Mobatec
model-based technology



Mobatec Modeller

INTRODUCTION COURSE

Model User II

Advanced Equation-Based Modelling

Mobatec Modeller Intro Course – Model User II

1. Simulation of the closed circulating flow loop

1.1 Introduction

This is the second exercise of **Mobatec Modeller Introduction Course** and will teach you how to build and run a model using predefined library units. The Introduction Course further consists of several constructive and easy to follow exercises that will teach you how to build (develop) your own models in Mobatec Modeller from scratch.

1.2 Objectives

By the end of this exercise, you will know:

- How to build a flowsheet from the library Unit-Models.
- How to input parameter values using Initialization Routines and initialize the systems.
- How to add variable displays.
- How to run a Real-Time dynamic simulation in Mobatec Modeller.

1.3 Model description

We want to model a real time dynamic simulation of a closed circulating flow loop.

Process P&ID:

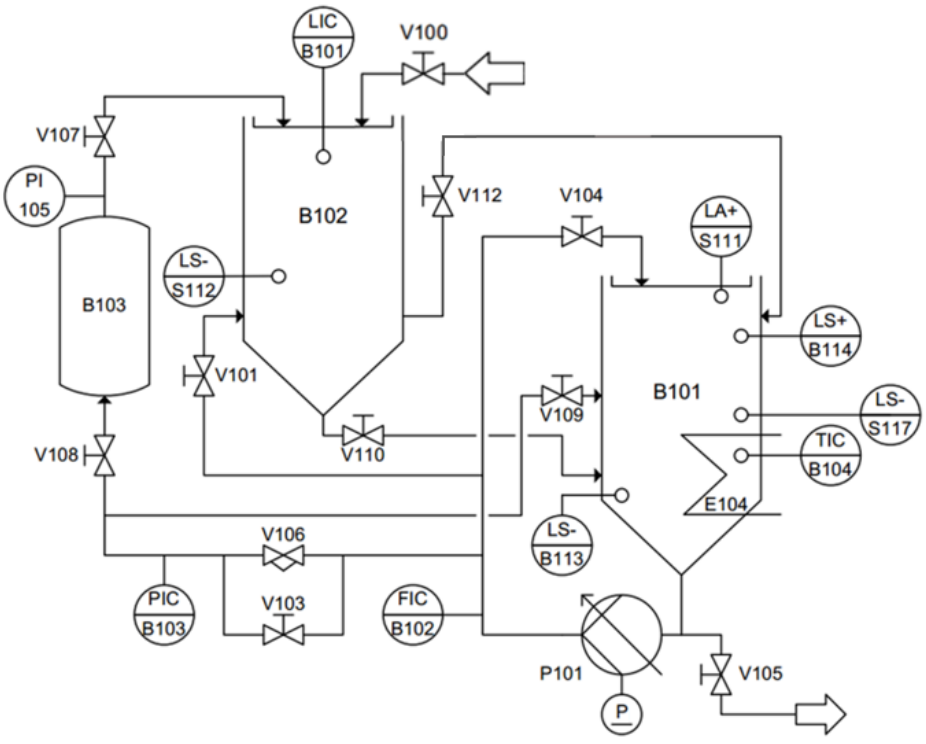


Figure 1 Closed circulating flow loop

Mobatec Modeller Simulation Environment:

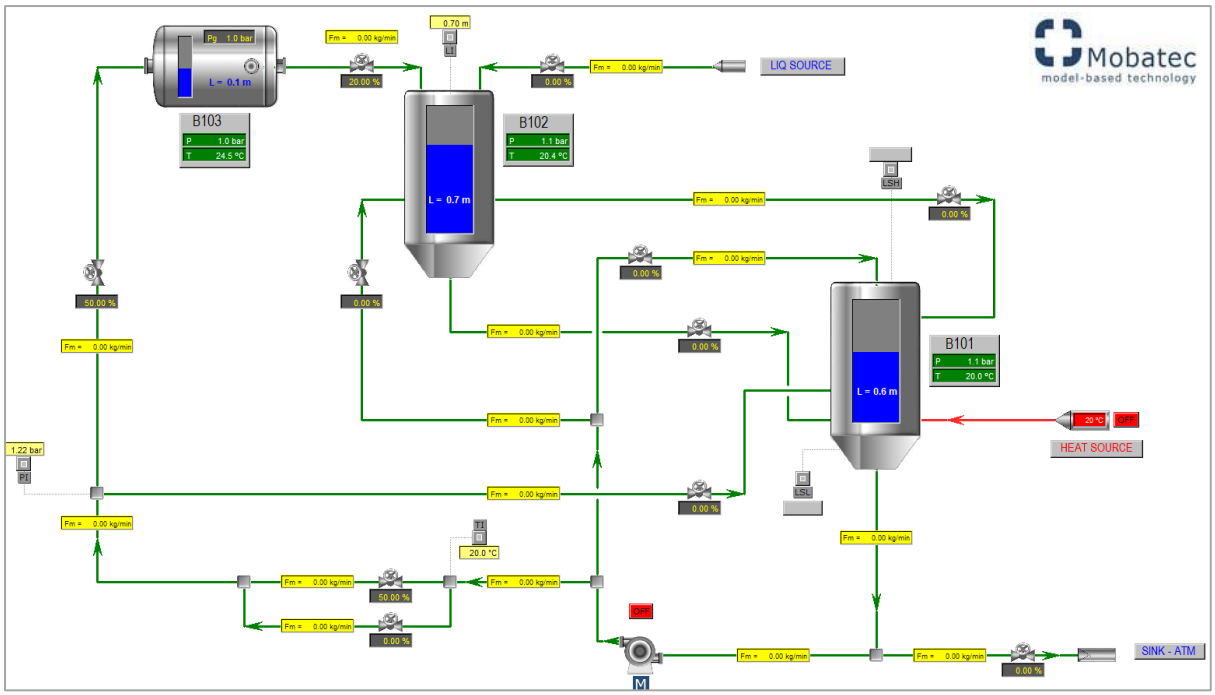


Figure 2 Mobatec Modeller Simulation Environment

The Model consists of 2 open (atmospheric) tanks (B101 & B102), 1 pressurized vessel (B103) and a pump. Model also has material SOURCE, SINK, HEAT SOURCE and 6 liquid "buffers" - stream lines junction elements.

1.4 Assumptions

- Atmospheric tanks and pressurised vessel are well-stirred.
- The cross-section area is constant along the heights of the units.
- Model has single phase definition (liquid phase).
- Liquid phase is containing single component (i.e. H_2O).
- Process is non-isothermal.

2. Things to do

1. Create a New Model

Open a new model, by clicking on a "New Model" button, or click on *File/New Model*. A new model called "Universe" will open. Save your model with a different name by clicking on a save as icon "", or click File/Save Model as, choose appropriate location for your model. Do NOT save you model in the Program Files directory as Windows might not give you proper rights to save, change or run your model.

2. Inserting systems/connections from the library

We will use dedicated library directory for this exercise called "Closed Circulating Flow Loop" instead the default one (Basic Library). To change to this library open the "Property Browser", by clicking on the icon "" in the toolbar, or by clicking on *Tools/Show Property Browser* (CTRL+ F10). Select "Insert Objects" tree folder and select the library used for this exercise: Click Browse and find and select "**Closed Circulating Flow Loop**" - Library. All the systems needed to build the process will be listed.

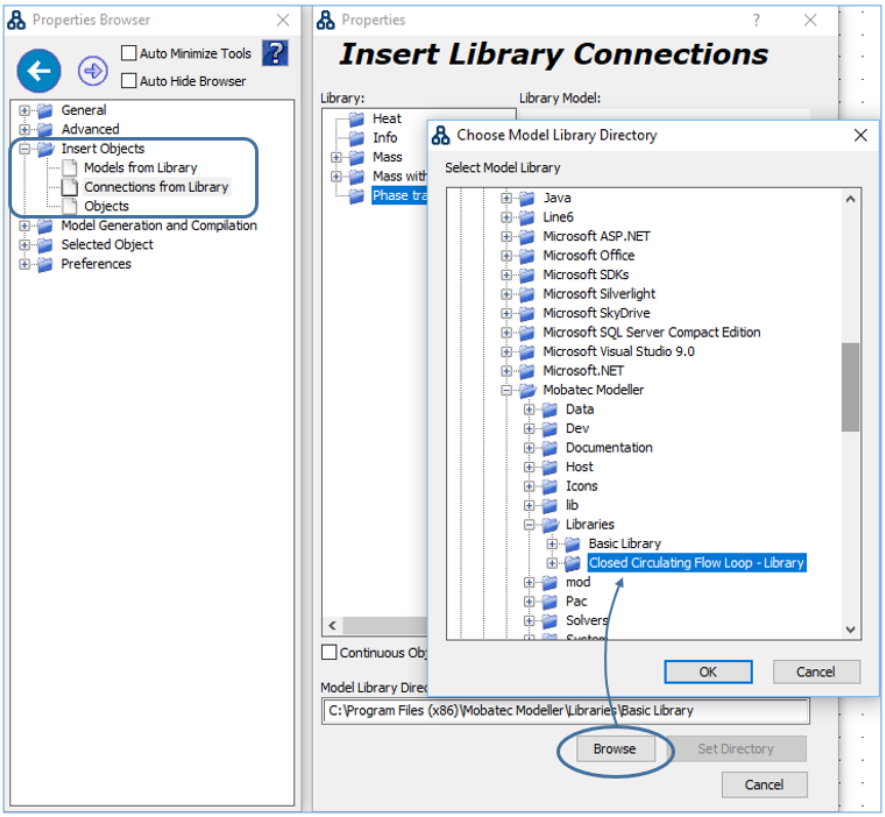


Figure 3 Chose "Closed Circulating Flow Loop" Library

By clicking on the desired library unit model (e.g. Boundaries, Mix and Split Points, Pumps, Vessels, Switches) and clicking anywhere on the work surface of Mobatec Modeller modelling environment you will insert the selected model object. Do so for all the needed model parts one by one looking at the process (Figure 2).

After inserting all needed systems give all the tanks model objects their names accordingly B101, B102 & B103. Select any tank, press "F2" keyboard button, rename dialog box will appear (same as in windows-os) where you can enter desired name. You can also give/change any model object name through the Physical Topology tab of the selected model object.

3. Reconnecting model parts – Making mass connections

There are 3 types of connections available. "**Liquid line with No valve - Pipeline**" which connects liquid junctions/pump. "**Liquid Line with Valve - Pipeline**" which connects liquid junctions or source or sink. "**Liquid Line with Valve – Relative Height**" which connect to vessels (it takes into account the pipe connection height to the vessel, liquid level and vessel elevation from the ground). Look at Figure 2 and check which connection type to use appropriately. To connect two model-units select appropriate mass connection in the library, then click on the connection origin system and make second click on the target system.

If you make the second click on the empty working surface, you will get connection loose-end. By clicking double click on the loose end of a connection ("green circle") or using shortcuts (previously select the connection active point) "**o**" for reconnect origin & "**t**" for reconnect target of selected connection you will make a physical connection. Connect all the systems as illustrated in Figure 1/Figure 2.

4. Adding Species to your Model

Click anywhere on the working environment and go to Property Browser/General/ Plant Species & Reactions (or click "Plant Species & Reactions" icon "" in the toolbar) and click "**Set Injected Species**" button. In the selected database drop down menu chose "**Default Database**"(contains 2000+ different species). Now you can find (**filter ➔ type H2O**) the species that you need, select desired species and click "Add" button, i.e. add **H_2O**, then click OK. Now H_2O is injected to selected system.

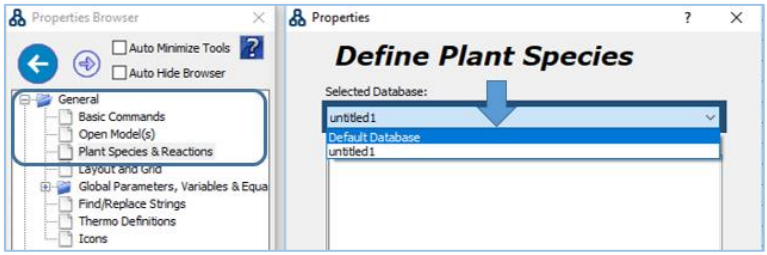


Figure 4 Chose Default Database

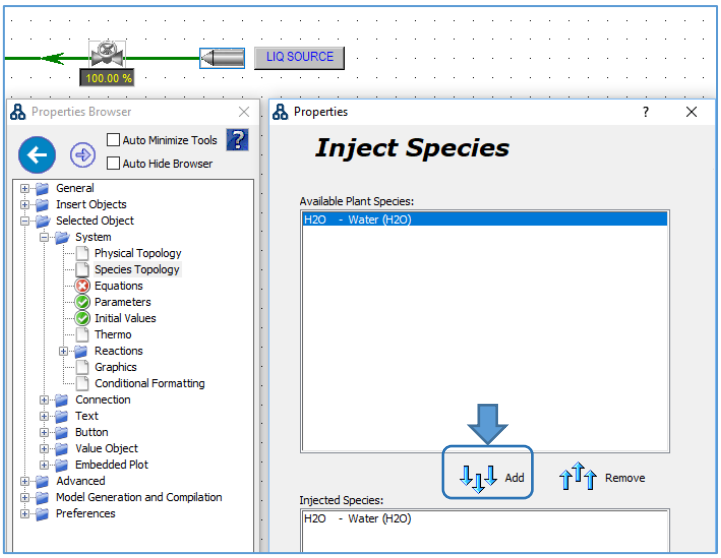


Figure 5 Injecting H_2O to Liquid Source battery limit system

It is enough to add a species to only one system (source system) because the species will propagate throughout the mass connections over the model and will appear in all mass connection connected systems as in reality.

5. Adding (flow [kg/min]) displays to the process streams

Displays are used to show a "current" calculated value of any variable or parameter given value in simulation environment. In modelling environment, the displays will show defined upper bound value by default. Displays are not necessary part of the model; they are used to provide overview of desired variables & parameter values and direct interaction with parameter values in simulation environment.

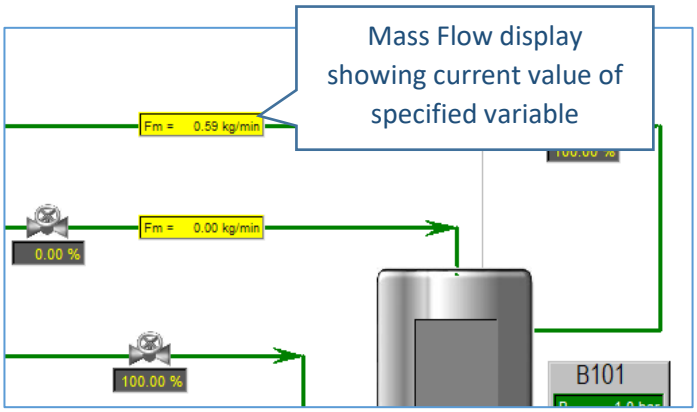


*Figure 6 Value display(s) in **SIM**ULATION environment*

To add a display, go to *Property Browser/Insert Objects/Objects.* Here you can choose between 2 types of value displays. "Value Access Object" used for valve position (parameter value) change while running dynamic simulation, which is already attached to the "liquid line with valve" model library mass connection, and "Value Display Object".

Select "**Value Display Object**" and simply click on the MM work surface to add a display. Display will appear where clicked. This display is used to show digit values of variables which we need as we want to display mass flow.

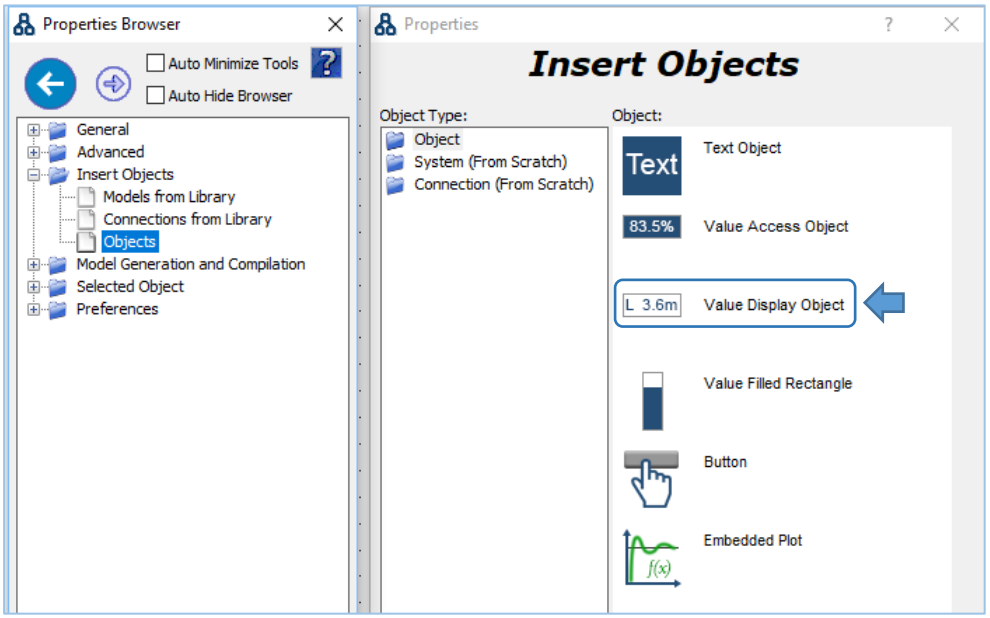


Figure 7 Chose "Value Display Object"

As we want to add display for the mass flow (kg/s), it is easier to add just one display, define that display, and then just copy it, paste it and re-link it to desired mass connection.

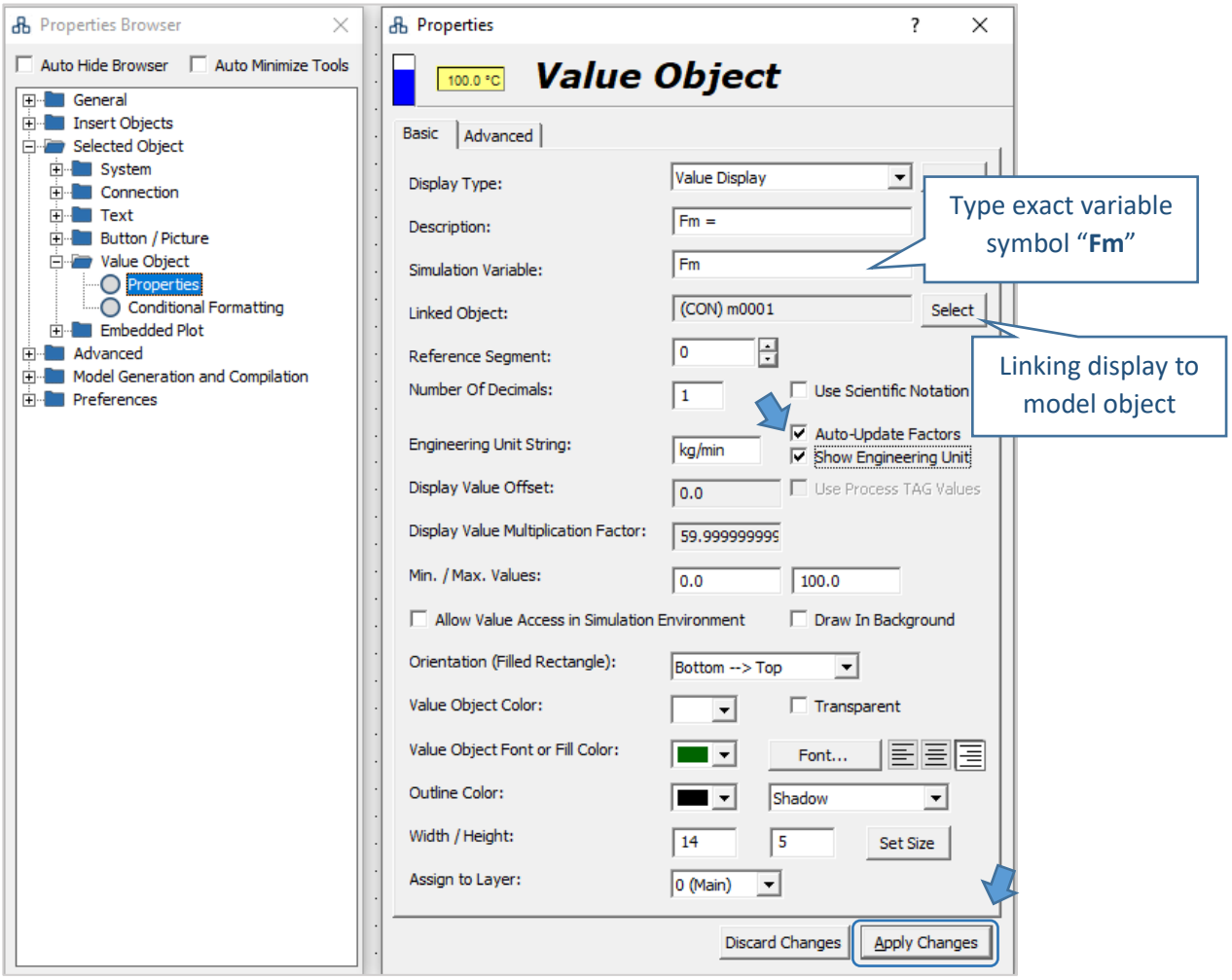


Figure 8 Defining Mass Flow value display object

Use information provided in Figure 8 to correctly define the mass flow display. To link the display with the desired variable, click on "Select" button next to "Linked Object" box. The list of available systems & connections will appear. You can either search by name within this list or **simply click on the object directly in the MM work environment**, (click on the connection active point). After making selection click "**OK**".

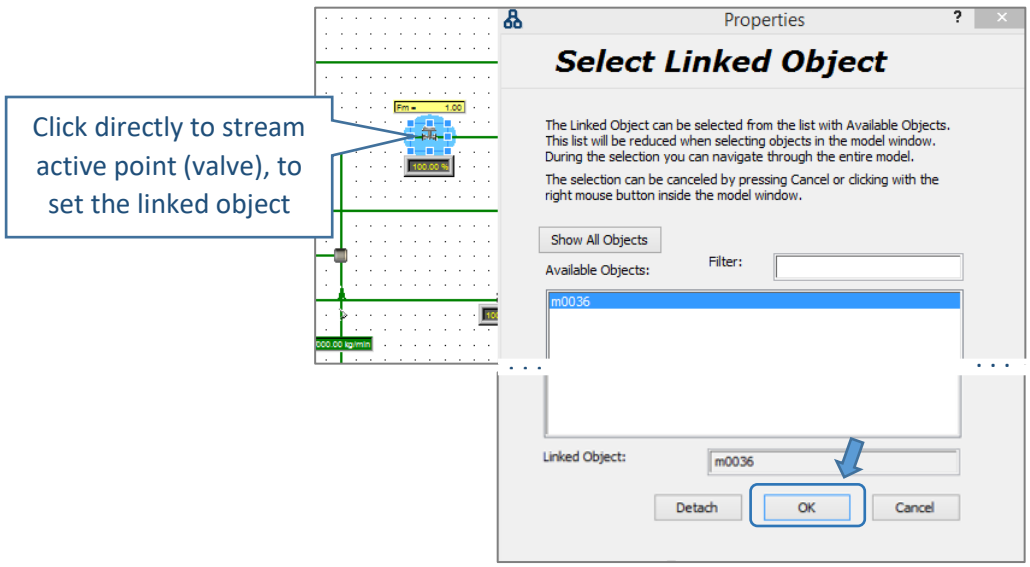


Figure 9 Linking value display to desired model object

To check which display is connected to which line, just click on the display while in modelling environment and the active point of the linked object will indicate a green “circle” around its active point. The same indication appears around the systems when clicked on the displays linked to systems.

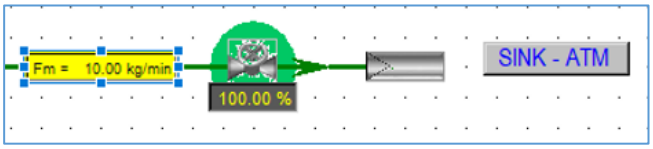


Figure 10 Linked object indication (green circle)

To set the units, in ”Engineering Unit String” text-box type the desired unit, in this case type “**kg/min**” unit and check “Auto-Update Factors” check-box next to it. This will set the “Display Value Multiplication Factor” automatically as in MM, all variables have SI basic units (kg/s in this case, so multiplication factor will be automatically set to 60). Set max and min of your display, for minimum set “-10” and for maximum set “10”, you can also adjust the colour of the font & the background, etc. **Once finished with all the settings click “Apply” button**.

(Now you can re-use defined display, just copy it, paste it where desired. Click on a display, the properties tab will open, there just change the linked object by using the same procedure as previously explained.) You can also add pressure, temperature and level indicators where desired as well as high and low level alarms for the tanks.

6. Initializing the Systems

All model variables (system & connections) need initial values to start dynamic simulation run of modelled process. All unit operation models and connections have automatic initialization routines which are performed via “**Initialization Tab**”. This tab will open first once unit operation model, or a connection is selected. This means that user only needs to fill in requested parameters within selected (specific) unit operation or connection routine. Once all parameters are filled press “**Initialize**” button within the Initialization Tab. If successful visual and textual feedback will be displayed that selected model object is successfully initialized as illustrated in Figure 11 below.

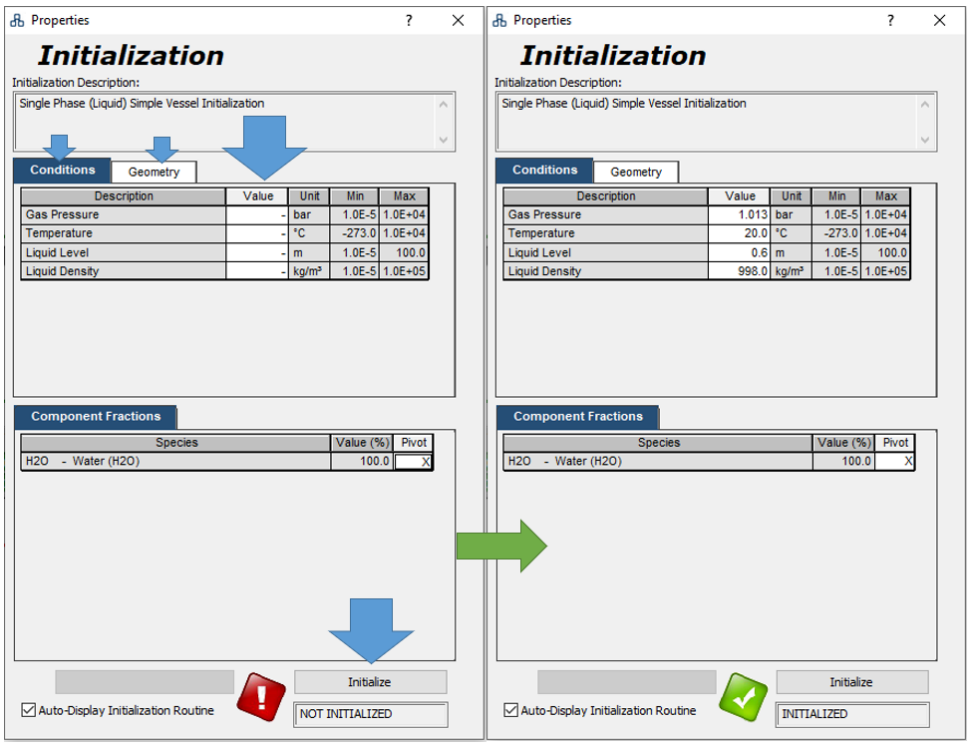


Figure 11 Automatic Initialization Tab of Atmospheric Vessel (B101/B102)

Use Table 1 below to fill all needed parameters for vessels & source/sink systems initialization and initialize them using Initialization Tab:

Initialization Sub-Tab	Parameter Symbol	Parameter Name	Value	Units
Conditions	*Pg*	**Gas Pressure** (B101/B102/ B103)	**1.013/1.013/1.2**	[bar]
Conditions	*T*	**Temperature** (B101/B102/B103)	**20**	[°C]
Conditions	*L*	**Liquid Level** (B101/B102/B103)	**0.6/0.6/0.1**	[m]
Conditions	*Dm*	**Liquid Density** (B101/B102/B103)	**998.2**	[m]
Geometry	*D*	**Vessel Diameter** (B101/B102/B103)	**0.2**	[m]
Geometry	*h*	**Vessel Height** (B101/ B102)	**1**	[m]
Geometry	*h*	**Vessel Length** (B103)	**0.5**	[m]
Geometry	*Eh*	**Elevation Height** (B101/B102/B103)	**1.0/2.0/3.0**	[m]
Input Values	*P*	**Liquid Pressure** (Source/Sink)	**1.5/1.0**	[bar]
Input Values	*T*	**Liquid Pressure** (Source/Sink)	**20**	[bar]
Input Values	*Eh*	**Elevation Height** (Source/Sink)	**3.2/0**	[m]

Table 1 B101/B102/B103 Initialization parameters values

Note: Pressurised vessel B103 is modelled as two-phase system with no phase-change connection (no mass flow between the two assumed). Air is introduced as species in the "Air" phase.

Use Table 2 below to fill all needed parameters for pump systems initialization and initialize them using Initialization Tab:

Initialization Sub-Tab	Parameter Symbol	Parameter Name	Value	Units
Conditions	*P*	**Suction Pressure**	**1.066**	[bar]
Conditions	*P*	**Discharge Pressure**	**1.066**	[bar]
Conditions	*T*	**Temperature**	**20**	[°C]
Geometry	*Eh*	**Elevation Height**	**0**	[m]
Geometry	*V0*	**Suction/Discharge Volume**	**2**	[l]

Table 2 Pipe-Element systems initialization parameters values

Use Table 3 below to fill all needed parameters for pipe element systems (pipe element systems represent volume of the piping while flow equations and pipe diameter are defined within mass connections) initialization and initialize them using Initialization Tab:

Initialization Sub-Tab	Parameter Symbol	Parameter Name	Value	Units
Conditions	*P*	**Liquid Pressure** (all pipe element systems)	**1.066**	[bar]
Conditions	*T*	**Temperature** (all pipe element systems)	**20**	[°C]
Geometry	*V0*	**Pipe Element Volume** (all pipe element systems)	**1**	[l]
Geometry	*Eh*	**Elevation Height** (all pipe element systems)	**Check Fig. 12.**	[m]

Table 3 Pipe-Element systems initialization parameters values

7. Initializing connections

Mass connections initialisation is a trivial operation since their equations usually do not contain differential equations. Use Table 4 below to fill all needed parameters for Liquid lines connections initialization and initialize them using Initialization Tab:

Initialization Sub-Tab	Parameter Symbol	Parameter Name	Value	Units
Input Values	*D*	**Diameter** (all connections)	**1**	[cm]
Input Values	*Length*	**Length** (all connections)	**1**	[m]
Input Values	*Zvset*	**Valve Opening** (all connections)	**0**	[%]
Input Values	*Cl/Cv*	**Line vs. Valve resistance** (all pipe element systems)	**10**	[-]
Input Values	*Zvstep*	**Valve Speed (perc/s)** (all connections)	**10**	[%]
Input Values	*hOr*	**Line Or. Rel. Height** (all connections)	**Check Fig. 12.**	[m]
Input Values	*hTar*	**Line Tar. Rel. Height** (all connections)	**Check Fig. 12.**	[m]

Table 4 Liquid connections initialization parameters values

Note different connection types require different inputs in Initialization Tabs:

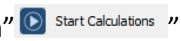
- Liquid line with no Valve: D & Length
- Liquid line with Valve (not connected to vessels): D, Length, Zvset, Cl/Cv & Zvstep
- Liquid line with Valve (connected to vessels): D, Length, Zvset, Cl/Cv & Zvstep, hOr & hTar

Once all parameters are filled you can initialise all mass connections and systems by making no selection and clicking "" button in the tool bar. Warning message that no selection is made causing initialisation of entire model will appear, **click OK**.

Note: you can also select each model object separately one by one and initialise it manually via Initial Values Tab. Manual model initialization will be covered in Exercise 3. – First Model Developer Exercise.

8. Running a Real Time Dynamic Simulation in Mobatec Modeller

To Compile the model, press the "**Compile Model and Switch to Simulation Environment**" icon in the toolbar "" (shortcut - F12), or go to Property Browser/General/Basic Commands and press "Compile Model and Switch to Simulation Environment" button.
When your Model is compiled you will get a message from Mobatec Modeller that compilation was successful!

Go to Property Browser/General/Basic Commands in Simulation environment and select "Dynamic" under the simulation type. Under integration method select "Fix Step Size" and enter "1" (sec), under "Calculation Delay (in ms)" enter "1000". Click the "Start Calculation" button"

" and run a real time (real seconds) dynamic simulation of the process.

If there are no errors your model should be running the simulation of the process and you are able to follow the *"Simulation time"* in seconds on the Basic Commands tab, or at the left bottom corner of the screen.

Start interacting with the model by turning the pump ON and opening the valves of the streamlines.

After completing all the modelling steps, ***Mobatec Modeller*** *is ready to generate a code file with consistent set of model equations. Since this code consists of mathematical equations, an interface to any problem-solving package could, in principle, be established. Several Differential Algebraic Equation (DAE) solvers are currently supported by Mobatec Modeller (e.g. Mobatec LauTrane Solver, Process Studio's e-Modeler, Aspen Custom Modeller, Matlab,…). Check your license ([Tools][License Settings]) to see which solvers are available to you.*

Select the Model Generation tab in the Property Browser and click on the ***Show Code*** *button to display the code that is generated by Mobatec Modeller. This code is compiled by the* ***Mobatec Compiler****. The compiled code can be used for doing dynamic simulation runs for testing and tuning. A (tuned and tested) model can be easily connected to other software and, for example, form the basis for an Operator Training Simulator.)*

9. Changing systems ground elevation & relative streamlines connection points

All physical systems are affected by gravity. Therefore, we have gravity flow due to hydrostatic pressure difference caused by different elevations of the origin and the target system. In this model you can change systems elevation height parameter "**Eh**" value (set to 0 by default) and stream lines relative connection elevation points of origin system "**hOr**" and the target system "**hTar**" (also set to 0 by default). By doing so you will directly affect the behaviour of the entire model. Look at Figure 12 on next page illustrating these parameters and their relation in space.

Play with different values of these parameters to check different behaviours of the process.

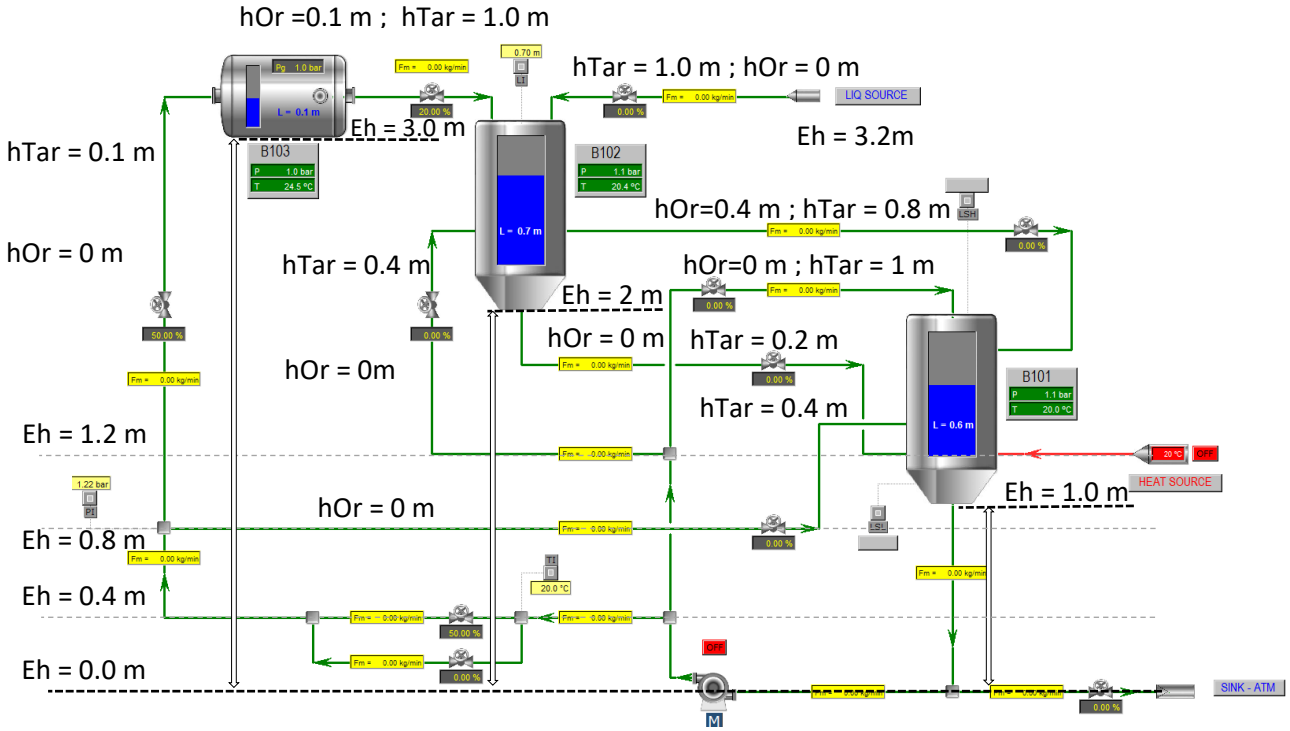


Figure 12 Systems & Connection elevation parameters relation

Parameters (**Eh,hOr & hTar**) can be changed in Modelling environment in systems and connections. In that case complete model initialisation and compilation is needed before running the simulation with new parameter values. **Note, all "hOr" parameter values for connections originating from liquid "buffers" are equal to "0 m".**

It is of course, also possible to change parameter values while the dynamic simulation is running through value access object displays (same as used for valve positions displays).

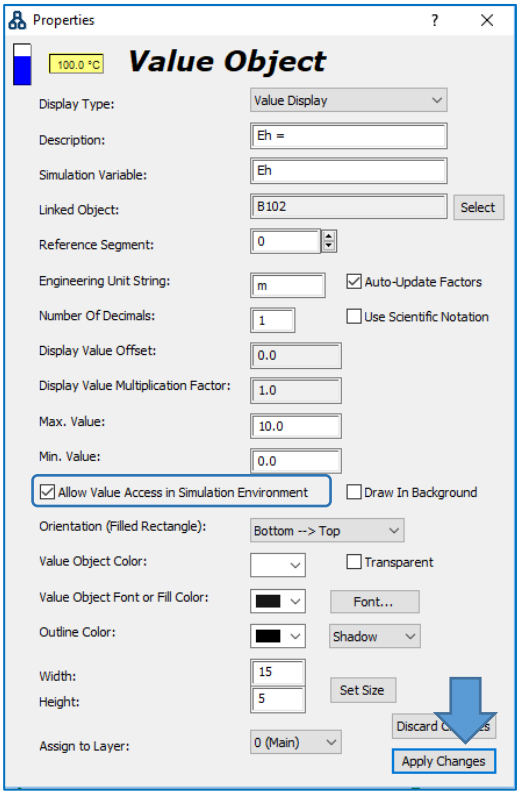


Figure 13 "Eh" parameter access value display definition

3. Appendix 1 – Used Parameters

1. Parameters - Atmospheric & Pressurised tanks

Symbol	Description	Units	Mobatec identifier
ρ	**Density**	[kg/m^3]	Dm_"tankname"
D	**Diameter**	[m]	D_"tankname"
P_g	**Gas Phase Pressure**	[bar]	Pg_"tankname"
V_{min}	**Minimal Liquid Volume**	[m^3]	Vmin_"tankname"
Eh	**Elevation height**	[m]	Eh_"tankname"

Table 5 Atmospheric Tanks parameters

2. Parameters – Pump

Symbol	Description	Units	Mobatec identifier
Q	**Operating flow**	[m^3/s]	F0_M
H	**Pump head**	[m]	Head0_M
α	**Flow resistance**	[m^4/s]	Alpha_M
T	**Pump response delay**	[s]	Tau_M
Wdis	**Pump work**	[W]	Wdis0_M
Sw	**Pump switch**	On/Off	Sw_M

Table 6 Pump parameters

3. Parameters – Liquid buffer(s)

Symbol	Description	Units	Mobatec identifier
P_o	**Referent pressure**	[bar]	P0_"buffername"
Vo	**Referent liquid volume**	[m^3]	V0_"buffername"
V_{min}	**Minimal liquid volume**	[m^3]	Vmin_"buffername"
Eh	**Elevation height**	[m]	Eh_"buffername"
L	**Liquid level**	[m]	L_"tankname"

Table 7 Liquid Buffer parameters

5. Parameters – Liquid lines

Symbol	Description	Units	Mobatec identifier
Cv	**Valve resistance**	[-]	Cvmanf_"linename"
D	**Diameter**	[m]	D_"linename"
ff	**Flow resistance**	[m^4/s]	ff_"linename"
h	**Line vertical coordinate**	[s]	h_"linename"
L	**Length**	[W]	L_"linename"
Zv	**Valve position**	[%]	Zv_"linename"
Zvset	**Vale set position**	[%]	Zvset_"linename"
Zvstep	**Valve speed**	[%/int. step]	Zvstep_"linename"
hOr	**Relative Elev. height**	[m]	hOr_" linename"
hTar	**Relative Elev. height**	[m]	hTar_" linename"

Table 8 Liquid Lines parameters

6. Parameters – Switches, Indicators & Alarms

Symbol	Description	Units	Mobatec identifier
Lmin	**Minimal level**	[m]	Lmin_ Lmin_/L_max"indicator/switchname"
Fm_min	**Minimal mass flow**	[kg/s]	FmMin_"indicator/switchname"
offset	**offset**	[-]	offset**P**_"indicator/switchname"
range	**range**	[-]	range**P**_"indicator/switchname"

Table 9 Switches, Indicators & Alarms parameters