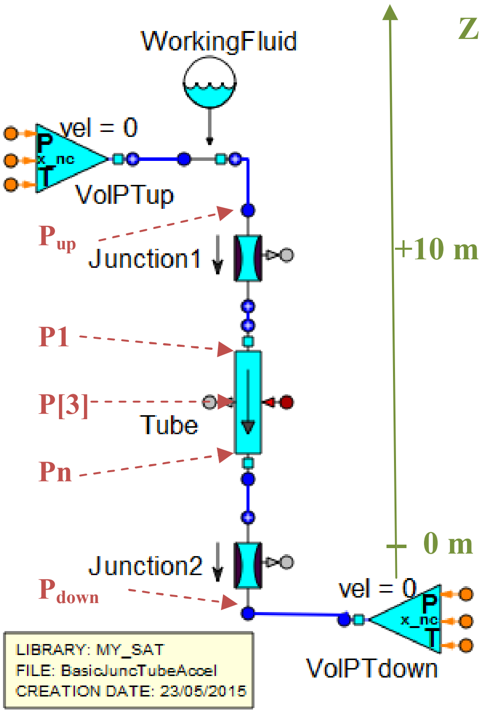
Analysis of a basic vertical tube without and with gravity

This example is however not so obvious: the model is shown right:

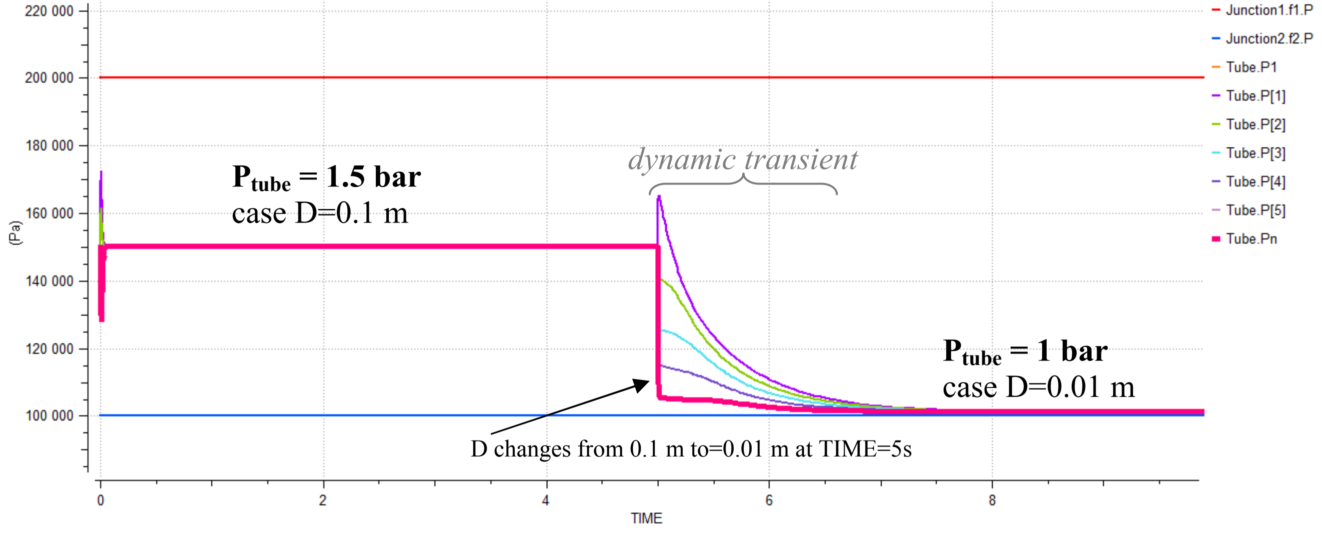
- the two junctions have the same area (= section of diameter 0.01m)
- pressure up P_{up} =2 bar ; pressure down P_{down}=1 bar, tube length= 10 m



1. First effect of Tube diameter 0.1 m and 0.01 m, with frictionless tube and without any acceleration:

- Tube diameter of 0.1 : the two junctions play the same role between infinite volume: their zeta is around 1.5 : the expected result is that the pressure in the frictionless tube is P_{tube} =P_{up} - 50% of the deltaP between P_{up} and P_{down}, so **P_{tube}= 1.5 bar**.
- Tube diameter of 0.01 : the two junctions have different zeta: Junction1 is from infinite volume to a continuation tube having same area: Junction1.$_{zeta}$ = **0.5** ; Junction2 is from a tube having same area to infinite volume: Junction2.$_{zeta}$ = **1**. *At first glance, an expected result could be that the pressure in the frictionless tube is P_{tube} =P_{up} - 0.5/(0.5+1) so =P_{up} - 33% of the deltaP between P_{up} and P_{down} = 1.66 bar. But this is not correct because the* ***pressure loss is an energy loss so between Total pressure!*** The dynamic pressure (½ρV²) is significant (and in this case, the pressure loss in the junction is zeta x the same dynamic pressure because junction and tube have same section with D=0.01m) so:
  - for Junction1: $(P_{up}+\frac{1}{2}\rho 0^2)-(P_{tube}+\frac{1}{2}\rho V^2)=$ Junction1.$_{zeta}$ $\frac{1}{2}\rho V^2=$ **0.5** $\frac{1}{2}\rho V^2$ this lead to the static pressure $P_{tube}= P_{up}-\frac{1}{2}\rho V^2-$**0.5** $\frac{1}{2}\rho V^2$ that is $P_{tube}= P_{up}-1.5\ \frac{1}{2}\rho V^2$
  - for Junction2: $(P_{tube}+\frac{1}{2}\rho V^2)-(P_{down}+\frac{1}{2}\rho 0^2)=$ Junction2.$_{zeta}$ $\frac{1}{2}\rho V^2=$ **1** $\frac{1}{2}\rho V^2$ this lead to the static pressure $P_{tube}= P_{down}+$**1** $\frac{1}{2}\rho V^2-\frac{1}{2}\rho V^2$ that is **$P_{tube}= P_{down}$=1 bar**

- Finally this is fully reproduced in the plot below where the change in diameter occur at 5s.



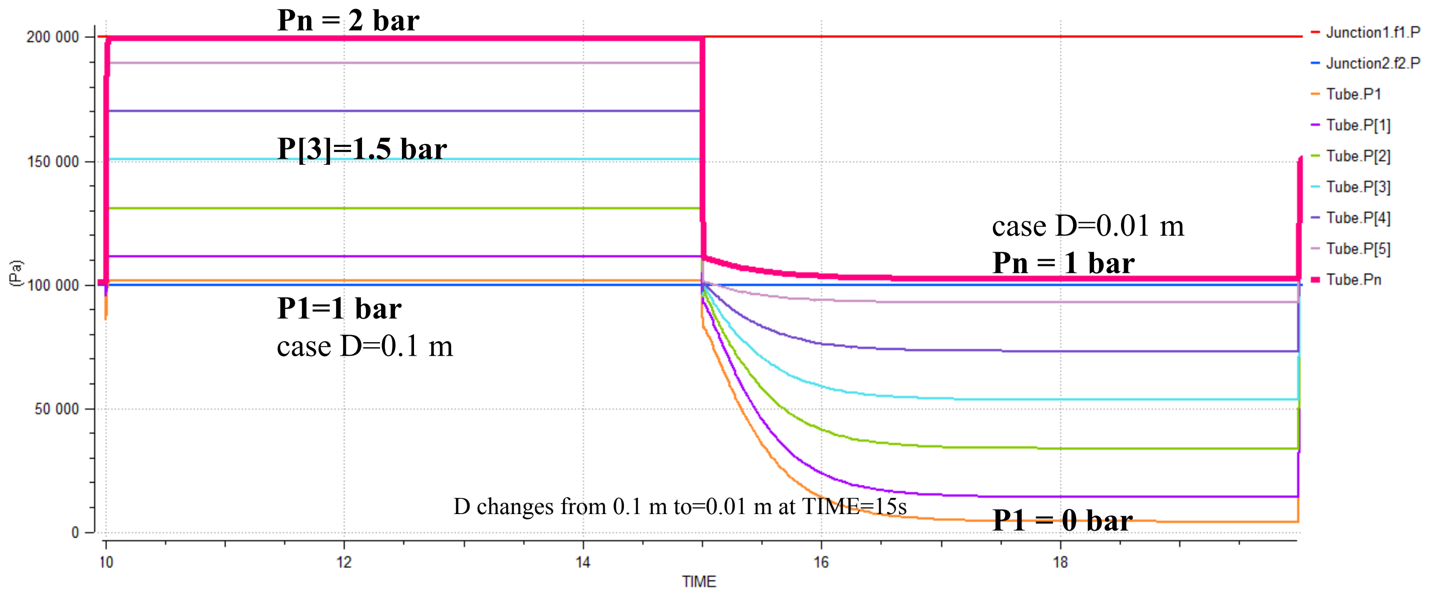
2. Effetc of Tube diameter, with frictionless tube but with acceleration of g=+9.8 m/s²:

- Tube diameter of 0.1 : the two junctions play the same role between infinite volume: their zeta is around 1.5 : the expected result is that the pressure in the frictionless tube depends on the location in the tube: for the middle of the tube (Tube.P[3]) there are no changes wrt to the case without acceleration, so **Tube.P[3]=1.5 bar**, but for the exit at the bottom " Tube.Pn" the pressure is increased by +1 bar (= –ρg(-10)) wrt the entrance " Tube.P1",

  Tube.Pn - Tube.P1 = 1 bar
  (Tube.Pn+ Tube.P1)/2= Tube.P[3]=1.5 bar

  Hence **Tube.Pn= Tube.P[3] +0.5 bar= 2 bar**

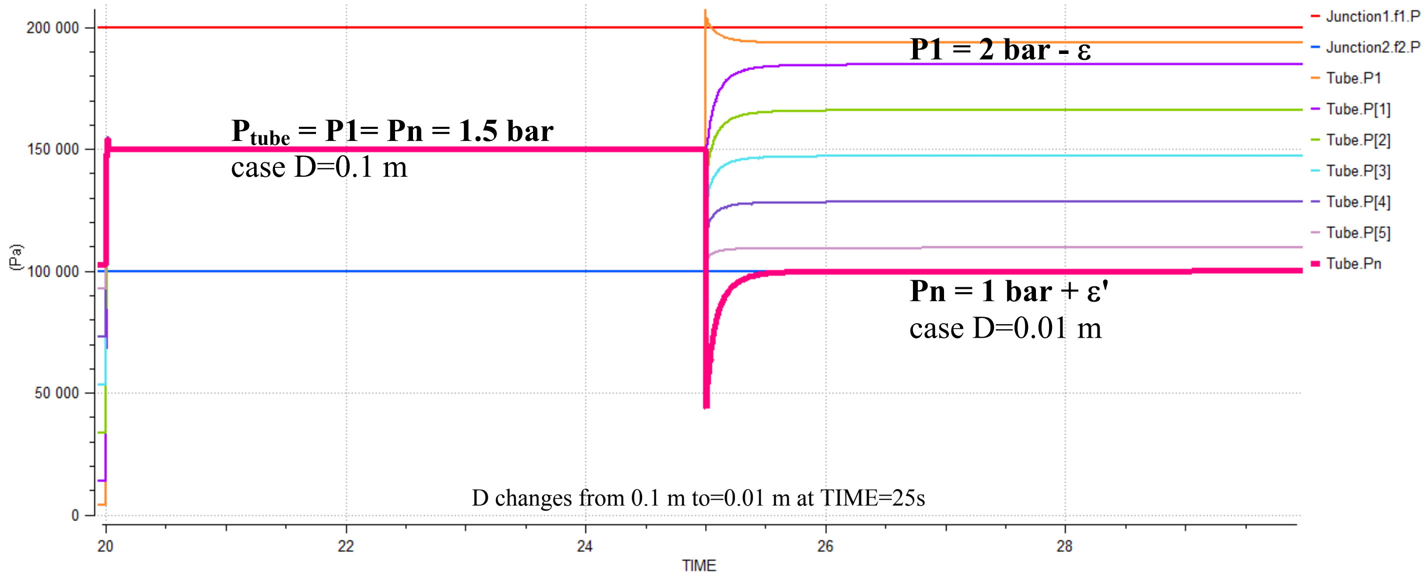
  Note that the right use of g on Earth is to put a positive value along an axis Z oriented to top (actually g=+9.8 m/s² is the reaction to the gravity acceleration, similar to acceleration due to a rocket engine)



- Tube diameter of 0.01 : Junction1 is from infinite volume to a continuation tube having same area: Junction1.$_{zeta}$ = 0.5 ; Junction2 from a tube having same area to an infinite volume: Junction2.$_{zeta}$ = 1. The dynamic pressure (½ρV²) is significant and Archimedes pressure too so:
  - for Junction1: $(P_{up}+½ρ0^2)-(P1+½ρ\ V^2)$= Junction1.$_{zeta}$ ½ρ V²= 0.5 ½ρV² this lead to the static pressure $P1= P_{up}-½ρ\ V^2-0.5\ ½ρV^2$ that is $P1= P_{up}-1.5\ ½ρ\ V^2$
  - for Junction2: $(Pn+½ρ\ V^2)-(P_{down}+½ρ0^2)$= Junction2.$_{zeta}$ ½ρ V²= **1**½ρV² this lead to the static pressure Pn= P_{down}+**1**½ρV² - ½ρV² that is **Pn = P_{down} = 1 bar** Hence, from Pn-P1=1 bar (= –ρg(-10)): **P1= P_{down}-1 bar= 0 bar : that is well known.**
- Finally this is fully reproduced in the plot above where the change in diameter occur at 15s.

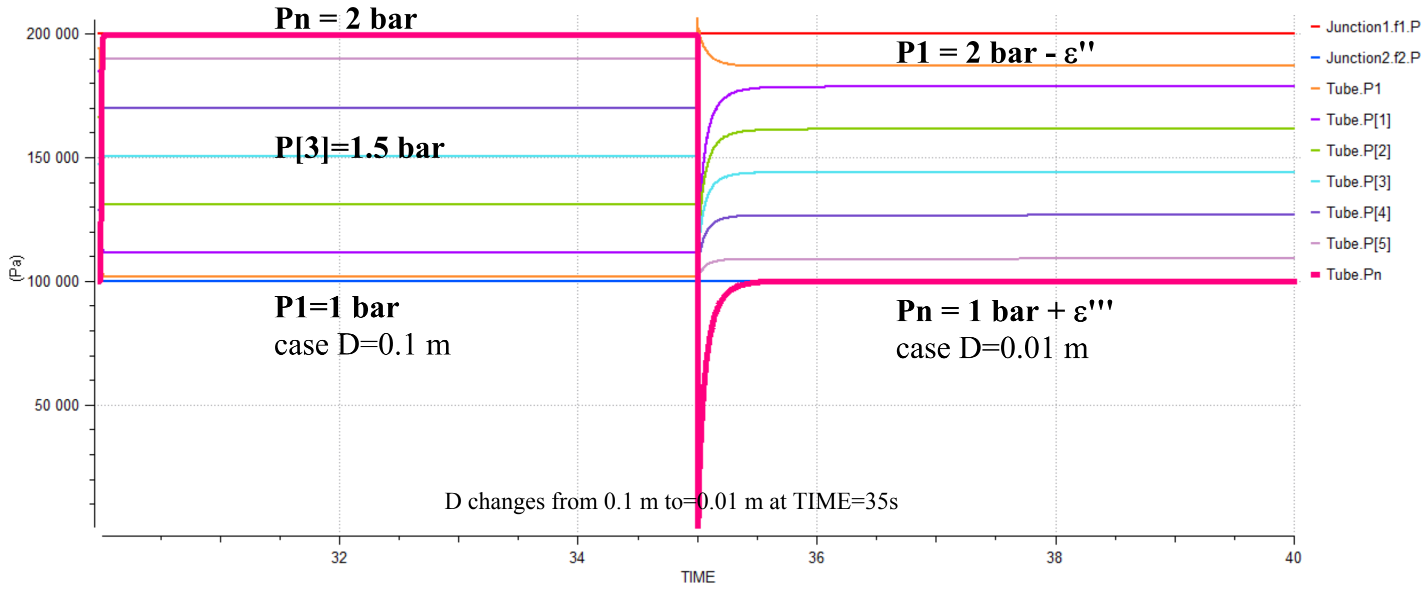
3. Effect of Tube diameter with friction in the tube and without any acceleration:

- Tube diameter of 0.1 : idem as §1) because the diameter is so large that the ΔP friction is very low
- Tube diameter of 0.01 : the mass flow rate reduce a lot due to friction in the 10 m of the small diameter tube (L/D=1000): the tube "eat" all the ΔP , the dynamic pressure become very low, thus the pressures in the tube from P1 (at the top) to Pn (at the bottom) are regularly spaced and decreasing.
  Note that between P1 and P[01] there is only half cell length, between P[01] and P[02]: one cell lenght.... and between P[05] and Pn there is only half cell length: this is shown in the plot below (where the change in diameter occured at 25s).



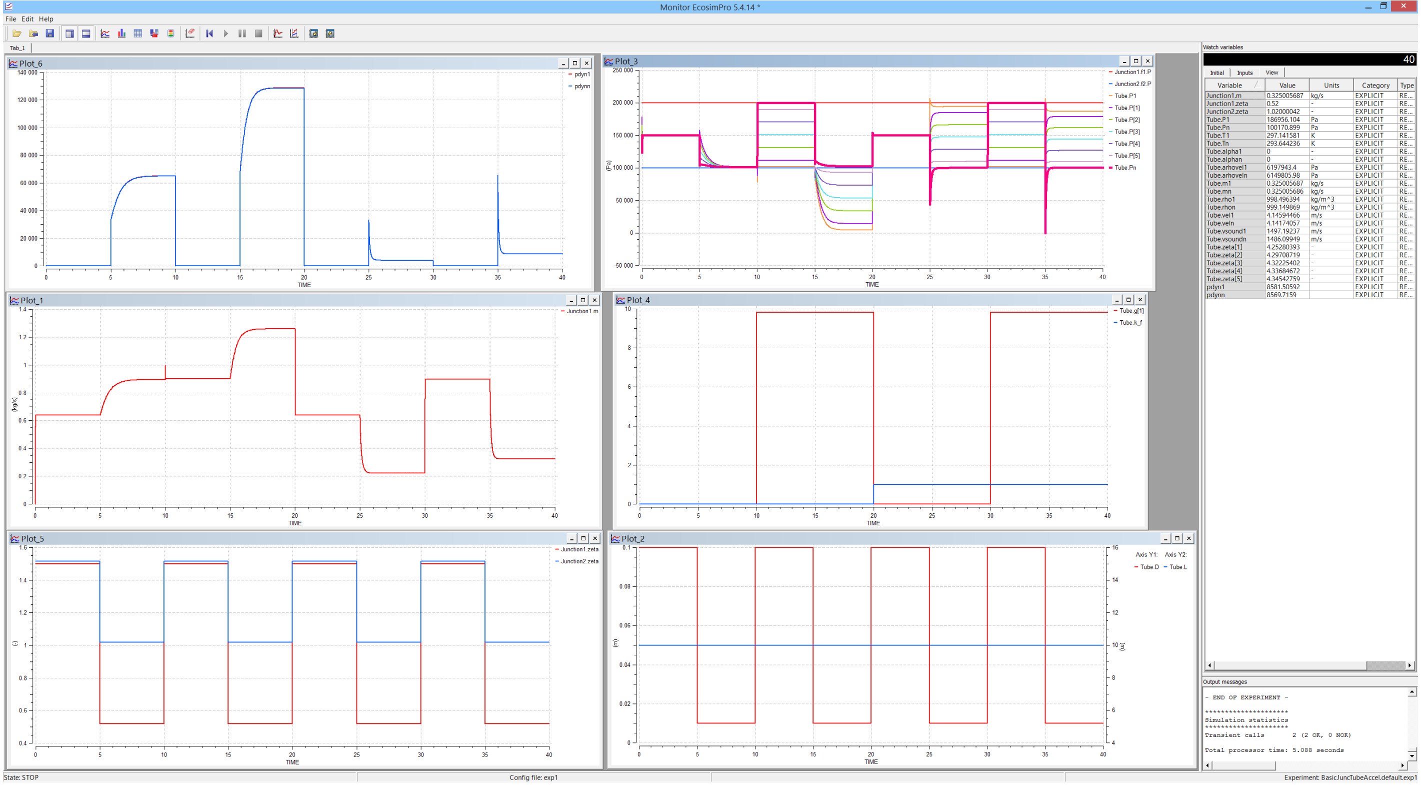
4. Effect of Tube diameter with friction in the tube and with acceleration:

- Tube diameter of 0.1 : idem as §2) because the diameter is so large that the ΔP friction is very low
- Tube diameter of 0.01 : very similar to the case above §3: the mass flow rate reduce a lot due to friction in the 10 m of the small diameter tube (L/D=1000): the tube "eat" all the ΔP , the dynamic pressure become very low, thus the pressures in the tube from P1 (at the top) to Pn (at the bottom) are regularly spaced and decreasing.



5. Traceability

- Full plot with Pdynamic, mass flow rate, zeta, pressures and the cases acceleration g[], friction k_f, diameter, length.



Variable	Value	Units	Category	Type
Junction1.m	0.325005687	kg/s	EXPLICIT	RE...
Junction1.zeta	0.52	-	EXPLICIT	RE...
Junction2.zeta	1.02000042	-	EXPLICIT	RE...
Tube.P1	186956.104	Pa	EXPLICIT	RE...
Tube.Pn	100170.899	Pa	EXPLICIT	RE...
Tube.T1	297.141581	K	EXPLICIT	RE...
Tube.Tn	293.644236	K	EXPLICIT	RE...
Tube.alpha1	0	-	EXPLICIT	RE...
Tube.alphan	0	-	EXPLICIT	RE...
Tube.arhovel1	6197943.4	Pa	EXPLICIT	RE...
Tube.arhoveln	6149805.98	Pa	EXPLICIT	RE...
Tube.m1	0.325005687	kg/s	EXPLICIT	RE...
Tube.mn	0.325005686	kg/s	EXPLICIT	RE...
Tube.rho1	998.496394	kg/m^3	EXPLICIT	RE...
Tube.rhon	999.149869	kg/m^3	EXPLICIT	RE...
Tube.vel1	4.14594466	m/s	EXPLICIT	RE...
Tube.veln	4.14174057	m/s	EXPLICIT	RE...
Tube.vsound1	1497.19237	m/s	EXPLICIT	RE...
Tube.vsoundn	1486.09949	m/s	EXPLICIT	RE...
Tube.zeta[1]	4.25280393	-	EXPLICIT	RE...
Tube.zeta[2]	4.29708719	-	EXPLICIT	RE...
Tube.zeta[3]	4.32225402	-	EXPLICIT	RE...
Tube.zeta[4]	4.33684672	-	EXPLICIT	RE...
Tube.zeta[5]	4.34542759	-	EXPLICIT	RE...
pdyn1	8581.50592		EXPLICIT	RE...
pdynn	8569.7159		EXPLICIT	RE...

```
- END OF EXPERIMENT -

*********************
Simulation statistics
*********************
Transient calls      2 (2 OK, 0 NOK)

Total processor time: 5.088 seconds
```

Experiment: BasicJuncTubeAccel.default.exp1

- Listing of the experiment

```
/*------------------------------------------------------------------------------------
------
LIBRARY: MY_SAT
COMPONENT: BasicJuncTubeAccel
PARTITION: default
EXPERIMENT: exp1
TEMPLATE: TRANSIENT
CREATION DATE: 28/05/2015
-------------------------------------------------------------------------------------
---*/
EXPERIMENT exp1 ON BasicJuncTubeAccel.default
DECLS
REAL g
OBJECTS
INIT
-- initial values for state variables
BOUNDS
-- Set equations for boundaries: boundVar = f(TIME;...)
FLUID_FLOW_1D.Damp = 1
FLUID_FLOW_1D.GRAV = g
FLUID_PROPERTIES.MinMolarFr = 1e-009
FLUID_PROPERTIES.VDW_option = 0
Tube.tp_in.Tk[1] = 293.15
Tube.tp_in.Tk[2] = 293.15
Tube.tp_in.Tk[3] = 293.15
Tube.tp_in.Tk[4] = 293.15
Tube.tp_in.Tk[5] = 293.15
VolPTup.s_pres.signal[1] = 2e5
VolPTup.s_temp.signal[1] = 300
VolPTup.s_xNonCond.signal[1] = 0
VolPTdown.s_pres.signal[1] = 1e5
VolPTdown.s_temp.signal[1] = 300
VolPTdown.s_xNonCond.signal[1] = 0
BODY
-- REPORT_TABLE("results.rpt", "*")-- creates an ASCII file with the
results in table format
DEBUG_LEVEL= 1 -- set the debug level (valid range [0,4])
IMETHOD= DASSL -- select default integration solver
setStopWhenBadOperation(FALSE)-- Set flag to stop when bad
numerical operation occurs (eg division by 0). By default do not stop.
REL_ERROR = 1e-006-- set relative and absolute tolerance for
DASSL solver (transient solver)
ABS_ERROR = REL_ERROR
TOLERANCE = 1e-006-- set relative tolerance for algebraics solver
(steady solver)
REPORT_MODE = IS_STEP --CINT ---- when to report results by
default report at every CINT time or event detection
--STEADY()-- calculates a steady state
TIME=0
Tube.rug=0 --smooth tube   --50e-6
Tube.k_f=0
Tube.D=0.1
Tube.L=10
Tube.P_o=(VolPTup.s_pres.signal[1]+VolPTdown.s_pres.signal[1])/2
Junction1.z_jun=Tube.L
Junction1.Ao=3.14159*0.25*0.01**2
Junction2.Ao=Junction1.Ao
FOR (i IN 1,2) --Loop for friction cases
g=0
g=9.81 AFTER 10
Tube.D=0.1
Tube.D=0.01 AFTER 5
--g=0 AFTER 15
Tube.D=0.1 AFTER 10
Tube.D=0.01 AFTER 15
INTEG_TO(20*i,0.1)-- INTEG
Tube.k_f=1
END FOR
END EXPERIMENT
```

- Listing of the modele

```
-- Generated automatically by - EcosimPro - 5.4.14
USE FLUID_FLOW_1D VERSION "3.1.0"
USE FLUID_PROPERTIES VERSION "3.1.0"
-- EL code of the schematic.
-- The COMPONENT definition lines are blocked
for edition.
-- You can edit the parameters clicking over them.
COMPONENT BasicJuncTubeAccel
DECLS
REAL pdyn1, pdynn
TOPOLOGY
FLUID_FLOW_1D.Junction(
burnerGasesOption =
FLUID_PROPERTIES.noBurnGases,
choked_option = TRUE ) Junction1(
x_jun = 0,
y_jun = 0,
z_jun = 1, -- Non default value.
Gcr_ideal = FALSE ,
Ao = 7e-005,
zetaf = 0,
zetab = 0,
m_o = 0,
Re_lam = 53 -- Non default value.
)
FLUID_FLOW_1D.Junction(
burnerGasesOption =
FLUID_PROPERTIES.noBurnGases,
choked_option = TRUE ) Junction2(
x_jun = 0,
y_jun = 0,
z_jun = 0,
Gcr_ideal = FALSE ,
Ao = 7e-005,
zetaf = 0,
zetab = 0,
m_o = 0,
Re_lam = 53 -- Non default value.
)
FLUID_FLOW_1D.Tube(
burnerGasesOption =
FLUID_PROPERTIES.noBurnGases,
AbsorOption = noActive,
nodes = 5,
n_bends = 1,
scheme = centred) Tube(
num = 1,
init_option = INIT_PT,
P_o = 100000,
T_o = 293.15,
x_o = 0,
rho_o = 1,
x_nco = 0,
m_o = 0,
rug = 5e-005,
k_f = 0, -- Non default value.
k_d = 1,
fld_add = 0,
fld_nod = 0,
alpha_bend = 0,
R_bend = 1,
fr_option = FR_tube_1ph,
ht_option = HT_tube_1ph,
hc_dat = 1,
Isent_Correl = FALSE ,
entropy_fix = no_fix,
entropy_fix_multiplier = 4,
integration_rule = midpoint,
dp_correction = FALSE ,
limiter = VanAlbada,
preconditioner = unprecond,
reconstructed_variables = primitive,
central_reconstruction = TRUE ,
source_upwind_smoothing = 0,
xd_nco = 0,
Po_nc = 0,
UserDefSolubData = TRUE ,
A_coef_sol = -521,
B_coef_sol = 2.3874,
TI = 0.03,
Cd = 2,
Ca = 0.1,
tau_d = 0.3,
tau_a = 2,
Diff_Turb_Factor = 1,
alfa = 3 / 16,
beta = 1 / 8,
K_u = 0.25,
K_p = 0.75,
sig = 1,
L = 1,
D = 0.1, -- Non default value.
D_vs_L = { { 0,0.5,1} ,{ 1,1,1} } ,
dx_vs_L = { { 0,0.5,1} ,{ 1,1,1} } )
FLUID_FLOW_1D.VolPT_TMD(
burnerGasesOption =
FLUID_PROPERTIES.noBurnGases) VolPTdown(
xd_nc = 0)
FLUID_FLOW_1D.VolPT_TMD(
burnerGasesOption =
FLUID_PROPERTIES.noBurnGases) VolPTup(
xd_nc = 0)
FLUID_FLOW_1D.WorkingFluid WorkingFluid(
fluid = PfLiq_H2O, -- Non default value.
fluid_nc = NoFluid)
CONNECT Junction1.f2 TO Tube.f1
CONNECT Junction1.f1 TO WorkingFluid.f1
CONNECT Junction2.f1 TO Tube.f2
CONNECT Junction2.f2 TO VolPTdown.f
CONNECT WorkingFluid.f2 TO VolPTup.f
CONTINUOUS
pdyn1=0.5*Tube.f1.rho*Tube.f1.v**2
pdynn=0.5*Tube.f2.rho*Tube.f2.v**2
END COMPONENT
```