

VisiMix PL. PIPELINE FOR PUMPING OF A NON-NEWTONIAN CMC SOLUTION

Calculations of hydraulic resistance of simple pipelines for liquid viscous and non-Newtonian products.

SUMMARY: This example is based on characteristics of a real temporary pipeline for transportation of a non-Newtonian liquid in a production plant. The calculated transportation time is somewhat less than 1 hour (3330 min), while the actual value is from 40 min to 1 hour.

1. Characteristics of the tank and pipeline:

2500 liter CMC solution (20%) is prepared in a jacketed mixing tank with elliptical bottom with Pfaudler impeller. After preparation, this solution is transferred to a mixing tank with ribbon agitator for preparation of an abrasive cleaning paste. Pumping is performed using a temporary pipeline and an air-operated double diaphragm pump. The program VisiMix PL is used for evaluation of the minimum duration of solution transfer.

Mixing tank:

Type of bottom – elliptical;
Tank diameter – 1800 mm;
Outlet pipe diameter – 3 in;
Volume of liquid in the mixing tank – 2500 liter.

Pump: a double-diaphragm pump.

Max. flow rate – 340 l/min.
Max. pressure – 7 bar.
Suction height -6 m.
Inlet and outlet diameter – 1 ½ in.

Table 1. Pipe sections of the pipeline.

Position	No.	Type	Diameter	Total length
Before pump	1	Riffled hose	2 in	5 m
After pump	1	Riffled hose	2 in	18 m

Table 2. Fittings and valves.

Position	No.	Item	Big diameter	Small diameter	Count
Before pump	1	Valve – globe standard	N/A	3 in	1
	2	Valve – globe standard	N/A	1 ½ in	1
	3	Reducer	3 in	2 in	1
	4	Reducer	2 in	1 ½ in	1

After pump	1	Valve – globe standard	N/A	1 ½ in	1
	2	Valve – globe standard	N/A	2 in	1
	3	Expander	2 in	1 ½ in	1

Table 3. General characteristics of pipeline.

Parameter	Value
Height of tank outlet (H)	0.5 m
Height of discharge point (H1)	8 m
Diameter of discharge pipe	2 inch
External pressure in discharge point	0

Table 4. Physical properties of the CMC solution.

Rheological model	Power law
Density	About 1100 kg/cub.m
Rheological constant K	19
Exponent n	0.5
Yeld stress	0

Note: The rheological constants are defined using rotational viscometer

2. Opening a project and entering initial data.

Start the program VisiMix PL. A scheme is presented that explains nomenclature used in the program (Figure 1).

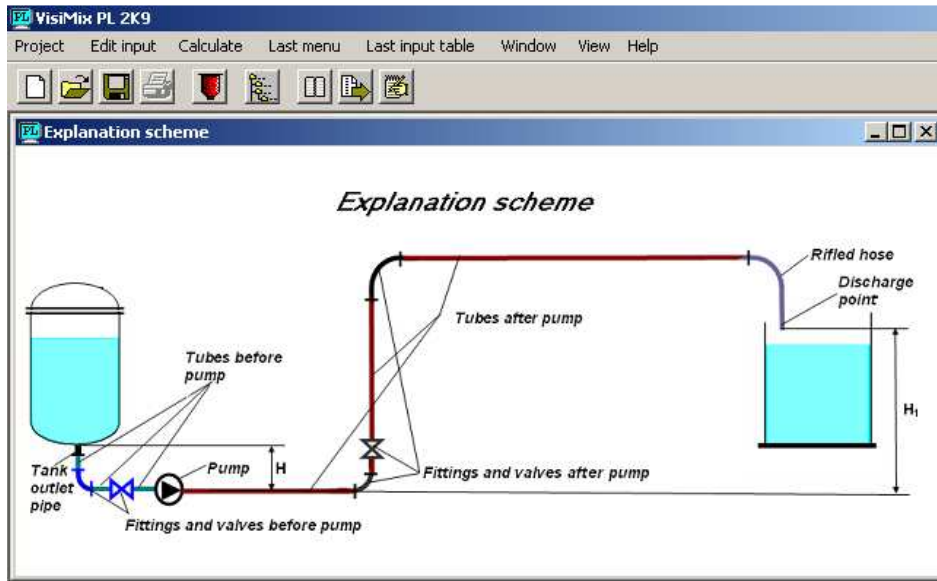


Figure 1.

Order of operations for opening a new project is the same as in all other VisiMix simulation programs.

Select **Project-New** or the corresponding button below the **Project** in the Main menu, and enter a name for the new project in dialog box – for example, **Prod_Test_CMC.vsp**.

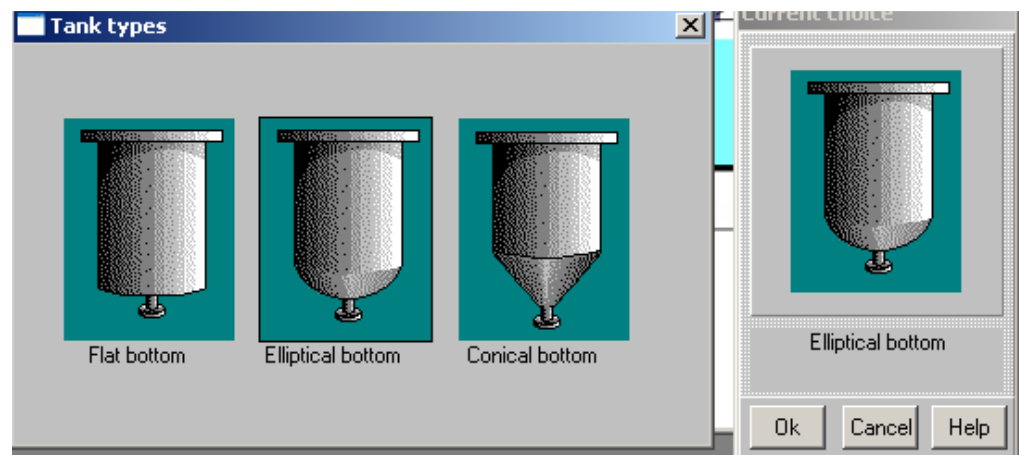


Figure 2.

After you click **Save**, the **Tank selection** screen appears (Figure 2). We can select a tank with the type of bottom corresponding to our initial data. In the current case – it is a tank with elliptical bottom. Select it by clicking on the corresponding picture. The selected type appears in the **Current choice** window on the right (Figure 2). Click **OK** to confirm your choice.

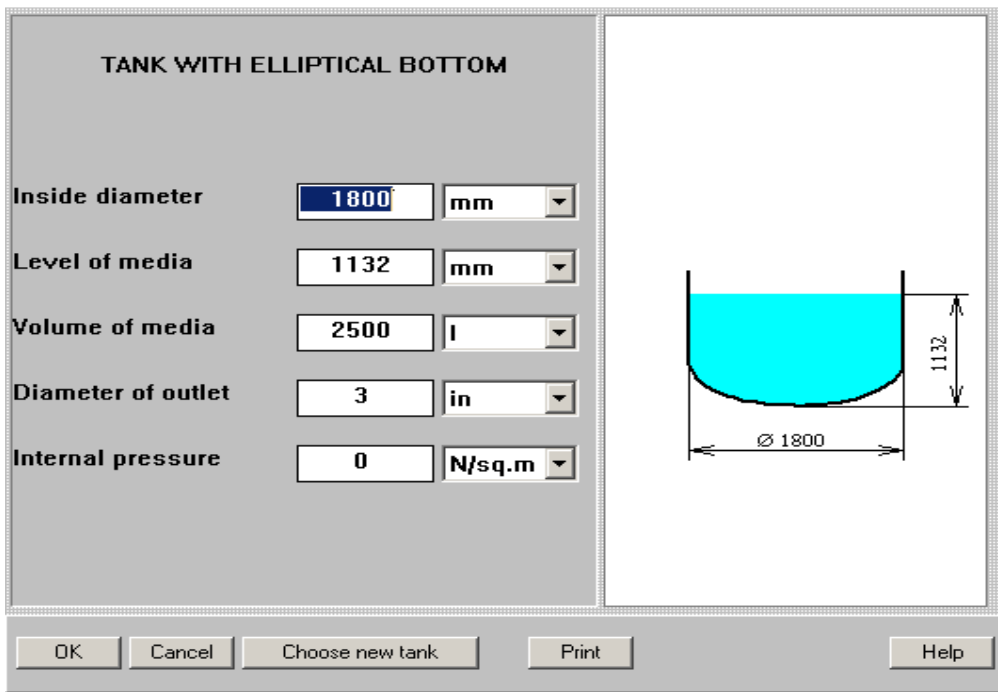


Figure 3.

After you confirm your tank choice, an input table with the selected tank diagram appears (Figure 3). Enter the internal dimensions of the selected tank accordingly to the initial data above - **Inside diameter**, **Volume of media**, **Diameter of outlet pipe** and **Internal pressure**. The **Level of media** will be calculated by the program and entered automatically.

Note. Volume of liquid is defined as volume that is placed above level of the outlet pipe. It is assumed that the outlet point corresponds to the lowest level of the tank space.

After the table has been completed, click anywhere on the field of the window, and the tank diagram on the screen will change to reflect your input. Click **OK** to confirm the input.

Now the program automatically opens input tables for pipes.

The pipe sections of the pipeline placed before and after the pump are entered separately. Accordingly to the Table 1, in our case the before-pump part of pipeline consists of a 2 inch riffled hose. When the first input table arrives (Figure 4), click **Add** and enter the 2 inch pipe data as 'riffled' (Figure 5).

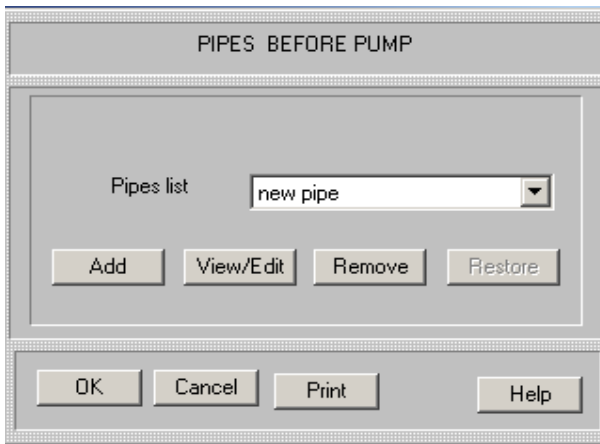
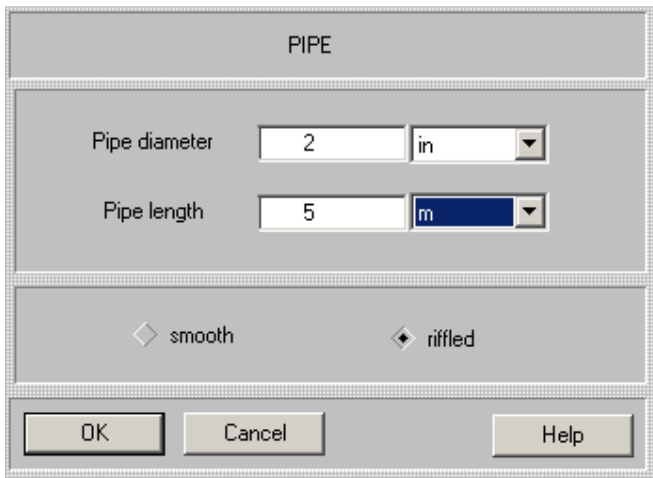


Figure 4.

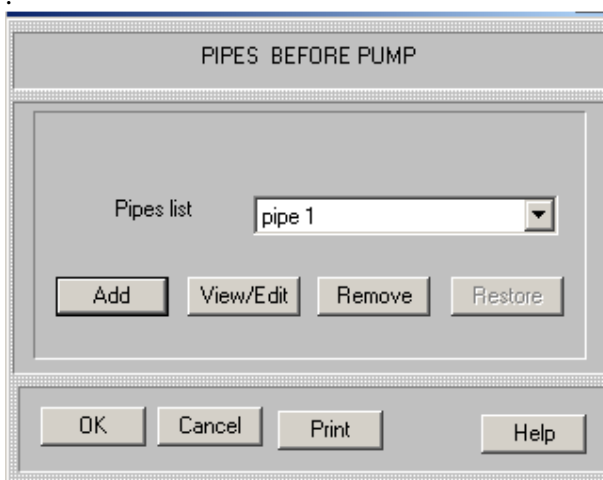
The valve and elbows separate the pipe in a few sections, but we can enter the total length – about 6 m. (Figure 6).



The 'PIPE' dialog box contains the following elements:

- PIPE** (Title bar)
- Pipe diameter**: Input field with '2' and a dropdown menu with 'in' selected.
- Pipe length**: Input field with '5' and a dropdown menu with 'm' selected.
- Surface type**: Two radio buttons, 'smooth' (selected) and 'ruffled'.
- Buttons**: 'OK', 'Cancel', and 'Help' at the bottom.

Figure 5



The 'PIPES BEFORE PUMP' dialog box contains the following elements:

- PIPES BEFORE PUMP** (Title bar)
- Pipes list**: A dropdown menu showing 'pipe 1'.
- Buttons**: 'Add', 'View/Edit', 'Remove', and 'Restore' in a row below the list.
- Buttons**: 'OK', 'Cancel', 'Print', and 'Help' at the bottom.

Figure 6.

The program will store the entered pipe as the '**pipe 1**' (Figure 6).

Confirm the input with **OK**.

There are no other pipes to enter, so close this input table with **OK**. The program opens dialog box for the after pump pipe sections (Figure 7).

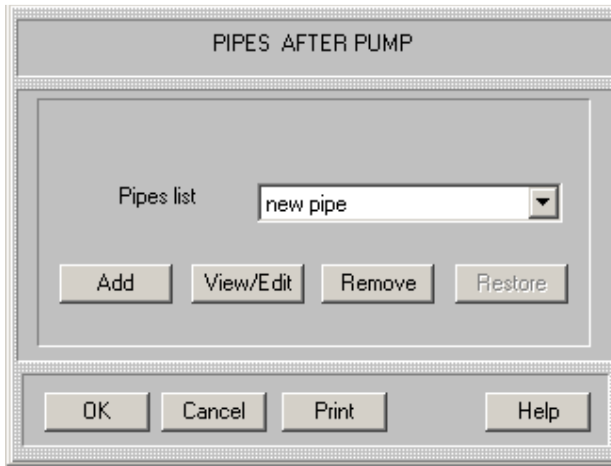


Figure 7.

In our case the pump is connected to the next mixing tank with another 2 inch riffled hose, the hose length is about 18 m. Enter it, the same as in the previous input, with **Add** and **OK** (Figure 8).

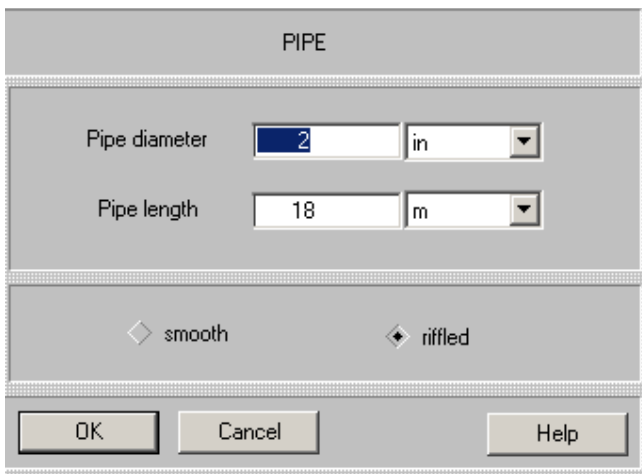


Figure 8.

After entering the last of the pipe section, close current dialog box by pressing **OK**. The input dialog box **FITTINGS AFTER PUMP** is displayed automatically (Figure 9). The next steps – entering of fittings and valves accordingly to the Table 2. The first element – standard globe 2 in. valve – is entered as follows:

Click **Add**, and the visual menu of fittings and valves will be displayed (Figure 9).

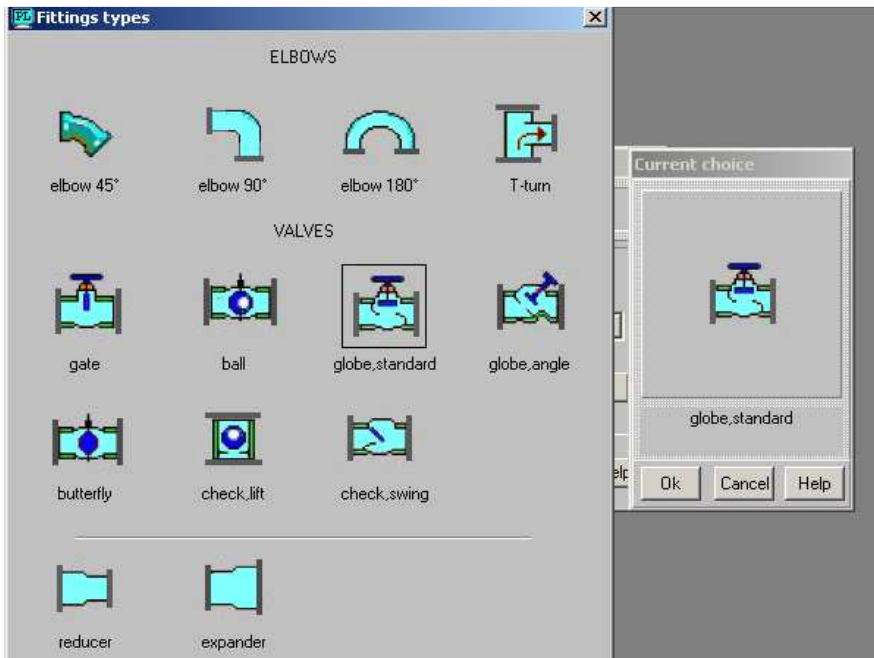


Figure 9.

Select the icon **globe, standard**. Corresponding icon arrives on the **Current choice** screen. Confirm selection with **OK**.

Enter the valve diameter and number (count) of these valves (Figure 10) and click **OK**.



Figure 10.

Proceed with entering of the next elements in the same way.

After entering the last element before pump (Figure 11), close the current dialog box by pressing **OK** (Figure 12).

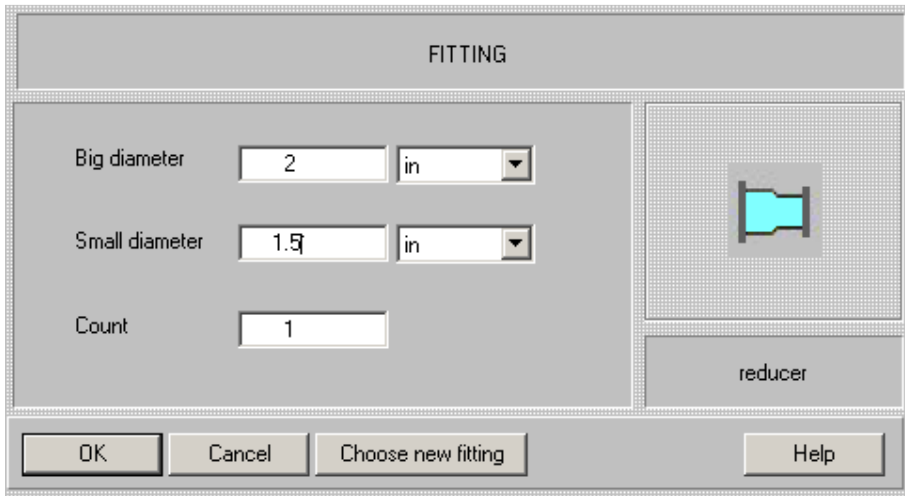


Figure 11.

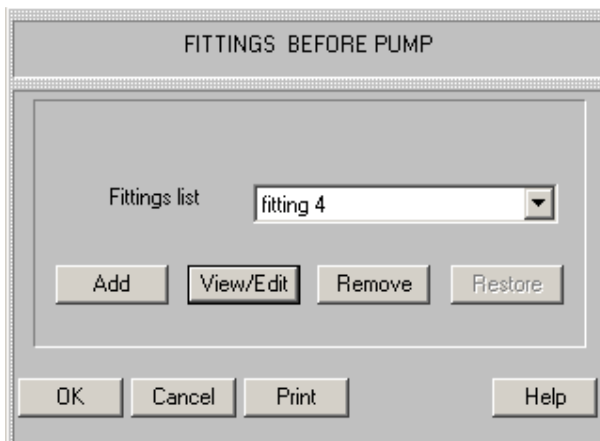


Figure 12.

Now the FITTINGS AFTER PUMP dialog box will be opened. Enter the corresponding elements (two valves and expander, Table 2) in the same way as before.

After the FITTINGS AFTER PUMP dialog box has been closed, the program displays a table for entering additional pipeline data and parameters of the pump. Enter the data accordingly to the Table 3 and characteristics of the pump presented in par.1 of the example (Figure 13).

After these data have been entered, you are asked to enter average properties of media. Order of input is the same as in other VisiMix programs. On the first stage, density of liquid is entered, and its rheological type is defined (Figure 17). On the next step, viscosity of Newtonian liquid or rheological constants of anon-Newtonian media are entered.

PIPELINE CHARACTERISTICS

Height of tank outlet (H) mm

Hight of discharge point (H1) mm

Diameter of discharge pipe in

External pressure in outlet point N/sq.m

Pump characteristics

Flow capacity l/min

Pressure N/sq.m

Suction head (water) mm

OK Cancel Print Help

Figure 13.

DENSITY AND TYPE OF MEDIA

Average density kg/cub.m

TYPE OF MEDIA

Newtonian
 $\tau = \mu * \gamma$

Power-law non-Newtonian
 $\tau = \tau_0 + K * \gamma^n$
 $\mu = \tau_0 * \gamma^{-1} + K * \gamma^{n-1}$

Carreau non-Newtonian

$$\frac{\mu - \mu_{min}}{\mu_{max} - \mu_{min}} = \left[1 + (\lambda * \gamma)^2 \right]^{\frac{n-1}{2}}$$

OK Cancel Print Help

Figure 14.

In our case rheological data for the CMC solution are known and presented in the Table 4, so they can be entered immediately (Figure 14,15).

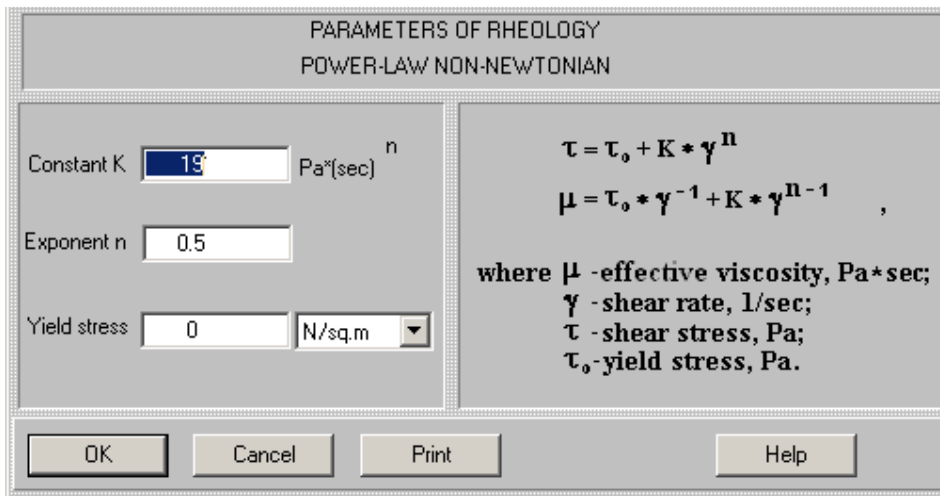


Figure 15.

If the rheological constants for a liquid are not known, it is possible to define them approximately. The program provides data for typical commercial non-Newtonian products. To find them, click **Calculate>Rheological constants** (Figure 16) and select name of a product, for example – **Shampoos**. A table of rheological data for different products of this type will be opened (Figure 17).

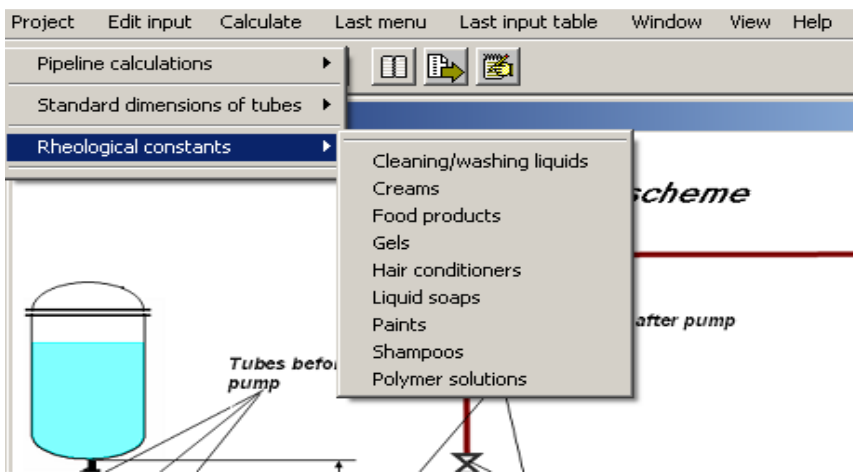
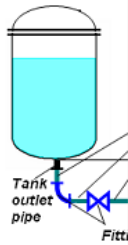


Figure 16.

Rheological constants

Shampoos



Rheological model – power law

Material	Density, kg/cub.m	τ_0 , Pa	K	n	Shear rate min, l/s	Shear rate max, l/s	Temper
Shampoo for hair	1050	0	12.3	0.61	0.06	2000	23
Shampoo for hair	1050	0	3	0.75	0.4	1600	45

Rheological model – Carreau

Material	Density, kg/cub.m	μ_{min} , Pa*s	μ_{max} , Pa*s	λ	n	Shear rate min, l/s	Shear rate max, l/s	Tem
Shampoo for hair	1100	<0.06	16.3	0.235	0.18	0.1	7000	22
Shampoo	1100	<0.013	8	0.007	0.28	10	1300	40

Figure 17.

3. Calculated characteristics of the pipeline.

3.1. In order to perform calculations, click **Calculate** in the main menu and select **Pipeline calculation>Total transportation time** (Figure 18).

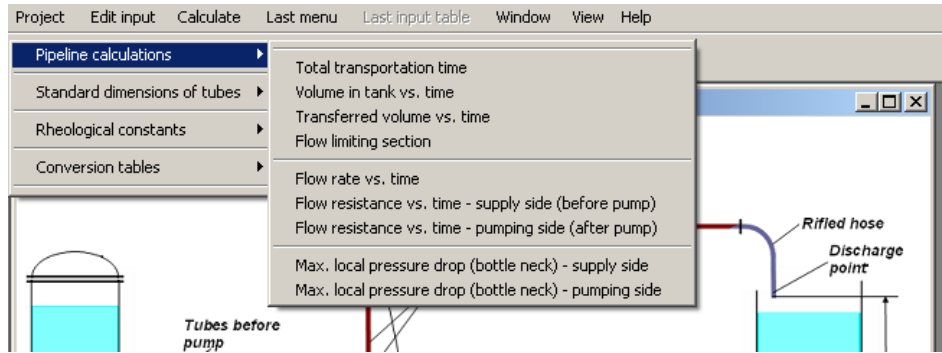


Figure 18.

TOTAL TRANSPORTATION TIME		
Parameter name	Units	Value
Total transportation time	s	3330

For HELP press F1

Figure 19.

As follows from the data in Figure 19, transfer of CMC solution from one tank to another must take somewhat less than 1 hour. Accordingly to data from the production plant, actual duration of CMC solution transfer was between 40 min and 1 hour.