a bottom outlet into the ambient**

#### Parameters

| Type | Name | Description |
|---|---|---|
| Boolean | stiffCharacteristicForEmptyPort | |

---

### Examples.IncompressibleFluidNetwork



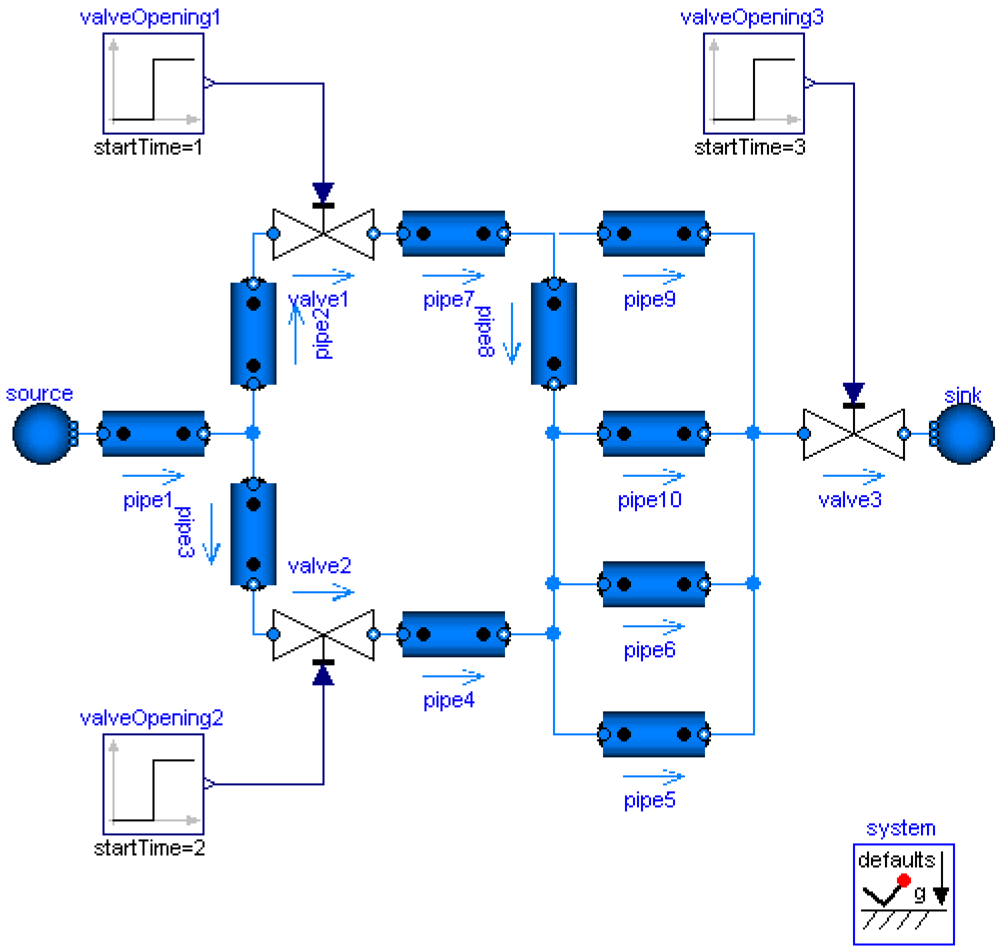

**Multi-way connections of pipes and incompressible medium model**

#### Information

This example demonstrates two aspects: the efficient treatment of multi-way connections and the usage of an incompressible medium model.

Normally one would expect bad equation systems in multi-way connections and possibly introduce mixing volumes to work around this. Here the problem is treated with the the modelStructure=av_vb in the DynamicPipe model. Each pipe exposes the states of the outer fluid segments to the respective fluid ports. Consequently the pressures of all connected pipe segments get lumped together into one mass balance spanning the whole connection set. With the stream concept in the fluid ports, the energy and substance balances remain independent in the connected pipe segments.

The model does not contain pressure dynamics as an incompressible medium is used (Essotherm650). Pressure dynamics becomes present with a compressible medium model (e.g. StandardWater).




Extends from Modelica.Icons.Example (Icon for an example model).

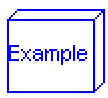
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | |

### Connectors

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | |

## Examples.BranchingDynamicPipes




**Multi-way connections of pipes with dynamic momentum balance, pressure wave and flow reversal**

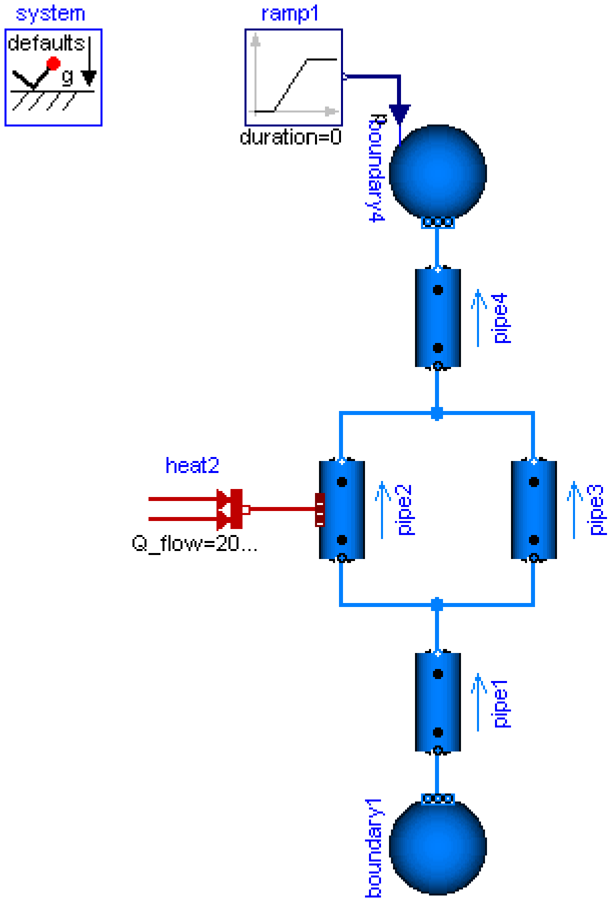
### Information

This model demonstrates the use of distributed pipe models with dynamic energy, mass and momentum balances. At time=2s the pressure of boundary4 jumps, which causes a pressure wave and flow reversal.

Change system.momentumDynamics on the Assumptions tab of the system object from DynamicFreeInitial to SteadyState, in order to assume a steady-state momentum balance. This is the default for all models of the library.

Change the Medium from MoistAir to StandardWater, in order to investigate a medium with significantly different density. Note the static head caused by the elevation of the pipes.

Note, pipe4.modelStructure = av_b, i.e., the pipe has no volume at port_b. It is not possible to have a volume at port_b, since otherwise the pressure of the volume is defined by the connected boundary source. This in turn means that the derivative of the pressure of the boundary source is needed, since the volume requires this derivative. It is, however, not possible to compute this derivative because the input pressure is changing disontinuously and its derivative would be a dirac impulse.




Extends from Modelica.Icons.Example (Icon for an example model).

## Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | |

## Connectors

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | |

## Examples.HeatExchanger

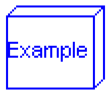
**Demo of a heat exchanger model**

### Package Content

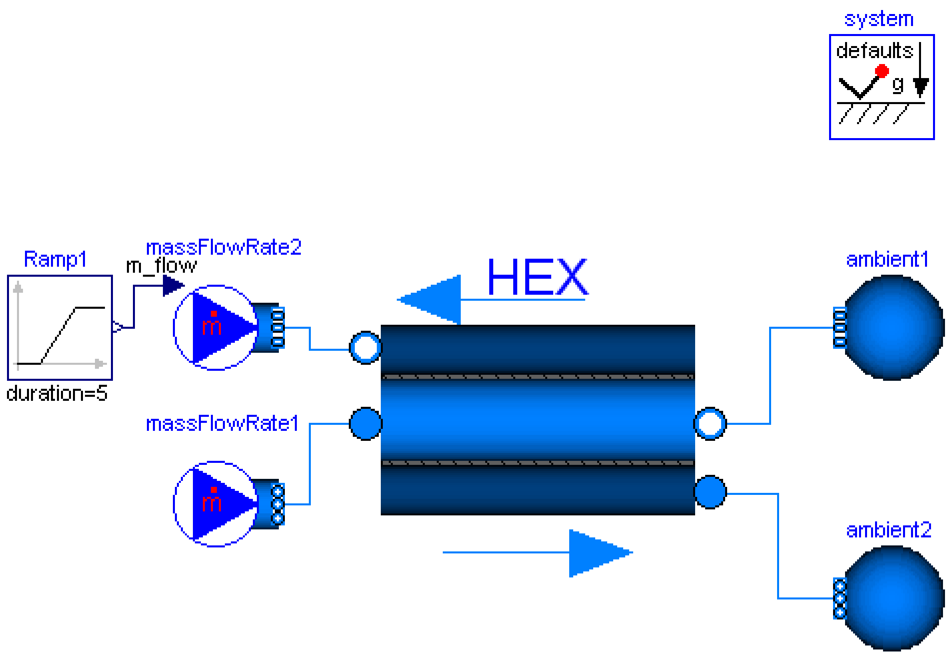
| Name | Description |
|---|---|
| HeatExchangerSimulation | simulation for the heat exchanger model |
| BaseClasses | Additional models for heat exchangers |

## Examples.HeatExchanger.HeatExchangerSimulation

**simulation for the heat exchanger model**




### Information




Extends from Modelica.Icons.Example (Icon for an example model).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | |

### Connectors

| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | |

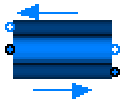
## Examples.HeatExchanger.BaseClasses

**Additional models for heat exchangers**

### Package Content

| Name | Description |
|---|---|
| BasicHX | Simple heat exchanger model |
| WallConstProps | Pipe wall with capacitance, assuming 1D heat conduction and constant material properties |

## Examples.HeatExchanger.BaseClasses.BasicHX



**Simple heat exchanger model**

### Information

Simple model of a heat exchanger consisting of two pipes and one wall in between. For both fluids geometry parameters, such as heat transfer area and cross section as well as heat transfer and pressure drop correlations may be chosen. The flow scheme may be concurrent or counterflow, defined by the respective flow directions of the fluids entering the component. The design flow direction with positive m_flow variables is counterflow.

### Parameters

| Type | Name | Description |
|---|---|---|
| Integer | nNodes | Spatial segmentation |
| Length | length | Length of flow path for both fluids [m] |
| Length | s_wall | Wall thickness [m] |
| Fluid 1 | | |
| Area | crossArea_1 | Cross sectional area [m2] |
| Length | perimeter_1 | Flow channel perimeter [m] |
| Area | area_h_1 | Heat transfer area [m2] |
| Length | roughness_1 | Absolute roughness of pipe (default = smooth steel pipe) [m] |
| Fluid 2 | | |
| Area | crossArea_2 | Cross sectional area [m2] |
| Length | perimeter_2 | Flow channel perimeter [m] |
| Area | area_h_2 | Heat transfer area [m2] |
| Length | roughness_2 | Absolute roughness of pipe (default = smooth steel pipe) [m] |
| Solid material properties | | |
| Density | rho_wall | Density of wall material [kg/m3] |
| SpecificHeatCapacity | c_wall | Specific heat capacity of wall material [J/(kg.K)] |
| ThermalConductivity | k_wall | Thermal conductivity of wall material [W/(m.K)] |
| **Assumptions** | | |
| Boolean | allowFlowReversal | allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |

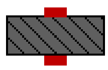
| | | |
|---|---|---|
| Dynamics | momentumDynamics | Formulation of momentum balance, if pressureLoss options available |
| **Initialization** | | |
| Wall | | |
| Temperature | Twall_start | Start value of wall temperature [K] |
| Temperature | dT | Start value for pipe_1.T - pipe_2.T [K] |
| Boolean | use_T_start | Use T_start if true, otherwise h_start |
| Fluid 1 | | |
| AbsolutePressure | p_a_start1 | Start value of pressure [Pa] |
| AbsolutePressure | p_b_start1 | Start value of pressure [Pa] |
| Temperature | T_start_1 | Start value of temperature [K] |
| SpecificEnthalpy | h_start_1 | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start_1[Medium_1.nX] | Start value of mass fractions m_i/m [kg/kg] |
| MassFlowRate | m_flow_start_1 | Start value of mass flow rate [kg/s] |
| Fluid 2 | | |
| AbsolutePressure | p_a_start2 | Start value of pressure [Pa] |
| AbsolutePressure | p_b_start2 | Start value of pressure [Pa] |
| Temperature | T_start_2 | Start value of temperature [K] |
| SpecificEnthalpy | h_start_2 | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start_2[Medium_2.nX] | Start value of mass fractions m_i/m [kg/kg] |
| MassFlowRate | m_flow_start_2 | Start value of mass flow rate [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_b | port_b1 | |
| FluidPort_a | port_a1 | |
| FluidPort_b | port_b2 | |
| FluidPort_a | port_a2 | |

## Examples.HeatExchanger.BaseClasses.WallConstProps

**Pipe wall with capacitance, assuming 1D heat conduction and constant material properties**



### Information

Simple model of circular (or any other closed shape) wall to be used for pipe (or duct) models. Heat conduction is regarded one dimensional, capacitance is lumped at the arithmetic mean temperature. The spatial discretization (parameter `n`) is meant to correspond to a connected fluid model discretization.

### Parameters

| Type | Name | Description |
|---|---|---|
| Integer | n | Segmentation perpendicular to heat conduction |
| Length | s | Wall thickness [m] |
| Area | area_h | Heat transfer area [m2] |
| Density | rho_wall | Density of wall material [kg/m3] |

| | | |
|---|---|---|
| SpecificHeatCapacity | c_wall | Specific heat capacity of wall material [J/(kg.K)] |
| ThermalConductivity | k_wall | Thermal conductivity of wall material [W/(m.K)] |
| Mass | m[n] | Distribution of wall mass [kg] |
| Temperature | T_start | Wall temperature start value [K] |
| Temperature | dT | Start value for port_b.T - port_a.T [K] |
| **Assumptions** | | |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |

### Connectors

| Type | Name | Description |
|---|---|---|
| HeatPort_a | heatPort_a[n] | Thermal port |
| HeatPort_a | heatPort_b[n] | Thermal port |

---

## Examples.TraceSubstances

**Library demonstrating the usage of trace substances**

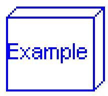
### Package Content

| Name | Description |
|---|---|
| RoomCO2 | Demonstrates a room volume with CO2 accumulation |
| RoomCO2WithControls | Demonstrates a room volume with CO2 controls |

---

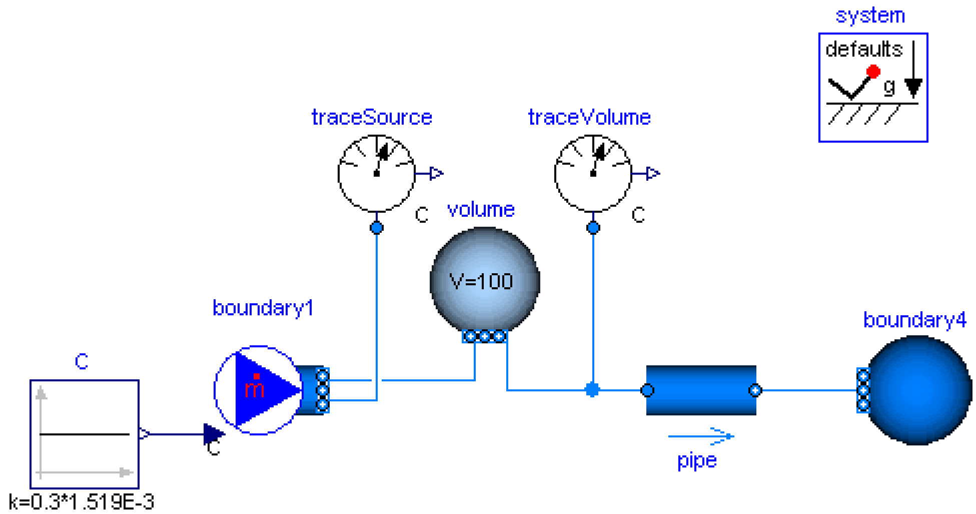
## Examples.TraceSubstances.RoomCO2

**Demonstrates a room volume with CO2 accumulation**




### Information

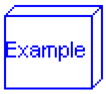
This example consists of a volume with a carbon dioxide concentration that corresponds to about 1000 PPM. There is a fresh air stream with a carbon dioxide concentration of about 300 PPM. The fresh air stream is such that the air exchange rate is about 5 air changes per hour. After 1 hour of ventilation, the volume's carbon dioxide concentration is close to the concentration of the fresh air.




Extends from Modelica.Icons.Example (Icon for an example model).

## Examples.TraceSubstances.RoomCO2WithControls

**Demonstrates a room volume with CO2 controls**



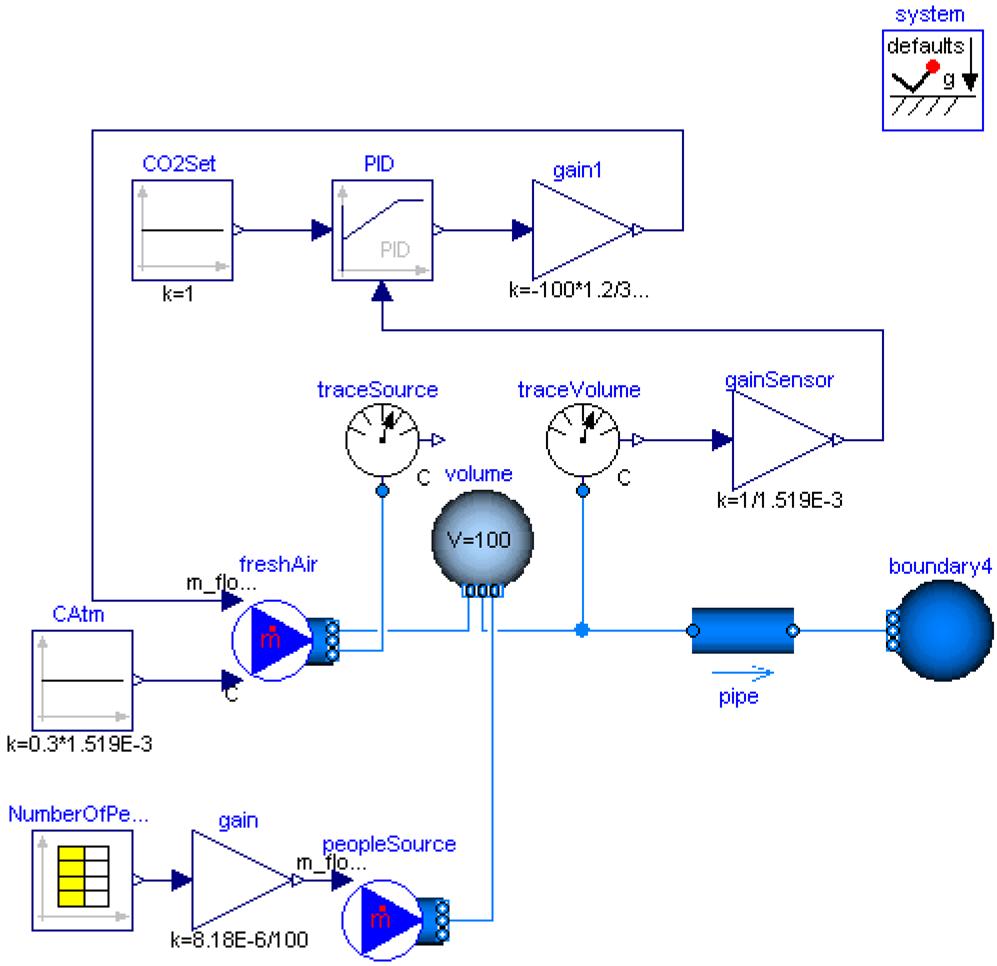

### Information

This example illustrates a room volume with a CO2 source and a fresh air supply with feedback control. The CO2 emission rate is proportional to the room occupancy, which is defined by a schedule. The fresh air flow rate is controlled such that the room CO2 concentration does not exceed `1000 PPM (=1.519E-3 kg/kg)`. The fresh air has a CO2 concentration of `300 PPM` which corresponds to a typical CO2 concentration in the outside air.

The CO2 emission from the occupants is implemented as a mass flow source. Depending on the activity and size, a person emits about `8.18E-6 kg/s` CO2. In the model, this value is multiplied by the number of occupants. Since the mass flow rate associate with the CO2 source model contributes to the volume's energy balance, this mass flow rate should be kept small. Thus, in the source model, we set the CO2 concentration to `C={100} kg/kg`, and scaled the mass flow rate using

```
m_flow = 1/100 * nPeo * 8.18E-6 kg/(s*person)
```

where `nPeo` is the number of people in the room. This results in a mass flow rate that is about 5 orders of magnitudes smaller than the supply air flow rate, and hence its contribution to the volume's energy balance is negligible.




Extends from Modelica.Icons.Example (Icon for an example model).

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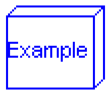
## Examples.InverseParameterization

**Demonstrates the parameterization of a pump and a pipe for given nominal values**



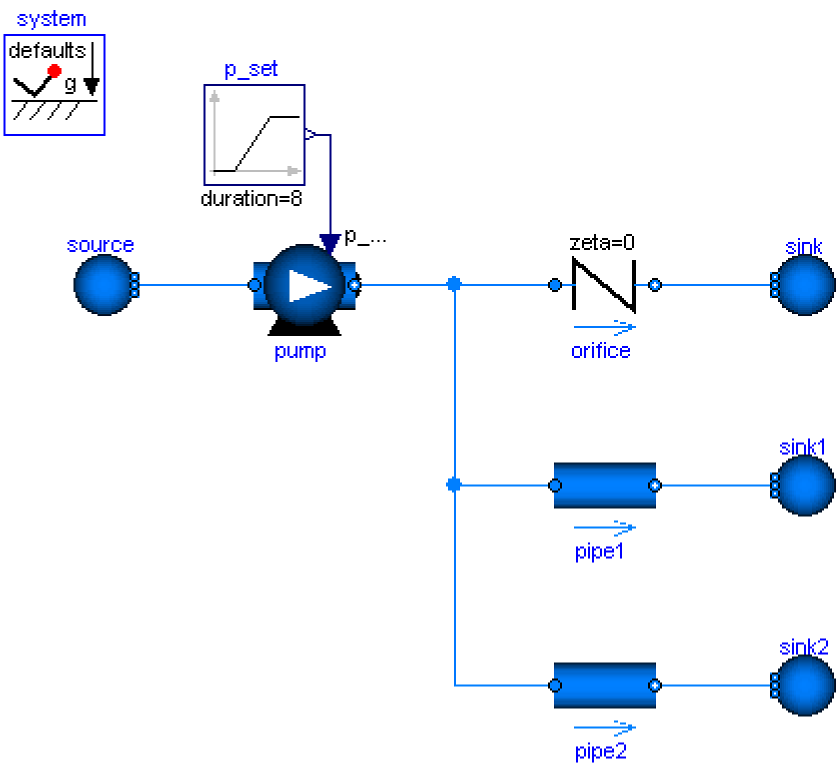

### Information

A pump, an orifice and two pipes are parameterized with simple nominal values. Note that pipe1 and pipe2 use the flowModel NominalTurbulentFlow and NominalLaminarFlow, respectively, which do not require the specification of geometry data. Instead pathLengths_nominal are obtained internally for given nominal pressure loss and nominal mass flow rate.

The pump controls a pressure ramp from 1.9 bar to 2.1 bar. This causes an appropriate ramp on the mass flow rate of the orifice, which has a boundary pressure of 1 bar. Flow reversal occurs in the pipes, which have a boundary pressure of 2 bar. The Command plotResults can be used to see the pump speed N, which is controlled ideally to obtain the pressure ramp. Moreover the internally obtained nominal design values that fulfill the nominal operating conditions as well as the Reynolds number, m_flows_turbulent, and dps_fg_turbulent are plotted.

Note that the large value for pipe2.flowModel.pathLengths_nominal[1] is only meaningful under the made assumption of laminar flow, which is hardly possible for a real pipe.

Once the geometries have been designed, the NominalTurbulentPipeFlow correlations can easily be replaced with TurbulentPipeFlow or DetailedPipeFlow correlations. Similarily the ControlledPump can be replaced with a PrescribedPump to investigate a real controller or with a Pump with rotational shaft to investigate inertia effects.




Extends from Modelica.Icons.Example (Icon for an example model).

## Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | |

## Connectors

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | |

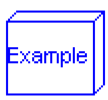
## Examples.Explanatory

**A set of examples illustrating when special attention has to be paid**

## Package Content

| Name | Description |
|---|---|
| MomentumBalanceFittings | Illustrating a case in which kinetic terms play a major role in the momentum balance |

## Examples.Explanatory.MomentumBalanceFittings




Modelica_Fluid Library 1.0 (J

**Illustrating a case in which kinetic terms play a major role in the momentum balance**

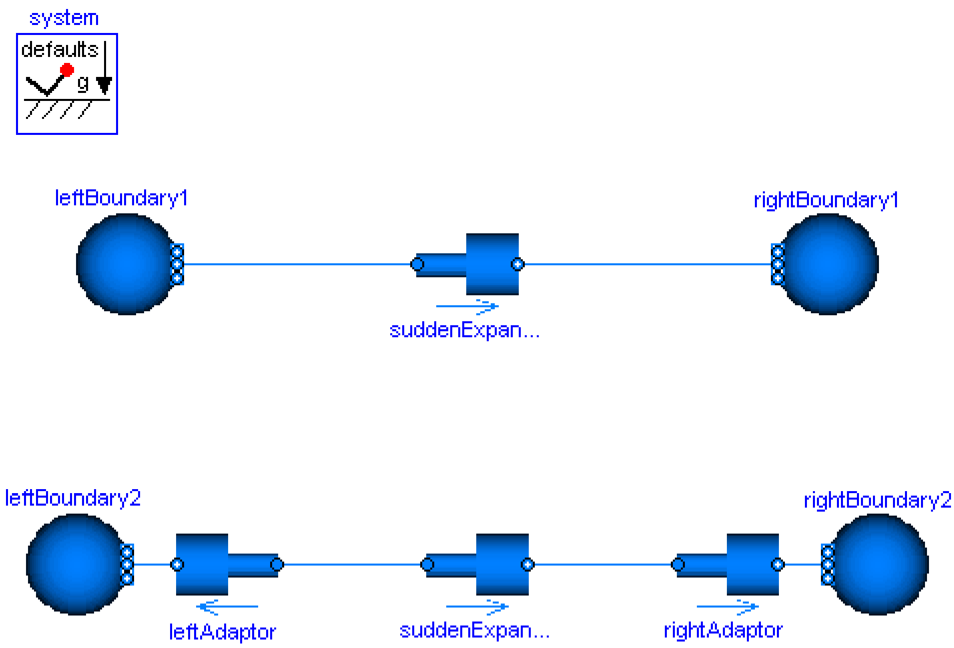
## Information

This example shows the use of a sudden expansion / contraction model, which is connected to two boundary conditions prescribing static pressure. Notice that the prescribed static pressure on the right boundary is higher than on the left one. Still, the fluid flows from left to right.

The reason for this is that the boundary conditions model infinite reservoirs with an infinite diameter and thus zero flow velocity. The sudden expansion model does however have two ends with finite diameters, and, as explained in the Overview of the Users' Guide, the momentum balance is not fulfilled exactly for this type of connections. Using a simple `connect()`-statement, the difference of the kinetic terms is neglected, which is not reasonable in the present model: At the left boundary condition it is zero, and on the left side of the sudden expansion it has a non-zero value. It is not reasonable to neglect it in the shown model, because there is little friction and therefore these kinetic effects dominate. Consequently, only modelling these effects explicitly leads to the correct results.

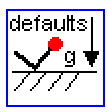
To do so, two additional sudden expansions / contractions are included in the model. The diameter is set to `inf` close to the boundaries and the proper values close to the original model. These additional components now introduce *exact* momentum balances and the results are as expected.

The total pressures offer an additional perspective on the model. After setting the parameter `show_totalPressures` on the Advanced tab of the `AbruptAdaptor`s to `true`, the total pressures are included in said models and may be plotted. This allows to confirm that the **total** pressure *always* reduces along the flow direction, even in the upper model.




Extends from Modelica.Icons.Example (Icon for an example model).

## Modelica_Fluid.System



**System properties and default values (ambient, flow direction, initialization)**

### Information

A system component is needed in each fluid model to provide system-wide settings, such as ambient conditions and overall modeling assumptions. The system settings are propagated to the fluid models using the inner/outer mechanism.

A model should never directly use system parameters. Instead a local parameter should be declared, which uses the global setting as default. The only exception currently made is the gravity system.g.

### Parameters

| Type | Name | Description |
|---|---|---|
| Environment | | |
| AbsolutePressure | p_ambient | Default ambient pressure [Pa] |
| Temperature | T_ambient | Default ambient temperature [K] |
| Acceleration | g | Constant gravity acceleration [m/s2] |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = false to restrict to design flow direction (port_a -> port_b) |
| Dynamics | | |
| Dynamics | energyDynamics | Default formulation of energy balances |
| Dynamics | massDynamics | Default formulation of mass balances |
| Dynamics | momentumDynamics | Default formulation of momentum balances, if options available |
| **Initialization** | | |
| MassFlowRate | m_flow_start | Default start value for mass flow rates [kg/s] |
| AbsolutePressure | p_start | Default start value for pressures [Pa] |
| Temperature | T_start | Default start value for temperatures [K] |
| **Advanced** | | |
| MassFlowRate | m_flow_small | Default small laminar mass flow rate for regularization of zero flow [kg/s] |
| AbsolutePressure | dp_small | Default small pressure drop for regularization of laminar and zero flow [Pa] |

## Modelica_Fluid.Vessels

**Devices for storing fluid**

### Information

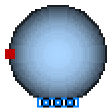
Extends from Icons.VariantLibrary (Icon for a library that contains several variants of one component).

### Package Content

| Name | Description |
|---|---|
| ClosedVolume | Volume of fixed size, closed to the ambient, with inlet/outlet ports |

| | |
|---|---|
| OpenTank | Simple tank with inlet/outlet ports |
| BaseClasses | Base classes used in the Vessels package (only of interest to build new component models) |

## Vessels.ClosedVolume



**Volume of fixed size, closed to the ambient, with inlet/outlet ports**

### Information

Ideally mixed volume of constant size with two fluid ports and one medium model. The flow properties are computed from the upstream quantities, pressures are equal in both nodes and the medium model if `use_portsData=false`. Heat transfer through a thermal port is possible, it equals zero if the port remains unconnected. A spherical shape is assumed for the heat transfer area, with V=4/3*pi*r^3, A=4*pi*r^2. Ideal heat transfer is assumed per default; the thermal port temperature is equal to the medium temperature.

If `use_portsData=true`, the port pressures represent the pressures just after the outlet (or just before the inlet) in the attached pipe. The hydraulic resistances `portsData.zeta_in` and `portsData.zeta_out` determine the dissipative pressure drop between volume and port depending on the direction of mass flow. See VesselPortsData and *[Idelchik, Handbook of Hydraulic Resistance, 2004]*.

Extends from Vessels.BaseClasses.PartialLumpedVessel (Lumped volume with a vector of fluid ports and replaceable heat transfer model).

### Parameters

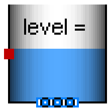
| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | Medium in the component |
| Volume | fluidVolume | Volume [m3] |
| Volume | V | Volume [m3] |
| Ports | | |
| Boolean | use_portsData | = false to neglect pressure loss and kinetic energy |
| VesselPortsData | portsData[nPorts] | Data of inlet/outlet ports |
| **Assumptions** | | |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use the HeatTransfer model |
| replaceable model | HeatTransfer | Wall heat transfer |
| **Initialization** | | |
| AbsolutePressure | p_start | Start value of pressure [Pa] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |

| | | |
|---|---|---|
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| **Advanced** | | |
| Port properties | | |
| MassFlowRate | m_flow_small | Regularization range at zero mass flow rate [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| VesselFluidPorts_b | ports[nPorts] | Fluid inlets and outlets |
| HeatPort_a | heatPort | |

## Vessels.OpenTank




**Simple tank with inlet/outlet ports**

### Information

Model of a tank that is open to the ambient at the fixed pressure `p_ambient`.

The vector of connectors **ports** represents fluid ports at configurable heights, relative to the bottom of tank. Fluid can flow either out of or in to each port.

The following assumptions are made:

- The tank is filled with a single or multiple-substance medium having a density higher than the density of the ambient medium.
- The fluid has uniform density, temperature and mass fractions
- No liquid is leaving the tank through the open top; the simulation breaks with an assertion if the liquid level growths over the height.

The port pressures represent the pressures just after the outlet (or just before the inlet) in the attached pipe. The hydraulic resistances `portsData.zeta_in` and `portsData.zeta_out` determine the dissipative pressure drop between tank and port depending on the direction of mass flow. See VesselPortsData and *[Idelchik, Handbook of Hydraulic Resistance, 2004]*.

With the setting `use_portsData=false`, the port pressure represents the static head at the height of the respective port. The relationship between pressure drop and mass flow rate at the port must then be provided by connected components; Heights of ports as well as kinetic and potential energy of fluid enering or leaving are not taken into account anymore.

Extends from Vessels.BaseClasses.PartialLumpedVessel (Lumped volume with a vector of fluid ports and replaceable heat transfer model).

### Parameters

| Type | Name | Description |
|---|---|---|
| Height | height | Height of tank [m] |
| Area | crossArea | Area of tank [m2] |
| replaceable package Medium | | Medium in the component |
| Volume | fluidVolume | Volume [m3] |
| Ports | | |

| | | |
|---|---|---|
| Boolean | use_portsData | = false to neglect pressure loss and kinetic energy |
| VesselPortsData | portsData[nPorts] | Data of inlet/outlet ports |
| **Assumptions** | | |
| Ambient | | |
| AbsolutePressure | p_ambient | Tank surface pressure [Pa] |
| Temperature | T_ambient | Tank surface Temperature [K] |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use the HeatTransfer model |
| replaceable model HeatTransfer | | Wall heat transfer |
| **Initialization** | | |
| Height | level_start | Start value of tank level [m] |
| AbsolutePressure | p_start | Start value of pressure [Pa] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| **Advanced** | | |
| Port properties | | |
| MassFlowRate | m_flow_small | Regularization range at zero mass flow rate [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| VesselFluidPorts_b | ports[nPorts] | Fluid inlets and outlets |
| HeatPort_a | heatPort | |

## Vessels.BaseClasses

**Base classes used in the Vessels package (only of interest to build new component models)**

### Package Content

| Name | Description |
|---|---|
| PartialLumpedVessel | Lumped volume with a vector of fluid ports and replaceable heat transfer model |
| HeatTransfer | HeatTransfer models for vessels |
| VesselPortsData | Data to describe inlet/outlet ports at vessels: diameter -- Inner (hydraulic) diameter of inlet/outlet port height -- Height over the bottom of the vessel zeta_out -- Hydraulic resistance out of vessel, default 0.5 for small diameter mounted flush with the wall zeta_in -- Hydraulic resistance into vessel, default 1.04 for small diameter mounted flush with the wall |
| | Fluid connector with filled, large icon to be used for horizontally aligned vectors of FluidPorts (vector dimensions must be added after dragging) |

| | |
|---|---|
| VesselFluidPorts_a | |
| VesselFluidPorts_b | Fluid connector with outlined, large icon to be used for horizontally aligned vectors of FluidPorts (vector dimensions must be added after dragging) |

## Vessels.BaseClasses.PartialLumpedVessel

**Lumped volume with a vector of fluid ports and replaceable heat transfer model**

### Information

This base class extends PartialLumpedVolume with a vector of fluid ports and a replaceable wall HeatTransfer model.

The following modeling assumption are made:

- homogenous medium, i.e. phase seperation is not taken into account,
- no kinetic energy in the fluid, i.e. kinetic energy dissipates into the internal energy,
- pressure loss definitions at vessel ports assume incompressible fluid,
- outflow of ambient media is prevented at each port assuming check valve behavior. If `fluidlevel < portsData_height[i]` and `ports[i].p < vessel_ps_static[i]` massflow at the port is set to 0.

Each port has a (hydraulic) diameter and a height above the bottom of the vessel, which can be configured using the **`portsData`** record. Alternatively the impact of port geometries can be neglected with `use_portsData=false`. This might be useful for early design studies. Note that this means to assume an infinite port diameter at the bottom of the vessel. Pressure drops and heights of the ports as well as kinetic and potential energy fluid entering or leaving the vessel are neglected then.

The following variables need to be defined by an extending model:

- `input fluidVolume`, the volume of the fluid in the vessel,
- `vessel_ps_static[nPorts]`, the static pressures inside the vessel at the height of the corresponding ports, at zero flow velocity, and
- `Wb_flow`, work term of the energy balance, e.g. p*der(V) if the volume is not constant or stirrer power.

An extending model should define:

- `parameter vesselArea` (default: Modelica.Constants.inf m2), the area of the vessel, to be related to cross flow areas of the ports for the consideration of dynamic pressure effects.

Optionally the fluid level may vary in the vessel, which effects the flow through the ports at configurable `portsData_height[nPorts]`. This is why an extending model with varying fluid level needs to define:

- `input fluidLevel (default: 0m)`, the level the fluid in the vessel, and
- `parameter fluidLevel_max (default: 1m)`, the maximum level that must not be exceeded. Ports at or above fluidLevel_max can only receive inflow.

An extending model should not access the `portsData` record defined in the configuration dialog, as an access to `portsData` may fail for `use_portsData=false` or `nPorts=0`. Instead the predefined variables

- `portsData_diameter[nPorts]`

  ,

- `portsData_height[nPorts]`

  ,
- `portsData_zeta_in[nPorts]`

  , and
- `portsData_zeta_out[nPorts]`

should be used if these values are needed.
Extends from Interfaces.PartialLumpedVolume (Lumped volume with mass and energy balance).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Ports | | |
| Boolean | use_portsData | = false to neglect pressure loss and kinetic energy |
| VesselPortsData | portsData[nPorts] | Data of inlet/outlet ports |
| **Assumptions** | | |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use the HeatTransfer model |
| **Initialization** | | |
| AbsolutePressure | p_start | Start value of pressure [Pa] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| **Advanced** | | |
| Port properties | | |
| MassFlowRate | m_flow_small | Regularization range at zero mass flow rate [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| VesselFluidPorts_b | ports[nPorts] | Fluid inlets and outlets |
| HeatPort_a | heatPort | |

## Vessels.BaseClasses.HeatTransfer

**HeatTransfer models for vessels**

### Information

Heat transfer correlations for pipe models

### Package Content

| Name | Description |
|---|---|
| PartialVesselHeatTransfer | Base class for vessel heat transfer models |
| IdealHeatTransfer | IdealHeatTransfer: Ideal heat transfer without thermal resistance |
| ConstantHeatTransfer | ConstantHeatTransfer: Constant heat transfer coefficient |

## Vessels.BaseClasses.HeatTransfer.PartialVesselHeatTransfer

**Base class for vessel heat transfer models**

### Information

Base class for vessel heat transfer models.
Extends from Interfaces.PartialHeatTransfer (Common interface for heat transfer models).

### Parameters

| Type | Name | Description |
|---|---|---|
| Ambient | | |
| CoefficientOfHeatTransfer | k | Heat transfer coefficient to ambient [W/(m2.K)] |
| Temperature | T_ambient | Ambient temperature [K] |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of heat transfer segments |
| Boolean | use_k | = true to use k value for thermal isolation |

### Connectors

| Type | Name | Description |
|---|---|---|
| HeatPorts_a | heatPorts[n] | Heat port to component boundary |

## Vessels.BaseClasses.HeatTransfer.IdealHeatTransfer

**IdealHeatTransfer: Ideal heat transfer without thermal resistance**

### Information

Ideal heat transfer without thermal resistance.
Extends from PartialVesselHeatTransfer (Base class for vessel heat transfer models).

### Parameters

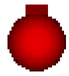
| Type | Name | Description |
|---|---|---|
| Ambient | | |
| CoefficientOfHeatTransfer | k | Heat transfer coefficient to ambient [W/(m2.K)] |
| Temperature | T_ambient | Ambient temperature [K] |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of heat transfer segments |

| | | |
|---|---|---|
| Boolean | use_k | = true to use k value for thermal isolation |

### Connectors

| Type | Name | Description |
|---|---|---|
| HeatPorts_a | heatPorts[n] | Heat port to component boundary |

## Vessels.BaseClasses.HeatTransfer.ConstantHeatTransfer



**ConstantHeatTransfer: Constant heat transfer coefficient**

### Information

Simple heat transfer correlation with constant heat transfer coefficient.
Extends from PartialVesselHeatTransfer (Base class for vessel heat transfer models).

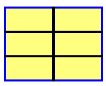
### Parameters

| Type | Name | Description |
|---|---|---|
| CoefficientOfHeatTransfer | alpha0 | constant heat transfer coefficient [W/(m2.K)] |
| Ambient | | |
| CoefficientOfHeatTransfer | k | Heat transfer coefficient to ambient [W/(m2.K)] |
| Temperature | T_ambient | Ambient temperature [K] |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of heat transfer segments |
| Boolean | use_k | = true to use k value for thermal isolation |

### Connectors

| Type | Name | Description |
|---|---|---|
| HeatPorts_a | heatPorts[n] | Heat port to component boundary |

## Vessels.BaseClasses.VesselPortsData



**Data to describe inlet/outlet ports at vessels: diameter -- Inner (hydraulic) diameter of inlet/outlet port height -- Height over the bottom of the vessel zeta_out -- Hydraulic resistance out of vessel, default 0.5 for small diameter mounted flush with the wall zeta_in -- Hydraulic resistance into vessel, default 1.04 for small diameter mounted flush with the wall**

### Information

#### Vessel Port Data

This record describes the **ports** of a **vessel**. The variables in it are mostly self-explanatory (see list below); only the $\zeta$ loss factors are discussed further. All data is quoted from Idelchik (1994).

### Outlet Coefficients

If a **straight pipe with constant cross section is mounted flush with the wall**, its outlet pressure loss coefficient will be `ζ = 0.5` (Idelchik, p. 160, Diagram 3-1, paragraph 2).

If a **straight pipe with constant cross section is mounted into a vessel such that the entrance into it is at a distance** `b` from the wall (inside) the following table can be used. Herein, δ is the tube wall thickness (Idelchik, p. 160, Diagram 3-1, paragraph 1).

| | | **b / D_hyd** | | | | |
|---|---|---|---|---|---|---|
| | | **0.000** | **0.005** | **0.020** | **0.100** | **0.500-∞** |
| **δ / D_hyd** | **0.000** | 0.50 | 0.63 | 0.73 | 0.86 | 1.00 |
| | **0.008** | 0.50 | 0.55 | 0.62 | 0.74 | 0.88 |
| | **0.016** | 0.50 | 0.51 | 0.55 | 0.64 | 0.77 |
| | **0.024** | 0.50 | 0.50 | 0.52 | 0.58 | 0.68 |
| | **0.040** | 0.50 | 0.50 | 0.51 | 0.51 | 0.54 |

Pressure loss coefficients for outlets, entrance at a distance from wall

If a **straight pipe with a circular bellmouth inlet (collector) without baffle is mounted flush with the wall** then its pressure loss coefficient can be established from the following table. Herein, r is the radius of the bellmouth inlet surface (Idelchik, p. 164 f., Diagram 3-4, paragraph b)

| | **r / D_hyd** | | | | | |
|---|---|---|---|---|---|---|
| | **0.01** | **0.03** | **0.05** | **0.08** | **0.16** | **≥0.20** |
| **ζ** | 0.44 | 0.31 | 0.22 | 0.15 | 0.06 | 0.03 |

Pressure loss coefficients for outlets, bellmouth flush with wall

If a **straight pipe with a circular bellmouth inlet (collector) without baffle is mounted at a distance from a wall** then its pressure loss coefficient can be established from the following table. Herein, r is the radius of the bellmouth inlet surface (Idelchik, p. 164 f., Diagram 3-4, paragraph a)

| | **r / D_hyd** | | | | | |
|---|---|---|---|---|---|---|
| | **0.01** | **0.03** | **0.05** | **0.08** | **0.16** | **≥0.20** |
| **ζ** | 0.87 | 0.61 | 0.40 | 0.20 | 0.06 | 0.03 |

Pressure loss coefficients for outlets, bellmouth at a distance of wall

### Inlet Coefficients

If a **straight pipe with constant circular cross section is mounted flush with the wall**, its vessel inlet pressure loss coefficient will be according to the following table (Idelchik, p. 209 f., Diagram 4-2 with `A_port/A_vessel = 0` and Idelchik, p. 640, Diagram 11-1, graph a). According to the text, `m = 9` is appropriate for fully developed turbulent flow.

| | **m** | | | | | |
|---|---|---|---|---|---|---|
| | **1.0** | **2.0** | **3.0** | **4.0** | **7.0** | **9.0** |
| **ζ** | 2.70 | 1.50 | 1.25 | 1.15 | 1.06 | 1.04 |

Pressure loss coefficients for inlets, circular tube flush with wall

For larger port diameters, relative to the area of the vessel, the inlet pressure loss coefficient will be according to the following table (Idelchik, p. 209 f., Diagram 4-2 with `m = 7`).

| | **A_port / A_vessel** |
|---|---|

| | 0.0 | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 |
|---|---|---|---|---|---|---|
| ζ | 1.04 | 0.84 | 0.67 | 0.39 | 0.18 | 0.06 |

Pressure loss coefficients for inlets, circular tube flush with wall

**References**

Idelchik I.E. (1994):
Handbook of Hydraulic Resistance. 3rd edition, Begell House, ISBN 0-8493-9908-4

Extends from Modelica.Icons.Record (Icon for a record).

## Parameters

| Type | Name | Description |
|---|---|---|
| Diameter | diameter | Inner (hydraulic) diameter of inlet/outlet port [m] |
| Height | height | Height over the bottom of the vessel [m] |
| Real | zeta_out | Hydraulic resistance out of vessel, default 0.5 for small diameter mounted flush with the wall |
| Real | zeta_in | Hydraulic resistance into vessel, default 1.04 for small diameter mounted flush with the wall |

## Modelica definition

```
record VesselPortsData "Data to describe inlet/outlet ports at vessels:
    diameter -- Inner (hydraulic) diameter of inlet/outlet port
    height -- Height over the bottom of the vessel
    zeta_out -- Hydraulic resistance out of vessel, default 0.5 for small diameter
mounted flush with the wall
    zeta_in -- Hydraulic resistance into vessel, default 1.04 for small diameter mounted
flush with the wall"
      extends Modelica.Icons.Record;
  parameter SI.Diameter diameter
    "Inner (hydraulic) diameter of inlet/outlet port";
  parameter SI.Height height = 0 "Height over the bottom of the vessel";
  parameter Real zeta_out(min=0)=0.5
    "Hydraulic resistance out of vessel, default 0.5 for small diameter mounted flush
with the wall";
  parameter Real zeta_in(min=0)=1.04
    "Hydraulic resistance into vessel, default 1.04 for small diameter mounted flush with
the wall";
end VesselPortsData;
```

## Vessels.BaseClasses.VesselFluidPorts_a

**Fluid connector with filled, large icon to be used for horizontally aligned vectors of FluidPorts (vector dimensions must be added after dragging)**

## Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium model |

## Contents

| Type | Name | Description |
|---|---|---|
| flow MassFlowRate | m_flow | Mass flow rate from the connection point into the component [kg/s] |
| AbsolutePressure | p | Thermodynamic pressure in the connection point [Pa] |
| stream | h_outflow | Specific thermodynamic enthalpy close to the connection |

| | | |
|---|---|---|
| SpecificEnthalpy | | point if m_flow < 0 [J/kg] |
| stream MassFraction | Xi_outflow[Medium.nXi] | Independent mixture mass fractions m_i/m close to the connection point if m_flow < 0 [kg/kg] |
| stream ExtraProperty | C_outflow[Medium.nC] | Properties c_i/m close to the connection point if m_flow < 0 |

## Vessels.BaseClasses.VesselFluidPorts_b

**Fluid connector with outlined, large icon to be used for horizontally aligned vectors of FluidPorts (vector dimensions must be added after dragging)**

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium model |

### Contents

| Type | Name | Description |
|---|---|---|
| flow MassFlowRate | m_flow | Mass flow rate from the connection point into the component [kg/s] |
| AbsolutePressure | p | Thermodynamic pressure in the connection point [Pa] |
| stream SpecificEnthalpy | h_outflow | Specific thermodynamic enthalpy close to the connection point if m_flow < 0 [J/kg] |
| stream MassFraction | Xi_outflow[Medium.nXi] | Independent mixture mass fractions m_i/m close to the connection point if m_flow < 0 [kg/kg] |
| stream ExtraProperty | C_outflow[Medium.nC] | Properties c_i/m close to the connection point if m_flow < 0 |

# Modelica_Fluid.Pipes

**Devices for conveying fluid**

### Information

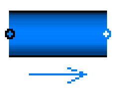
Extends from Icons.VariantLibrary (Icon for a library that contains several variants of one component).

### Package Content

| Name | Description |
|---|---|
| StaticPipe | Basic pipe flow model without storage of mass or energy |
| DynamicPipe | Dynamic pipe model with storage of mass and energy |
| BaseClasses | Base classes used in the Pipes package (only of interest to build new component models) |

## Pipes.StaticPipe

**Basic pipe flow model without storage of mass or energy**



### Information

Model of a straight pipe with constant cross section and with steady-state mass, momentum and energy balances, i.e. the model does not store mass or energy. There exist two thermodynamic states, one at each fluid port. The momentum balance is formulated for the two states, taking into account momentum flows, friction and gravity. The same result can be obtained by using DynamicPipe with steady-state dynamic settings. The intended use is to provide simple connections of vessels or other devices with storage, as it is done in:

- Examples.Tanks.EmptyTanks
- Examples.InverseParameterization

.

#### Numerical Issues

With the stream connectors the thermodynamic states on the ports are generally defined by models with storage or by sources placed upstream and downstream of the static pipe. Other non storage components in the flow path may yield to state transformation. Note that this generally leads to nonlinear equation systems if multiple static pipes, or other flow models without storage, are directly connected.

Extends from Pipes.BaseClasses.PartialStraightPipe (Base class for straight pipe models).

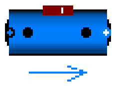
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Geometry | | |
| Real | nParallel | Number of identical parallel pipes |
| Length | length | Length [m] |
| Boolean | isCircular | = true if cross sectional area is circular |
| Diameter | diameter | Diameter of circular pipe [m] |
| Area | crossArea | Inner cross section area [m2] |
| Length | perimeter | Inner perimeter [m] |
| Height | roughness | Average height of surface asperities (default: smooth steel pipe) [m] |
| Static head | | |
| Length | height_ab | Height(port_b) - Height(port_a) [m] |
| Pressure loss | | |
| replaceable model FlowModel | | Wall friction, gravity, momentum flow |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Initialization** | | |
| AbsolutePressure | p_a_start | Start value of pressure at port a [Pa] |
| AbsolutePressure | p_b_start | Start value of pressure at port b [Pa] |
| MassFlowRate | m_flow_start | Start value for mass flow rate [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

## Pipes.DynamicPipe



**Dynamic pipe model with storage of mass and energy**

### Information

Model of a straight pipe with distributed mass, energy and momentum balances. It provides the complete balance equations for one-dimensional fluid flow as formulated in UsersGuide.ComponentDefinition.BalanceEquations.

The partial differential equations are treated with the finite volume method and a staggered grid scheme for momentum balances. The pipe is split into nNodes equally spaced segments along the flow path. The default value is nNodes=2. This results in two lumped mass and energy balances and one lumped momentum balance across the dynamic pipe.

Note that this generally leads to high-index DAEs for pressure states if dynamic pipes are directly connected to each other, or generally to models with storage exposing a thermodynamic state through the port. This may not be valid if the dynamic pipe is connected to a model with non-differentiable pressure, like a Sources.Boundary_pT with prescribed jumping pressure. The **`modelStructure`** can be configured as appropriate in such situations, in order to place a momentum balance between a pressure state of the pipe and a non-differentiable boundary condition.

The default **`modelStructure`** is `av_vb` (see Advanced tab). The simplest possible alternative symetric configuration, avoiding potential high-index DAEs at the cost of the potential introduction of nonlinear equation systems, is obtained with the setting `nNodes=1, modelStructure=a_v_b`. Depending on the configured model structure, the first and the last pipe segment, or the flow path length of the first and the last momentum balance, are of half size. See the documentation of the base class Pipes.BaseClasses.PartialTwoPortFlow, also covering asymmetric configurations.

The **`HeatTransfer`** component specifies the source term `Qb_flows` of the energy balance. The default component uses a constant coefficient for the heat transfer between the bulk flow and the segment boundaries exposed through the `heatPorts`. The `HeatTransfer` model is replaceable and can be exchanged with any model extended from BaseClasses.HeatTransfer.PartialFlowHeatTransfer.

The intended use is for complex networks of pipes and other flow devices, like valves. See e.g.

- Examples.BranchingDynamicPipes, or
- Examples.IncompressibleFluidNetwork.

Extends from Pipes.BaseClasses.PartialStraightPipe (Base class for straight pipe models), BaseClasses.PartialTwoPortFlow (Base class for distributed flow models).

### Parameters

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Geometry | | |
| Real | nParallel | Number of identical parallel pipes |
| Length | length | Length [m] |
| Boolean | isCircular | = true if cross sectional area is circular |
| Diameter | diameter | Diameter of circular pipe [m] |
| Area | crossArea | Inner cross section area [m2] |
| Length | perimeter | Inner perimeter [m] |
| Height | roughness | Average height of surface asperities (default: smooth steel pipe) [m] |
| Length | lengths[n] | lengths of flow segments [m] |
| Area | crossAreas[n] | cross flow areas of flow segments [m2] |
| Length | dimensions[n] | hydraulic diameters of flow segments [m] |
| Height | roughnesses[n] | Average heights of surface asperities [m] |
| Static head | | |
| Length | height_ab | Height(port_b) - Height(port_a) [m] |
| Length | dheights[n] | Differences in heigths of flow segments [m] |
| Pressure loss | | |
| replaceable model FlowModel | | Wall friction, gravity, momentum flow |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balances |
| Dynamics | massDynamics | Formulation of mass balances |
| Dynamics | momentumDynamics | Formulation of momentum balances |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use the HeatTransfer model |
| **Initialization** | | |
| AbsolutePressure | p_a_start | Start value of pressure at port a [Pa] |
| AbsolutePressure | p_b_start | Start value of pressure at port b [Pa] |
| Boolean | use_T_start | Use T_start if true, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| MassFlowRate | m_flow_start | Start value for mass flow rate [kg/s] |
| **Advanced** | | |
| Integer | nNodes | Number of discrete flow volumes |
| ModelStructure | modelStructure | Determines whether flow or volume models are present at the ports |
| Boolean | useLumpedPressure | =true to lump pressure states together |
| Boolean | useInnerPortProperties | =true to take port properties for flow models from internal control volumes |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| HeatPorts_a | heatPorts[nNodes] | |

## Pipes.BaseClasses

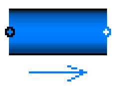
**Base classes used in the Pipes package (only of interest to build new component models)**

### Package Content

| Name | Description |
|---|---|
| PartialStraightPipe | Base class for straight pipe models |
| PartialTwoPortFlow | Base class for distributed flow models |
| FlowModels | Flow models for pipes, including wall friction, static head and momentum flow |
| HeatTransfer | Heat transfer for flow models |
| CharacteristicNumbers | Functions to compute characteristic numbers |
| WallFriction | Different variants for pressure drops due to pipe wall friction |

## Pipes.BaseClasses.PartialStraightPipe

**Base class for straight pipe models**



### Information

Base class for one dimensional flow models. It specializes a PartialTwoPort with a parameter interface and icon graphics.

Extends from Interfaces.PartialTwoPort (Partial component with two ports).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Geometry | | |
| Real | nParallel | Number of identical parallel pipes |
| Length | length | Length [m] |
| Boolean | isCircular | = true if cross sectional area is circular |
| Diameter | diameter | Diameter of circular pipe [m] |
| Area | crossArea | Inner cross section area [m2] |
| Length | perimeter | Inner perimeter [m] |
| Height | roughness | Average height of surface asperities (default: smooth steel pipe) [m] |
| Static head | | |
| Length | height_ab | Height(port_b) - Height(port_a) [m] |

| Assumptions | | |
|---|---|---|
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

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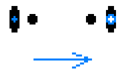
## Pipes.BaseClasses.PartialTwoPortFlow

**Base class for distributed flow models**



### Information

Base class for distributed flow models. The total volume is split into nNodes segments along the flow path. The default value is nNodes=2.

#### Mass and Energy balances

The mass and energy balances are inherited from Interfaces.PartialDistributedVolume. One total mass and one energy balance is formed across each segment according to the finite volume approach. Substance mass balances are added if the medium contains more than one component.

An extending model needs to define the geometry and the difference in heights between the flow segments (static head). Moreover it needs to define two vectors of source terms for the distributed energy balance:

- **`Qb_flows[nNodes]`**, the heat flow source terms, e.g. conductive heat flows across segment boundaries, and
- **`Wb_flows[nNodes]`**, the work source terms.

#### Momentum balance

The momentum balance is determined by the **`FlowModel`** component, which can be replaced with any model extended from BaseClasses.FlowModels.PartialStaggeredFlowModel. The default setting is DetailedPipeFlow. This considers

- pressure drop due to friction and other dissipative losses, and
- gravity effects for non-horizontal devices.
- variation of flow velocity along the flow path, which occur due to changes in the cross sectional area or the fluid density, provided that `flowModel.use_Ib_flows` is true.

#### Model Structure

The momentum balances are formulated across the segment boundaries along the flow path according to the staggered grid approach. The configurable **`modelStructure`** determines the formulation of the boundary conditions at `port_a` and `port_b`. The options include (default: av_vb):

- `av_vb`: Symmetric setting with nNodes-1 momentum balances between nNodes flow segments. The ports `port_a` and `port_b` expose the first and the last thermodynamic state, respectively. Connecting two or more flow devices therefore may result in high-index DAEs for the pressures of connected flow segments.

- a_v_b: Alternative symmetric setting with nNodes+1 momentum balances across nNodes flow segments. Half momentum balances are placed between port_a and the first flow segment as well as between the last flow segment and port_b. Connecting two or more flow devices therefore results in algebraic pressures at the ports. The specification of good start values for the port pressures is essential for the solution of large nonlinear equation systems.
- av_b: Unsymmetric setting with nNodes momentum balances, one between nth volume and port_b, potential pressure state at port_a
- a_vb: Unsymmetric setting with nNodes momentum balance, one between first volume and port_a, potential pressure state at port_b

When connecting two components, e.g. two pipes, the momentum balance across the connection point reduces to
`pipe1.port_b.p = pipe2.port_a.p`

This is only true if the flow velocity remains the same on each side of the connection. Consider using a fitting for any significant change in diameter or fluid density, if the resulting effects, such as change in kinetic energy, cannot be neglected. This also allows for taking into account friction losses with respect to the actual geometry of the connection point.

Extends from Interfaces.PartialTwoPort (Partial component with two ports), Interfaces.PartialDistributedVolume (Base class for distributed volume models).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of discrete volumes |
| Volume | fluidVolumes[n] | Discretized volume, determine in inheriting class [m3] |
| Geometry | | |
| Real | nParallel | Number of identical parallel flow devices |
| Length | lengths[n] | lengths of flow segments [m] |
| Area | crossAreas[n] | cross flow areas of flow segments [m2] |
| Length | dimensions[n] | hydraulic diameters of flow segments [m] |
| Height | roughnesses[n] | Average heights of surface asperities [m] |
| Static head | | |
| Length | dheights[n] | Differences in heigths of flow segments [m] |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balances |
| Dynamics | massDynamics | Formulation of mass balances |
| Dynamics | momentumDynamics | Formulation of momentum balances |
| **Initialization** | | |
| AbsolutePressure | p_a_start | Start value of pressure at port a [Pa] |
| AbsolutePressure | p_b_start | Start value of pressure at port b [Pa] |
| Boolean | use_T_start | Use T_start if true, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |

| | | |
|---|---|---|
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| MassFlowRate | m_flow_start | Start value for mass flow rate [kg/s] |
| **Advanced** | | |
| Integer | nNodes | Number of discrete flow volumes |
| ModelStructure | modelStructure | Determines whether flow or volume models are present at the ports |
| Boolean | useLumpedPressure | =true to lump pressure states together |
| Boolean | useInnerPortProperties | =true to take port properties for flow models from internal control volumes |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

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## Pipes.BaseClasses.FlowModels

**Flow models for pipes, including wall friction, static head and momentum flow**

### Package Content

| Name | Description |
|---|---|
| PartialStaggeredFlowModel | Base class for momentum balances in flow models |
| NominalLaminarFlow | NominalLaminarFlow: Linear pressure loss for nominal values |
| PartialGenericPipeFlow | GenericPipeFlow: Pipe flow pressure loss and gravity with replaceable WallFriction package |
| NominalTurbulentPipeFlow | NominalTurbulentPipeFlow: Quadratic turbulent pressure loss for nominal values |
| TurbulentPipeFlow | TurbulentPipeFlow: Pipe wall friction in the quadratic turbulent regime (simple characteristic, mu not used) |
| DetailedPipeFlow | DetailedPipeFlow: Pipe wall friction in the laminar and turbulent regime (detailed characteristic) |

---

## Pipes.BaseClasses.FlowModels.PartialStaggeredFlowModel

**Base class for momentum balances in flow models**

### Information

This paratial model defines a common interface for `m=n-1` flow models between `n` device segments. The flow models provide a steady-state or dynamic momentum balance using an upwind discretization scheme per default. Extending models must add pressure loss terms for friction and gravity.

The fluid is specified in the interface with the thermodynamic `states[n]` for a given `Medium` model. The geometry is specified with the `pathLengths[n-1]` between the device segments as well as with the `crossAreas[n]` and the `roughnesses[n]` of the device segments. Moreover the fluid flow is characterized for different types of devices by the characteristic `dimensions[n]` and the average velocities `vs[n]` of fluid flow in the device segments. See Pipes.BaseClasses.CharacteristicNumbers.ReynoldsNumber for examplary definitions.

The parameter `Re_turbulent` can be specified for the least mass flow rate of the turbulent regime. It defaults to 4000, which is appropriate for pipe flow. The `m_flows_turbulent[n-1]` resulting from `Re_turbulent` can optionally be calculated together with the Reynolds numbers `Res[n]` of the device segments (`show_Res=true`).

Using the thermodynamic states[n] of the device segments, the densities rhos[n] and the dynamic viscosities mus[n] of the segments as well as the actual densities rhos_act[n-1] and the actual viscosities mus_act[n-1] of the flows are predefined in this base model. Note that no events are raised on flow reversal. This needs to be treated by an extending model, e.g. with numerical smoothing or by raising events as appropriate.

Extends from Interfaces.PartialDistributedFlow (Base class for a distributed momentum balance).

## Parameters

| Type | Name | Description |
|---|---|---|
| Integer | m | Number of flow segments |
| ReynoldsNumber | Re_turbulent | Start of turbulent regime, depending on type of flow device [1] |
| Advanced | | |
| Boolean | useUpstreamScheme | = false to average upstream and downstream properties across flow segments |
| Boolean | use_Ib_flows | = true to consider differences in flow of momentum through boundaries |
| Diagnostics | | |
| Boolean | show_Res | = true, if Reynolds numbers are included for plotting |
| **Internal Interface** | | |
| Integer | n | Number of discrete flow volumes |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |
| Static head | | |
| Acceleration | g | Constant gravity acceleration [m/s2] |
| Assumptions | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (states[1] -> states[n+1]) |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| Initialization | | |
| MassFlowRate | m_flow_start | Start value of mass flow rates [kg/s] |
| AbsolutePressure | p_a_start | Start value for p[1] at design inflow [Pa] |
| AbsolutePressure | p_b_start | Start value for p[n+1] at design outflow [Pa] |

## Pipes.BaseClasses.FlowModels.NominalLaminarFlow

**NominalLaminarFlow: Linear pressure loss for nominal values**

### Information

This model defines a simple lineaer pressure loss assuming laminar flow for specified `dp_nominal` and `m_flow_nominal`.

Select `show_Res = true` to analyze the actual flow and the lengths of a pipe that would fulfill the specified nominal values for given geometry parameters `crossAreas`, `dimensions` and `roughnesses`.

Extends from Pipes.BaseClasses.FlowModels.PartialStaggeredFlowModel (Base class for momentum balances in flow models).

### Parameters

| Type | Name | Description |
|---|---|---|
| ReynoldsNumber | Re_turbulent | Start of turbulent regime, depending on type of flow device [1] |
| AbsolutePressure | dp_nominal | Nominal pressure loss [Pa] |
| MassFlowRate | m_flow_nominal | Mass flow rate for dp_nominal [kg/s] |
| Advanced | | |
| Boolean | useUpstreamScheme | = false to average upstream and downstream properties across flow segments |
| Boolean | use_Ib_flows | = true to consider differences in flow of momentum through boundaries |
| Diagnostics | | |
| Boolean | show_Res | = true, if Reynolds numbers are included for plotting |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of discrete flow volumes |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |
| Static head | | |
| Acceleration | g | Constant gravity acceleration [m/s2] |
| Assumptions | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (states[1] -> states[n+1]) |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| Initialization | | |
| MassFlowRate | m_flow_start | Start value of mass flow rates [kg/s] |
| AbsolutePressure | p_a_start | Start value for p[1] at design inflow [Pa] |
| AbsolutePressure | p_b_start | Start value for p[n+1] at design outflow [Pa] |

---

## Pipes.BaseClasses.FlowModels.PartialGenericPipeFlow

**GenericPipeFlow: Pipe flow pressure loss and gravity with replaceable WallFriction package**

## Information

This model describes pressure losses due to **wall friction** in a pipe and due to **gravity**. Correlations of different complexity and validity can be seleted via the replaceable package **WallFriction** (see parameter menu below). The details of the pipe wall friction model are described in the UsersGuide. Basically, different variants of the equation

```
dp = λ(Re,Δ)*(L/D)*ρ*v*|v|/2.
```

By default, the correlations are computed with media data at the actual time instant. In order to reduce non-linear equation systems, the parameters **use_mu_nominal** and **use_rho_nominal** provide the option to compute the correlations with constant media values at the desired operating point. This might speed-up the simulation and/or might give a more robust simulation.

Extends from Pipes.BaseClasses.FlowModels.PartialStaggeredFlowModel (Base class for momentum balances in flow models).

## Parameters

| Type | Name | Description |
|---|---|---|
| ReynoldsNumber | Re_turbulent | Start of turbulent regime, depending on type of flow device [1] |
| AbsolutePressure | dp_nominal | Nominal pressure loss (for nominal models) [Pa] |
| MassFlowRate | m_flow_nominal | Mass flow rate for dp_nominal (for nominal models) [kg/s] |
| Boolean | from_dp | = true, use m_flow = f(dp), otherwise dp = f(m_flow) |
| AbsolutePressure | dp_small | Within regularization if \|dp\| < dp_small (may be wider for large discontinuities in static head) [Pa] |
| MassFlowRate | m_flow_small | Within regularization if \|m_flows\| < m_flow_small (may be wider for large discontinuities in static head) [kg/s] |
| Advanced | | |
| Boolean | useUpstreamScheme | = false to average upstream and downstream properties across flow segments |
| Boolean | use_Ib_flows | = true to consider differences in flow of momentum through boundaries |
| Diagnostics | | |
| Boolean | show_Res | = true, if Reynolds numbers are included for plotting |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of discrete flow volumes |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |
| Static head | | |
| Acceleration | g | Constant gravity acceleration [m/s2] |
| Assumptions | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (states[1] -> states[n+1]) |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| Initialization | | |
| MassFlowRate | m_flow_start | Start value of mass flow rates [kg/s] |
| AbsolutePressure | p_a_start | Start value for p[1] at design inflow [Pa] |

| | | |
|---|---|---|
| AbsolutePressure | p_b_start | Start value for p[n+1] at design outflow [Pa] |

## Pipes.BaseClasses.FlowModels.NominalTurbulentPipeFlow

**NominalTurbulentPipeFlow: Quadratic turbulent pressure loss for nominal values**

### Information

This model defines the pressure loss assuming turbulent flow for specified `dp_nominal` and `m_flow_nominal`. It takes into account the fluid density of each flow segment and obtaines appropriate `pathLengths_nominal` values for an inverse parameterization of the TurbulentPipeFlow model. Per default the upstream and downstream densities are averaged with the setting `useUpstreamScheme = false`, in order to avoid discontinuous `pathLengths_nominal` values in the case of flow reversal.

The geometry parameters `crossAreas`, `diameters` and `roughnesses` do not effect simulation results of this nominal pressure loss model. As the geometry is specified however, the optionally calculated Reynolds number as well as `m_flows_turbulent` and `dps_fg_turbulent` become meaningful and can be related to `m_flow_small` and `dp_small`.

#### Optional Variables if show_Res

| Type | Name | Description |
|---|---|---|
| ReynoldsNumber | Res[n] | Reynolds numbers of pipe flow per flow segment |
| MassFlowRate | m_flows_turbulent[n-1] | mass flow rates at start of turbulent region for Re_turbulent=4000 |
| AbsolutePressure | dps_fg_turbulent[n-1] | pressure losses due to friction and gravity corresponding to m_flows_turbulent |

Extends from Pipes.BaseClasses.FlowModels.PartialGenericPipeFlow (GenericPipeFlow: Pipe flow pressure loss and gravity with replaceable WallFriction package).

### Parameters

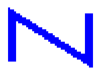
| Type | Name | Description |
|---|---|---|
| Length | pathLengths_internal[n - 1] | pathLengths used internally; to be defined by extending class [m] |
| AbsolutePressure | dp_nominal | Nominal pressure loss (for nominal models) [Pa] |
| MassFlowRate | m_flow_nominal | Mass flow rate for dp_nominal (for nominal models) [kg/s] |
| Boolean | from_dp | = true, use m_flow = f(dp), otherwise dp = f(m_flow) |
| AbsolutePressure | dp_small | Within regularization if \|dp\| < dp_small (may be wider for large discontinuities in static head) [Pa] |
| MassFlowRate | m_flow_small | Within regularization if \|m_flows\| < m_flow_small (may be wider for large discontinuities in static head) [kg/s] |
| Advanced | | |
| Boolean | useUpstreamScheme | = false to average upstream and downstream properties across flow segments |
| Boolean | use_Ib_flows | = true to consider differences in flow of momentum through boundaries |
| Diagnostics | | |
| Boolean | show_Res | = true, if Reynolds numbers are included for plotting |

| | | |
|---|---|---|
| Wall friction | | |
| replaceable package WallFriction | | Wall friction model |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of discrete flow volumes |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |
| Static head | | |
| Acceleration | g | Constant gravity acceleration [m/s2] |
| Assumptions | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (states[1] -> states[n+1]) |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| Initialization | | |
| MassFlowRate | m_flow_start | Start value of mass flow rates [kg/s] |
| AbsolutePressure | p_a_start | Start value for p[1] at design inflow [Pa] |
| AbsolutePressure | p_b_start | Start value for p[n+1] at design outflow [Pa] |

## Connectors

| Type | Name | Description |
|---|---|---|
| Wall friction | | |
| replaceable package WallFriction | | Wall friction model |

## Pipes.BaseClasses.FlowModels.TurbulentPipeFlow



**TurbulentPipeFlow: Pipe wall friction in the quadratic turbulent regime (simple characteristic, mu not used)**

## Information

This model defines only the quadratic turbulent regime of wall friction: dp = k*m_flow*|m_flow|, where "k" depends on density and the roughness of the pipe and is not a function of the Reynolds number. This relationship is only valid for large Reynolds numbers. The turbulent pressure loss correlation might be useful to optimize models that are only facing turbular flow.

Extends from Pipes.BaseClasses.FlowModels.PartialGenericPipeFlow (GenericPipeFlow: Pipe flow pressure loss and gravity with replaceable WallFriction package).

## Parameters

| Type | Name | Description |
|---|---|---|
| Length | pathLengths_internal[n - 1] | pathLengths used internally; to be defined by extending class [m] |
| AbsolutePressure | dp_nominal | Nominal pressure loss (for nominal models) [Pa] |
| MassFlowRate | m_flow_nominal | Mass flow rate for dp_nominal (for nominal models) [kg/s] |
| Boolean | from_dp | = true, use m_flow = f(dp), otherwise dp = f(m_flow) |
| AbsolutePressure | dp_small | Within regularization if \|dp\| < dp_small (may be wider for large discontinuities in static head) [Pa] |

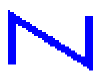
| | | |
|---|---|---|
| MassFlowRate | m_flow_small | Within regularization if \|m_flows\| < m_flow_small (may be wider for large discontinuities in static head) [kg/s] |
| Advanced | | |
| Boolean | useUpstreamScheme | = false to average upstream and downstream properties across flow segments |
| Boolean | use_Ib_flows | = true to consider differences in flow of momentum through boundaries |
| Diagnostics | | |
| Boolean | show_Res | = true, if Reynolds numbers are included for plotting |
| Wall friction | | |
| replaceable package WallFriction | | Wall friction model |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of discrete flow volumes |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |
| Static head | | |
| Acceleration | g | Constant gravity acceleration [m/s2] |
| Assumptions | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (states[1] -> states[n+1]) |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| Initialization | | |
| MassFlowRate | m_flow_start | Start value of mass flow rates [kg/s] |
| AbsolutePressure | p_a_start | Start value for p[1] at design inflow [Pa] |
| AbsolutePressure | p_b_start | Start value for p[n+1] at design outflow [Pa] |

### Connectors

| Type | Name | Description |
|---|---|---|
| Wall friction | | |
| replaceable package WallFriction | | Wall friction model |

---

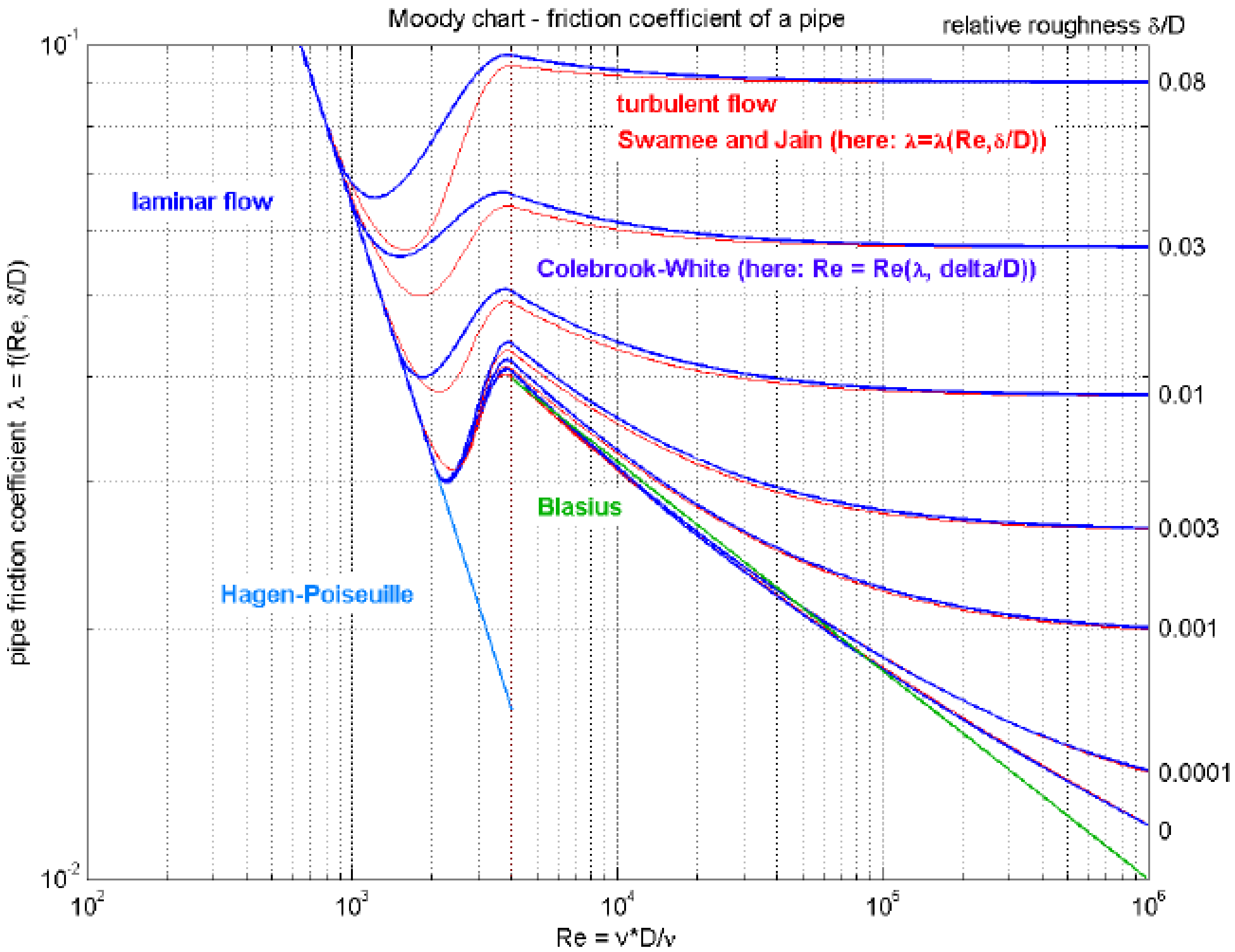
## Pipes.BaseClasses.FlowModels.DetailedPipeFlow



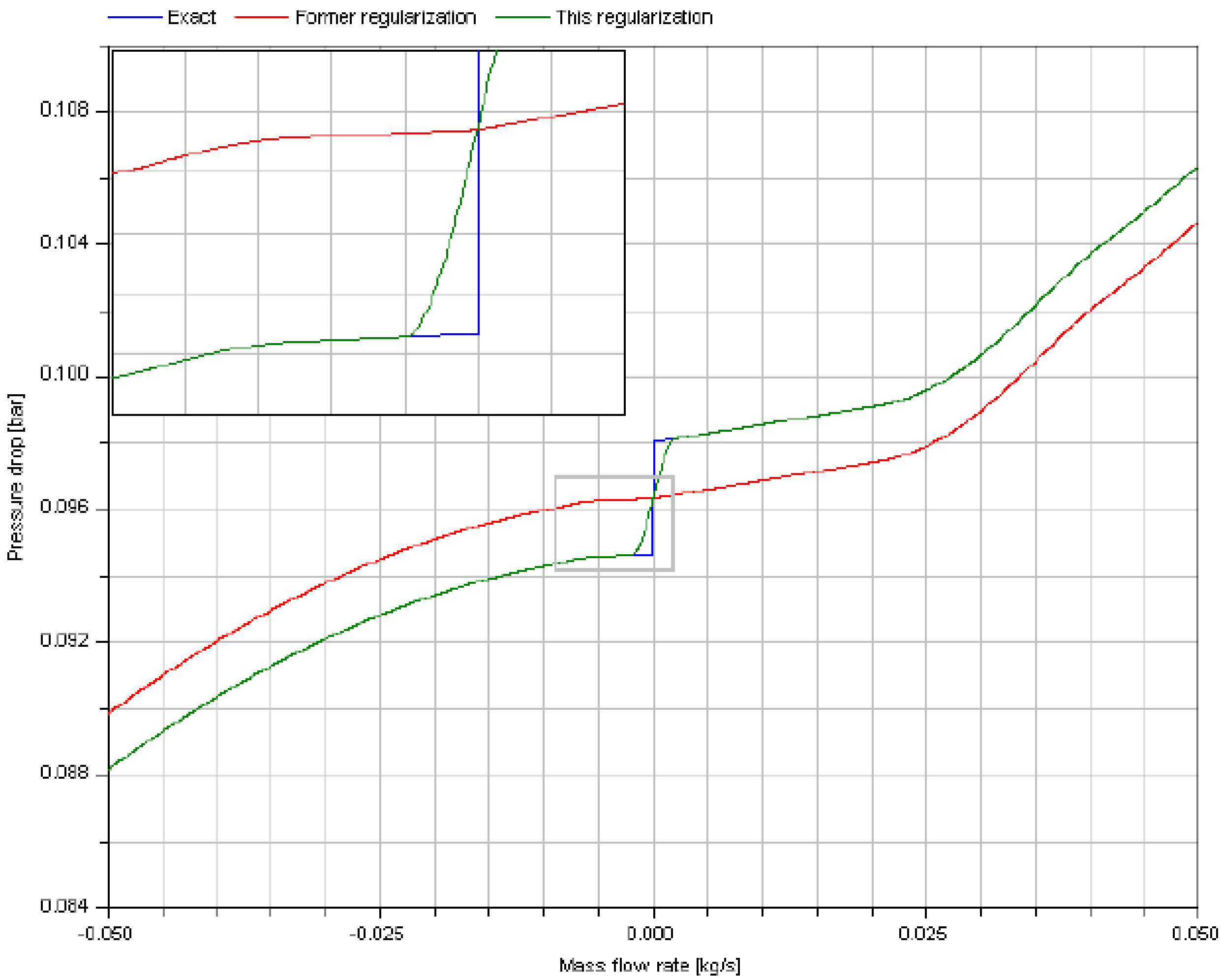
**DetailedPipeFlow: Pipe wall friction in the laminar and turbulent regime (detailed characteristic)**

### Information

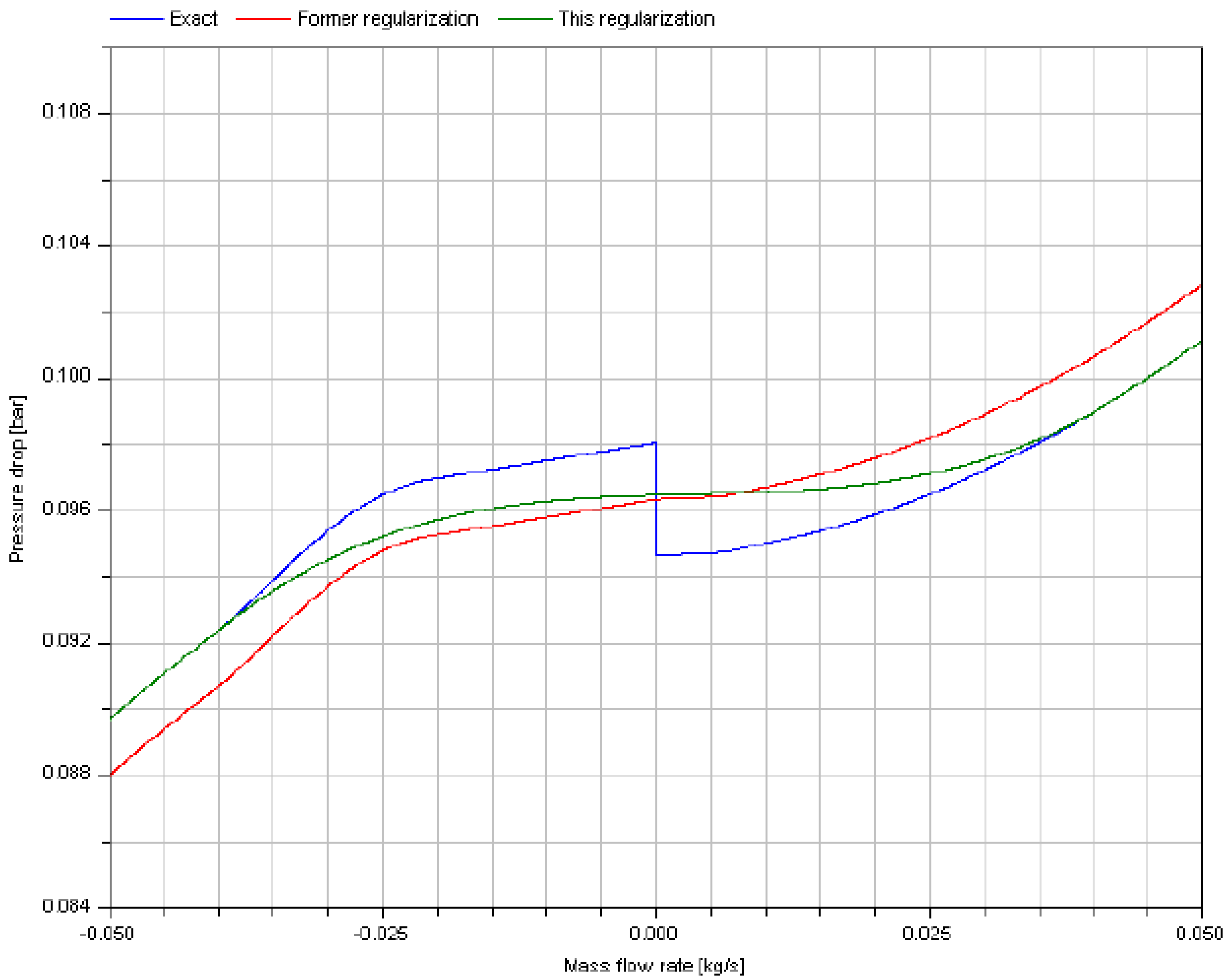
This component defines the complete regime of wall friction. The details are described in the UsersGuide. The functional relationship of the friction loss factor λ is displayed in the next figure. Function massFlowRate_dp() defines the "red curve" ("Swamee and Jain"), where as function pressureLoss_m_flow() defines the "blue curve" ("Colebrook-White"). The two functions are inverses from each other and give slightly different results in the transition region between Re = 1500 .. 4000, in order to get explicit equations without solving a non-linear equation.




Additionally to wall friction, this component properly implements static head. With respect to the latter, two cases can be distinguished. In the case shown next, the change of elevation with the path from a to b has the opposite sign of the change of density.




In the case illustrated second, the change of elevation with the path from a to b has the same sign of the change of density.




Extends from Pipes.BaseClasses.FlowModels.PartialGenericPipeFlow (GenericPipeFlow: Pipe flow pressure loss and gravity with replaceable WallFriction package).

## Parameters

| Type | Name | Description |
|---|---|---|
| Length | pathLengths_internal[n - 1] | pathLengths used internally; to be defined by extending class [m] |
| AbsolutePressure | dp_nominal | Nominal pressure loss (for nominal models) [Pa] |
| MassFlowRate | m_flow_nominal | Mass flow rate for dp_nominal (for nominal models) [kg/s] |
| Boolean | from_dp | = true, use m_flow = f(dp), otherwise dp = f(m_flow) |
| AbsolutePressure | dp_small | Within regularization if \|dp\| < dp_small (may be wider for large discontinuities in static head) [Pa] |
| MassFlowRate | m_flow_small | Within regularization if \|m_flows\| < m_flow_small (may be wider for large discontinuities in static head) [kg/s] |
| Advanced | | |
| Boolean | useUpstreamScheme | = false to average upstream and downstream properties across flow segments |
| Boolean | use_Ib_flows | = true to consider differences in flow of momentum through boundaries |
| Diagnostics | | |

| | | |
|---|---|---|
| Boolean | show_Res | = true, if Reynolds numbers are included for plotting |
| Wall friction | | |
| replaceable package WallFriction | | Wall friction model |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of discrete flow volumes |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |
| Static head | | |
| Acceleration | g | Constant gravity acceleration [m/s2] |
| Assumptions | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (states[1] -> states[n+1]) |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| Initialization | | |
| MassFlowRate | m_flow_start | Start value of mass flow rates [kg/s] |
| AbsolutePressure | p_a_start | Start value for p[1] at design inflow [Pa] |
| AbsolutePressure | p_b_start | Start value for p[n+1] at design outflow [Pa] |

## Connectors

| Type | Name | Description |
|---|---|---|
| Wall friction | | |
| replaceable package WallFriction | | Wall friction model |

## Pipes.BaseClasses.HeatTransfer

**Heat transfer for flow models**

## Information

Heat transfer correlations for pipe models

## Package Content

| Name | Description |
|---|---|
| PartialFlowHeatTransfer | base class for any pipe heat transfer correlation |
| IdealFlowHeatTransfer | IdealHeatTransfer: Ideal heat transfer without thermal resistance |
| ConstantFlowHeatTransfer | ConstantHeatTransfer: Constant heat transfer coefficient |
| PartialPipeFlowHeatTransfer | Base class for pipe heat transfer correlation in terms of Nusselt number heat transfer in a circular pipe for laminar and turbulent one-phase flow |
| LocalPipeFlowHeatTransfer | LocalPipeFlowHeatTransfer: Laminar and turbulent forced convection in pipes, local coefficients |

## Pipes.BaseClasses.HeatTransfer.PartialFlowHeatTransfer

**base class for any pipe heat transfer correlation**

## Information

Base class for heat transfer models of flow devices.

The geometry is specified in the interface with the `surfaceAreas[n]`, the `roughnesses[n]` and the lengths[n] along the flow path. Moreover the fluid flow is characterized for different types of devices by the characteristic `dimensions[n+1]` and the average velocities `vs[n+1]` of fluid flow. See Pipes.BaseClasses.CharacteristicNumbers.ReynoldsNumber for examplary definitions.

Extends from Interfaces.PartialHeatTransfer (Common interface for heat transfer models).

## Parameters

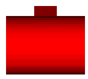
| Type | Name | Description |
|---|---|---|
| Ambient | | |
| CoefficientOfHeatTransfer | k | Heat transfer coefficient to ambient [W/(m2.K)] |
| Temperature | T_ambient | Ambient temperature [K] |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of heat transfer segments |
| Boolean | use_k | = true to use k value for thermal isolation |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |

## Connectors

| Type | Name | Description |
|---|---|---|
| HeatPorts_a | heatPorts[n] | Heat port to component boundary |

---

## Pipes.BaseClasses.HeatTransfer.IdealFlowHeatTransfer



**IdealHeatTransfer: Ideal heat transfer without thermal resistance**

## Information

Ideal heat transfer without thermal resistance.
Extends from PartialFlowHeatTransfer (base class for any pipe heat transfer correlation).

## Parameters

| Type | Name | Description |
|---|---|---|
| Ambient | | |
| CoefficientOfHeatTransfer | k | Heat transfer coefficient to ambient [W/(m2.K)] |
| Temperature | T_ambient | Ambient temperature [K] |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of heat transfer segments |
| Boolean | use_k | = true to use k value for thermal isolation |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |

### Connectors

| Type | Name | Description |
|---|---|---|
| HeatPorts_a | heatPorts[n] | Heat port to component boundary |

## Pipes.BaseClasses.HeatTransfer.ConstantFlowHeatTransfer

**ConstantHeatTransfer: Constant heat transfer coefficient**

### Information

Simple heat transfer correlation with constant heat transfer coefficient, used as default component in
Extends from PartialFlowHeatTransfer (base class for any pipe heat transfer correlation).

### Parameters

| Type | Name | Description |
|---|---|---|
| CoefficientOfHeatTransfer | alpha0 | heat transfer coefficient [W/(m2.K)] |
| Ambient | | |
| CoefficientOfHeatTransfer | k | Heat transfer coefficient to ambient [W/(m2.K)] |
| Temperature | T_ambient | Ambient temperature [K] |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of heat transfer segments |
| Boolean | use_k | = true to use k value for thermal isolation |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |

### Connectors

| Type | Name | Description |
|---|---|---|
| HeatPorts_a | heatPorts[n] | Heat port to component boundary |

## Pipes.BaseClasses.HeatTransfer.PartialPipeFlowHeatTransfer

**Base class for pipe heat transfer correlation in terms of Nusselt number heat transfer in a circular pipe for laminar and turbulent one-phase flow**

### Information

Base class for heat transfer models that are expressed in terms of the Nusselt number and which can be used in distributed pipe models.
Extends from PartialFlowHeatTransfer (base class for any pipe heat transfer correlation).

### Parameters

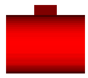
| Type | Name | Description |
|---|---|---|
| CoefficientOfHeatTransfer | alpha0 | guess value for heat transfer coefficients [W/(m2.K)] |
| Ambient | | |
| CoefficientOfHeatTransfer | k | Heat transfer coefficient to ambient [W/(m2.K)] |
| Temperature | T_ambient | Ambient temperature [K] |

| | | |
|---|---|---|
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of heat transfer segments |
| Boolean | use_k | = true to use k value for thermal isolation |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |

## Connectors

| Type | Name | Description |
|---|---|---|
| HeatPorts_a | heatPorts[n] | Heat port to component boundary |

## Pipes.BaseClasses.HeatTransfer.LocalPipeFlowHeatTransfer



**LocalPipeFlowHeatTransfer: Laminar and turbulent forced convection in pipes, local coefficients**

## Information

Heat transfer model for laminar and turbulent flow in pipes. Range of validity:

- fully developed pipe flow
- forced convection
- one phase Newtonian fluid
- (spatial) constant wall temperature in the laminar region
- $0 \leq Re \leq 1e6$, $0.6 \leq Pr \leq 100$, $d/L \leq 1$
- The correlation holds for non-circular pipes only in the turbulent region. Use diameter=4*crossArea/perimeter as characteristic length.

The correlation takes into account the spatial position along the pipe flow, which changes discontinuously at flow reversal. However, the heat transfer coefficient itself is continuous around zero flow rate, but not its derivative.

### References

Verein Deutscher Ingenieure (1997):
**VDI Wärmeatlas**. Springer Verlag, Ed. 8, 1997.
Extends from PartialPipeFlowHeatTransfer (Base class for pipe heat transfer correlation in terms of Nusselt number heat transfer in a circular pipe for laminar and turbulent one-phase flow).

## Parameters

| Type | Name | Description |
|---|---|---|
| CoefficientOfHeatTransfer | alpha0 | guess value for heat transfer coefficients [W/(m2.K)] |
| Ambient | | |
| CoefficientOfHeatTransfer | k | Heat transfer coefficient to ambient [W/(m2.K)] |
| Temperature | T_ambient | Ambient temperature [K] |
| **Internal Interface** | | |
| replaceable package Medium | | Medium in the component |
| Integer | n | Number of heat transfer segments |

| | | |
|---|---|---|
| Boolean | use_k | = true to use k value for thermal isolation |
| Geometry | | |
| Real | nParallel | number of identical parallel flow devices |

### Connectors

| Type | Name | Description |
|---|---|---|
| HeatPorts_a | heatPorts[n] | Heat port to component boundary |

## Pipes.BaseClasses.CharacteristicNumbers

**Functions to compute characteristic numbers**

### Package Content

| Name | Description |
|---|---|
| ReynoldsNumber | Return Reynolds number from v, rho, mu, D |
| ReynoldsNumber_m_flow | Return Reynolds number from m_flow, mu, D, A |
| NusseltNumber | Return Nusselt number |

## Pipes.BaseClasses.CharacteristicNumbers.ReynoldsNumber

**Return Reynolds number from v, rho, mu, D**

### Information

Calculation of Reynolds Number

```
  Re = |v|ρD/μ
```

a measure of the relationship between inertial forces (vρ) and viscous forces (D/μ).

The following table gives examples for the characteristic dimension D and the velocity v for different fluid flow devices:

| Device Type | Characteristic Dimension D | Velocity v |
|---|---|---|
| Circular Pipe | diameter | m_flow/ρ/crossArea |
| Rectangular Duct | 4*crossArea/perimeter | m_flow/ρ/crossArea |
| Wide Duct | distance between narrow, parallel walls | m_flow/ρ/crossArea |
| Packed Bed | diameterOfSpericalParticles/(1-fluidFractionOfTotalVolume) | m_flow/ρ/crossArea (without particles) |
| Device with rotating agitator | diameterOfRotor | RotationalSpeed*diameterOfRotor |

### Inputs

| Type | Name | Description |
|---|---|---|
| Velocity | v | Mean velocity of fluid flow [m/s] |
| Density | rho | Fluid density [kg/m3] |
| DynamicViscosity | mu | Dynamic (absolute) viscosity [Pa.s] |

| | | |
|---|---|---|
| Length | D | Characteristic dimension (hydraulic diameter of pipes) [m] |

### Outputs

| Type | Name | Description |
|---|---|---|
| ReynoldsNumber | Re | Reynolds number [1] |

## Pipes.BaseClasses.CharacteristicNumbers.ReynoldsNumber_m_flow

**Return Reynolds number from m_flow, mu, D, A**

### Information

Simplified calculation of Reynolds Number for flow through pipes or orifices; using the mass flow rate `m_flow` instead of the velocity `v` to express inertial forces.

```
  Re = |m_flow|*diameter/A/μ
with
  m_flow = v*ρ*A
```

See also Pipes.BaseClasses.CharacteristicNumbers.ReynoldsNumber.

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate [kg/s] |
| DynamicViscosity | mu | Dynamic viscosity [Pa.s] |
| Length | D | Characteristic dimension (hydraulic diameter of pipes or orifices) [m] |
| Area | A | Cross sectional area of fluid flow [m2] |

### Outputs

| Type | Name | Description |
|---|---|---|
| ReynoldsNumber | Re | Reynolds number [1] |

## Pipes.BaseClasses.CharacteristicNumbers.NusseltNumber

**Return Nusselt number**

### Information

```
Nusselt number Nu = alpha*D/lambda
```

### Inputs

| Type | Name | Description |
|---|---|---|
| CoefficientOfHeatTransfer | alpha | Coefficient of heat transfer [W/(m2.K)] |
| Length | D | Characteristic dimension [m] |
| ThermalConductivity | lambda | Thermal conductivity [W/(m.K)] |

### Outputs

| Type | Name | Description |
|---|---|---|
| NusseltNumber | Nu | Nusselt number [1] |

## Pipes.BaseClasses.WallFriction

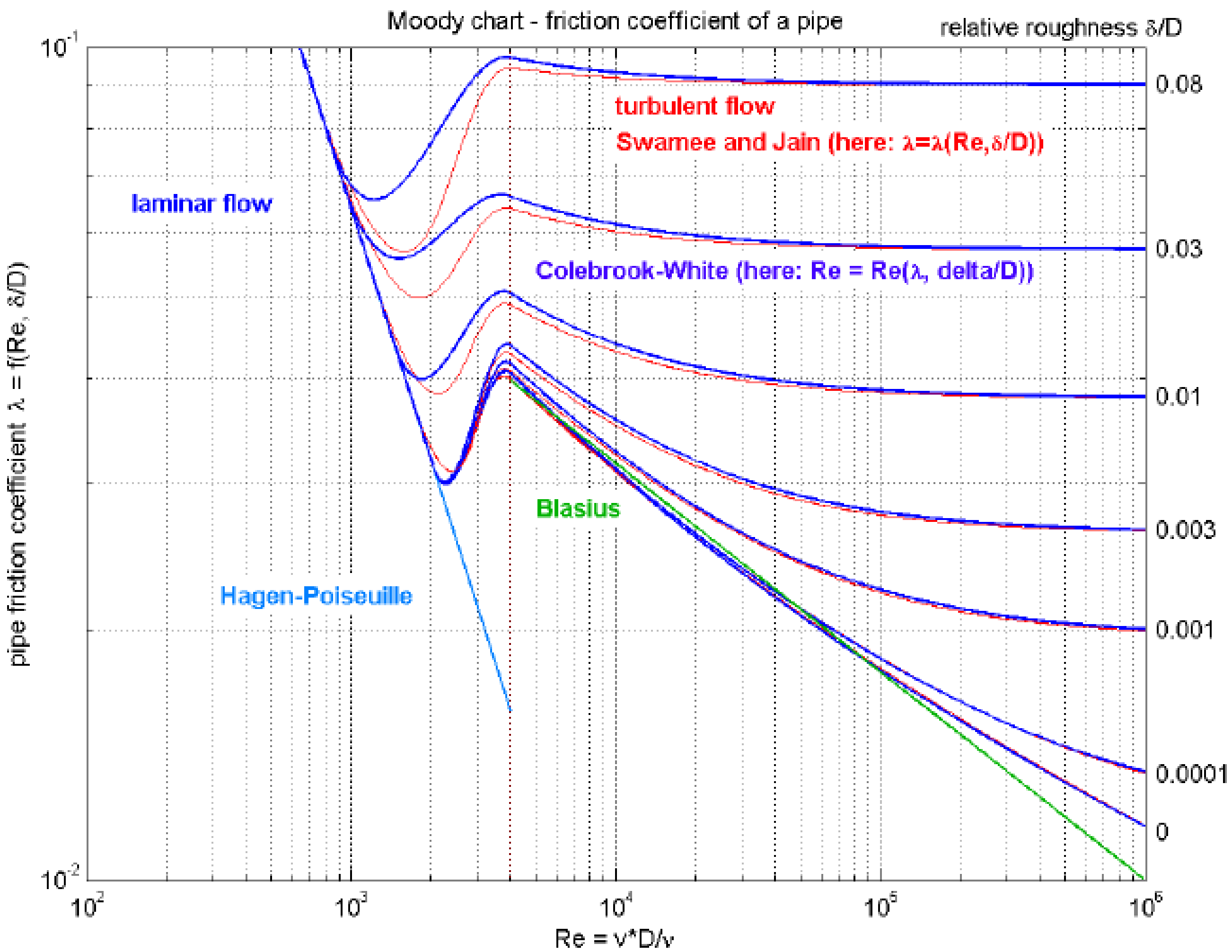
**Different variants for pressure drops due to pipe wall friction**

### Information

This package provides functions to compute pressure losses due to **wall friction** in a pipe. Every correlation is defined by a package that is derived by inheritance from the package WallFriction.PartialWallFriction. The details of the underlying pipe wall friction model are described in the UsersGuide. Basically, different variants of the equation

```
dp = λ(Re,Δ)*(L/D)*ρ*v*|v|/2
```

are used, where the friction loss factor λ is shown in the next figure:




### Package Content

| Name | Description |
|---|---|
| PartialWallFriction | Partial wall friction characteristic (base package of all wall friction characteristics) |
| NoFriction | No pipe wall friction, no static head |

| | |
|---|---|
| Laminar | Pipe wall friction in the laminar regime (linear correlation) |
| QuadraticTurbulent | Pipe wall friction in the quadratic turbulent regime (simple characteristic, mu not used) |
| LaminarAndQuadraticTurbulent | Pipe wall friction in the laminar and quadratic turbulent regime (simple characteristic) |
| Detailed | Pipe wall friction in the whole regime (detailed characteristic) |
| TestWallFrictionAndGravity | Pressure loss in pipe due to wall friction and gravity (only for test purposes; if needed use Pipes.StaticPipe instead) |

## Pipes.BaseClasses.WallFriction.PartialWallFriction

**Partial wall friction characteristic (base package of all wall friction characteristics)**

### Information

### Package Content

| Name | Description |
|---|---|
| use_mu=true | = true, if mu_a/mu_b are used in function, otherwise value is not used |
| use_roughness=true | = true, if roughness is used in function, otherwise value is not used |
| use_dp_small=true | = true, if dp_small is used in function, otherwise value is not used |
| use_m_flow_small=true | = true, if m_flow_small is used in function, otherwise value is not used |
| dp_is_zero=false | = true, if no wall friction is present, i.e., dp = 0 (function massFlowRate_dp() cannot be used) |
| massFlowRate_dp | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction |
| massFlowRate_dp_staticHead | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head |
| pressureLoss_m_flow | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction |
| pressureLoss_m_flow_staticHead | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head |

## Pipes.BaseClasses.WallFriction.PartialWallFriction.massFlowRate_dp

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction**

### Information

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |

| | | |
|---|---|---|
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Pipes.BaseClasses.WallFriction.PartialWallFriction.massFlowRate_dp_staticHead

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head**

### Information

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Pipes.BaseClasses.WallFriction.PartialWallFriction.pressureLoss_m_flow

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction**

### Information

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.PartialWallFriction.pressureLoss_m_flow_staticHead

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head**

### Information

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.NoFriction

**No pipe wall friction, no static head**

### Information

This component sets the pressure loss due to wall friction to zero, i.e., it allows to switch off pipe wall friction.

Extends from PartialWallFriction (Partial wall friction characteristic (base package of all wall friction characteristics)).

### Package Content

| Name | Description |
|---|---|
| massFlowRate_dp | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction |
| pressureLoss_m_flow | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction |
| massFlowRate_dp_staticHead | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head |
| pressureLoss_m_flow_staticHead | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head |
| **Inherited** | |
| use_mu=true | = true, if mu_a/mu_b are used in function, otherwise value is not used |
| use_roughness=true | = true, if roughness is used in function, otherwise value is not used |
| use_dp_small=true | = true, if dp_small is used in function, otherwise value is not used |
| use_m_flow_small=true | = true, if m_flow_small is used in function, otherwise value is not used |
| dp_is_zero=false | = true, if no wall friction is present, i.e., dp = 0 (function massFlowRate_dp() cannot be used) |

## Pipes.BaseClasses.WallFriction.NoFriction.massFlowRate_dp

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction**

### Information

Extends from (Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |

| | | |
|---|---|---|
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Pipes.BaseClasses.WallFriction.NoFriction.pressureLoss_m_flow

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction**

### Information

Extends from (Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.NoFriction.massFlowRate_dp_staticHead

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head**

### Information

Extends from (Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head).

### Inputs

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Pipes.BaseClasses.WallFriction.NoFriction.pressureLoss_m_flow_staticHead

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head**

### Information

Extends from (Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.Laminar

**Pipe wall friction in the laminar regime (linear correlation)**

### Information

This component defines only the laminar region of wall friction: dp = k*m_flow, where "k" depends on density and dynamic viscosity. The roughness of the wall does not have an influence on the laminar flow and therefore argument roughness is ignored. Since this is a linear relationship, the occuring systems of equations are usually much simpler (e.g. either linear instead of non-linear). By using nominal values for density and dynamic viscosity, the systems of equations can still further be reduced.

In UsersGuide the complete friction regime is illustrated. This component describes only the **Hagen-Poiseuille** equation.

Extends from PartialWallFriction (Partial wall friction characteristic (base package of all wall friction characteristics)).

### Package Content

| Name | Description |
|---|---|
| massFlowRate_dp | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction |
| pressureLoss_m_flow | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction |
| massFlowRate_dp_staticHead | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head |
| pressureLoss_m_flow_staticHead | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head |
| **Inherited** | |
| use_mu=true | = true, if mu_a/mu_b are used in function, otherwise value is not used |
| use_roughness=true | = true, if roughness is used in function, otherwise value is not used |
| use_dp_small=true | = true, if dp_small is used in function, otherwise value is not used |
| use_m_flow_small=true | = true, if m_flow_small is used in function, otherwise value is not used |
| dp_is_zero=false | = true, if no wall friction is present, i.e., dp = 0 (function massFlowRate_dp() cannot be used) |

## Pipes.BaseClasses.WallFriction.Laminar.massFlowRate_dp

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction**

### Information

Extends from (Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction).

### Inputs

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Pipes.BaseClasses.WallFriction.Laminar.pressureLoss_m_flow

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction**

### Information

Extends from (Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.Laminar.massFlowRate_dp_staticHead

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head**

### Information

Extends from (Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

---

## Pipes.BaseClasses.WallFriction.Laminar.pressureLoss_m_flow_staticHead

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head**

### Information

Extends from (Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.QuadraticTurbulent

**Pipe wall friction in the quadratic turbulent regime (simple characteristic, mu not used)**

### Information

This component defines only the quadratic turbulent regime of wall friction: dp = k*m_flow*|m_flow|, where "k" depends on density and the roughness of the pipe and is no longer a function of the Reynolds number. This relationship is only valid for large Reynolds numbers.

In UsersGuide the complete friction regime is illustrated. This component describes only the asymptotic behaviour for large Reynolds numbers, i.e., the values at the right ordinate where $\lambda$ is constant.

Extends from PartialWallFriction (Partial wall friction characteristic (base package of all wall friction characteristics)).

### Package Content

| Name | Description |
|---|---|
| massFlowRate_dp | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction |
| pressureLoss_m_flow | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction |
| massFlowRate_dp_staticHead | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head |
| pressureLoss_m_flow_staticHead | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head |
| **Inherited** | |
| use_mu=true | = true, if mu_a/mu_b are used in function, otherwise value is not used |
| use_roughness=true | = true, if roughness is used in function, otherwise value is not used |
| use_dp_small=true | = true, if dp_small is used in function, otherwise value is not used |
| use_m_flow_small=true | = true, if m_flow_small is used in function, otherwise value is not used |
| dp_is_zero=false | = true, if no wall friction is present, i.e., dp = 0 (function massFlowRate_dp() cannot be used) |

## Pipes.BaseClasses.WallFriction.QuadraticTurbulent.massFlowRate_dp

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction**

### Information

Extends from (Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction).

### Inputs

<table>
<tr><th>Type</th><th>Name</th><th>Description</th></tr>
<tr><td>Pressure</td><td>dp</td><td>Pressure loss (dp = port_a.p - port_b.p) [Pa]</td></tr>
<tr><td>Density</td><td>rho_a</td><td>Density at port_a [kg/m3]</td></tr>
<tr><td>Density</td><td>rho_b</td><td>Density at port_b [kg/m3]</td></tr>
<tr><td>DynamicViscosity</td><td>mu_a</td><td>Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s]</td></tr>
<tr><td>DynamicViscosity</td><td>mu_b</td><td>Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s]</td></tr>
<tr><td>Length</td><td>length</td><td>Length of pipe [m]</td></tr>
<tr><td>Diameter</td><td>diameter</td><td>Inner (hydraulic) diameter of pipe [m]</td></tr>
<tr><td>Length</td><td>roughness</td><td>Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m]</td></tr>
<tr><td>AbsolutePressure</td><td>dp_small</td><td>Turbulent flow if |dp| >= dp_small (dummy if use_dp_small = false) [Pa]</td></tr>
</table>

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

---

## Pipes.BaseClasses.WallFriction.QuadraticTurbulent.pressureLoss_m_flow

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction**

### Information

Extends from (Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction).

### Inputs

<table>
<tr><th>Type</th><th>Name</th><th>Description</th></tr>
<tr><td>MassFlowRate</td><td>m_flow</td><td>Mass flow rate from port_a to port_b [kg/s]</td></tr>
<tr><td>Density</td><td>rho_a</td><td>Density at port_a [kg/m3]</td></tr>
<tr><td>Density</td><td>rho_b</td><td>Density at port_b [kg/m3]</td></tr>
<tr><td>DynamicViscosity</td><td>mu_a</td><td>Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s]</td></tr>
<tr><td>DynamicViscosity</td><td>mu_b</td><td>Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s]</td></tr>
<tr><td>Length</td><td>length</td><td>Length of pipe [m]</td></tr>
<tr><td>Diameter</td><td>diameter</td><td>Inner (hydraulic) diameter of pipe [m]</td></tr>
<tr><td>Length</td><td>roughness</td><td>Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m]</td></tr>
<tr><td>MassFlowRate</td><td>m_flow_small</td><td>Turbulent flow if |m_flow| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s]</td></tr>
</table>

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

---

## Pipes.BaseClasses.WallFriction.QuadraticTurbulent.massFlowRate_dp_staticHead

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head**

### Information

Extends from (Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Pipes.BaseClasses.WallFriction.QuadraticTurbulent.pressureLoss_m_flow_staticHead

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head**

### Information

Extends from (Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |

| | | |
|---|---|---|
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

---

## Pipes.BaseClasses.WallFriction.LaminarAndQuadraticTurbulent

**Pipe wall friction in the laminar and quadratic turbulent regime (simple characteristic)**

### Information

This component defines the quadratic turbulent regime of wall friction: dp = k*m_flow*|m_flow|, where "k" depends on density and the roughness of the pipe and is no longer a function of the Reynolds number. This relationship is only valid for large Reynolds numbers. At Re=4000, a polynomial is constructed that approaches the constant λ (for large Reynolds-numbers) at Re=4000 smoothly and has a derivative at zero mass flow rate that is identical to laminar wall friction.

Extends from PartialWallFriction (Partial wall friction characteristic (base package of all wall friction characteristics)).

### Package Content

| Name | Description |
|---|---|
| massFlowRate_dp | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction |
| pressureLoss_m_flow | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction |
| massFlowRate_dp_staticHead | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head |
| pressureLoss_m_flow_staticHead | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head |
| **Inherited** | |
| use_mu=true | = true, if mu_a/mu_b are used in function, otherwise value is not used |
| use_roughness=true | = true, if roughness is used in function, otherwise value is not used |
| use_dp_small=true | = true, if dp_small is used in function, otherwise value is not used |
| use_m_flow_small=true | = true, if m_flow_small is used in function, otherwise value is not used |
| dp_is_zero=false | = true, if no wall friction is present, i.e., dp = 0 (function massFlowRate_dp() cannot be used) |

---

## Pipes.BaseClasses.WallFriction.LaminarAndQuadraticTurbulent.massFlowRate_dp

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction**

### Information

Extends from (Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

---

## Pipes.BaseClasses.WallFriction.LaminarAndQuadraticTurbulent.pressureLoss_m_flow

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction**

### Information

Extends from (Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.LaminarAndQuadraticTurbulent.massFlowRate_dp_staticHead

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head**

### Information

Extends from (Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Pipes.BaseClasses.WallFriction.LaminarAndQuadraticTurbulent.pressureLoss_m_flow_staticHead

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head**

### Information

Extends from (Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |

| | | |
|---|---|---|
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

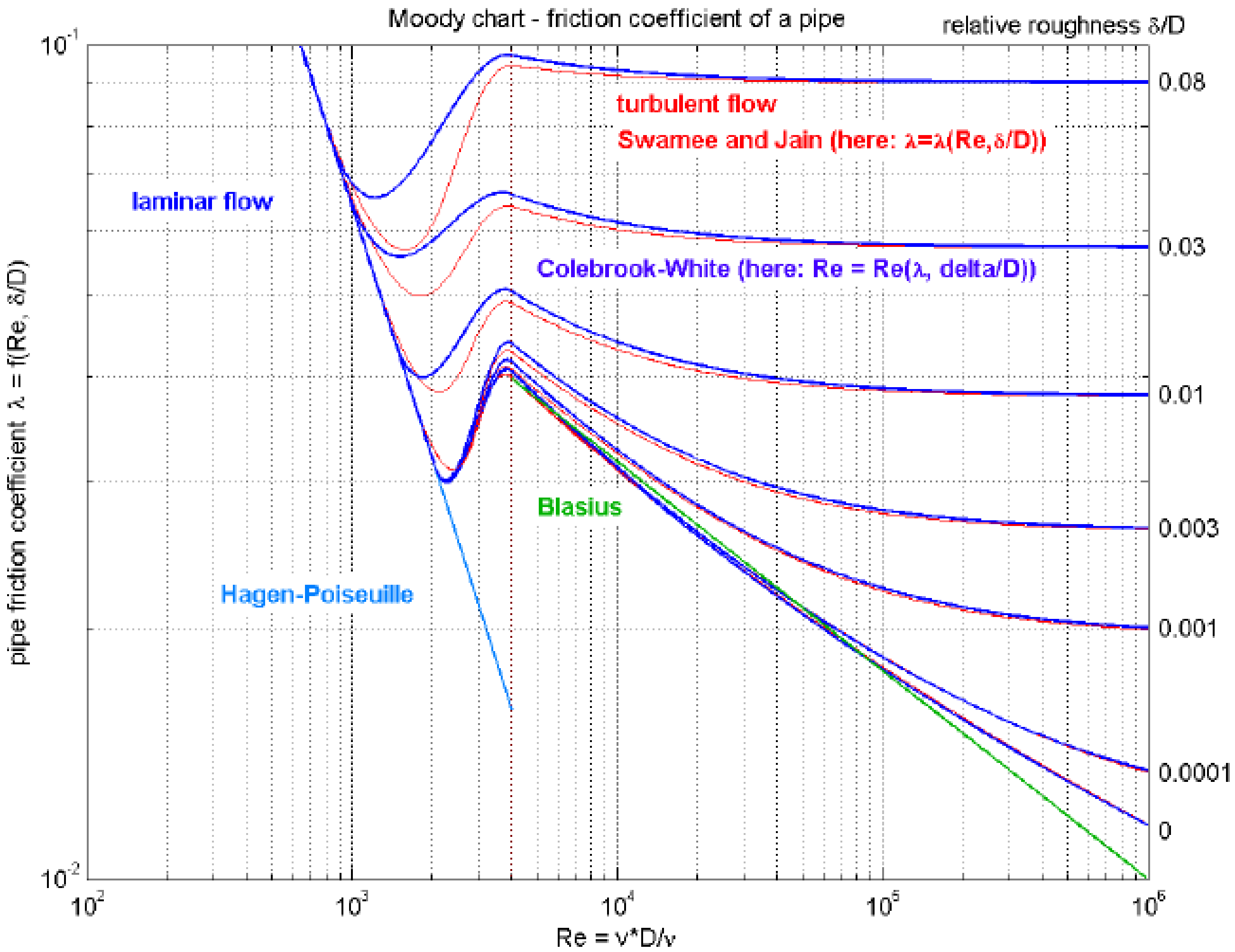
| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.Detailed

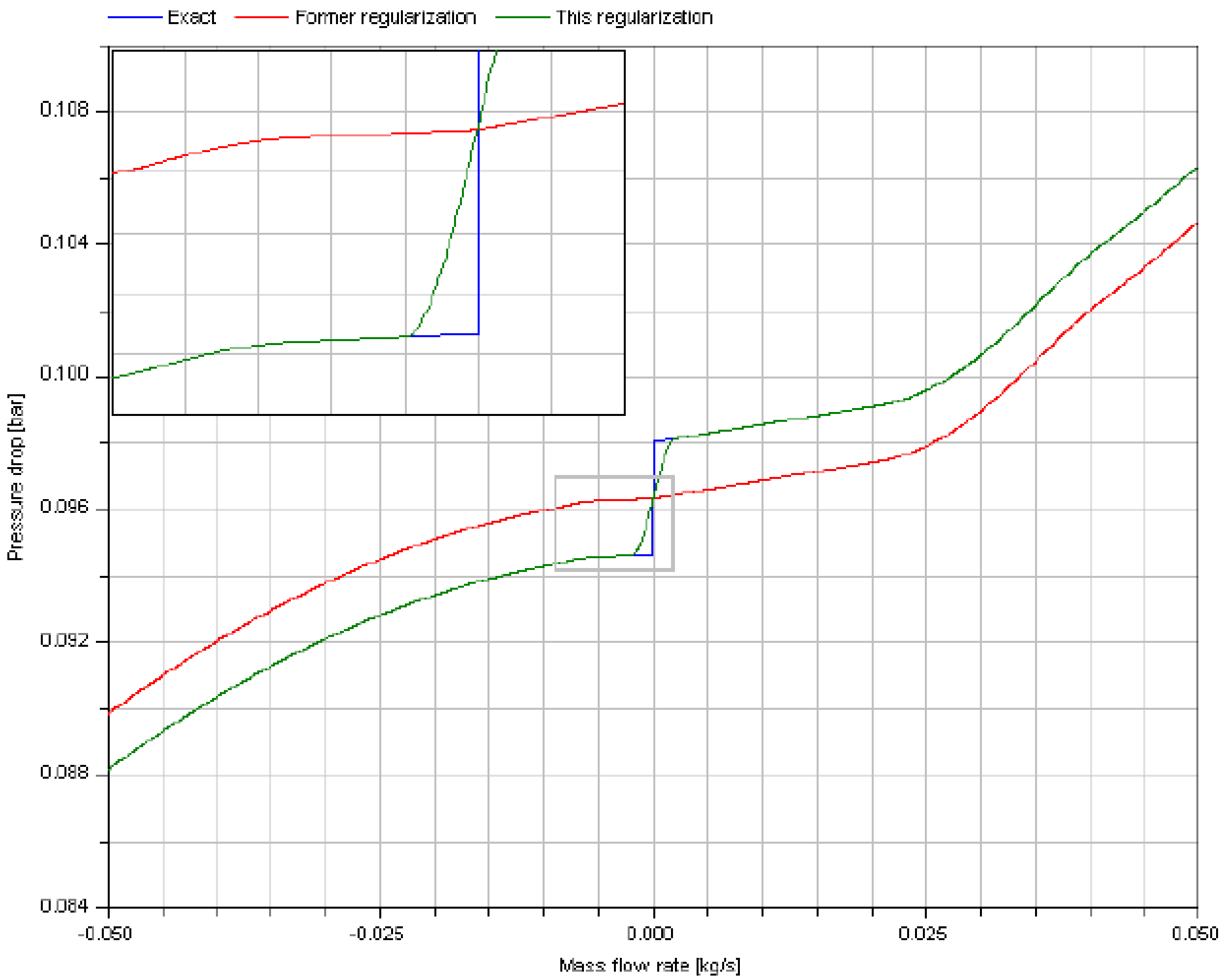
**Pipe wall friction in the whole regime (detailed characteristic)**

### Information

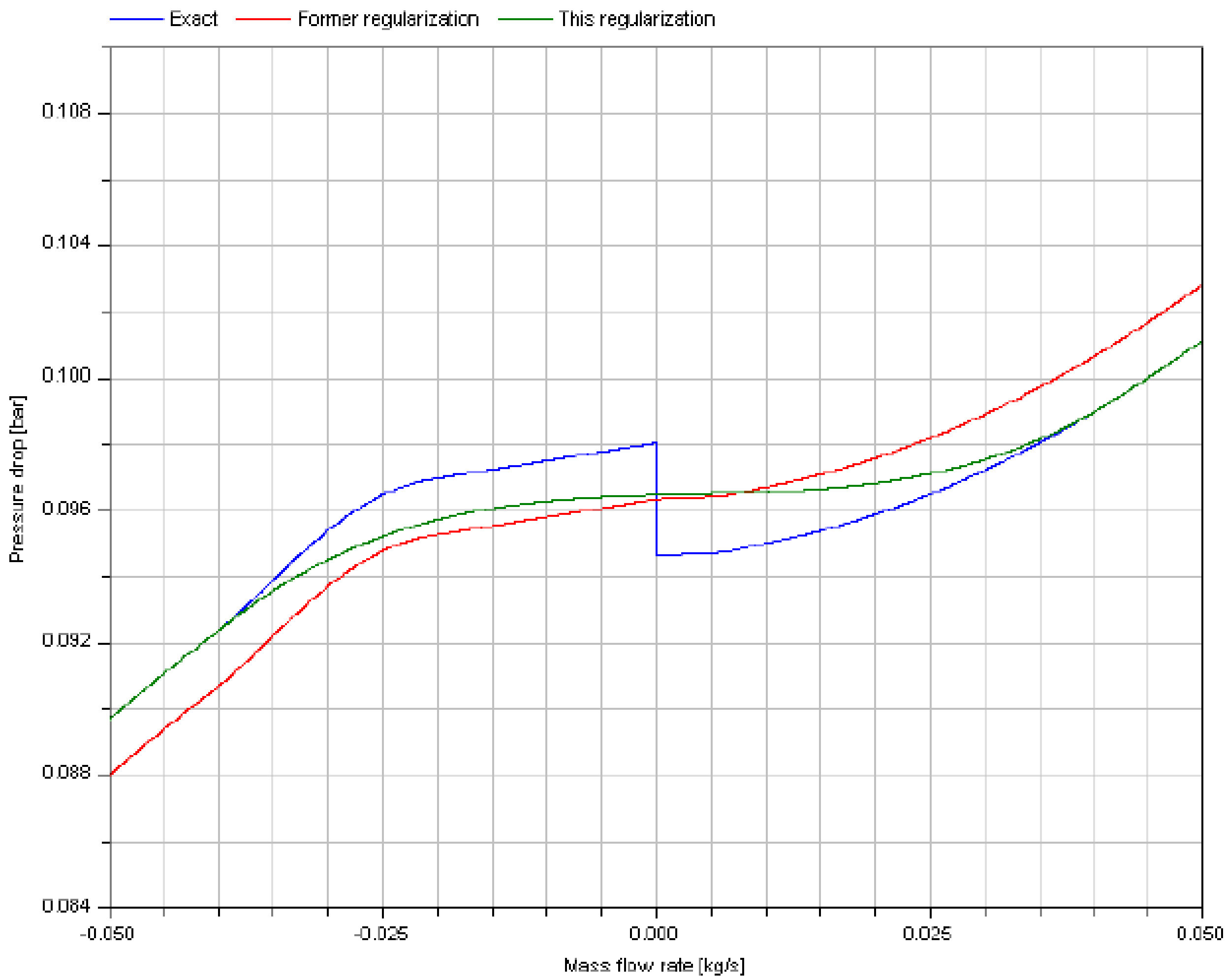
This component defines the complete regime of wall friction. The details are described in the UsersGuide. The functional relationship of the friction loss factor λ is displayed in the next figure. Function massFlowRate_dp() defines the "red curve" ("Swamee and Jain"), where as function pressureLoss_m_flow() defines the "blue curve" ("Colebrook-White"). The two functions are inverses from each other and give slightly different results in the transition region between Re = 1500 .. 4000, in order to get explicit equations without solving a non-linear equation.




Additionally to wall friction, this component properly implements static head. With respect to the latter, two cases can be distinguished. In the case shown next, the change of elevation with the path from a to b has the opposite sign of the change of density.




In the case illustrated second, the change of elevation with the path from a to b has the same sign of the change of density.




Extends from PartialWallFriction (Partial wall friction characteristic (base package of all wall friction characteristics)).

## Package Content

| Name | Description |
|---|---|
| massFlowRate_dp | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction |
| pressureLoss_m_flow | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction |
| massFlowRate_dp_staticHead | Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head |
| pressureLoss_m_flow_staticHead | Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head |
| **Inherited** | |
| use_mu=true | = true, if mu_a/mu_b are used in function, otherwise value is not used |
| use_roughness=true | = true, if roughness is used in function, otherwise value is not used |
| use_dp_small=true | = true, if dp_small is used in function, otherwise value is not used |
| use_m_flow_small=true | = true, if m_flow_small is used in function, otherwise value is not used |
| dp_is_zero=false | = true, if no wall friction is present, i.e., dp = 0 (function |

| | |
|---|---|
| | massFlowRate_dp() cannot be used) |

## Pipes.BaseClasses.WallFriction.Detailed.massFlowRate_dp

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction**

### Information

Extends from (Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Pipes.BaseClasses.WallFriction.Detailed.pressureLoss_m_flow

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction**

### Information

Extends from (Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |

| | | |
|---|---|---|
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.Detailed.massFlowRate_dp_staticHead

**Return mass flow rate m_flow as function of pressure loss dp, i.e., m_flow = f(dp), due to wall friction and static head**

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small (dummy if use_dp_small = false) [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Pipes.BaseClasses.WallFriction.Detailed.pressureLoss_m_flow_staticHead

**Return pressure loss dp as function of mass flow rate m_flow, i.e., dp = f(m_flow), due to wall friction and static head**

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a (dummy if use_mu = false) [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b (dummy if use_mu = false) [Pa.s] |

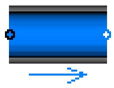
| | | |
|---|---|---|
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Real | g_times_height_ab | Gravity times (Height(port_b) - Height(port_a)) |
| Length | roughness | Absolute roughness of pipe, with a default for a smooth steel pipe (dummy if use_roughness = false) [m] |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small (dummy if use_m_flow_small = false) [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure loss (dp = port_a.p - port_b.p) [Pa] |

## Pipes.BaseClasses.WallFriction.TestWallFrictionAndGravity

**Pressure loss in pipe due to wall friction and gravity (only for test purposes; if needed use Pipes.StaticPipe instead)**

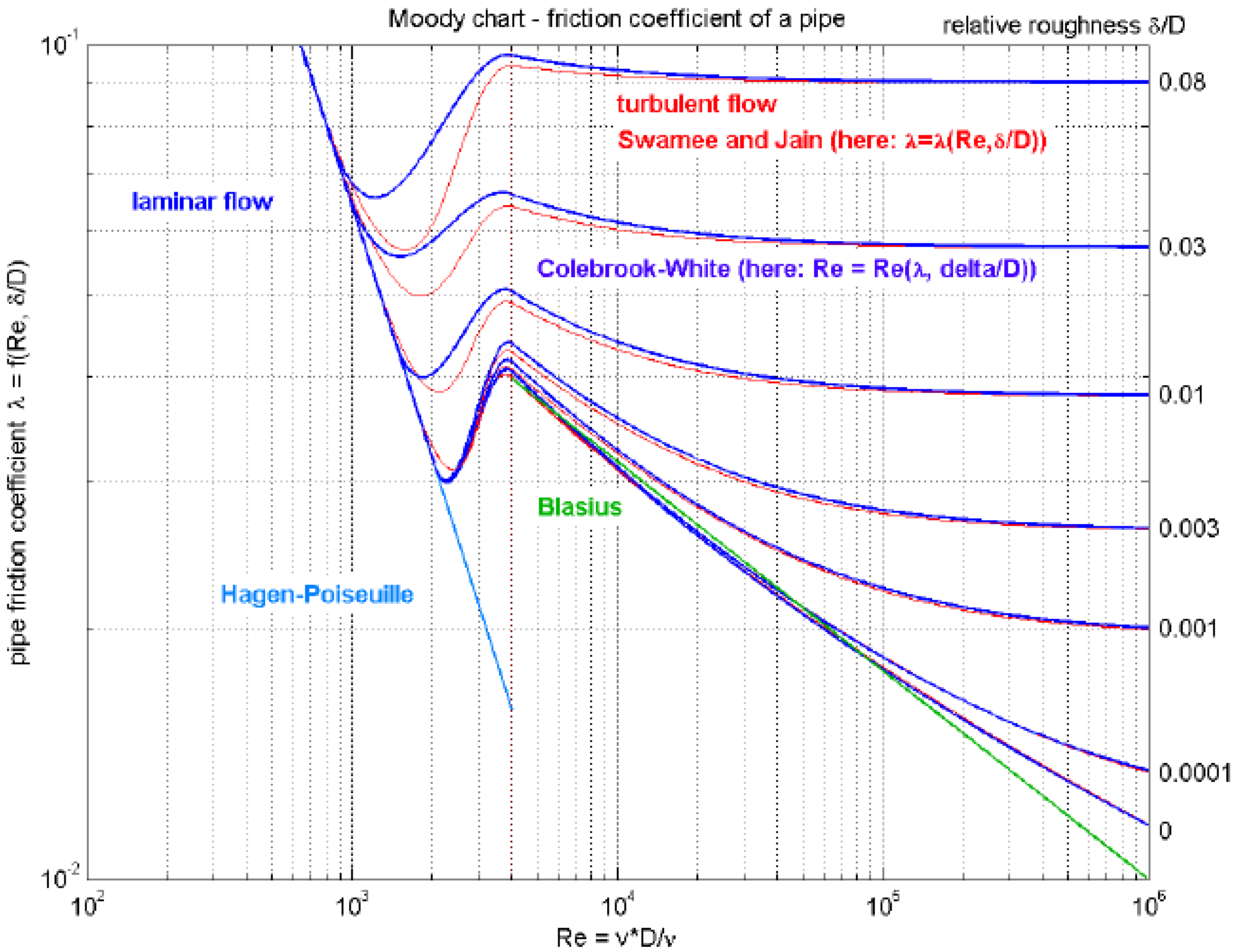


### Information

This model describes pressure losses due to **wall friction** in a pipe and due to gravity. It is assumed that no mass or energy is stored in the pipe. Correlations of different complexity and validity can be seleted via the replaceable package **WallFriction** (see parameter menu below). The details of the pipe wall friction model are described in the UsersGuide. Basically, different variants of the equation

$$dp = \lambda(Re,\Delta)*(L/D)*\rho*v*|v|/2$$

are used, where the friction loss factor λ is shown in the next figure:




By default, the correlations are computed with media data at the actual time instant. In order to reduce non-linear equation systems, parameter **use_nominal** provides the option to compute the correlations with constant media values at the desired operating point. This might speed-up the simulation and/or might give a more robust simulation.

Extends from Interfaces.PartialTwoPortTransport (Partial element transporting fluid between two ports without storage of mass or energy).

## Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner (hydraulic) diameter of pipe [m] |
| Length | height_ab | Height(port_b) - Height(port_a) [m] |
| Length | roughness | Absolute roughness of pipe (default = smooth steel pipe) [m] |
| Boolean | use_nominal | = true, if mu_nominal and rho_nominal are used, otherwise computed from medium |
| DynamicViscosity | mu_nominal | Nominal dynamic viscosity (e.g. mu_liquidWater = 1e-3, mu_air = 1.8e-5) [Pa.s] |
| Density | rho_nominal | Nominal density (e.g. rho_liquidWater = 995, rho_air = 1.2) [kg/m3] |

| | | |
|---|---|---|
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Boolean | show_Re | = true, if Reynolds number is included for plotting |
| Boolean | from_dp | = true, use m_flow = f(dp), otherwise dp = f(m_flow) |
| AbsolutePressure | dp_small | Within regularization if \|dp\| < dp_small (may be wider for large discontinuities in static head) [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

## Modelica_Fluid.Machines

**Devices for converting between energy held in a fluid and mechanical energy**

### Information

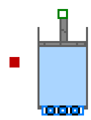
Extends from Icons.VariantLibrary (Icon for a library that contains several variants of one component).

### Package Content

| Name | Description |
|---|---|
| SweptVolume | varying cylindric volume depending on the postition of the piston |
| Pump | Centrifugal pump with mechanical connector for the shaft |
| ControlledPump | Centrifugal pump with ideally controlled mass flow rate |
| PrescribedPump | Centrifugal pump with ideally controlled speed |
| BaseClasses | Base classes used in the Machines package (only of interest to build new component models) |

## Machines.SweptVolume

**varying cylindric volume depending on the postition of the piston**



### Information

Mixing volume with varying size. The size of the volume is given by:

- cross sectional piston area
- piston stroke given by the flange position s
- clearance (volume at flang position = 0)

Losses are neglected. The shaft power is completely converted into mechanical work on the fluid.

The flange position has to be equal or greater than zero. Otherwise the simulation stops. The force of the flange results from the pressure difference between medium and ambient pressure and the cross sectional piston area. For using the component, a top level instance of the ambient model with the inner attribute is needed.

The pressure at both fluid ports equals the medium pressure in the volume. No suction nor discharge valve is included in the model.

The thermal port is directly connected to the medium. The temperature of the thermal port equals the medium temperature. The heat capacity of the cylinder and the piston are not includes in the model.

Extends from Vessels.BaseClasses.PartialLumpedVessel (Lumped volume with a vector of fluid ports and replaceable heat transfer model).

### Parameters

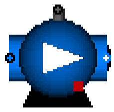
| Type | Name | Description |
|---|---|---|
| Area | pistonCrossArea | cross sectional area of pistion [m2] |
| Volume | clearance | remaining volume at zero piston stroke [m3] |
| replaceable package Medium | | Medium in the component |
| Volume | fluidVolume | Volume [m3] |
| Ports | | |
| Boolean | use_portsData | = false to neglect pressure loss and kinetic energy |
| VesselPortsData | portsData[nPorts] | Data of inlet/outlet ports |
| **Assumptions** | | |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use the HeatTransfer model |
| replaceable model HeatTransfer | | Wall heat transfer |
| **Initialization** | | |
| AbsolutePressure | p_start | Start value of pressure [Pa] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |

| | | |
|---|---|---|
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| **Advanced** | | |
| Port properties | | |
| MassFlowRate | m_flow_small | Regularization range at zero mass flow rate [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| VesselFluidPorts_b | ports[nPorts] | Fluid inlets and outlets |
| HeatPort_a | heatPort | |
| Flange_b | flange | translation flange for piston |

## Machines.Pump



**Centrifugal pump with mechanical connector for the shaft**

### Information

This model describes a centrifugal pump (or a group of `nParallel` pumps) with a mechanical rotational connector for the shaft, to be used when the pump drive has to be modelled explicitly. In the case of `nParallel` pumps, the mechanical connector is relative to a single pump.

The model extends `PartialPump`

Extends from Machines.BaseClasses.PartialPump (Base model for centrifugal pumps).

### Parameters

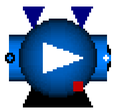
| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | Medium in the component |
| Characteristics | | |
| Integer | nParallel | Number of pumps in parallel |
| replaceable function | flowCharacteristic | Head vs. V_flow characteristic at nominal speed and density |
| AngularVelocity_rpm | N_nominal | Nominal rotational speed for flow characteristic [1/min] |
| Density | rho_nominal | Nominal fluid density for characteristic [kg/m3] |
| Boolean | use_powerCharacteristic | Use powerCharacteristic (vs. efficiencyCharacteristic) |
| replaceable function | powerCharacteristic | Power consumption vs. V_flow at nominal speed and density |
| replaceable function | efficiencyCharacteristic | Efficiency vs. V_flow at nominal speed and density |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Boolean | checkValve | = true to prevent reverse flow |
| Volume | V | Volume inside the pump [m3] |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use a HeatTransfer model, e.g. for a housing |

| | | |
|---|---|---|
| replaceable model HeatTransfer | | Wall heat transfer |
| **Initialization** | | |
| AbsolutePressure | p_a_start | Guess value for inlet pressure [Pa] |
| AbsolutePressure | p_b_start | Guess value for outlet pressure [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| **Advanced** | | |
| Diagnostics | | |
| Boolean | show_NPSHa | = true to compute Net Positive Suction Head available |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| HeatPort_a | heatPort | |
| Flange_a | shaft | |

## Machines.ControlledPump



**Centrifugal pump with ideally controlled mass flow rate**

### Information

This model describes a centrifugal pump (or a group of `nParallel` pumps) with ideally controlled mass flow rate or pressure.

Nominal values are used to predefine an exemplary pump characteristics and to define the operation of the pump. The input connectors `m_flow_set` or `p_set` can optionally be enabled to provide time varying set points.

Use this model if the pump characteristics is of secondary interest. The actual characteristics can be configured later on for the appropriate rotational speed N. Then the model can be replaced with a Pump with rotational shaft or with a PrescribedPump.

Extends from Machines.BaseClasses.PartialPump (Base model for centrifugal pumps).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| AbsolutePressure | p_a_nominal | Nominal inlet pressure for predefined pump characteristics [Pa] |
| AbsolutePressure | p_b_nominal | Nominal outlet pressure, fixed if not control_m_flow and not use_p_set [Pa] |

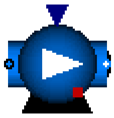
| | | |
|---|---|---|
| MassFlowRate | m_flow_nominal | Nominal mass flow rate, fixed if control_m_flow and not use_m_flow_set [kg/s] |
| Boolean | control_m_flow | = false to control outlet pressure port_b.p instead of m_flow |
| Boolean | use_m_flow_set | = true to use input signal m_flow_set instead of m_flow_nominal |
| Boolean | use_p_set | = true to use input signal p_set instead of p_b_nominal |
| Characteristics | | |
| Integer | nParallel | Number of pumps in parallel |
| replaceable function flowCharacteristic | | Head vs. V_flow characteristic at nominal speed and density |
| AngularVelocity_rpm | N_nominal | Nominal rotational speed for flow characteristic [1/min] |
| Density | rho_nominal | Nominal fluid density for characteristic [kg/m3] |
| Boolean | use_powerCharacteristic | Use powerCharacteristic (vs. efficiencyCharacteristic) |
| replaceable function powerCharacteristic | | Power consumption vs. V_flow at nominal speed and density |
| replaceable function efficiencyCharacteristic | | Efficiency vs. V_flow at nominal speed and density |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Boolean | checkValve | = true to prevent reverse flow |
| Volume | V | Volume inside the pump [m3] |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use a HeatTransfer model, e.g. for a housing |
| replaceable model HeatTransfer | | Wall heat transfer |
| **Initialization** | | |
| AbsolutePressure | p_a_start | Guess value for inlet pressure [Pa] |
| AbsolutePressure | p_b_start | Guess value for outlet pressure [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| **Advanced** | | |
| Diagnostics | | |
| Boolean | show_NPSHa | = true to compute Net Positive Suction Head available |

## Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| HeatPort_a | heatPort | |

| | | |
|---|---|---|
| input RealInput | m_flow_set | Prescribed mass flow rate |
| input RealInput | p_set | Prescribed outlet pressure |
| Characteristics | | |
| replaceable function flowCharacteristic | | Head vs. V_flow characteristic at nominal speed and density |

## Machines.PrescribedPump



**Centrifugal pump with ideally controlled speed**

### Information

This model describes a centrifugal pump (or a group of `nParallel` pumps) with prescribed speed, either fixed or provided by an external signal.

The model extends `PartialPump`

If the `N_in` input connector is wired, it provides rotational speed of the pumps (rpm); otherwise, a constant rotational speed equal to `n_const` (which can be different from `N_nominal`) is assumed.

Extends from Machines.BaseClasses.PartialPump (Base model for centrifugal pumps).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | Medium in the component |
| Boolean | use_N_in | Get the rotational speed from the input connector |
| AngularVelocity_rpm | N_const | Constant rotational speed [1/min] |
| Characteristics | | |
| Integer | nParallel | Number of pumps in parallel |
| replaceable function | flowCharacteristic | Head vs. V_flow characteristic at nominal speed and density |
| AngularVelocity_rpm | N_nominal | Nominal rotational speed for flow characteristic [1/min] |
| Density | rho_nominal | Nominal fluid density for characteristic [kg/m3] |
| Boolean | use_powerCharacteristic | Use powerCharacteristic (vs. efficiencyCharacteristic) |
| replaceable function | powerCharacteristic | Power consumption vs. V_flow at nominal speed and density |
| replaceable function | efficiencyCharacteristic | Efficiency vs. V_flow at nominal speed and density |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Boolean | checkValve | = true to prevent reverse flow |
| Volume | V | Volume inside the pump [m3] |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use a HeatTransfer model, e.g. for a housing |
| replaceable model | HeatTransfer | Wall heat transfer |
| **Initialization** | | |

| | | |
|---|---|---|
| AbsolutePressure | p_a_start | Guess value for inlet pressure [Pa] |
| AbsolutePressure | p_b_start | Guess value for outlet pressure [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| **Advanced** | | |
| Diagnostics | | |
| Boolean | show_NPSHa | = true to compute Net Positive Suction Head available |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| HeatPort_a | heatPort | |
| input RealInput | N_in | Prescribed rotational speed [1/min] |

## Machines.BaseClasses

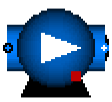
**Base classes used in the Machines package (only of interest to build new component models)**

### Package Content

| Name | Description |
|---|---|
| PartialPump | Base model for centrifugal pumps |
| PumpCharacteristics | Functions for pump characteristics |
| assertPositiveDifference | |

## Machines.BaseClasses.PartialPump

**Base model for centrifugal pumps**



### Information

This is the base model for pumps.

The model describes a centrifugal pump, or a group of `nParallel` identical pumps. The pump model is based on the theory of kinematic similarity: the pump characteristics are given for nominal operating conditions (rotational speed and fluid density), and then adapted to actual operating condition, according to the similarity equations.

#### Pump characteristics

The nominal hydraulic characteristic (head vs. volume flow rate) is given by the the replaceable function `flowCharacteristic`.

The pump energy balance can be specified in two alternative ways:

- `use_powerCharacteristic = false` (default option): the replaceable function `efficiencyCharacteristic` (efficiency vs. volume flow rate in nominal conditions) is used to determine the efficiency, and then the power consumption. The default is a constant efficiency of 0.8.
- `use_powerCharacteristic = true`: the replaceable function `powerCharacteristic` (power consumption vs. volume flow rate in nominal conditions) is used to determine the power consumption, and then the efficiency. Use `powerCharacteristic` to specify a non-zero power consumption for zero flow rate.

Several functions are provided in the package `PumpCharacteristics` to specify the characteristics as a function of some operating points at nominal conditions.

Depending on the value of the `checkValve` parameter, the model either supports reverse flow conditions, or includes a built-in check valve to avoid flow reversal.

It is possible to take into account the heat capacity of the fluid inside the pump by specifying its volume `V`; this is necessary to avoid singularities in the computation of the outlet enthalpy in case of zero flow rate. If zero flow rate conditions are always avoided, this dynamic effect can be neglected by leaving the default value `V = 0`, thus avoiding a fast state variable in the model.

### Dynamics options

Steady-state mass and energy balances are assumed per default, neglecting the holdup of fluid in the pump. Dynamic mass and energy balance can be used by setting the corresponding dynamic parameters. This might be desirable if the pump is assembled together with valves before port_a and behind port_b. If both valves are closed, then the fluid is useful to define the thermodynamic state and in particular the absolute pressure in the pump. Note that the `flowCharacteristic` only specifies a pressure difference.

### Heat transfer

The boolean paramter `use_HeatTransfer` can be set to true if heat exchanged with the environment should be taken into account or to model a housing. This might be desirable if a pump with realistic `powerCharacteristic` for zero flow operates while a valve prevents fluid flow.

### Diagnostics of Cavitation

The boolean parameter show_NPSHa can set true to compute the Net Positive Suction Head available and check for cavitation, provided a two-phase medium model is used.

Extends from Interfaces.PartialTwoPort (Partial component with two ports), Interfaces.PartialLumpedVolume (Lumped volume with mass and energy balance).

## Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | Medium in the component |
| Volume | fluidVolume | Volume [m3] |

| | | |
|---|---|---|
| Characteristics | | |
| Integer | nParallel | Number of pumps in parallel |
| AngularVelocity_rpm | N_nominal | Nominal rotational speed for flow characteristic [1/min] |
| Density | rho_nominal | Nominal fluid density for characteristic [kg/m3] |
| Boolean | use_powerCharacteristic | Use powerCharacteristic (vs. efficiencyCharacteristic) |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Boolean | checkValve | = true to prevent reverse flow |
| Volume | V | Volume inside the pump [m3] |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| Heat transfer | | |
| Boolean | use_HeatTransfer | = true to use a HeatTransfer model, e.g. for a housing |
| **Initialization** | | |
| AbsolutePressure | p_a_start | Guess value for inlet pressure [Pa] |
| AbsolutePressure | p_b_start | Guess value for outlet pressure [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| AbsolutePressure | p_start | Start value of pressure [Pa] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |
| **Advanced** | | |
| Diagnostics | | |
| Boolean | show_NPSHa | = true to compute Net Positive Suction Head available |

### Connectors

| Type | Name | Description |
|---|---|---|
| HeatPort_a | heatPort | |

## Machines.BaseClasses.PumpCharacteristics

**Functions for pump characteristics**

### Package Content

| Name | Description |
|---|---|
| baseFlow | Base class for pump flow characteristics |
| basePower | Base class for pump power consumption characteristics |
| baseEfficiency | Base class for efficiency characteristics |
| linearFlow | Linear flow characteristic |

| | |
|---|---|
| quadraticFlow | Quadratic flow characteristic |
| polynomialFlow | Polynomial flow characteristic |
| constantEfficiency | Constant efficiency characteristic |
| linearPower | Linear power consumption characteristic |
| quadraticPower | Quadratic power consumption characteristic |

## Machines.BaseClasses.PumpCharacteristics.baseFlow

**Base class for pump flow characteristics**

### Inputs

| Type | Name | Description |
|---|---|---|
| VolumeFlowRate | V_flow | Volumetric flow rate [m3/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Height | head | Pump head [m] |

## Machines.BaseClasses.PumpCharacteristics.basePower

**Base class for pump power consumption characteristics**

### Inputs

| Type | Name | Description |
|---|---|---|
| VolumeFlowRate | V_flow | Volumetric flow rate [m3/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Power | consumption | Power consumption [W] |

## Machines.BaseClasses.PumpCharacteristics.baseEfficiency

**Base class for efficiency characteristics**

### Inputs

| Type | Name | Description |
|---|---|---|
| VolumeFlowRate | V_flow | Volumetric flow rate [m3/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | eta | Efficiency |

## Machines.BaseClasses.PumpCharacteristics.linearFlow

**Linear flow characteristic**

### Inputs

| Type | Name | Description |
|---|---|---|
| VolumeFlowRate | V_flow | Volumetric flow rate [m3/s] |
| VolumeFlowRate | V_flow_nominal[2] | Volume flow rate for two operating points (single pump) [m3/s] |
| Height | head_nominal[2] | Pump head for two operating points [m] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Height | head | Pump head [m] |

## Machines.BaseClasses.PumpCharacteristics.quadraticFlow

**Quadratic flow characteristic**

### Inputs

| Type | Name | Description |
|---|---|---|
| VolumeFlowRate | V_flow | Volumetric flow rate [m3/s] |
| VolumeFlowRate | V_flow_nominal[3] | Volume flow rate for three operating points (single pump) [m3/s] |
| Height | head_nominal[3] | Pump head for three operating points [m] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Height | head | Pump head [m] |

## Machines.BaseClasses.PumpCharacteristics.polynomialFlow

**Polynomial flow characteristic**

### Inputs

| Type | Name | Description |
|---|---|---|
| VolumeFlowRate | V_flow | Volumetric flow rate [m3/s] |
| VolumeFlowRate | V_flow_nominal[:] | Volume flow rate for N operating points (single pump) [m3/s] |
| Height | head_nominal[:] | Pump head for N operating points [m] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Height | head | Pump head [m] |

## Machines.BaseClasses.PumpCharacteristics.constantEfficiency

**Constant efficiency characteristic**

### Inputs

| Type | Name | Description |
|---|---|---|
| VolumeFlowRate | V_flow | Volumetric flow rate [m3/s] |
| Real | eta_nominal | Nominal efficiency |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | eta | Efficiency |

## Machines.BaseClasses.PumpCharacteristics.linearPower

**Linear power consumption characteristic**

### Inputs

| Type | Name | Description |
|---|---|---|
| VolumeFlowRate | V_flow | Volumetric flow rate [m3/s] |
| VolumeFlowRate | V_flow_nominal[2] | Volume flow rate for two operating points (single pump) [m3/s] |
| Power | W_nominal[2] | Power consumption for two operating points [W] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Power | consumption | Power consumption [W] |

## Machines.BaseClasses.PumpCharacteristics.quadraticPower

**Quadratic power consumption characteristic**

### Inputs

| Type | Name | Description |
|---|---|---|
| VolumeFlowRate | V_flow | Volumetric flow rate [m3/s] |
| VolumeFlowRate | V_flow_nominal[3] | Volume flow rate for three operating points (single pump) [m3/s] |
| Power | W_nominal[3] | Power consumption for three operating points [W] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Power | consumption | Power consumption [W] |

## Machines.BaseClasses.assertPositiveDifference

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | p | [Pa] |
| Pressure | p_sat | [Pa] |

| | | |
|---|---|---|
| String | message | |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | [Pa] |

## Modelica_Fluid.Valves

**Components for the regulation and control of fluid flow**

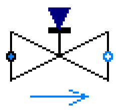
### Information

Extends from Icons.VariantLibrary (Icon for a library that contains several variants of one component).

### Package Content

| Name | Description |
|---|---|
| ValveIncompressible | Valve for (almost) incompressible fluids |
| ValveVaporizing | Valve for possibly vaporizing (almost) incompressible fluids, accounts for choked flow conditions |
| ValveCompressible | Valve for compressible fluids, accounts for choked flow conditions |
| ValveLinear | Valve for water/steam flows with linear pressure drop |
| ValveDiscrete | Valve for water/steam flows with linear pressure drop |
| BaseClasses | Base classes used in the Valves package (only of interest to build new component models) |

## Valves.ValveIncompressible



**Valve for (almost) incompressible fluids**

### Information

Valve model according to the IEC 534/ISA S.75 standards for valve sizing, incompressible fluids.

This model assumes that the fluid has a low compressibility, which is always the case for liquids. It can also be used with gases, provided that the pressure drop is lower than 0.2 times the absolute pressure at the inlet, so that the fluid density does not change much inside the valve.

If `checkValve` is false, the valve supports reverse flow, with a symmetric flow characteric curve. Otherwise, reverse flow is stopped (check valve behaviour).

The treatment of parameters **Kv** and **Cv** is explained in detail in the Users Guide.

Extends from BaseClasses.PartialValve (Base model for valves).

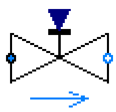
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| replaceable function valveCharacteristic | | Inherent flow characteristic |
| Flow Coefficient | | |
| CvTypes | CvData | Selection of flow coefficient |
| Area | Av | Av (metric) flow coefficient [m2] |
| Real | Kv | Kv (metric) flow coefficient [m3/h] |
| Real | Cv | Cv (US) flow coefficient [USG/min] |
| Nominal operating point | | |
| Pressure | dp_nominal | Nominal pressure drop [Pa] |
| MassFlowRate | m_flow_nominal | Nominal mass flowrate [kg/s] |
| Density | rho_nominal | Nominal inlet density [kg/m3] |
| Real | opening_nominal | Nominal opening |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Boolean | checkValve | Reverse flow stopped |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Pressure | dp_small | Regularisation of zero flow [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| input RealInput | opening | Valve position in the range 0-1 |

## Valves.ValveVaporizing



**Valve for possibly vaporizing (almost) incompressible fluids, accounts for choked flow conditions**

### Information

Valve model according to the IEC 534/ISA S.75 standards for valve sizing, incompressible fluid at the inlet, and possibly two-phase fluid at the outlet, including choked flow conditions.

The model operating range includes choked flow operation, which takes place for low outlet pressures due to flashing in the vena contracta; otherwise, non-choking conditions are assumed.

This model requires a two-phase medium model, to describe the liquid and (possible) two-phase conditions.

The default liquid pressure recovery coefficient `Fl` is constant and given by the parameter `Fl_nominal`. The relative change (per unit) of the recovery coefficient can be specified as a given function of the valve opening by replacing the `FlCharacteristic` function.

If `checkValve` is false, the valve supports reverse flow, with a symmetric flow characteric curve. Otherwise, reverse flow is stopped (check valve behaviour).

The treatment of parameters **Kv** and **Cv** is explained in detail in the Users Guide.

Extends from BaseClasses.PartialValve (Base model for valves).

### Parameters

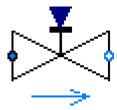
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| replaceable function valveCharacteristic | | Inherent flow characteristic |
| Real | Fl_nominal | Liquid pressure recovery factor |
| replaceable function FlCharacteristic | | Pressure recovery characteristic |
| Flow Coefficient | | |
| CvTypes | CvData | Selection of flow coefficient |
| Area | Av | Av (metric) flow coefficient [m2] |
| Real | Kv | Kv (metric) flow coefficient [m3/h] |
| Real | Cv | Cv (US) flow coefficient [USG/min] |
| Nominal operating point | | |
| Pressure | dp_nominal | Nominal pressure drop [Pa] |
| MassFlowRate | m_flow_nominal | Nominal mass flowrate [kg/s] |
| Density | rho_nominal | Nominal inlet density [kg/m3] |
| Real | opening_nominal | Nominal opening |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Boolean | checkValve | Reverse flow stopped |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Pressure | dp_small | Regularisation of zero flow [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |

### Connectors

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |

| | | |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| input RealInput | opening | Valve position in the range 0-1 |
| replaceable function FlCharacteristic | | Pressure recovery characteristic |

## Valves.ValveCompressible



**Valve for compressible fluids, accounts for choked flow conditions**

### Information

Valve model according to the IEC 534/ISA S.75 standards for valve sizing, compressible fluid, no phase change, also covering choked-flow conditions.

This model can be used with gases and vapours, with arbitrary pressure ratio between inlet and outlet.

The product Fk*xt is given by the parameter `Fxt_full`, and is assumed constant by default. The relative change (per unit) of the xt coefficient with the valve opening can be specified by replacing the `xtCharacteristic` function.

If `checkValve` is false, the valve supports reverse flow, with a symmetric flow characteric curve. Otherwise, reverse flow is stopped (check valve behaviour).

The treatment of parameters **Kv** and **Cv** is explained in detail in the Users Guide.

Extends from BaseClasses.PartialValve (Base model for valves).

### Parameters

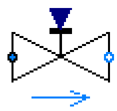
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| replaceable function valveCharacteristic | | Inherent flow characteristic |
| Real | Fxt_full | Fk*xt critical ratio at full opening |
| replaceable function xtCharacteristic | | Critical ratio characteristic |
| Flow Coefficient | | |
| CvTypes | CvData | Selection of flow coefficient |
| Area | Av | Av (metric) flow coefficient [m2] |
| Real | Kv | Kv (metric) flow coefficient [m3/h] |
| Real | Cv | Cv (US) flow coefficient [USG/min] |
| Nominal operating point | | |
| Pressure | dp_nominal | Nominal pressure drop [Pa] |
| MassFlowRate | m_flow_nominal | Nominal mass flowrate [kg/s] |
| Density | rho_nominal | Nominal inlet density [kg/m3] |
| Real | opening_nominal | Nominal opening |
| AbsolutePressure | p_nominal | Nominal inlet pressure [Pa] |

| | | |
|---|---|---|
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Boolean | checkValve | Reverse flow stopped |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Pressure | dp_small | Regularisation of zero flow [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| input RealInput | opening | Valve position in the range 0-1 |
| replaceable function xtCharacteristic | | Critical ratio characteristic |

## Valves.ValveLinear



**Valve for water/steam flows with linear pressure drop**

### Information

This very simple model provides a pressure drop which is proportional to the flowrate and to the `opening` input, without computing any fluid property. It can be used for testing purposes, when a simple model of a variable pressure loss is needed.

A medium model must be nevertheless be specified, so that the fluid ports can be connected to other components using the same medium model.

The model is adiabatic (no heat losses to the ambient) and neglects changes in kinetic energy from the inlet to the outlet.

Extends from Interfaces.PartialTwoPortTransport (Partial element transporting fluid between two ports without storage of mass or energy).

### Parameters

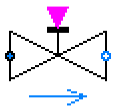
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| AbsolutePressure | dp_nominal | Nominal pressure drop at full opening [Pa] |
| MassFlowRate | m_flow_nominal | Nominal mass flowrate at full opening [kg/s] |
| **Assumptions** | | |

| | | |
|---|---|---|
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| input RealInput | opening | =1: completely open, =0: completely closed |

## Valves.ValveDiscrete



**Valve for water/steam flows with linear pressure drop**

### Information

This very simple model provides a (small) pressure drop which is proportional to the flowrate if the Boolean open signal is **true**. Otherwise, the mass flow rate is zero. If opening_min > 0, a small leakage mass flow rate occurs when open = **false**.

This model can be used for simplified modelling of on-off valves, when it is not important to accurately describe the pressure loss when the valve is open. Although the medium model is not used to determine the pressure loss, it must be nevertheless be specified, so that the fluid ports can be connected to other components using the same medium model.

The model is adiabatic (no heat losses to the ambient) and neglects changes in kinetic energy from the inlet to the outlet.

In a diagram animation, the valve is shown in "green", when it is open.

Extends from Interfaces.PartialTwoPortTransport (Partial element transporting fluid between two ports without storage of mass or energy).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Pressure | dp_nominal | Nominal pressure drop at full opening=1 [Pa] |
| MassFlowRate | m_flow_nominal | Nominal mass flowrate at full opening=1 [kg/s] |
| Real | opening_min | Remaining opening if closed, causing small leakage flow |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |

| | | |
|---|---|---|
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| input BooleanInput | open | |

---

## Valves.BaseClasses

**Base classes used in the Valves package (only of interest to build new component models)**

### Package Content

| Name | Description |
|---|---|
| PartialValve | Base model for valves |
| ValveCharacteristics | Functions for valve characteristics |

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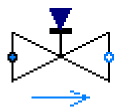
## Valves.BaseClasses.PartialValve



**Base model for valves**

### Information

This is the base model for the `ValveIncompressible`, `ValveVaporizing`, and `ValveCompressible` valve models. The model is based on the IEC 534 / ISA S.75 standards for valve sizing.

The model optionally supports reverse flow conditions (assuming symmetrical behaviour) or check valve operation, and has been suitably regularized, compared to the equations in the standard, in order to avoid numerical singularities around zero pressure drop operating conditions.

The model assumes adiabatic operation (no heat losses to the ambient); changes in kinetic energy from inlet to outlet are neglected in the energy balance.

#### Modelling options

The following options are available to specify the valve flow coefficient in fully open conditions:

- `CvData = Modelica_Fluid.Types.CvTypes.Av`: the flow coefficient is given by the metric `Av` coefficient (m^2).

- `CvData = Modelica_Fluid.Types.CvTypes.Kv`: the flow coefficient is given by the metric `Kv` coefficient (m^3/h).
- `CvData = Modelica_Fluid.Types.CvTypes.Cv`: the flow coefficient is given by the US `Cv` coefficient (USG/min).
- `CvData = Modelica_Fluid.Types.CvTypes.OpPoint`: the flow is computed from the nominal operating point specified by `p_nominal`, `dp_nominal`, `m_flow_nominal`, `rho_nominal`, `opening_nominal`.

The nominal pressure drop `dp_nominal` must always be specified; to avoid numerical singularities, the flow characteristic is modified for pressure drops less than `b*dp_nominal` (the default value is 1% of the nominal pressure drop). Increase this parameter if numerical problems occur in valves with very low pressure drops.

If `checkValve` is true, then the flow is stopped when the outlet pressure is higher than the inlet pressure; otherwise, reverse flow takes place. Use this option only when neede, as it increases the numerical complexity of the problem.

The valve opening characteristic `valveCharacteristic`, linear by default, can be replaced by any user-defined function. Quadratic and equal percentage with customizable rangeability are already provided by the library.

The treatment of parameters **Kv** and **Cv** is explained in detail in the Users Guide.

Extends from Interfaces.PartialTwoPortTransport (Partial element transporting fluid between two ports without storage of mass or energy).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Flow Coefficient | | |
| CvTypes | CvData | Selection of flow coefficient |
| Area | Av | Av (metric) flow coefficient [m2] |
| Real | Kv | Kv (metric) flow coefficient [m3/h] |
| Real | Cv | Cv (US) flow coefficient [USG/min] |
| Nominal operating point | | |
| Pressure | dp_nominal | Nominal pressure drop [Pa] |
| MassFlowRate | m_flow_nominal | Nominal mass flowrate [kg/s] |
| Density | rho_nominal | Nominal inlet density [kg/m3] |
| Real | opening_nominal | Nominal opening |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Boolean | checkValve | Reverse flow stopped |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |

| | | |
|---|---|---|
| Pressure | dp_small | Regularisation of zero flow [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| input RealInput | opening | Valve position in the range 0-1 |

## Valves.BaseClasses.ValveCharacteristics

**Functions for valve characteristics**

### Package Content

| Name | Description |
|---|---|
| baseFun | Base class for valve characteristics |
| linear | Linear characteristic |
| one | Constant characteristic |
| quadratic | Quadratic characteristic |
| equalPercentage | Equal percentage characteristic |

## Valves.BaseClasses.ValveCharacteristics.baseFun

**Base class for valve characteristics**

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | pos | Opening position (per unit) |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | rc | Relative flow coefficient (per unit) |

## Valves.BaseClasses.ValveCharacteristics.linear

**Linear characteristic**

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | pos | Opening position (per unit) |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | rc | Relative flow coefficient (per unit) |

## Valves.BaseClasses.ValveCharacteristics.one

**Constant characteristic**

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | pos | Opening position (per unit) |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | rc | Relative flow coefficient (per unit) |

## Valves.BaseClasses.ValveCharacteristics.quadratic

**Quadratic characteristic**

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | pos | Opening position (per unit) |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | rc | Relative flow coefficient (per unit) |

## Valves.BaseClasses.ValveCharacteristics.equalPercentage

**Equal percentage characteristic**

### Information

This characteristic is such that the relative change of the flow coefficient is proportional to the change in the opening position:

d(rc)/d(pos) = k d(pos).

The constant k is expressed in terms of the rangeability, i.e. the ratio between the maximum and the minimum useful flow coefficient:

rangeability = exp(k) = rc(1.0)/rc(0.0).

The theoretical characteristic has a non-zero opening when pos = 0; the implemented characteristic is modified so that the valve closes linearly when pos < delta.

Extends from baseFun (Base class for valve characteristics).

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | pos | Opening position (per unit) |
| Real | rangeability | Rangeability |
| Real | delta | |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | rc | Relative flow coefficient (per unit) |

## Modelica_Fluid.Fittings

**Adaptors for connections of fluid components and the regulation of fluid flow**

### Information

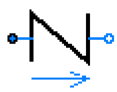
Extends from Icons.VariantLibrary (Icon for a library that contains several variants of one component).

### Package Content

| Name | Description |
|---|---|
| SimpleGenericOrifice | Simple generic orifice defined by pressure loss coefficient and diameter (only for flow from port_a to port_b) |
| SharpEdgedOrifice | Pressure drop due to sharp edged orifice (for both flow directions) |
| AbruptAdaptor | Pressure drop in pipe due to suddenly expanding or reducing area (for both flow directions) |
| MultiPort | Multiply a port; useful if multiple connections shall be made to a port exposing a state |
| TeeJunctionIdeal | Splitting/joining component with static balances for an infinitesimal control volume |
| TeeJunctionVolume | Splitting/joining component with static balances for a dynamic control volume |
| BaseClasses | Base classes used in the Fittings package (only of interest to build new component models) |

## Fittings.SimpleGenericOrifice

**Simple generic orifice defined by pressure loss coefficient and diameter (only for flow from port_a to port_b)**



### Information

This pressure drop component defines a simple, generic orifice, where the loss factor ζ is provided for one flow direction (e.g., from loss table of a book):

```
Δp = 0.5*ζ*ρ*v*|v|
   = 8*ζ/(π^2*D^4*ρ) * m_flow*|m_flow|
```

where

- Δp is the pressure drop: Δp = port_a.p - port_b.p
- D is the diameter of the orifice at the position where ζ is defined (either at port_a or port_b). If the orifice has not a circular cross section, D = 4*A/P, where A is the cross section area and P is the wetted perimeter.
- ζ is the loss factor with respect to D that depends on the geometry of the orifice. In the turbulent flow regime, it is assumed that ζ is constant.
  For small mass flow rates, the flow is laminar and is approximated by a polynomial that has a finite derivative for m_flow=0.
- v is the mean velocity.
- ρ is the upstream density.

Since the pressure loss factor zeta is provided only for a mass flow from port_a to port_b, the pressure loss is not correct when the flow is reversing. If reversing flow only occurs in a short time interval, this is most likely uncritical. If significant reversing flow can appear, this component should not be used.

Extends from Interfaces.PartialTwoPortTransport (Partial element transporting fluid between two ports without storage of mass or energy), Interfaces.PartialLumpedFlow (Base class for a lumped momentum balance).

## Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Length | pathLength | Length flow path [m] |
| Diameter | diameter | Diameter of orifice [m] |
| Real | zeta | Loss factor for flow of port_a -> port_b |
| Boolean | use_zeta | = false to obtain zeta from dp_nominal and m_flow_nominal |
| AbsolutePressure | dp_nominal | Nominal pressure drop [Pa] |
| MassFlowRate | m_flow_nominal | Mass flow rate for dp_nominal [kg/s] |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Dynamics | | |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Boolean | from_dp | = true, use m_flow = f(dp) else dp = f(m_flow) |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |

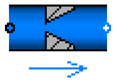
## Connectors

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

## Fittings.SharpEdgedOrifice

**Pressure drop due to sharp edged orifice (for both flow directions)**



### Information

Extends from BaseClasses.QuadraticTurbulent.BaseModel (Generic pressure drop component with constant turbulent loss factor data and without an icon).

### Parameters

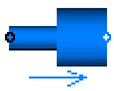
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| LossFactorData | data | Loss factor data |
| Length | length | Length of orifice [m] |
| Diameter | diameter | Inner diameter of pipe (= same at port_a and port_b) [m] |
| Diameter | leastDiameter | Smallest diameter of orifice [m] |
| Angle_deg | alpha | Angle of orifice [deg] |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Boolean | from_dp | = true, use m_flow = f(dp) else dp = f(m_flow) |
| Boolean | use_Re | = true, if turbulent region is defined by Re, otherwise by dp_small or m_flow_small |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |
| Boolean | show_Re | = true, if Reynolds number is included for plotting |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

## Fittings.AbruptAdaptor

**Pressure drop in pipe due to suddenly expanding or reducing area (for both flow directions)**



### Information

Extends from BaseClasses.QuadraticTurbulent.BaseModelNonconstantCrossSectionArea (Generic pressure drop component with constant turbulent loss factor data and without an icon, for non-constant cross section area).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| LossFactorData | data | Loss factor data |
| Diameter | diameter_a | Inner diameter of pipe at port_a [m] |
| Diameter | diameter_b | Inner diameter of pipe at port_b [m] |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |
| Boolean | show_Re | = true, if Reynolds number is included for plotting |
| Boolean | show_totalPressures | = true, if total pressures are included for plotting |
| Boolean | show_portVelocities | = true, if port velocities are included for plotting |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

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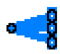
## Fittings.MultiPort

**Multiply a port; useful if multiple connections shall be made to a port exposing a state**



### Information

This model is useful if multiple connections shall be made to a port of a volume model exposing a state, like a pipe with ModelStructure av_vb. The mixing is shifted into the volume connected to port_a and the result is propageted back to each ports_b.

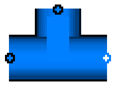
If multiple connections were directly made to the volume, then ideal mixing would take place in the connection set, outside the volume. This is normally not intended.

### Connectors

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| FluidPort_a | port_a | |
| FluidPorts_b | ports_b[nPorts_b] | |

## Fittings.TeeJunctionIdeal



**Splitting/joining component with static balances for an infinitesimal control volume**

### Information

This model is the simplest implementation for a splitting/joining component for three flows. Its use is not required. It just formulates the balance equations in the same way that the connect symmantics would formulate them anyways. The main advantage of using this component is, that the user does not get confused when looking at the specific enthalpy at each port which might be confusing when not using a splitting/joining component. The reason for the confusion is that one exmanins the mixing enthalpy of the infinitesimal control volume introduced with the connect statement when looking at the specific enthalpy in the connector which might not be equal to the specific enthalpy at the port in the "real world".
Extends from Fittings.BaseClasses.PartialTeeJunction (Base class for a splitting/joining component with three ports).

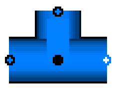
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_1 | |
| FluidPort_b | port_2 | |
| FluidPort_a | port_3 | |

## Fittings.TeeJunctionVolume



**Splitting/joining component with static balances for a dynamic control volume**

### Information

This model introduces a mixing volume into a junction. This might be useful to examine the non-ideal mixing taking place in a real junction.
Extends from Fittings.BaseClasses.PartialTeeJunction (Base class for a splitting/joining component with three ports), Interfaces.PartialLumpedVolume (Lumped volume with mass and energy balance).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Volume | fluidVolume | Volume [m3] |
| Volume | V | Mixing volume inside junction [m3] |
| **Assumptions** | | |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |

| Initialization | | |
|---|---|---|
| AbsolutePressure | p_start | Start value of pressure [Pa] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_1 | |
| FluidPort_b | port_2 | |
| FluidPort_a | port_3 | |

## Fittings.BaseClasses

**Base classes used in the Fittings package (only of interest to build new component models)**

### Package Content

| Name | Description |
|---|---|
| lossConstant_D_zeta | Return the loss constant 8*zeta/(pi^2*D^4) |
| QuadraticTurbulent | Pressure loss components that are mainly defined by a quadratic turbulent regime with constant loss factor data |
| PartialTeeJunction | Base class for a splitting/joining component with three ports |

## Fittings.BaseClasses.lossConstant_D_zeta

**Return the loss constant 8*zeta/(pi^2*D^4)**

### Information

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Diameter | D | Diameter at port_a or port_b [m] |
| Real | zeta | Constant pressure loss factor with respect to D (i.e., either port_a or port_b) |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | k | Loss constant (= 8*zeta/(pi^2*D^4)) |

## Fittings.BaseClasses.QuadraticTurbulent

**Pressure loss components that are mainly defined by a quadratic turbulent regime with constant loss factor data**

### Information

This library provides pressure loss factors of a pipe segment (orifice, bending etc.) with a minimum amount of data. If available, data can be provided for **both flow directions**, i.e., flow from port_a to port_b and from port_b to port_a, as well as for the **laminar** and the **turbulent** region. It is also an option to provide the loss factor **only** for the **turbulent** region for a flow from port_a to port_b. Basically, the pressure drop is defined by the following equation:

```
Δp = 0.5*ζ*ρ*v*|v|
   = 0.5*ζ/A^2 * (1/ρ) * m_flow*|m_flow|
   = 8*ζ/(π^2*D^4*ρ) * m_flow*|m_flow|
```

where

- Δp is the pressure drop: Δp = port_a.p - port_b.p
- v is the mean velocity.
- ρ is the density.
- ζ is the loss factor that depends on the geometry of the pipe. In the turbulent flow regime, it is assumed that ζ is constant and is given by "zeta1" and "zeta2" depending on the flow direction.
- 
- D is the diameter of the pipe segment. If this is not a circular cross section, D = 4*A/P, where A is the cross section area and P is the wetted perimeter.

### Package Content

| Name | Description |
| --- | --- |
| LossFactorData | Data structure defining constant loss factor data for dp = zeta*rho*v*\|v\|/2 and functions providing the data for some loss types |
| massFlowRate_dp | Return mass flow rate from constant loss factor data and pressure drop (m_flow = f(dp)) |
| massFlowRate_dp_and_Re | Return mass flow rate from constant loss factor data, pressure drop and Re (m_flow = f(dp)) |
| pressureLoss_m_flow | Return pressure drop from constant loss factor and mass flow rate (dp = f(m_flow)) |
| pressureLoss_m_flow_and_Re | Return pressure drop from constant loss factor, mass flow rate and Re (dp = f(m_flow)) |
| BaseModel | Generic pressure drop component with constant turbulent loss factor data and without an icon |
| TestWallFriction | Pressure drop in pipe due to wall friction (only for test purposes; if needed use Pipes.StaticPipe instead) |
| BaseModelNonconstantCrossSectionArea | Generic pressure drop component with constant turbulent loss factor data and without an icon, for non-constant cross section area |
| pressureLoss_m_flow_totalPressure | Return pressure drop from constant loss factor and mass flow rate (dp = f(m_flow)) |

## Fittings.BaseClasses.QuadraticTurbulent.LossFactorData

**Data structure defining constant loss factor data for dp = zeta*rho*v*|v|/2 and functions providing the data for some loss types**

### Information

This record defines the pressure loss factors of a pipe segment (orifice, bending etc.) with a minimum amount of data. If available, data should be provided for **both flow directions**, i.e., flow from port_a to port_b and from port_b to port_a, as well as for the **laminar** and the **turbulent** region. It is also an option to provide the loss factor **only** for the **turbulent** region for a flow from port_a to port_b.

The following equations are used:

```
   Δp = 0.5*ζ*ρ*v*|v|
      = 0.5*ζ/A^2 * (1/ρ) * m_flow*|m_flow|
      = 8*ζ/(π^2*D^4*ρ) * m_flow*|m_flow|
        Re = |v|*D*ρ/μ
```

| **flow type** | **ζ =** | **flow region** |
|---|---|---|
| turbulent | **zeta1** = const. | Re ≥ Re_turbulent, v ≥ 0 |
| | **zeta2** = const. | Re ≥ Re_turbulent, v < 0 |
| laminar | **c0**/Re | both flow directions, Re small; c0 = const. |

where

- Δp is the pressure drop: Δp = port_a.p - port_b.p
- v is the mean velocity.
- ρ is the density.
- ζ is the loss factor that depends on the geometry of the pipe. In the turbulent flow regime, it is assumed that ζ is constant and is given by "zeta1" and "zeta2" depending on the flow direction. When the Reynolds number Re is below "Re_turbulent", the flow is laminar for small flow velocities. For higher velocities there is a transition region from laminar to turbulent flow. The loss factor for laminar flow at small velocities is defined by the often occuring approximation c0/Re. If c0 is different for the two flow directions, the mean value has to be used (c0 = (c0_ab + c0_ba)/2).
- 
- The equation "Δp = 0.5*ζ*ρ*v*|v|" is either with respect to port_a or to port_b, depending on the definition of the particular loss factor ζ (in some references loss factors are defined with respect to port_a, in other references with respect to port_b).
- Re = |v|*D_Re*ρ/μ = |m_flow|*D_Re/(A_Re*μ) is the Reynolds number at the smallest cross section area. This is often at port_a or at port_b, but can also be between the two ports. In the record, the diameter D_Re of this smallest cross section area has to be provided, as well, as Re_turbulent, the absolute value of the Reynolds number at which the turbulent flow starts. If Re_turbulent is different for the two flow directions, use the smaller value as Re_turbulent.
- D is the diameter of the pipe. If the pipe has not a circular cross section, D = 4*A/P, where A is the cross section area and P is the wetted perimeter.
- A is the cross section area with A = π(D/2)^2.

- μ is the dynamic viscosity.

The laminar and the transition region is usually of not much technical interest because the operating point is mostly in the turbulent regime. For simplification and for numercial reasons, this whole region is described by two polynomials of third order, one polynomial for m_flow ≥ 0 and one for m_flow < 0. The polynomials start at Re = |m_flow|*4/(π*D_Re*μ), where D_Re is the smallest diameter between port_a and port_b. The common derivative of the two polynomials at Re = 0 is computed from the equation "c0/Re". Note, the pressure drop equation above in the laminar region is always defined with respect to the smallest diameter D_Re.

If no data for c0 is available, the derivative at Re = 0 is computed in such a way, that the second derivatives of the two polynomials are identical at Re = 0. The polynomials are constructed, such that they smoothly touch the characteristic curves in the turbulent regions. The whole characteristic is therefore **continuous** and has a **finite**, **continuous first derivative everywhere**. In some cases, the constructed polynomials would "vibrate". This is avoided by reducing the derivative at Re=0 in such a way that the polynomials are guaranteed to be monotonically increasing. The used sufficient criteria for monotonicity follows from:

Fritsch F.N. and Carlson R.E. (1980):
**Monotone piecewise cubic interpolation**. SIAM J. Numerc. Anal., Vol. 17, No. 2, April 1980, pp. 238-246

Extends from Modelica.Icons.Record (Icon for a record).

### Parameters

| Type | Name | Description |
|---|---|---|
| Diameter | diameter_a | Diameter at port_a [m] |
| Diameter | diameter_b | Diameter at port_b [m] |
| Real | zeta1 | Loss factor for flow port_a -> port_b |
| Real | zeta2 | Loss factor for flow port_b -> port_a |
| ReynoldsNumber | Re_turbulent | Loss factors suited for Re >= Re_turbulent [1] |
| Diameter | D_Re | Diameter used to compute Re [m] |
| Boolean | zeta1_at_a | dp = zeta1*(if zeta1_at_a then rho_a*v_a^2/2 else rho_b*v_b^2/2) |
| Boolean | zeta2_at_a | dp = -zeta2*(if zeta2_at_a then rho_a*v_a^2/2 else rho_b*v_b^2/2) |
| Boolean | zetaLaminarKnown | = true, if zeta = c0/Re in laminar region |
| Real | c0 | zeta = c0/Re; dp = zeta*rho_Re*v_Re^2/2, Re=v_Re*D_Re*rho_Re/mu_Re) |

### Modelica definition

```
record LossFactorData
  "Data structure defining constant loss factor data for dp = zeta*rho*v*|v|/2 and
functions providing the data for some loss types"

       extends Modelica.Icons.Record;

 SI.Diameter diameter_a "Diameter at port_a";
 SI.Diameter diameter_b "Diameter at port_b";
 Real zeta1 "Loss factor for flow port_a -> port_b";
 Real zeta2 "Loss factor for flow port_b -> port_a";
 SI.ReynoldsNumber Re_turbulent "Loss factors suited for Re >= Re_turbulent";
 SI.Diameter D_Re "Diameter used to compute Re";
 Boolean zeta1_at_a = true
    "dp = zeta1*(if zeta1_at_a then rho_a*v_a^2/2 else rho_b*v_b^2/2)";
 Boolean zeta2_at_a = false
    "dp = -zeta2*(if zeta2_at_a then rho_a*v_a^2/2 else rho_b*v_b^2/2)";
```

```
 Boolean zetaLaminarKnown = false "= true, if zeta = c0/Re in laminar region";
 Real c0 = 1
    "zeta = c0/Re; dp = zeta*rho_Re*v_Re^2/2, Re=v_Re*D_Re*rho_Re/mu_Re)";


  encapsulated function wallFriction
    "Return pressure loss data due to friction in a straight pipe with walls of
nonuniform roughness (not useful for smooth pipes, since zeta is no function of Re)"
     import Fittings.BaseClasses.QuadraticTurbulent.LossFactorData;
     import lg = Modelica.Math.log10;
     import SI = Modelica.SIunits;

    input SI.Length length "Length of pipe";
    input SI.Diameter diameter "Inner diameter of pipe";
    input SI.Length roughness(min=1e-10)
      "Absolute roughness of pipe (> 0 required, details see info layer)";
    output LossFactorData data "Pressure loss factors for both flow directions";
  protected
    Real Delta = roughness/diameter "relative roughness";
  algorithm
    data.diameter_a          := diameter;
    data.diameter_b          := diameter;
    data.zeta1        := (length/diameter)/(2*lg(3.7 /Delta))^2;
    data.zeta2        := data.zeta1;
    data.Re_turbulent := 4000
      ">= 560/Delta flow does not depend on Re, but interpolation is bad";
    data.D_Re         := diameter;
    data.zeta1_at_a   := true;
    data.zeta2_at_a   := false;
    data.zetaLaminarKnown := true;
    data.c0              := 64*(length/diameter);
  end wallFriction;

  encapsulated function suddenExpansion
    "Return pressure loss data for sudden expansion or contraction in a pipe (for both
flow directions)"
     import Fittings.BaseClasses.QuadraticTurbulent.LossFactorData;
     import SI = Modelica.SIunits;
    input SI.Diameter diameter_a "Inner diameter of pipe at port_a";
    input SI.Diameter diameter_b "Inner diameter of pipe at port_b";
    output LossFactorData data "Pressure loss factors for both flow directions";
  protected
    Real A_rel;
  algorithm
    data.diameter_a          := diameter_a;
    data.diameter_b          := diameter_b;
    data.Re_turbulent := 100;
    data.zetaLaminarKnown := true;
    data.c0 := 30;

    if diameter_a <= diameter_b then
       A_rel :=(diameter_a/diameter_b)^2;
       data.zeta1 :=(1 - A_rel)^2;
       data.zeta2 :=0.5*(1 - A_rel)^0.75;
       data.zeta1_at_a :=true;
       data.zeta2_at_a :=true;
       data.D_Re := diameter_a;
    else
       A_rel :=(diameter_b/diameter_a)^2;
       data.zeta1 :=0.5*(1 - A_rel)^0.75;
       data.zeta2 :=(1 - A_rel)^2;
       data.zeta1_at_a :=false;
       data.zeta2_at_a :=false;
       data.D_Re := diameter_b;
    end if;
  end suddenExpansion;

  encapsulated function sharpEdgedOrifice
    "Return pressure loss data for sharp edged orifice (for both flow directions)"
     import NonSI = Modelica.SIunits.Conversions.NonSIunits;
     import Fittings.BaseClasses.QuadraticTurbulent.LossFactorData;
     import SI = Modelica.SIunits;
     input SI.Diameter diameter
```

```
     "Inner diameter of pipe (= same at port_a and port_b)";
    input SI.Diameter leastDiameter "Smallest diameter of orifice";
    input SI.Diameter length "Length of orifice";
    input NonSI.Angle_deg alpha "Angle of orifice";
    output LossFactorData data
     "Pressure loss factors for both flow directions";
  protected
    Real D_rel=leastDiameter/diameter;
    Real LD=length/leastDiameter;
    Real k=0.13 + 0.34*10^(-(3.4*LD + 88.4*LD^2.3));
  algorithm
    data.diameter_a := diameter;
    data.diameter_b := diameter;
    data.zeta1 := ((1 - D_rel) + 0.707*(1 - D_rel)^0.375)^2*(1/D_rel)^2;
    data.zeta2 := k*(1 - D_rel)^0.75 + (1 - D_rel)^2 + 2*sqrt(k*(1 -
      D_rel)^0.375) + (1 - D_rel);
    data.Re_turbulent := 1e4;
    data.D_Re := leastDiameter;
    data.zeta1_at_a := true;
    data.zeta2_at_a := false;
    data.zetaLaminarKnown := false;
    data.c0 := 0;
  end sharpEdgedOrifice;

end LossFactorData;
```

## Fittings.BaseClasses.QuadraticTurbulent.massFlowRate_dp

**Return mass flow rate from constant loss factor data and pressure drop (m_flow = f(dp))**

### Information

Compute mass flow rate from constant loss factor and pressure drop (m_flow = f(dp)). For small pressure drops (dp < dp_small), the characteristic is approximated by a polynomial in order to have a finite derivative at zero mass flow rate.

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure drop (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| LossFactorData | data | Constant loss factors for both flow directions |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small [Pa] |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Fittings.BaseClasses.QuadraticTurbulent.massFlowRate_dp_and_Re

**Return mass flow rate from constant loss factor data, pressure drop and Re (m_flow = f(dp))**

### Information

Compute mass flow rate from constant loss factor and pressure drop (m_flow = f(dp)). If the Reynolds-number Re ≥ data.Re_turbulent, the flow is treated as a turbulent flow with constant loss factor zeta. If the Reynolds-number Re < data.Re_turbulent, the flow is laminar and/or in a transition region between laminar and turbulent. This region is approximated by two polynomials of third order, one polynomial for m_flow ≥ 0 and one for m_flow < 0. The common derivative of the two polynomials at Re = 0 is computed from the equation "data.c0/Re".

If no data for c0 is available, the derivative at Re = 0 is computed in such a way, that the second derivatives of the two polynomials are identical at Re = 0. The polynomials are constructed, such that they smoothly touch the characteristic curves in the turbulent regions. The whole characteristic is therefore **continuous** and has a **finite**, **continuous first derivative everywhere**. In some cases, the constructed polynomials would "vibrate". This is avoided by reducing the derivative at Re=0 in such a way that the polynomials are guaranteed to be monotonically increasing. The used sufficient criteria for monotonicity follows from:

Fritsch F.N. and Carlson R.E. (1980):
**Monotone piecewise cubic interpolation**. SIAM J. Numerc. Anal., Vol. 17, No. 2, April 1980, pp. 238-246

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure drop (dp = port_a.p - port_b.p) [Pa] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b [Pa.s] |
| LossFactorData | data | Constant loss factors for both flow directions |

### Outputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

---

## Fittings.BaseClasses.QuadraticTurbulent.pressureLoss_m_flow

**Return pressure drop from constant loss factor and mass flow rate (dp = f(m_flow))**

### Information

Compute pressure drop from constant loss factor and mass flow rate (dp = f(m_flow)). For small mass flow rates(|m_flow| < m_flow_small), the characteristic is approximated by a polynomial in order to have a finite derivative at zero mass flow rate.

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |

| | | |
|---|---|---|
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| LossFactorData | data | Constant loss factors for both flow directions |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure drop (dp = port_a.p - port_b.p) [Pa] |

## Fittings.BaseClasses.QuadraticTurbulent.pressureLoss_m_flow_and_Re

**Return pressure drop from constant loss factor, mass flow rate and Re (dp = f(m_flow))**

### Information

Compute pressure drop from constant loss factor and mass flow rate (dp = f(m_flow)). If the Reynolds-number Re $\geq$ data.Re_turbulent, the flow is treated as a turbulent flow with constant loss factor zeta. If the Reynolds-number Re < data.Re_turbulent, the flow is laminar and/or in a transition region between laminar and turbulent. This region is approximated by two polynomials of third order, one polynomial for m_flow $\geq 0$ and one for m_flow $< 0$. The common derivative of the two polynomials at Re = 0 is computed from the equation "data.c0/Re".

If no data for c0 is available, the derivative at Re = 0 is computed in such a way, that the second derivatives of the two polynomials are identical at Re = 0. The polynomials are constructed, such that they smoothly touch the characteristic curves in the turbulent regions. The whole characteristic is therefore **continuous** and has a **finite**, **continuous first derivative everywhere**. In some cases, the constructed polynomials would "vibrate". This is avoided by reducing the derivative at Re=0 in such a way that the polynomials are guaranteed to be monotonically increasing. The used sufficient criteria for monotonicity follows from:

Fritsch F.N. and Carlson R.E. (1980):
> **Monotone piecewise cubic interpolation**. SIAM J. Numerc. Anal., Vol. 17, No. 2, April 1980, pp. 238-246

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a | Density at port_a [kg/m3] |
| Density | rho_b | Density at port_b [kg/m3] |
| DynamicViscosity | mu_a | Dynamic viscosity at port_a [Pa.s] |
| DynamicViscosity | mu_b | Dynamic viscosity at port_b [Pa.s] |
| LossFactorData | data | Constant loss factors for both flow directions |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure drop (dp = port_a.p - port_b.p) [Pa] |

## Fittings.BaseClasses.QuadraticTurbulent.BaseModel

**Generic pressure drop component with constant turbulent loss factor data and without an icon**

### Information

This model computes the pressure loss of a pipe segment (orifice, bending etc.) with a minimum amount of data provided via parameter **data**. If available, data should be provided for **both flow directions**, i.e., flow from port_a to port_b and from port_b to port_a, as well as for the **laminar** and the **turbulent** region. It is also an option to provide the loss factor **only** for the **turbulent** region for a flow from port_a to port_b.

The following equations are used:

```
   Δp = 0.5*ζ*ρ*v*|v|
      = 0.5*ζ/A^2 * (1/ρ) * m_flow*|m_flow|
        Re = |v|*D*ρ/μ
```

| flow type | ζ = | flow region |
|---|---|---|
| turbulent | **zeta1** = const. | Re ≥ Re_turbulent, v ≥ 0 |
| | **zeta2** = const. | Re ≥ Re_turbulent, v < 0 |
| laminar | **c0**/Re | both flow directions, Re small; c0 = const. |

where

- Δp is the pressure drop: Δp = port_a.p - port_b.p
- v is the mean velocity.
- ρ is the density.
- ζ is the loss factor that depends on the geometry of the pipe. In the turbulent flow regime, it is assumed that ζ is constant and is given by "zeta1" and "zeta2" depending on the flow direction. When the Reynolds number Re is below "Re_turbulent", the flow is laminar for small flow velocities. For higher velocities there is a transition region from laminar to turbulent flow. The loss factor for laminar flow at small velocities is defined by the often occuring approximation c0/Re. If c0 is different for the two flow directions, the mean value has to be used (c0 = (c0_ab + c0_ba)/2).
- 
- The equation "Δp = 0.5*ζ*ρ*v*|v|" is either with respect to port_a or to port_b, depending on the definition of the particular loss factor ζ (in some references loss factors are defined with respect to port_a, in other references with respect to port_b).
- Re = |v|*D_Re*ρ/μ = |m_flow|*D_Re/(A_Re*μ) is the Reynolds number at the smallest cross section area. This is often at port_a or at port_b, but can also be between the two ports. In the record, the diameter D_Re of this smallest cross section area has to be provided, as well, as Re_turbulent, the absolute value of the Reynolds number at which the turbulent flow starts. If Re_turbulent is different for the two flow directions, use the smaller value as Re_turbulent.
- D is the diameter of the pipe. If the pipe has not a circular cross section, D = 4*A/P, where A is the cross section area and P is the wetted perimeter.
- A is the cross section area with A = π(D/2)^2.
- μ is the dynamic viscosity.

The laminar and the transition region is usually of not much technical interest because the operating point is mostly in the turbulent regime. For simplification and for numercial reasons, this whole region is described by two polynomials of third order, one polynomial for m_flow ≥ 0 and one for m_flow < 0. The polynomials start at Re = |m_flow|*4/(π*D_Re*μ), where D_Re is the smallest diameter between port_a and port_b. The common derivative of the two polynomials at Re = 0 is computed from the equation "c0/Re". Note, the pressure drop equation above in the laminar region is always defined with respect to the smallest diameter D_Re.

If no data for c0 is available, the derivative at Re = 0 is computed in such a way, that the second derivatives of the two polynomials are identical at Re = 0. The polynomials are constructed, such that they smoothly touch the characteristic curves in the turbulent regions. The whole characteristic is therefore **continuous** and has a **finite**, **continuous first derivative everywhere**. In some cases, the constructed polynomials would "vibrate". This is avoided by reducing the derivative at Re=0 in such a way that the polynomials are guaranteed to be monotonically increasing. The used sufficient criteria for monotonicity follows from:

Fritsch F.N. and Carlson R.E. (1980):
: **Monotone piecewise cubic interpolation**. SIAM J. Numerc. Anal., Vol. 17, No. 2, April 1980, pp. 238-246

Extends from Interfaces.PartialTwoPortTransport (Partial element transporting fluid between two ports without storage of mass or energy), Interfaces.PartialLumpedFlow (Base class for a lumped momentum balance).

### Parameters

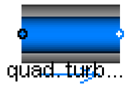
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Length | pathLength | Length flow path [m] |
| LossFactorData | data | Loss factor data |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Dynamics | | |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Boolean | from_dp | = true, use m_flow = f(dp) else dp = f(m_flow) |
| Boolean | use_Re | = true, if turbulent region is defined by Re, otherwise by dp_small or m_flow_small |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |
| Boolean | show_Re | = true, if Reynolds number is included for plotting |

### Connectors

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

## Fittings.BaseClasses.QuadraticTurbulent.TestWallFriction




**Pressure drop in pipe due to wall friction (only for test purposes; if needed use Pipes.StaticPipe instead)**

### Information

Extends from BaseModel (Generic pressure drop component with constant turbulent loss factor data and without an icon).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| LossFactorData | data | Loss factor data |
| Length | length | Length of pipe [m] |
| Diameter | diameter | Inner diameter of pipe [m] |
| Length | roughness | Absolute roughness of pipe (> 0 required, details see info layer) [m] |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Boolean | from_dp | = true, use m_flow = f(dp) else dp = f(m_flow) |
| Boolean | use_Re | = true, if turbulent region is defined by Re, otherwise by dp_small or m_flow_small |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |
| Boolean | show_Re | = true, if Reynolds number is included for plotting |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

## Fittings.BaseClasses.QuadraticTurbulent.BaseModelNonconstantCrossSectionArea

**Generic pressure drop component with constant turbulent loss factor data and without an icon, for non-constant cross section area**

## Information

This model computes the pressure loss of a pipe segment (orifice, bending etc.) with a minimum amount of data provided via parameter **data**. If available, data should be provided for **both flow directions**, i.e., flow from port_a to port_b and from port_b to port_a, as well as for the **laminar** and the **turbulent** region. It is also an option to provide the loss factor **only** for the **turbulent** region for a flow from port_a to port_b.

The following equations are used:

```
   Δp = 0.5*ζ*ρ*v*|v|
      = 0.5*ζ/A^2 * (1/ρ) * m_flow*|m_flow|
        Re = |v|*D*ρ/μ
```

| flow type | ζ = | flow region |
|---|---|---|
| turbulent | **zeta1** = const. | Re ≥ Re_turbulent, v ≥ 0 |
| | **zeta2** = const. | Re ≥ Re_turbulent, v < 0 |
| laminar | **c0**/Re | both flow directions, Re small; c0 = const. |

where

- Δp is the pressure drop: Δp = port_a.p - port_b.p
- v is the mean velocity.
- ρ is the density.
- ζ is the loss factor that depends on the geometry of the pipe. In the turbulent flow regime, it is assumed that ζ is constant and is given by "zeta1" and "zeta2" depending on the flow direction. When the Reynolds number Re is below "Re_turbulent", the flow is laminar for small flow velocities. For higher velocities there is a transition region from laminar to turbulent flow. The loss factor for laminar flow at small velocities is defined by the often occuring approximation c0/Re. If c0 is different for the two flow directions, the mean value has to be used (c0 = (c0_ab + c0_ba)/2).
- 
- The equation "Δp = 0.5*ζ*ρ*v*|v|" is either with respect to port_a or to port_b, depending on the definition of the particular loss factor ζ (in some references loss factors are defined with respect to port_a, in other references with respect to port_b).
- Re = |v|*D_Re*ρ/μ = |m_flow|*D_Re/(A_Re*μ) is the Reynolds number at the smallest cross section area. This is often at port_a or at port_b, but can also be between the two ports. In the record, the diameter D_Re of this smallest cross section area has to be provided, as well, as Re_turbulent, the absolute value of the Reynolds number at which the turbulent flow starts. If Re_turbulent is different for the two flow directions, use the smaller value as Re_turbulent.
- D is the diameter of the pipe. If the pipe has not a circular cross section, D = 4*A/P, where A is the cross section area and P is the wetted perimeter.
- A is the cross section area with A = π(D/2)^2.
- μ is the dynamic viscosity.

The laminar and the transition region is usually of not much technical interest because the operating point is mostly in the turbulent regime. For simplification and for numercial reasons, this whole region is described by two polynomials of third order, one polynomial for m_flow ≥ 0 and one for m_flow < 0. The polynomials start at Re = |m_flow|*4/(π*D_Re*μ), where D_Re is the smallest diameter between port_a and port_b. The common derivative of the two polynomials at Re = 0 is computed from the equation "c0/Re". Note, the pressure drop equation above in the laminar region is always defined with respect to the smallest diameter D_Re.

If no data for c0 is available, the derivative at Re = 0 is computed in such a way, that the second derivatives of the two polynomials are identical at Re = 0. The polynomials are constructed, such that they smoothly touch the characteristic curves in the turbulent regions. The whole characteristic is therefore **continuous** and has a **finite**, **continuous first derivative everywhere**. In some cases, the constructed polynomials would "vibrate". This is avoided by reducing the derivative at Re=0 in such a way that the polynomials are guaranteed to be monotonically increasing. The used sufficient criteria for monotonicity follows from:

Fritsch F.N. and Carlson R.E. (1980):

> **Monotone piecewise cubic interpolation**. SIAM J. Numerc. Anal., Vol. 17, No. 2, April 1980, pp. 238-246

Extends from Interfaces.PartialTwoPortTransport (Partial element transporting fluid between two ports without storage of mass or energy), Interfaces.PartialLumpedFlow (Base class for a lumped momentum balance).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Length | pathLength | Length flow path [m] |
| LossFactorData | data | Loss factor data |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| Dynamics | | |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| AbsolutePressure | dp_small | Turbulent flow if \|dp\| >= dp_small [Pa] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |
| Boolean | show_Re | = true, if Reynolds number is included for plotting |
| Boolean | show_totalPressures | = true, if total pressures are included for plotting |
| Boolean | show_portVelocities | = true, if port velocities are included for plotting |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

---

### Fittings.BaseClasses.QuadraticTurbulent.pressureLoss_m_flow_totalPressure

**Return pressure drop from constant loss factor and mass flow rate (dp = f(m_flow))**

### Information

Compute pressure drop from constant loss factor and mass flow rate (dp = f(m_flow)). For small mass flow rates(|m_flow| < m_flow_small), the characteristic is approximated by a polynomial in order to have a finite derivative at zero mass flow rate.

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

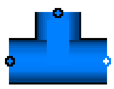
| Type | Name | Description |
|---|---|---|
| MassFlowRate | m_flow | Mass flow rate from port_a to port_b [kg/s] |
| Density | rho_a_des | Density at port_a, mass flow in design direction a -> b [kg/m3] |
| Density | rho_b_des | Density at port_b, mass flow in design direction a -> b [kg/m3] |
| Density | rho_b_nondes | Density at port_b, mass flow against design direction a <- b [kg/m3] |
| Density | rho_a_nondes | Density at port_a, mass flow against design direction a <- b [kg/m3] |
| LossFactorData | data | Constant loss factors for both flow directions |
| MassFlowRate | m_flow_small | Turbulent flow if \|m_flow\| >= m_flow_small [kg/s] |

### Outputs

| Type | Name | Description |
|---|---|---|
| Pressure | dp | Pressure drop (dp = port_a.p - port_b.p) [Pa] |

---

## Fittings.BaseClasses.PartialTeeJunction



**Base class for a splitting/joining component with three ports**

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_1 | |
| FluidPort_b | port_2 | |
| FluidPort_a | port_3 | |

---

## Modelica_Fluid.Sources

**Define fixed or prescribed boundary conditions**

### Information

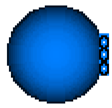
Package **Sources** contains generic sources for fluid connectors to define fixed or prescribed ambient conditions.

Extends from Icons.VariantLibrary (Icon for a library that contains several variants of one component).

## Package Content

| Name | Description |
|---|---|
| FixedBoundary | Boundary source component |
| Boundary_pT | Boundary with prescribed pressure, temperature, composition and trace substances |
| Boundary_ph | Boundary with prescribed pressure, specific enthalpy, composition and trace substances |
| MassFlowSource_T | Ideal flow source that produces a prescribed mass flow with prescribed temperature, mass fraction and trace substances |
| MassFlowSource_h | Ideal flow source that produces a prescribed mass flow with prescribed specific enthalpy, mass fraction and trace substances |
| BaseClasses | Base classes used in the Sources package (only of interest to build new component models) |

## Sources.FixedBoundary



**Boundary source component**

### Information

Model **FixedBoundary** defines constant values for boundary conditions:

- Boundary pressure or boundary density.
- Boundary temperature or boundary specific enthalpy.
- Boundary composition (only for multi-substance or trace-substance flow).

Note, that boundary temperature, density, specific enthalpy, mass fractions and trace substances have only an effect if the mass flow is from the Boundary into the port. If mass is flowing from the port into the boundary, the boundary definitions, with exception of boundary pressure, do not have an effect.

Extends from Sources.BaseClasses.PartialSource (Partial component source with one fluid connector).

### Parameters

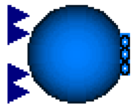
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium model within the source |
| Boundary pressure or Boundary density | | |
| Boolean | use_p | select p or d |
| AbsolutePressure | p | Boundary pressure [Pa] |
| Density | d | Boundary density [kg/m3] |
| Boundary temperature or Boundary specific enthalpy | | |
| Boolean | use_T | select T or h |
| Temperature | T | Boundary temperature [K] |
| SpecificEnthalpy | h | Boundary specific enthalpy [J/kg] |
| Only for multi-substance flow | | |
| MassFraction | X[Medium.nX] | Boundary mass fractions m_i/m [kg/kg] |
| Only for trace-substance flow | | |

| | | |
|---|---|---|
| ExtraProperty | C[Medium.nC] | Boundary trace substances |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPorts_b | ports[nPorts] | |

## Sources.Boundary_pT



**Boundary with prescribed pressure, temperature, composition and trace substances**

### Information

Defines prescribed values for boundary conditions:

- Prescribed boundary pressure.
- Prescribed boundary temperature.
- Boundary composition (only for multi-substance or trace-substance flow).

If `use_p_in` is false (default option), the `p` parameter is used as boundary pressure, and the `p_in` input connector is disabled; if `use_p_in` is true, then the `p` parameter is ignored, and the value provided by the input connector is used instead.

The same thing goes for the temperature, composition and trace substances.

Note, that boundary temperature, mass fractions and trace substances have only an effect if the mass flow is from the boundary into the port. If mass is flowing from the port into the boundary, the boundary definitions, with exception of boundary pressure, do not have an effect.

Extends from Sources.BaseClasses.PartialSource (Partial component source with one fluid connector).

### Parameters

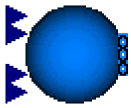
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium model within the source |
| Boolean | use_p_in | Get the pressure from the input connector |
| Boolean | use_T_in | Get the temperature from the input connector |
| Boolean | use_X_in | Get the composition from the input connector |
| Boolean | use_C_in | Get the trace substances from the input connector |
| AbsolutePressure | p | Fixed value of pressure [Pa] |
| Temperature | T | Fixed value of temperature [K] |
| MassFraction | X[Medium.nX] | Fixed value of composition [kg/kg] |
| ExtraProperty | C[Medium.nC] | Fixed values of trace substances |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPorts_b | ports[nPorts] | |
| input RealInput | p_in | Prescribed boundary pressure |
| input RealInput | T_in | Prescribed boundary temperature |

| | | |
|---|---|---|
| input RealInput | X_in[Medium.nX] | Prescribed boundary composition |
| input RealInput | C_in[Medium.nC] | Prescribed boundary trace substances |

## Sources.Boundary_ph



**Boundary with prescribed pressure, specific enthalpy, composition and trace substances**

### Information

Defines prescribed values for boundary conditions:

- Prescribed boundary pressure.
- Prescribed boundary temperature.
- Boundary composition (only for multi-substance or trace-substance flow).

If `use_p_in` is false (default option), the `p` parameter is used as boundary pressure, and the `p_in` input connector is disabled; if `use_p_in` is true, then the `p` parameter is ignored, and the value provided by the input connector is used instead.

The same thing goes for the specific enthalpy and composition

Note, that boundary temperature, mass fractions and trace substances have only an effect if the mass flow is from the boundary into the port. If mass is flowing from the port into the boundary, the boundary definitions, with exception of boundary pressure, do not have an effect.

Extends from Sources.BaseClasses.PartialSource (Partial component source with one fluid connector).

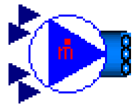
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium model within the source |
| Boolean | use_p_in | Get the pressure from the input connector |
| Boolean | use_h_in | Get the specific enthalpy from the input connector |
| Boolean | use_X_in | Get the composition from the input connector |
| Boolean | use_C_in | Get the trace substances from the input connector |
| AbsolutePressure | p | Fixed value of pressure [Pa] |
| SpecificEnthalpy | h | Fixed value of specific enthalpy [J/kg] |
| MassFraction | X[Medium.nX] | Fixed value of composition [kg/kg] |
| ExtraProperty | C[Medium.nC] | Fixed values of trace substances |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPorts_b | ports[nPorts] | |
| input RealInput | p_in | Prescribed boundary pressure |
| input RealInput | h_in | Prescribed boundary specific enthalpy |
| input RealInput | X_in[Medium.nX] | Prescribed boundary composition |
| input RealInput | C_in[Medium.nC] | Prescribed boundary trace substances |

## Sources.MassFlowSource_T



**Ideal flow source that produces a prescribed mass flow with prescribed temperature, mass fraction and trace substances**

### Information

Models an ideal flow source, with prescribed values of flow rate, temperature, composition and trace substances:

- Prescribed mass flow rate.
- Prescribed temperature.
- Boundary composition (only for multi-substance or trace-substance flow).

If `use_m_flow_in` is false (default option), the `m_flow` parameter is used as boundary pressure, and the `m_flow_in` input connector is disabled; if `use_m_flow_in` is true, then the `m_flow` parameter is ignored, and the value provided by the input connector is used instead.

The same thing goes for the temperature and composition

Note, that boundary temperature, mass fractions and trace substances have only an effect if the mass flow is from the boundary into the port. If mass is flowing from the port into the boundary, the boundary definitions, with exception of boundary flow rate, do not have an effect.

Extends from Sources.BaseClasses.PartialSource (Partial component source with one fluid connector).

### Parameters

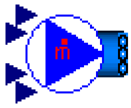
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium model within the source |
| Boolean | use_m_flow_in | Get the mass flow rate from the input connector |
| Boolean | use_T_in | Get the temperature from the input connector |
| Boolean | use_X_in | Get the composition from the input connector |
| Boolean | use_C_in | Get the trace substances from the input connector |
| MassFlowRate | m_flow | Fixed mass flow rate going out of the fluid port [kg/s] |
| Temperature | T | Fixed value of temperature [K] |
| MassFraction | X[Medium.nX] | Fixed value of composition [kg/kg] |
| ExtraProperty | C[Medium.nC] | Fixed values of trace substances |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPorts_b | ports[nPorts] | |
| input RealInput | m_flow_in | Prescribed mass flow rate |
| input RealInput | T_in | Prescribed fluid temperature |
| input RealInput | X_in[Medium.nX] | Prescribed fluid composition |
| input RealInput | C_in[Medium.nC] | Prescribed boundary trace substances |

## Sources.MassFlowSource_h

**Ideal flow source that produces a prescribed mass flow with prescribed specific enthalpy, mass fraction and trace substances**



### Information

Models an ideal flow source, with prescribed values of flow rate, temperature and composition:

- Prescribed mass flow rate.
- Prescribed specific enthalpy.
- Boundary composition (only for multi-substance or trace-substance flow).

If `use_m_flow_in` is false (default option), the `m_flow` parameter is used as boundary pressure, and the `m_flow_in` input connector is disabled; if `use_m_flow_in` is true, then the `m_flow` parameter is ignored, and the value provided by the input connector is used instead.

The same thing goes for the temperature and composition

Note, that boundary temperature, mass fractions and trace substances have only an effect if the mass flow is from the boundary into the port. If mass is flowing from the port into the boundary, the boundary definitions, with exception of boundary flow rate, do not have an effect.

Extends from Sources.BaseClasses.PartialSource (Partial component source with one fluid connector).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium model within the source |
| Boolean | use_m_flow_in | Get the mass flow rate from the input connector |
| Boolean | use_h_in | Get the specific enthalpy from the input connector |
| Boolean | use_X_in | Get the composition from the input connector |
| Boolean | use_C_in | Get the trace substances from the input connector |
| MassFlowRate | m_flow | Fixed mass flow rate going out of the fluid port [kg/s] |
| SpecificEnthalpy | h | Fixed value of specific enthalpy [J/kg] |
| MassFraction | X[Medium.nX] | Fixed value of composition [kg/kg] |
| ExtraProperty | C[Medium.nC] | Fixed values of trace substances |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPorts_b | ports[nPorts] | |
| input RealInput | m_flow_in | Prescribed mass flow rate |
| input RealInput | h_in | Prescribed fluid specific enthalpy |
| input RealInput | X_in[Medium.nX] | Prescribed fluid composition |
| input RealInput | C_in[Medium.nC] | Prescribed boundary trace substances |

## Sources.BaseClasses

**Base classes used in the Sources package (only of interest to build new component models)**

### Package Content

| Name | Description |
|---|---|
| PartialSource | Partial component source with one fluid connector |

## Sources.BaseClasses.PartialSource

**Partial component source with one fluid connector**

### Information

Partial component to model the **volume interface** of a **source** component, such as a mass flow source. The essential features are:

- The pressure in the connection port (= ports.p) is identical to the pressure in the volume.
- The outflow enthalpy rate (= port.h_outflow) and the composition of the substances (= port.Xi_outflow) are identical to the respective values in the volume.

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPorts_b | ports[nPorts] | |

## Modelica_Fluid.Sensors

**Ideal sensor components to extract signals from a fluid connector**

### Information

Package **Sensors** consists of idealized sensor components that provide variables of a medium model and/or fluid ports as output signals. These signals can be, e.g., further processed with components of the Modelica.Blocks library. Also more realistic sensor models can be built, by further processing (e.g., by attaching block Modelica.Blocks.FirstOrder to model the time constant of the sensor).

For the thermodynamic state variables temperature, specific entalpy, specific entropy and density the fluid library provides two different types of sensors: **regular one port** and **two port** sensors.

- The **regular one port** sensors have the advantage of easy introduction and removal from a model, as no connections have to be broken. A potential drawback is that the obtained value jumps as flow reverts. Test.TestComponents.Sensors.TestTemperatureSensor provides a test case, which demonstrates this.
- The **two port** sensors offer the advantages of an adjustable regularized step function around zero flow. Moreover the obtained result is restricted to the value flowing into port_a if allowFlowReversal is false.

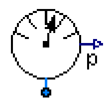
Extends from Icons.VariantLibrary (Icon for a library that contains several variants of one component).

### Package Content

| Name | Description |
|---|---|
| Pressure | Ideal pressure sensor |
| Density | Ideal one port density sensor |
| DensityTwoPort | Ideal two port density sensor |
| Temperature | Ideal one port temperature sensor |
| TemperatureTwoPort | Ideal two port temperature sensor |
| SpecificEnthalpy | Ideal one port specific enthalpy sensor |
| SpecificEnthalpyTwoPort | Ideal two port sensor for the specific enthalpy |
| SpecificEntropy | Ideal one port specific entropy sensor |
| SpecificEntropyTwoPort | Ideal two port sensor for the specific entropy |
| TraceSubstances | Ideal one port trace substances sensor |
| TraceSubstancesTwoPort | Ideal two port sensor for trace substance |
| MassFlowRate | Ideal sensor for mass flow rate |
| VolumeFlowRate | Ideal sensor for volume flow rate |
| RelativePressure | Ideal relative pressure sensor |
| RelativeTemperature | Ideal relative temperature sensor |
| BaseClasses | Base classes used in the Sensors package (only of interest to build new component models) |

## Sensors.Pressure

**Ideal pressure sensor**




### Information

This component monitors the absolute pressure at its fluid port. The sensor is ideal, i.e., it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialAbsoluteSensor (Partial component to model a sensor that measures a potential variable), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | Medium in the sensor |

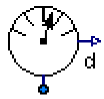
### Connectors

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| FluidPort_a | port | |
| output RealOutput | p | Pressure at port [Pa] |

## Sensors.Density

**Ideal one port density sensor**




### Information

This component monitors the density of the fluid passing its port. The sensor is ideal, i.e. it does not influence the fluid.

If using the one port sensor please read the Information first.

Extends from Sensors.BaseClasses.PartialAbsoluteSensor (Partial component to model a sensor that measures a potential variable), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

### Parameters

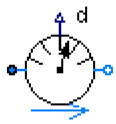
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the sensor |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port | |
| output RealOutput | d | Density in port medium [kg/m3] |

## Sensors.DensityTwoPort

**Ideal two port density sensor**




### Information

This component monitors the density of the fluid flowing from port_a to port_b. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialFlowSensor (Partial component to model sensors that measure flow properties), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

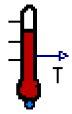
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| MassFlowRate | m_flow_small | For bi-directional flow, density is regularized in the region \|m_flow\| < m_flow_small (m_flow_small > 0 required) [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| output RealOutput | d | Density of the passing fluid [kg/m3] |

## Sensors.Temperature




**Ideal one port temperature sensor**

### Information

This component monitors the temperature of the fluid passing its port. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialAbsoluteSensor (Partial component to model a sensor that measures a potential variable).

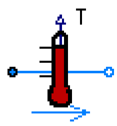
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | Medium in the sensor |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port | |
| output RealOutput | T | Temperature in port medium [K] |

## Sensors.TemperatureTwoPort




**Ideal two port temperature sensor**

### Information

This component monitors the temperature of the passing fluid. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialFlowSensor (Partial component to model sensors that measure flow properties).

### Parameters

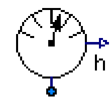
| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | Medium in the component |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| MassFlowRate | m_flow_small | For bi-directional flow, temperature is regularized in the region \|m_flow\| < |

| | | |
|---|---|---|
| | | m_flow_small (m_flow_small > 0 required) [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| output RealOutput | T | Temperature of the passing fluid [K] |

## Sensors.SpecificEnthalpy




**Ideal one port specific enthalpy sensor**

### Information

This component monitors the specific enthalpy of the fluid passing its port. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialAbsoluteSensor (Partial component to model a sensor that measures a potential variable), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

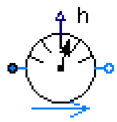
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the sensor |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port | |
| output RealOutput | h_out | Specific enthalpy in port medium [J/kg] |

## Sensors.SpecificEnthalpyTwoPort




**Ideal two port sensor for the specific enthalpy**

### Information

This component monitors the specific enthalpy of a passing fluid. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialFlowSensor (Partial component to model sensors that measure flow properties), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

### Parameters

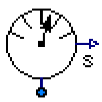
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |

| Advanced | | |
|---|---|---|
| MassFlowRate | m_flow_small | For bi-directional flow, specific enthalpy is regularized in the region \|m_flow\| < m_flow_small (m_flow_small > 0 required) [kg/s] |

#### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| output RealOutput | h_out | Specific enthalpy of the passing fluid [J/kg] |

### Sensors.SpecificEntropy



**Ideal one port specific entropy sensor**

#### Information

This component monitors the specific entropy of the fluid passing its port. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialAbsoluteSensor (Partial component to model a sensor that measures a potential variable), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

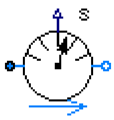
#### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the sensor |

#### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port | |
| output RealOutput | s | Specific entropy in port medium [J/(kg.K)] |

### Sensors.SpecificEntropyTwoPort



**Ideal two port sensor for the specific entropy**

#### Information

This component monitors the specific entropy of the passing fluid. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialFlowSensor (Partial component to model sensors that measure flow properties), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

#### Parameters

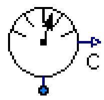
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| **Assumptions** | | |

<table>
<tr><td>Boolean</td><td>allowFlowReversal</td><td>= true to allow flow reversal, false restricts to design direction (port_a -> port_b)</td></tr>
<tr><td colspan="3">Advanced</td></tr>
<tr><td>MassFlowRate</td><td>m_flow_small</td><td>For bi-directional flow, specific entropy is regularized in the region |m_flow| < m_flow_small (m_flow_small > 0 required) [kg/s]</td></tr>
</table>

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| output RealOutput | s | Specific entropy of the passing fluid [J/(kg.K)] |

## Sensors.TraceSubstances




**Ideal one port trace substances sensor**

### Information

This component monitors the trace substances contained in the fluid passing its port. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialAbsoluteSensor (Partial component to model a sensor that measures a potential variable), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

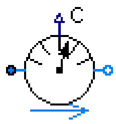
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the sensor |
| String | substanceName | Name of trace substance |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port | |
| output RealOutput | C | Trace substance in port medium |

## Sensors.TraceSubstancesTwoPort




**Ideal two port sensor for trace substance**

### Information

This component monitors the trace substance of the passing fluid. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialFlowSensor (Partial component to model sensors that measure flow properties), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

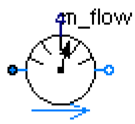
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| String | substanceName | Name of trace substance |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| MassFlowRate | m_flow_small | For bi-directional flow, trace substance is regularized in the region \|m_flow\| < m_flow_small (m_flow_small > 0 required) [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| output RealOutput | C | Trace substance of the passing fluid |

## Sensors.MassFlowRate




**Ideal sensor for mass flow rate**

### Information

This component monitors the mass flow rate flowing from port_a to port_b. The sensor is ideal, i.e., it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialFlowSensor (Partial component to model sensors that measure flow properties), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

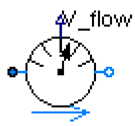
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| output RealOutput | m_flow | Mass flow rate from port_a to port_b [kg/s] |

## Sensors.VolumeFlowRate




**Ideal sensor for volume flow rate**

### Information

This component monitors the volume flow rate flowing from port_a to port_b. The sensor is ideal, i.e. it does not influence the fluid.

Extends from Sensors.BaseClasses.PartialFlowSensor (Partial component to model sensors that measure flow properties), Modelica.Icons.RotationalSensor (Icon representing rotational measurement device).

### Parameters

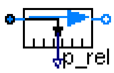
| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| MassFlowRate | m_flow_small | For bi-directional flow, density is regularized in the region \|m_flow\| < m_flow_small (m_flow_small > 0 required) [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |
| output RealOutput | V_flow | Volume flow rate from port_a to port_b [m3/s] |

## Sensors.RelativePressure

**Ideal relative pressure sensor**




### Information

The relative pressure "port_a.p - port_b.p" is determined between the two ports of this component and is provided as output signal. The sensor should be connected in parallel with other equipment, no flow through the sensor is allowed.

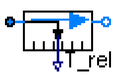
Extends from Modelica.Icons.TranslationalSensor (Icon representing translational measurement device).

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | |
| FluidPort_b | port_b | |
| output RealOutput | p_rel | Relative pressure signal [Pa] |

## Sensors.RelativeTemperature

**Ideal relative temperature sensor**



### Information

The relative temperature "T(port_a) - T(port_b)" is determined between the two ports of this component and is provided as output signal. The sensor should be connected in parallel with other equipment, no flow through the sensor is allowed.

Extends from Modelica.Icons.TranslationalSensor (Icon representing translational measurement device).

### Connectors

| Type | Name | Description |
| --- | --- | --- |
| FluidPort_a | port_a | |
| FluidPort_b | port_b | |
| output RealOutput | T_rel | Relative temperature signal [K] |

---

## Sensors.BaseClasses

**Base classes used in the Sensors package (only of interest to build new component models)**

### Package Content

| Name | Description |
| --- | --- |
| PartialAbsoluteSensor | Partial component to model a sensor that measures a potential variable |
| PartialFlowSensor | Partial component to model sensors that measure flow properties |

---

## Sensors.BaseClasses.PartialAbsoluteSensor

**Partial component to model a sensor that measures a potential variable**

### Information

Partial component to model an **absolute sensor**. Can be used for pressure sensor models. Use for other properties such as temperature or density is discouraged, because the enthalpy at the connector can have different meanings, depending on the connection topology. Use `PartialFlowSensor` instead. as signal.

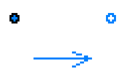
### Connectors

| Type | Name | Description |
| --- | --- | --- |
| FluidPort_a | port | |

---

## Sensors.BaseClasses.PartialFlowSensor

**Partial component to model sensors that measure flow properties**



### Information

Partial component to model a **sensor** that measures any intensive properties of a flow, e.g., to get temperature or density in the flow between fluid connectors.

The model includes zero-volume balance equations. Sensor models inheriting from this partial class should add a medium instance to calculate the measured property.

Extends from Interfaces.PartialTwoPort (Partial component with two ports).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

## Modelica_Fluid.Interfaces

**Interfaces for steady state and unsteady, mixed-phase, multi-substance, incompressible and compressible flow**

### Information

Extends from Modelica.Icons.Library (Icon for library).

### Package Content

| Name | Description |
|---|---|
| FluidPort | Interface for quasi one-dimensional fluid flow in a piping network (incompressible or compressible, one or more phases, one or more substances) |
| FluidPort_a | Generic fluid connector at design inlet |
| FluidPort_b | Generic fluid connector at design outlet |
| FluidPorts_a | Fluid connector with filled, large icon to be used for vectors of FluidPorts (vector dimensions must be added after dragging) |
| FluidPorts_b | Fluid connector with outlined, large icon to be used for vectors of FluidPorts (vector dimensions must be added after dragging) |
| PartialTwoPort | Partial component with two ports |
| PartialTwoPortTransport | Partial element transporting fluid between two ports without storage of mass or energy |
| HeatPorts_a | HeatPort connector with filled, large icon to be used for vectors of HeatPorts (vector dimensions must be added after dragging) |
| HeatPorts_b | HeatPort connector with filled, large icon to be used for vectors of HeatPorts (vector dimensions must be added after dragging) |
| PartialHeatTransfer | Common interface for heat transfer models |

| | |
|---|---|
| PartialLumpedVolume | Lumped volume with mass and energy balance |
| PartialLumpedFlow | Base class for a lumped momentum balance |
| PartialDistributedVolume | Base class for distributed volume models |
| PartialDistributedFlow | Base class for a distributed momentum balance |

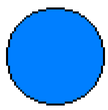
## Interfaces.FluidPort

**Interface for quasi one-dimensional fluid flow in a piping network (incompressible or compressible, one or more phases, one or more substances)**

### Contents

| Type | Name | Description |
|---|---|---|
| flow MassFlowRate | m_flow | Mass flow rate from the connection point into the component [kg/s] |
| AbsolutePressure | p | Thermodynamic pressure in the connection point [Pa] |
| stream SpecificEnthalpy | h_outflow | Specific thermodynamic enthalpy close to the connection point if m_flow < 0 [J/kg] |
| stream MassFraction | Xi_outflow[Medium.nXi] | Independent mixture mass fractions m_i/m close to the connection point if m_flow < 0 [kg/kg] |
| stream ExtraProperty | C_outflow[Medium.nC] | Properties c_i/m close to the connection point if m_flow < 0 |

## Interfaces.FluidPort_a



**Generic fluid connector at design inlet**

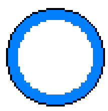
### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package | Medium | Medium model |

### Contents

| Type | Name | Description |
|---|---|---|
| flow MassFlowRate | m_flow | Mass flow rate from the connection point into the component [kg/s] |
| AbsolutePressure | p | Thermodynamic pressure in the connection point [Pa] |
| stream SpecificEnthalpy | h_outflow | Specific thermodynamic enthalpy close to the connection point if m_flow < 0 [J/kg] |
| stream MassFraction | Xi_outflow[Medium.nXi] | Independent mixture mass fractions m_i/m close to the connection point if m_flow < 0 [kg/kg] |
| stream ExtraProperty | C_outflow[Medium.nC] | Properties c_i/m close to the connection point if m_flow < 0 |

## Interfaces.FluidPort_b



**Generic fluid connector at design outlet**

### Parameters

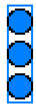
| Type | Name | Description |
|---|---|---|

| | |
|---|---|
| replaceable package Medium | Medium model |

### Contents

| Type | Name | Description |
|---|---|---|
| flow MassFlowRate | m_flow | Mass flow rate from the connection point into the component [kg/s] |
| AbsolutePressure | p | Thermodynamic pressure in the connection point [Pa] |
| stream SpecificEnthalpy | h_outflow | Specific thermodynamic enthalpy close to the connection point if m_flow < 0 [J/kg] |
| stream MassFraction | Xi_outflow[Medium.nXi] | Independent mixture mass fractions m_i/m close to the connection point if m_flow < 0 [kg/kg] |
| stream ExtraProperty | C_outflow[Medium.nC] | Properties c_i/m close to the connection point if m_flow < 0 |

## Interfaces.FluidPorts_a



**Fluid connector with filled, large icon to be used for vectors of FluidPorts (vector dimensions must be added after dragging)**

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium model |

### Contents

| Type | Name | Description |
|---|---|---|
| flow MassFlowRate | m_flow | Mass flow rate from the connection point into the component [kg/s] |
| AbsolutePressure | p | Thermodynamic pressure in the connection point [Pa] |
| stream SpecificEnthalpy | h_outflow | Specific thermodynamic enthalpy close to the connection point if m_flow < 0 [J/kg] |
| stream MassFraction | Xi_outflow[Medium.nXi] | Independent mixture mass fractions m_i/m close to the connection point if m_flow < 0 [kg/kg] |
| stream ExtraProperty | C_outflow[Medium.nC] | Properties c_i/m close to the connection point if m_flow < 0 |

## Interfaces.FluidPorts_b

**Fluid connector with outlined, large icon to be used for vectors of FluidPorts (vector dimensions must be added after dragging)**

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium model |

### Contents

| Type | Name | Description |
|---|---|---|
| flow MassFlowRate | m_flow | Mass flow rate from the connection point into the component [kg/s] |

| | | |
|---|---|---|
| AbsolutePressure | p | Thermodynamic pressure in the connection point [Pa] |
| stream SpecificEnthalpy | h_outflow | Specific thermodynamic enthalpy close to the connection point if m_flow < 0 [J/kg] |
| stream MassFraction | Xi_outflow[Medium.nXi] | Independent mixture mass fractions m_i/m close to the connection point if m_flow < 0 [kg/kg] |
| stream ExtraProperty | C_outflow[Medium.nC] | Properties c_i/m close to the connection point if m_flow < 0 |

## Interfaces.PartialTwoPort

**Partial component with two ports**

### Information

This partial model defines an interface for components with two ports. The treatment of the design flow direction and of flow reversal are predefined based on the parameter **`allowFlowReversal`**. The component may transport fluid and may have internal storage for a given fluid **`Medium`**.

An extending model providing direct access to internal storage of mass or energy through port_a or port_b should redefine the protected parameters **`port_a_exposesState`** and **`port_b_exposesState`** appropriately. This will be visualized at the port icons, in order to improve the understanding of fluid model diagrams.

### Parameters

| Type | Name | Description |
|---|---|---|
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

## Interfaces.PartialTwoPortTransport

**Partial element transporting fluid between two ports without storage of mass or energy**

### Information

This component transports fluid between its two ports, without storing mass or energy. Energy may be exchanged with the environment though, e.g. in the form of work. `PartialTwoPortTransport` is intended as base class for devices like orifices, valves and simple fluid machines.

Three equations need to be added by an extending class using this component:

- the momentum balance specifying the relationship between the pressure drop `dp` and the mass flow rate `m_flow`

  ,
- `port_b.h_outflow` for flow in design direction, and

- `port_a.h_outflow` for flow in reverse direction.

Extends from PartialTwoPort (Partial component with two ports).

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (port_a -> port_b) |
| **Advanced** | | |
| AbsolutePressure | dp_start | Guess value of dp = port_a.p - port_b.p [Pa] |
| MassFlowRate | m_flow_start | Guess value of m_flow = port_a.m_flow [kg/s] |
| MassFlowRate | m_flow_small | Small mass flow rate for regularization of zero flow [kg/s] |
| Diagnostics | | |
| Boolean | show_T | = true, if temperatures at port_a and port_b are computed |
| Boolean | show_V_flow | = true, if volume flow rate at inflowing port is computed |

### Connectors

| Type | Name | Description |
|---|---|---|
| FluidPort_a | port_a | Fluid connector a (positive design flow direction is from port_a to port_b) |
| FluidPort_b | port_b | Fluid connector b (positive design flow direction is from port_a to port_b) |

---

## Interfaces.HeatPorts_a

**HeatPort connector with filled, large icon to be used for vectors of HeatPorts (vector dimensions must be added after dragging)**

### Contents

| Type | Name | Description |
|---|---|---|
| Temperature | T | Port temperature [K] |
| flow HeatFlowRate | Q_flow | Heat flow rate (positive if flowing from outside into the component) [W] |

---

## Interfaces.HeatPorts_b

**HeatPort connector with filled, large icon to be used for vectors of HeatPorts (vector dimensions must be added after dragging)**

### Contents

| Type | Name | Description |
|---|---|---|
| Temperature | T | Port temperature [K] |
| flow HeatFlowRate | Q_flow | Heat flow rate (positive if flowing from outside into the component) [W] |

---

## Interfaces.PartialHeatTransfer

**Common interface for heat transfer models**

### Information

This component is a common interface for heat transfer models. The heat flow rates `Q_flows[n]` through the boundaries of n flow segments are obtained as function of the thermodynamic `states` of the flow segments for a given fluid `Medium`, the `surfaceAreas[n]` and the boundary temperatures `heatPorts[n].T`.

The heat loss coefficient `k` can be used to model a thermal isolation between `heatPorts.T` and `T_ambient`.

An extending model implementing this interface needs to define one equation: the relation between the predefined fluid temperatures `Ts[n]`, the boundary temperatures `heatPorts[n].T`, and the heat flow rates `Q_flows[n]`.

### Parameters

| Type | Name | Description |
|---|---|---|
| Ambient | | |
| CoefficientOfHeatTransfer | k | Heat transfer coefficient to ambient [W/(m2.K)] |
| Temperature | T_ambient | Ambient temperature [K] |
| **Internal Interface** | | |
| Integer | n | Number of heat transfer segments |
| Boolean | use_k | = true to use k value for thermal isolation |

### Connectors

| Type | Name | Description |
|---|---|---|
| HeatPorts_a | heatPorts[n] | Heat port to component boundary |

---

## Interfaces.PartialLumpedVolume

**Lumped volume with mass and energy balance**

### Information

Interface and base class for an ideally mixed fluid volume with the ability to store mass and energy. The following boundary flow and source terms are part of the energy balance and must be specified in an extending class:

- **`Qb_flow`**, e.g. convective or latent heat flow rate across segment boundary, and
- **`Wb_flow`**, work term, e.g. p*der(fluidVolume) if the volume is not constant.

The component volume **`fluidVolume`** is an input that needs to be set in the extending class to complete the model.

Further source terms must be defined by an extending class for fluid flow across the segment boundary:

- **`Hb_flow`**, enthalpy flow,
- **`mb_flow`**, mass flow,
- **`mbXi_flow`**, substance mass flow, and

- **mbC_flow**, trace substance mass flow.

### Parameters

| Type | Name | Description |
|---|---|---|
| **Assumptions** | | |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balance |
| Dynamics | massDynamics | Formulation of mass balance |
| **Initialization** | | |
| AbsolutePressure | p_start | Start value of pressure [Pa] |
| Boolean | use_T_start | = true, use T_start, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |

## Interfaces.PartialLumpedFlow

**Base class for a lumped momentum balance**

### Information

Interface and base class for a momentum balance, defining the mass flow rate **m_flow** of a given Medium in a flow model.

The following boundary flow and force terms are part of the momentum balance and must be specified in an extending model (to zero if not considered):

- **Ib_flow**, the flow of momentum across model boundaries,
- **F_p[m]**, pressure force, and
- **F_fg[m]**, friction and gravity forces.

The length of the flow path **pathLength** is an input that needs to be set in an extending class to complete the model.

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (m_flow >= 0) |
| Dynamics | | |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| **Initialization** | | |
| MassFlowRate | m_flow_start | Start value of mass flow rates [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |

## Interfaces.PartialDistributedVolume

**Base class for distributed volume models**

### Information

Interface and base class for **n** ideally mixed fluid volumes with the ability to store mass and energy. It is inteded to model a one-dimensional spatial discretization of fluid flow according to the finite volume method. The following boundary flow and source terms are part of the energy balance and must be specified in an extending class:

- **`Qb_flows[n]`**, heat flow term, e.g. conductive heat flows across segment boundaries, and
- **`Wb_flows[n]`**, work term.

The component volumes **`fluidVolumes[n]`** are an input that needs to be set in an extending class to complete the model.

Further source terms must be defined by an extending class for fluid flow across the segment boundary:

- **`Hb_flows[n]`**, enthalpy flow,
- **`mb_flows[n]`**, mass flow,
- **`mbXi_flows[n]`**, substance mass flow, and
- **`mbC_flows[n]`**, trace substance mass flow.

### Parameters

| Type | Name | Description |
|---|---|---|
| Integer | n | Number of discrete volumes |
| **Assumptions** | | |
| Dynamics | | |
| Dynamics | energyDynamics | Formulation of energy balances |
| Dynamics | massDynamics | Formulation of mass balances |
| **Initialization** | | |
| AbsolutePressure | p_a_start | Start value of pressure at port a [Pa] |
| AbsolutePressure | p_b_start | Start value of pressure at port b [Pa] |
| Boolean | use_T_start | Use T_start if true, otherwise h_start |
| Temperature | T_start | Start value of temperature [K] |
| SpecificEnthalpy | h_start | Start value of specific enthalpy [J/kg] |
| MassFraction | X_start[Medium.nX] | Start value of mass fractions m_i/m [kg/kg] |
| ExtraProperty | C_start[Medium.nC] | Start value of trace substances |

## Interfaces.PartialDistributedFlow

**Base class for a distributed momentum balance**

### Information

Interface and base class for **m** momentum balances, defining the mass flow rates **m_flows[m]** of a given Medium in **m** flow segments.

The following boundary flow and force terms are part of the momentum balances and must be specified in an extending model (to zero if not considered):

- **Ib_flows[m]**, the flows of momentum across segment boundaries,
- **Fs_p[m]**, pressure forces, and
- **Fs_fg[m]**, friction and gravity forces.

The lengths along the flow path **pathLengths[m]** are an input that needs to be set in an extending class to complete the model.

### Parameters

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |
| Integer | m | Number of flow segments |
| **Assumptions** | | |
| Boolean | allowFlowReversal | = true to allow flow reversal, false restricts to design direction (m_flows >= zeros(m)) |
| Dynamics | | |
| Dynamics | momentumDynamics | Formulation of momentum balance |
| **Initialization** | | |
| MassFlowRate | m_flow_start | Start value of mass flow rates [kg/s] |

### Connectors

| Type | Name | Description |
|---|---|---|
| replaceable package Medium | | Medium in the component |

## Modelica_Fluid.Types

**Common types for fluid models**

### Information

### Package Content

| Name | Description |
|---|---|
| HydraulicConductance | Real type for hydraulic conductance |
| HydraulicResistance | Real type for hydraulic resistance |
| Dynamics | Enumeration to define definition of balance equations |
| CvTypes | Enumeration to define the choice of valve flow coefficient |

| | |
|---|---|
| PortFlowDirection | Enumeration to define whether flow reversal is allowed |
| ModelStructure | Enumeration with choices for model structure in distributed pipe model |

## Types.HydraulicConductance

**Real type for hydraulic conductance**

### Parameters

| Type | Name | Description |
|---|---|---|
| | quantity | |
| | unit | |

## Types.HydraulicResistance

**Real type for hydraulic resistance**

### Parameters

| Type | Name | Description |
|---|---|---|
| | quantity | |
| | unit | |

## Types.Dynamics

**Enumeration to define definition of balance equations**

### Information

Enumeration to define the formulation of balance equations (to be selected via choices menu):

| Dynamics. | Meaning |
|---|---|
| DynamicFreeInitial | Dynamic balance, Initial guess value |
| FixedInitial | Dynamic balance, Initial value fixed |
| SteadyStateInitial | Dynamic balance, Steady state initial with guess value |
| SteadyState | Steady state balance, Initial guess value |

The enumeration "Dynamics" is used for the mass, energy and momentum balance equations respectively. The exact meaning for the three balance equations is stated in the following tables:

| **Mass balance** | | |
|---|---|---|
| **Dynamics.** | **Balance equation** | **Initial condition** |
| DynamicFreeInitial | no restrictions | no initial conditions |
| FixedInitial | no restrictions | **if** Medium.singleState **then**<br>no initial condition<br>**else** p=p_start |
| SteadyStateInitial | no restrictions | **if** Medium.singleState **then**<br>no initial condition<br>**else der**(p)=0 |
| SteadyState | **der**(m)=0 | |

| | |
|---|---|
| no initial conditions | |

| Energy balance | | |
|---|---|---|
| **Dynamics.** | **Balance equation** | **Initial condition** |
| DynamicFreeInitial | no restrictions | no initial conditions |
| FixedInitial | no restrictions | T=T_start or h=h_start |
| SteadyStateInitial | no restrictions | **der**(T)=0 or **der**(h)=0 |
| SteadyState | **der**(U)=0 | |
| no initial conditions | | |

| Momentum balance | | |
|---|---|---|
| **Dynamics.** | **Balance equation** | **Initial condition** |
| DynamicFreeInitial | no restrictions | no initial conditions |
| FixedInitial | no restrictions | m_flow = m_flow_start |
| SteadyStateInitial | no restrictions | **der**(m_flow)=0 |
| SteadyState | **der**(m_flow)=0 | |
| no initial conditions | | |

In the tables above, the equations are given for one-substance fluids. For multiple-substance fluids and for trace substances, equivalent equations hold.

Medium.singleState is a medium property and defines whether the medium is only described by one state (+ the mass fractions in case of a multi-substance fluid). In such a case one initial condition less must be provided. For example, incompressible media have Medium.singleState = **true**.

---

## Types.CvTypes

**Enumeration to define the choice of valve flow coefficient**

### Information

Enumeration to define the choice of valve flow coefficient (to be selected via choices menu):

| CvTypes. | Meaning |
|---|---|
| Av | Av (metric) flow coefficient |
| Kv | Kv (metric) flow coefficient |
| Cv | Cv (US) flow coefficient |
| OpPoint | Av defined by operating point |

The details of the coefficients are explained in the Users Guide .

---

## Types.PortFlowDirection

**Enumeration to define whether flow reversal is allowed**

### Information

Enumeration to define the assumptions on the model for the direction of fluid flow at a port (to be selected via choices menu):

| PortFlowDirection. | Meaning |
|---|---|
| Entering | Fluid flow is only entering the port from the outside |
| Leaving | Fluid flow is only leaving the port to the outside |
| Bidirectional | No restrictions on fluid flow (flow reversal possible) |

The default is "PortFlowDirection.Bidirectional". If you are completely sure that the flow is only in one direction, then the other settings may make the simulation of your model faster.

---

## Types.ModelStructure

**Enumeration with choices for model structure in distributed pipe model**

### Information

Enumeration to define the discretization structure of distributed pipe models according to the staggered grid scheme:

| ModelStructure. | Meaning |
|---|---|
| av_vb | port_a - volume - flow model - volume - port_b |
| a_v_b | port_a - flow model - volume - flow model - port_b |
| av_b | port_a - volume - flow model - port_b |
| a_vb | port_a - flow model - volume - port_b |

The default is "ModelStructure.av_vb", i.e., the distributed pipe has "volumes" at its both ends. The advantage is that connections of the pipe to flow models (like fittings) lead to the desirable structure of alternating volume and flow models, which means that no non-linear algebraic equations occur.

Direct connections of distributed pipes with this option means that two volumes are directly connected together. Due to the stream concept this means that the pressures of the two connected volumes are identical, but the temperatures are not set equal (this corresponds to volumes that are connected together with a very short distance and it needs some time until different volume temperatures are equilibrated). Since the pressures of the volumes are identical, the number of states is reduced and index reduction takes place (which means that medium equations depending on pressure are differentiated and the number of required initial conditions is reduced by one).

The default option "av_vb" cannot be used, if the dynamic pipe is connected to a model with non-differentiable pressure, like a Sources.Boundary_pT with prescribed jumping pressure. The modelStructure can be configured as appropriate in such situations, in order to place a momentum balance between a pressure state of the pipe and a non-differentiable boundary condition (e.g. if the jumping pressure component is connected to port_a, use model structure ModelStructure.a_vb).

---

# Modelica_Fluid.Utilities

**Utility models to construct fluid components (should not be used directly)**

### Information

Extends from Modelica.Icons.Library (Icon for library).

### Package Content

| Name | Description |
|---|---|
| checkBoundary | Check whether boundary definition is correct |
| regRoot | Anti-symmetric square root approximation with finite derivative in the origin |
| regRoot_der | Derivative of regRoot |
| regSquare | Anti-symmetric square approximation with non-zero derivative in the origin |
| regPow | Anti-symmetric power approximation with non-zero derivative in the origin |
| regRoot2 | Anti-symmetric approximation of square root with discontinuous factor so that the first derivative is finite and continuous |
| regSquare2 | Anti-symmetric approximation of square with discontinuous factor so that the first derivative is non-zero and is continuous |
| regStep | Approximation of a general step, such that the characteristic is continuous and differentiable |
| evaluatePoly3_derivativeAtZero | Evaluate polynomial of order 3 that passes the origin with a predefined derivative |
| regFun3 | Co-monotonic and C1 smooth regularization function |
| cubicHermite | Evaluate a cubic Hermite spline |
| cubicHermite_withDerivative | Evaluate a cubic Hermite spline, return value and derivative |

## Utilities.checkBoundary

**Check whether boundary definition is correct**

### Inputs

| Type | Name | Description |
|---|---|---|
| String | mediumName | |
| String | substanceNames[:] | Names of substances |
| Boolean | singleState | |
| Boolean | define_p | |
| Real | X_boundary[:] | |
| String | modelName | |

## Utilities.regRoot

**Anti-symmetric square root approximation with finite derivative in the origin**

### Information

This function approximates sqrt(abs(x))*sgn(x), such that the derivative is finite and smooth in x=0.

| Function | Approximation | Range |
|---|---|---|
| y = regRoot(x) | y ~= sqrt(abs(x))*sgn(x) | abs(x) >> delta |
| y = regRoot(x) | y ~= x/sqrt(delta) | abs(x) << delta |

With the default value of delta=0.01, the difference between sqrt(x) and regRoot(x) is 16% around x=0.01, 0.25% around x=0.1 and 0.0025% around x=1.

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | |
| Real | delta | Range of significant deviation from sqrt(abs(x))*sgn(x) |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | |

---

## Utilities.regRoot_der

**Derivative of regRoot**

### Information

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | |
| Real | delta | Range of significant deviation from sqrt(x) |
| Real | dx | Derivative of x |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | dy | |

---

## Utilities.regSquare

**Anti-symmetric square approximation with non-zero derivative in the origin**

### Information

This function approximates x^2*sgn(x), such that the derivative is non-zero in x=0.

| Function | Approximation | Range |
|---|---|---|
| y = regSquare(x) | y ~= x^2*sgn(x) | abs(x) >> delta |
| y = regSquare(x) | y ~= x*delta | abs(x) << delta |

With the default value of delta=0.01, the difference between x^2 and regSquare(x) is 41% around x=0.01, 0.4% around x=0.1 and 0.005% around x=1.

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | |
| Real | delta | Range of significant deviation from x^2*sgn(x) |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | |

---

## Utilities.regPow

**Anti-symmetric power approximation with non-zero derivative in the origin**

### Information

This function approximates abs(x)^a*sign(x), such that the derivative is positive, finite and smooth in x=0.

| Function | Approximation | Range |
|---|---|---|
| y = regPow(x) | y ~= abs(x)^a*sgn(x) | abs(x) >> delta |
| y = regPow(x) | y ~= x*delta^(a-1) | abs(x) << delta |

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | |
| Real | a | |
| Real | delta | Range of significant deviation from x^a*sgn(x) |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | |

---

## Utilities.regRoot2

**Anti-symmetric approximation of square root with discontinuous factor so that the first derivative is finite and continuous**

### Information

Approximates the function

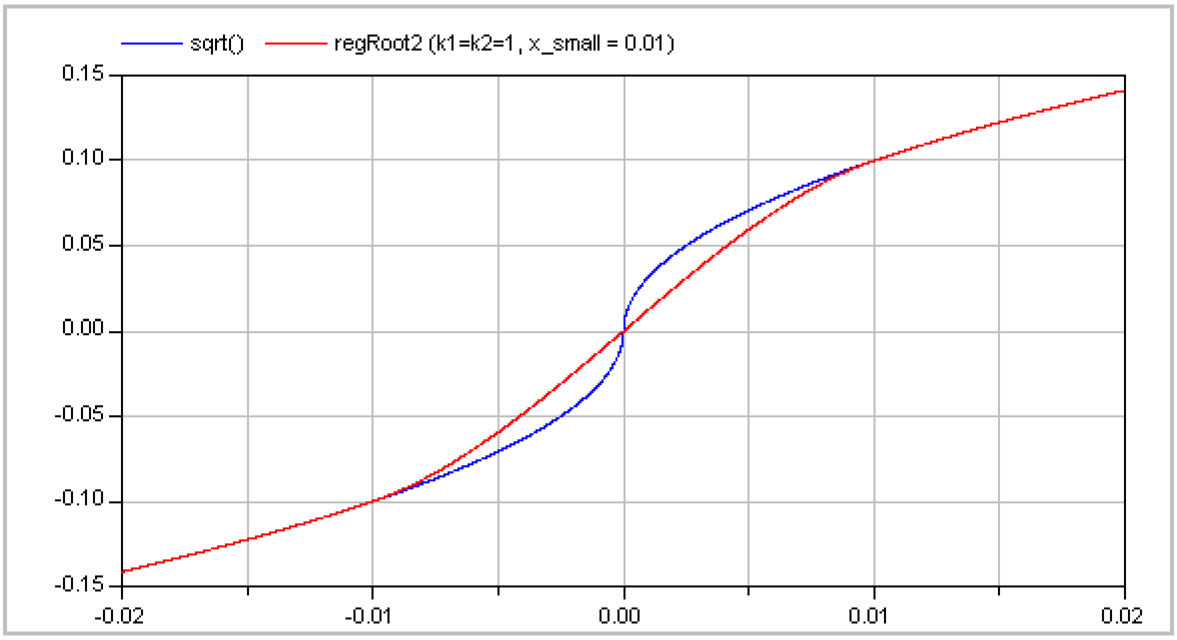
```
y = if x ≥ 0 then sqrt(k1*x) else -sqrt(k2*abs(x)), with k1, k2 > 0
```

in such a way that within the region -x_small ≤ x ≤ x_small, the function is described by two polynomials of third order (one in the region -x_small .. 0 and one within the region 0 .. x_small) such that

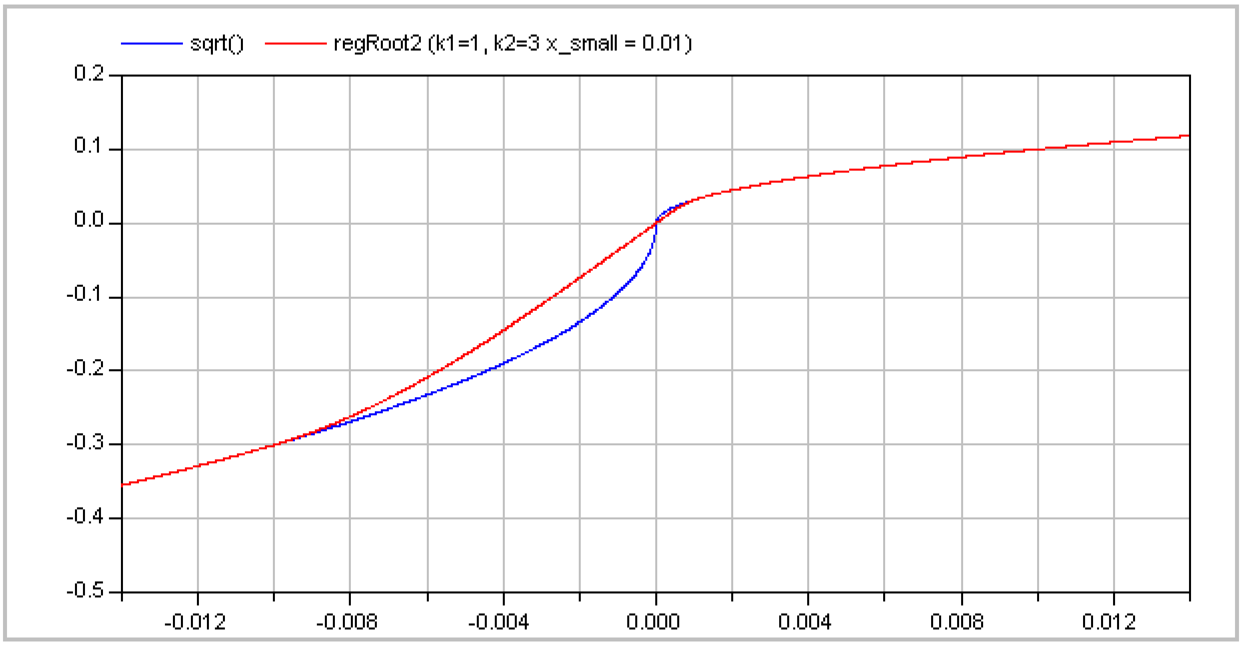
- The derivative at x=0 is finite.

- The overall function is continuous with a continuous first derivative everywhere.
- If parameter use_yd0 = **false**, the two polynomials are constructed such that the second derivatives at x=0 are identical. If use_yd0 = **true**, the derivative at x=0 is explicitly provided via the additional argument yd0. If necessary, the derivative yd0 is automatically reduced in order that the polynomials are strict monotonically increasing *[Fritsch and Carlson, 1980]*.

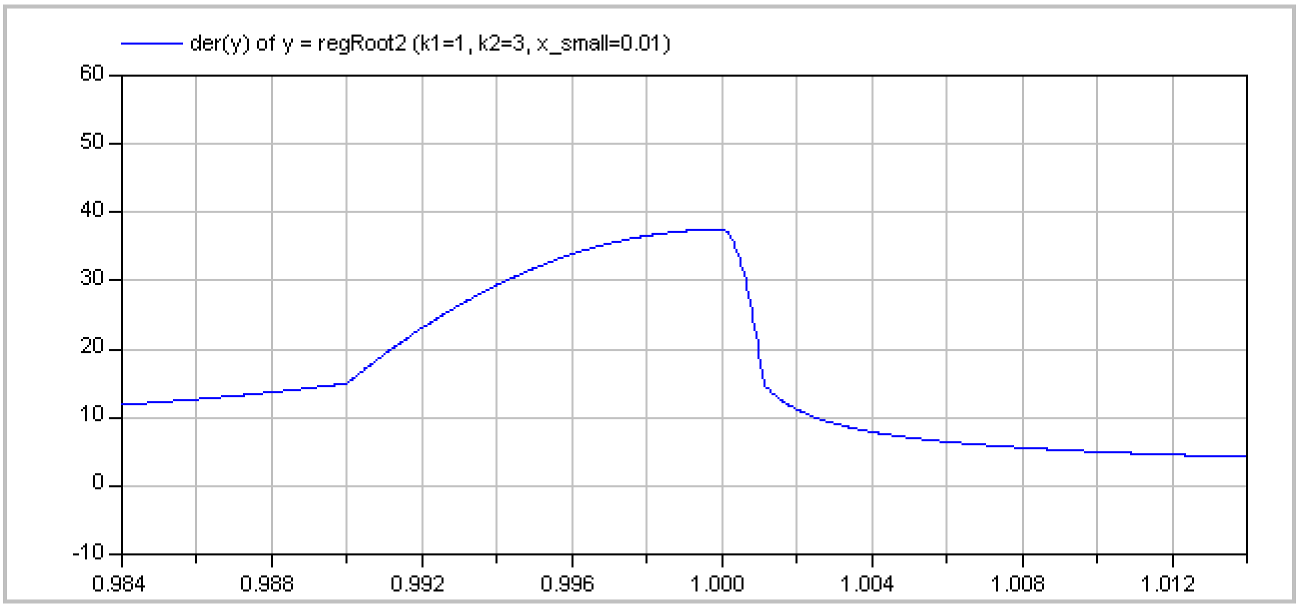
Typical screenshots for two different configurations are shown below. The first one with k1=k2=1:




and the second one with k1=1 and k2=3:




The (smooth) derivative of the function with k1=1, k2=3 is shown in the next figure:




### Literature

Fritsch F.N. and Carlson R.E. (1980):

> **Monotone piecewise cubic interpolation**. SIAM J. Numerc. Anal., Vol. 17, No. 2, April 1980, pp. 238-246

Extends from Modelica.Icons.Function (Icon for a function).

#### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | abscissa value |
| Real | x_small | approximation of function for \|x\| <= x_small |
| Real | k1 | y = if x>=0 then sqrt(k1*x) else -sqrt(k2*\|x\|) |
| Real | k2 | y = if x>=0 then sqrt(k1*x) else -sqrt(k2*\|x\|) |
| Boolean | use_yd0 | = true, if yd0 shall be used |
| Real | yd0 | Desired derivative at x=0: dy/dx = yd0 |

#### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | ordinate value |

---

## Utilities.regSquare2

**Anti-symmetric approximation of square with discontinuous factor so that the first derivative is non-zero and is continuous**

#### Information

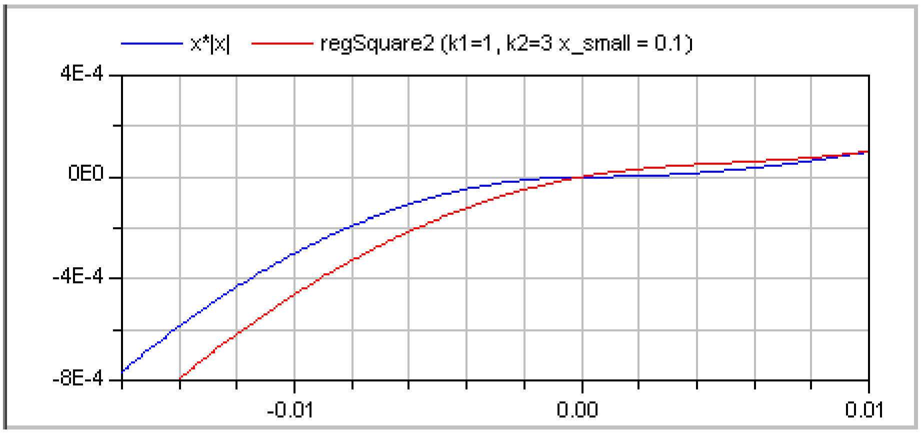
Approximates the function

```
y = if x ≥ 0 then k1*x*x else -k2*x*x, with k1, k2 > 0
```

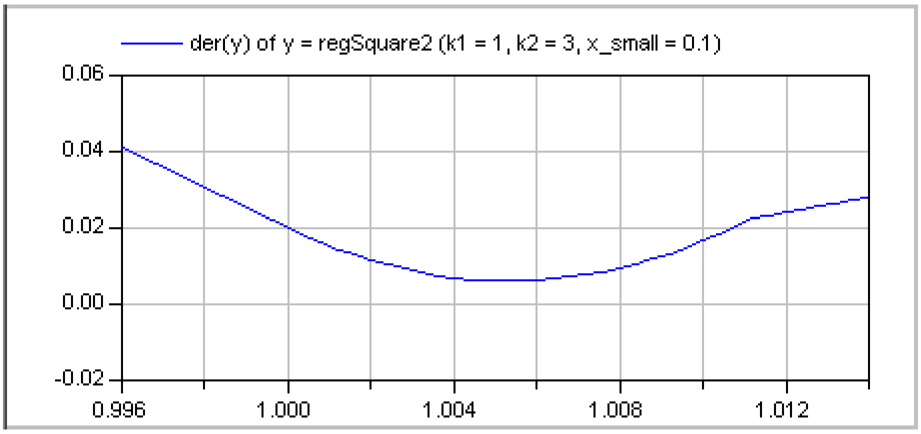
in such a way that within the region -x_small ≤ x ≤ x_small, the function is described by two polynomials of third order (one in the region -x_small .. 0 and one within the region 0 .. x_small) such that

- The derivative at x=0 is non-zero (in order that the inverse of the function does not have an infinite derivative).
- The overall function is continuous with a continuous first derivative everywhere.
- If parameter use_yd0 = **false**, the two polynomials are constructed such that the second derivatives at x=0 are identical. If use_yd0 = **true**, the derivative at x=0 is explicitly provided via the additional argument yd0. If necessary, the derivative yd0 is automatically reduced in order that the polynomials are strict monotonically increasing *[Fritsch and Carlson, 1980]*.

A typical screenshot for k1=1, k2=3 is shown in the next figure:




The (smooth, non-zero) derivative of the function with k1=1, k2=3 is shown in the next figure:




### Literature

Fritsch F.N. and Carlson R.E. (1980):
**Monotone piecewise cubic interpolation**. SIAM J. Numerc. Anal., Vol. 17, No. 2, April 1980, pp. 238-246

Extends from Modelica.Icons.Function (Icon for a function).

#### Inputs

| Type | Name | Description |
|---|---|---|

| | | |
|---|---|---|
| Real | x | abscissa value |
| Real | x_small | approximation of function for \|x\| <= x_small |
| Real | k1 | y = (if x>=0 then k1 else k2)*x*\|x\| |
| Real | k2 | y = (if x>=0 then k1 else k2)*x*\|x\| |
| Boolean | use_yd0 | = true, if yd0 shall be used |
| Real | yd0 | Desired derivative at x=0: dy/dx = yd0 |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | ordinate value |

---

## Utilities.regStep

**Approximation of a general step, such that the characteristic is continuous and differentiable**

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | Abscissa value |
| Real | y1 | Ordinate value for x > 0 |
| Real | y2 | Ordinate value for x < 0 |
| Real | x_small | Approximation of step for -x_small <= x <= x_small; x_small > 0 required |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | Ordinate value to approximate y = if x > 0 then y1 else y2 |

---

## Utilities.evaluatePoly3_derivativeAtZero

**Evaluate polynomial of order 3 that passes the origin with a predefined derivative**

### Information

Extends from Modelica.Icons.Function (Icon for a function).

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | Value for which polynomial shall be evaluated |
| Real | x1 | Abscissa value |
| Real | y1 | y1=f(x1) |
| Real | y1d | First derivative at y1 |
| Real | y0d | First derivative at f(x=0) |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | |

## Utilities.regFun3

**Co-monotonic and C1 smooth regularization function**

### Information

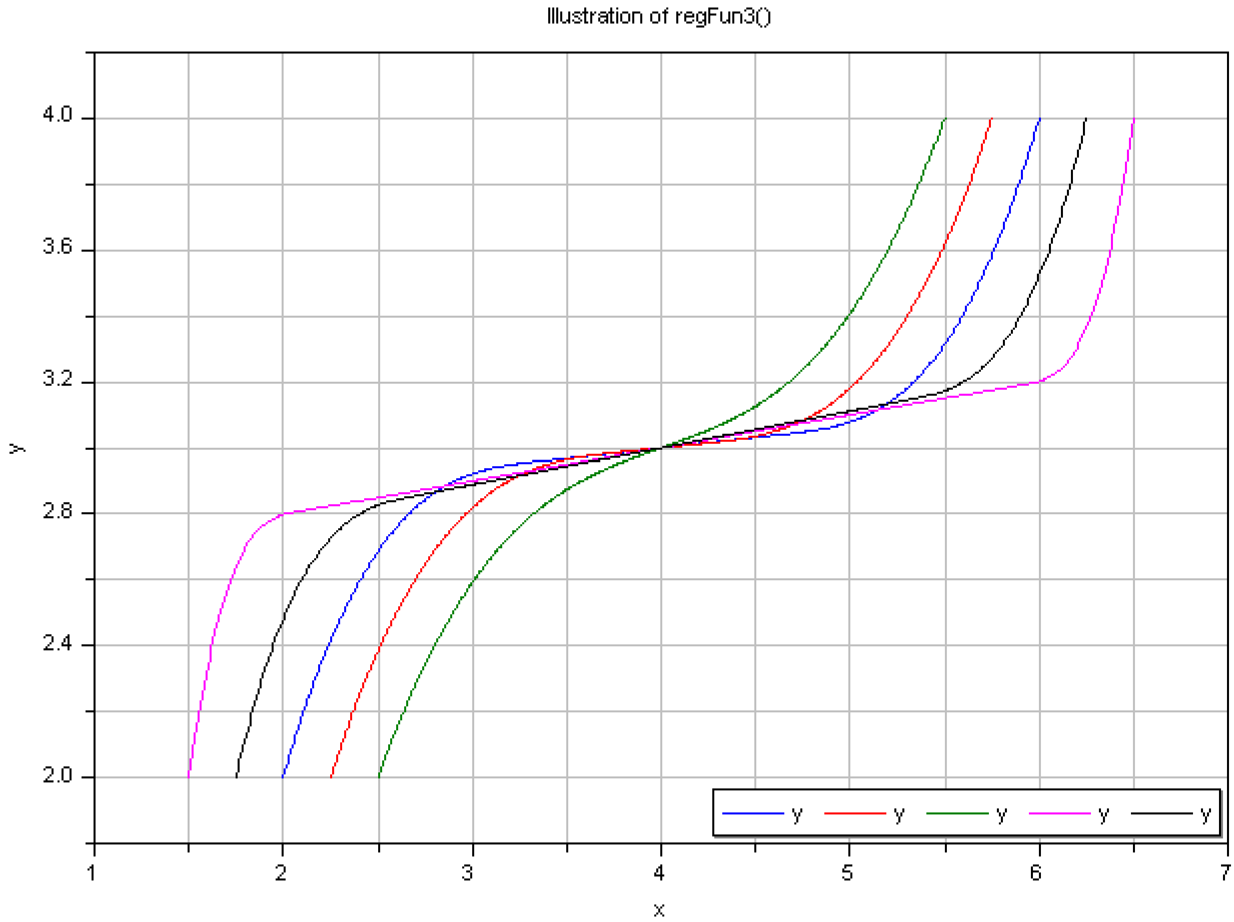
Approximates a function in a region between `x0` and `x1` such that

- The overall function is continuous with a continuous first derivative everywhere.
- The function is co-monotone with the given data points.

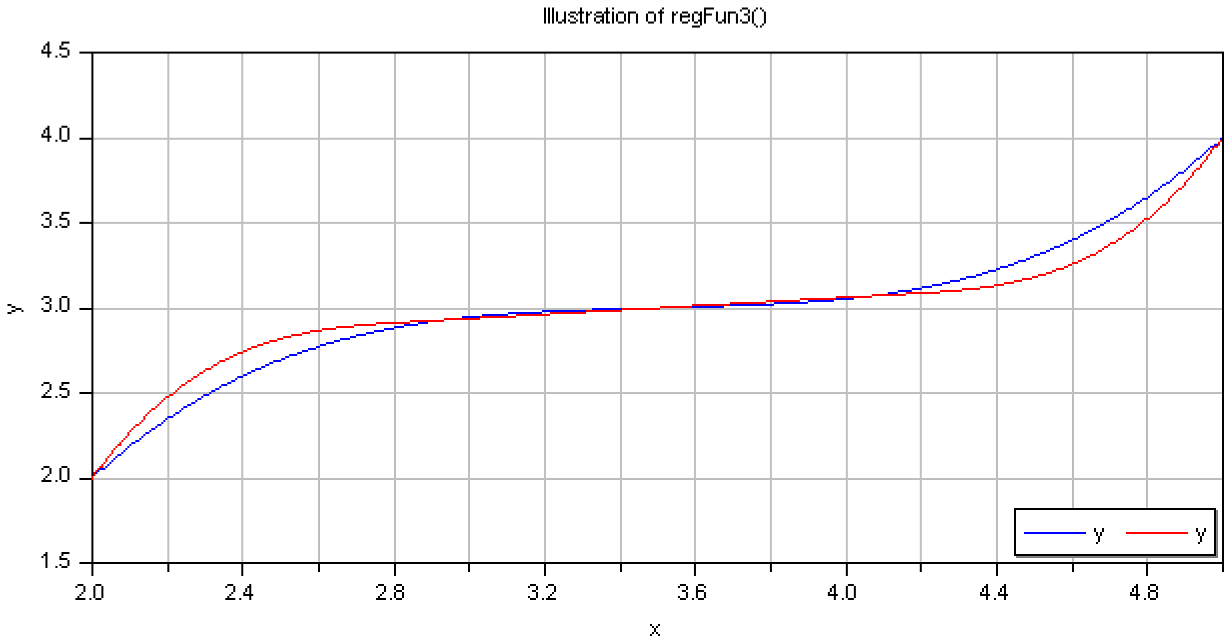
In this region, a continuation is constructed from the given points `(x0, y0)`, `(x1, y1)` and the respective derivatives. For this purpose, a single polynomial of third order or two cubic polynomials with a linear section in between are used *[Gasparo and Morandi, 1991]*. This algorithm was extended with two additional conditions to avoid saddle points with zero/infinite derivative that lead to integrator step size reduction to zero.

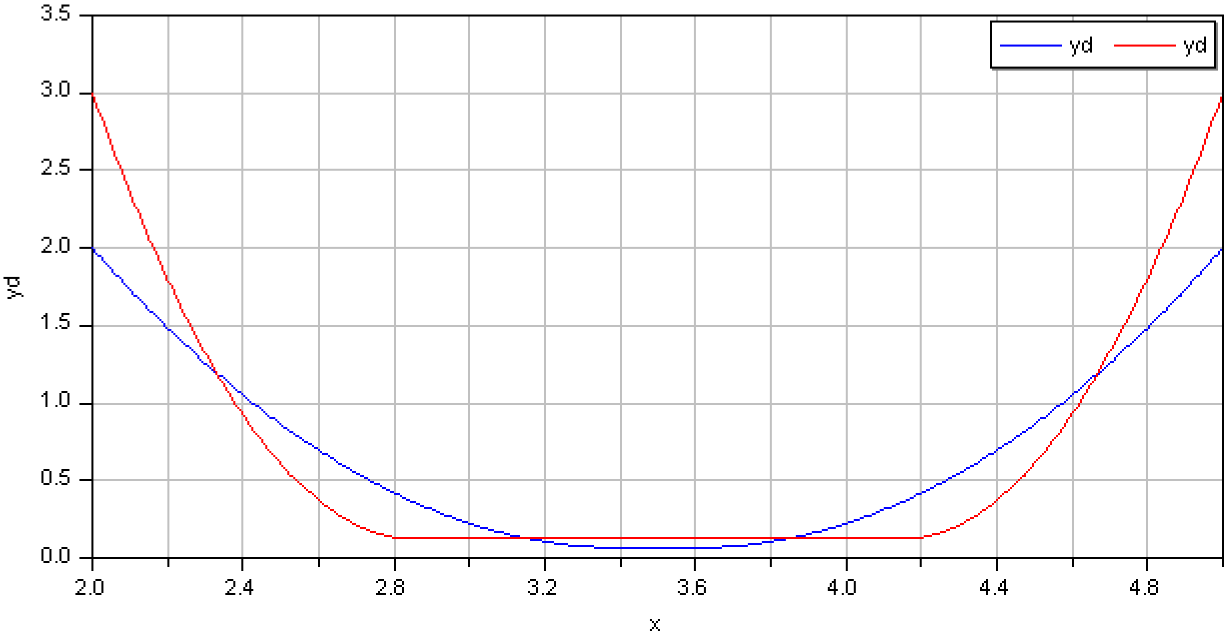
This function was developed for pressure loss correlations properly addressing the static head on top of the established requirements for monotonicity and smoothness. In this case, the present function allows to implement the exact solution in the limit of `x1-x0 -> 0` or `y1-y0 -> 0`.

Typical screenshots for two different configurations are shown below. The first one illustrates five different settings of `xi` and `yid`:




The second graph shows the continous derivative of this regularization function:




## Literature

Gasparo M. G. and Morandi R. (1991):
**Piecewise cubic monotone interpolation with assigned slopes**. Computing, Vol. 46, Issue 4, December 1991, pp. 355 - 365.

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | Abscissa value |
| Real | x0 | Lower abscissa value |
| Real | x1 | Upper abscissa value |

| | | |
|---|---|---|
| Real | y0 | Ordinate value at lower ordinate value |
| Real | y1 | Ordinate value at upper ordinate value |
| Real | y0d | Derivative at lower abscissa value |
| Real | y1d | Derivative at upper abscissa value |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | Ordinate value |
| Real | c | Slope of linear section between two cubic polynomials or dummy linear section slope if single cubic is used |

---

## Utilities.cubicHermite

**Evaluate a cubic Hermite spline**

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | Abscissa value |
| Real | x1 | Lower abscissa value |
| Real | x2 | Upper abscissa value |
| Real | y1 | Lower ordinate value |
| Real | y2 | Upper ordinate value |
| Real | y1d | Lower gradient |
| Real | y2d | Upper gradient |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | Interpolated ordinate value |

---

## Utilities.cubicHermite_withDerivative

**Evaluate a cubic Hermite spline, return value and derivative**

### Inputs

| Type | Name | Description |
|---|---|---|
| Real | x | Abscissa value |
| Real | x1 | Lower abscissa value |
| Real | x2 | Upper abscissa value |
| Real | y1 | Lower ordinate value |
| Real | y2 | Upper ordinate value |
| Real | y1d | Lower gradient |
| Real | y2d | Upper gradient |

### Outputs

| Type | Name | Description |
|---|---|---|
| Real | y | Interpolated ordinate value |
| Real | dy_dx | Derivative dy/dx at abscissa value x |

## Modelica_Fluid.Icons

**Library of resuable icons**

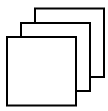
### Information

Extends from Modelica.Icons.Library (Icon for library).

### Package Content

| Name | Description |
|---|---|
| VariantLibrary | Icon for a library that contains several variants of one component |
| BaseClassLibrary | Icon for library |
| ObsoleteFunction | Icon for an interal function |

### Icons.VariantLibrary

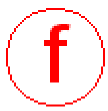


**Icon for a library that contains several variants of one component**

### Icons.BaseClassLibrary

**Icon for library**

### Icons.ObsoleteFunction




**Icon for an interal function**

### Information

This icon is designed for a **function**

*HTML-documentation generated by Dymola Mon Feb 02 14:30:42 2009.*

# Index

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