

VISIMIX PL. PIPELINE FOR DISCHARGING OF A SHAMPOO

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

The task: to build a temporary pipeline in order to transfer a batch of shampoo from a flat-bottom 4 cub.m. mixing tank to feeding container of filling machine. The program VisiMix PL is used for evaluation of the minimum duration of the transfer.

1. Characteristics of the tank and pipeline:

Mixing tank:

- Type of bottom – flat;
- Tank diameter – 1600 mm;
- Outlet pipe diameter – 2 in.
- Volume of liquid in the mixing tank – 3000 l.

Pump: a double-diaphragm pump.

- Max. flow rate – 350 LPM.
- Max. pressure – 8.6 BAR
- Inlet and outlet diameters – 1 ½ in.
- Suction head – 6.9 m (of water).

Table 1. Pipe sections of the pipeline.

Position	No.	Type	Diameter	Total length
Before pump	1	Steel pipe	2 in.	6 m
	2	Steel pipe	1 ½ in.	0.5 m
After pump	1	Riffled hose	1 ½ in.	21 m

Table 2. Fittings and valves.

Position	No.	Item	Small diameter	Big diameter	Count
Before pump	1	Valve – globe standard	2 in	N/A	1
	2	Elbow 90 deg	2 in.	N/A	2
	3	Reducer	1 ½ in.	2 in	1
	4	Valve – globe standard	1 ½ in.	N/A	1
After pump	1	Valve – globe standard	1 ½ in.	N/A	2

Table 3. General characteristics of pipeline.

Parameter	Value
Height of tank outlet (H)	2 m
Height of discharge point (H1)	8 m

Diameter of discharge pipe	1.5 inch
External pressure in discharge point	0

Table 4. Physical properties of the liquid media (shampoo).

Rheological model	Carreau
Density	1020 kg/cub.m.
Minimum viscosity, Pa.s	0.22
Maximum viscosity, Pa.s	18.4
Constant λ	0.385
Exponent n	0.18

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).

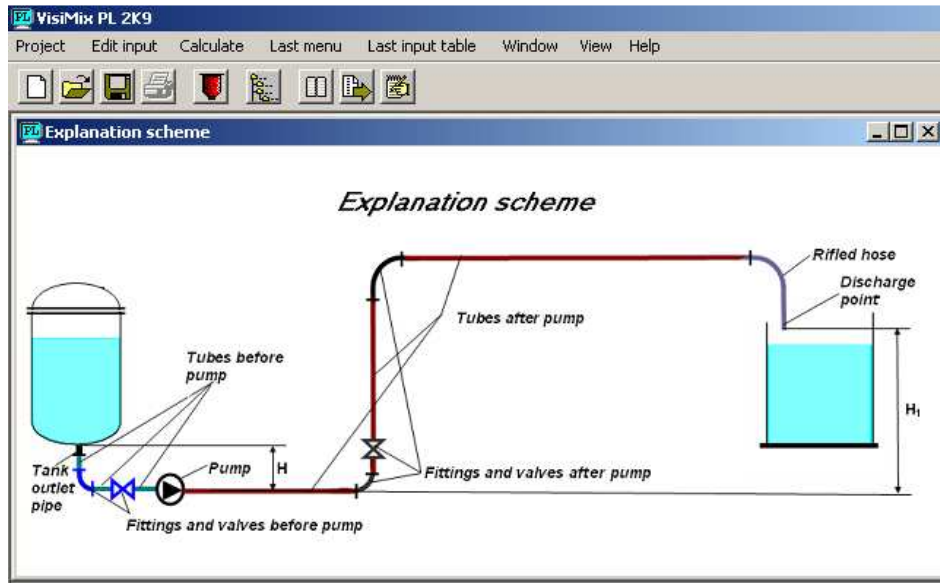


Figure 1.

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, **Ex.1-PL** (Figure 2).

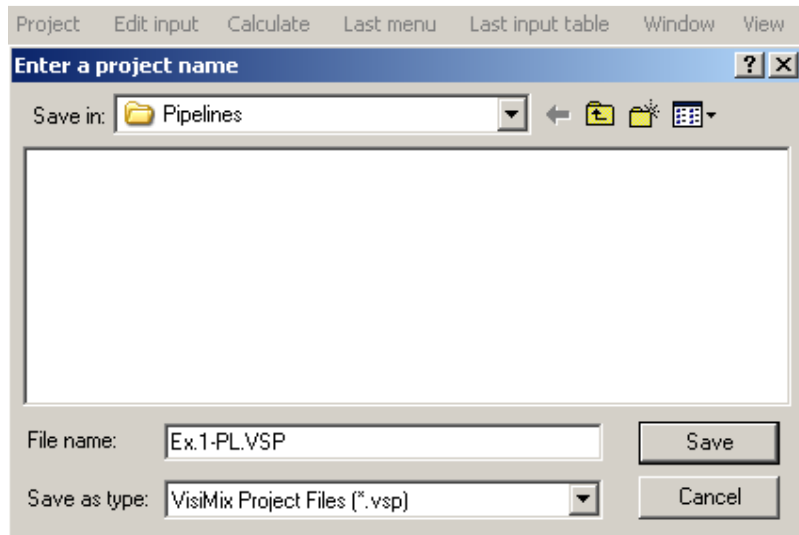


Figure 2.

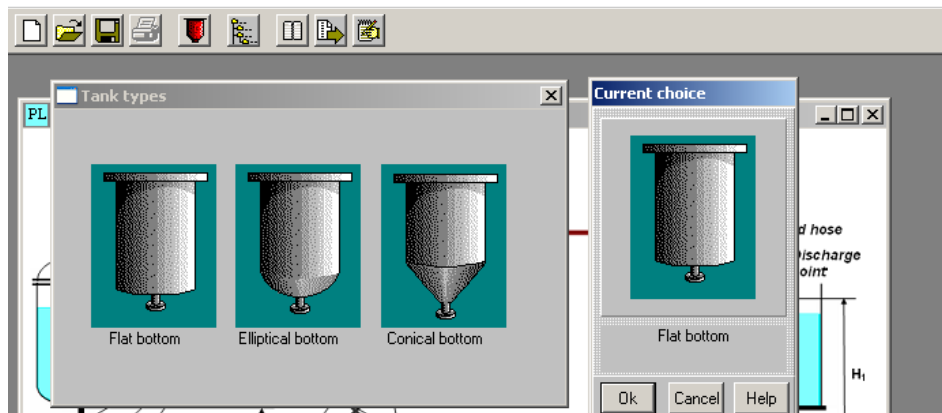


Figure 3.

After you click **Save**, the **Tank selection** screen appears (Figure 3). We can select a tank with the type of bottom corresponding to our initial data. In the current case – it is a tank with a flat bottom. Select it by clicking on the corresponding picture. The selected type appears in the **Current choice** window on the right (Figure 3). Click **OK** to confirm your choice.

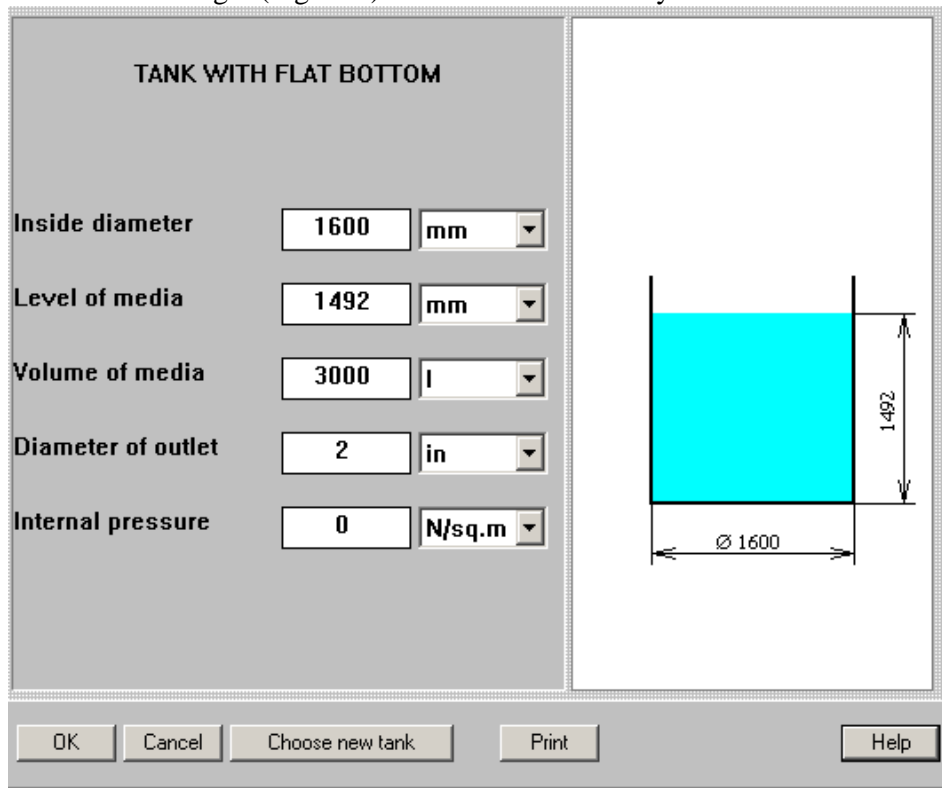


Figure 4.

After you confirm your tank choice, TANK WITH FLAT BOTTOM input table with the selected tank diagram appears (Figure 4). Enter the internal dimensions of the selected tank accordingly to the initial data above - **Inside diameter**, **Volume of media** 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 pipe connected to the tank outlet and 1 ½ inch pipe connected to the pump inlet. When the first input table arrives (Figure 5), click **Add** and enter the 2 inch pipe data as a 'smooth' pipe.

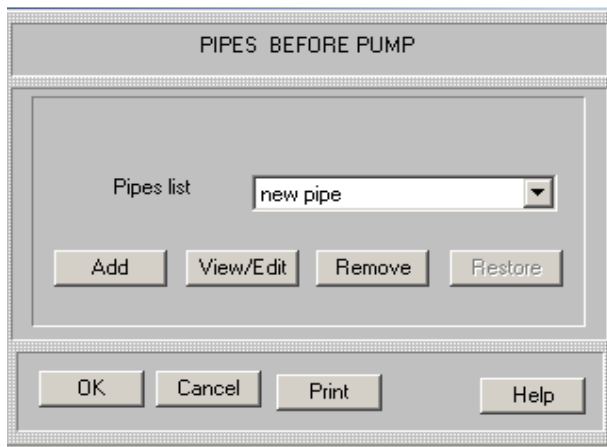


Figure 5.

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

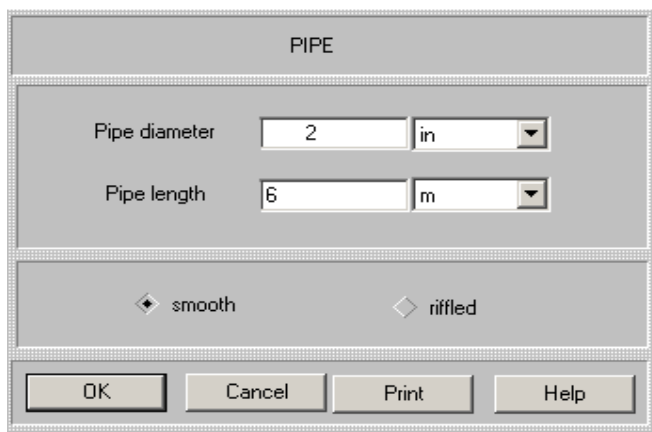


Figure 6.

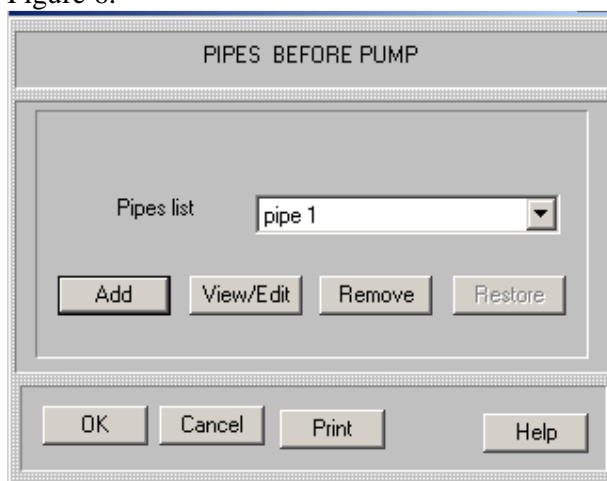
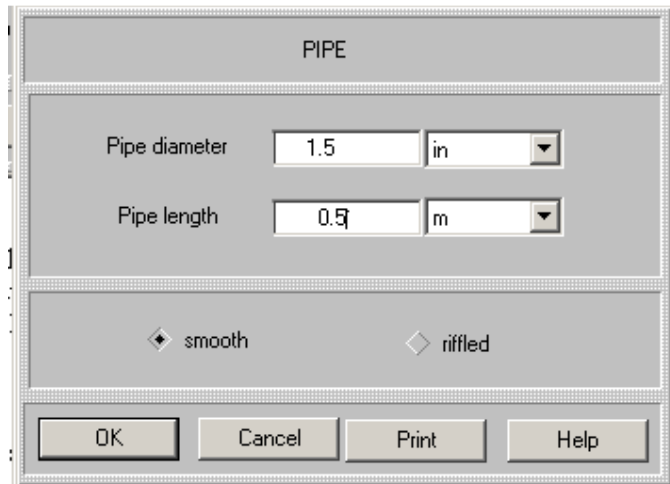


Figure 7.

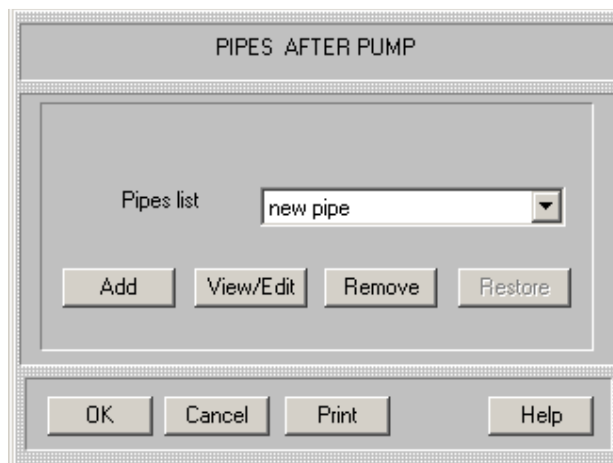
The program will store the entered pipe as the '**pipe 1**' (Figure 7).
Confirm the input with **OK** and enter the 1 ½ inch part of the pipe (with **Add** and **OK**, Figure 8).



The image shows a dialog box titled "PIPE". It has two input fields: "Pipe diameter" with the value "1.5" and a unit dropdown set to "in"; and "Pipe length" with the value "0.5" and a unit dropdown set to "m". Below these fields are two radio buttons: "smooth" (which is selected) and "ruffled". At the bottom of the dialog are four buttons: "OK", "Cancel", "Print", and "Help".

Figure 8.

After the **pipe 2** is entered, close this input table with **OK**. The program opens dialog box for the after pump pipe sections (Figure 9).



The image shows a dialog box titled "PIPES AFTER PUMP". It contains a "Pipes list" dropdown menu with "new pipe" selected. Below the dropdown are four buttons: "Add", "View/Edit", "Remove", and "Restore". At the bottom of the dialog are four buttons: "OK", "Cancel", "Print", and "Help".

Figure 9.

In our case the pump is connected to the feeding tank of filling machine with 1 ½ inch ruffled hose, the hose length is about 12 m. Enter it, the same as in the previous input, with **Add** and **OK** (Figure 10).

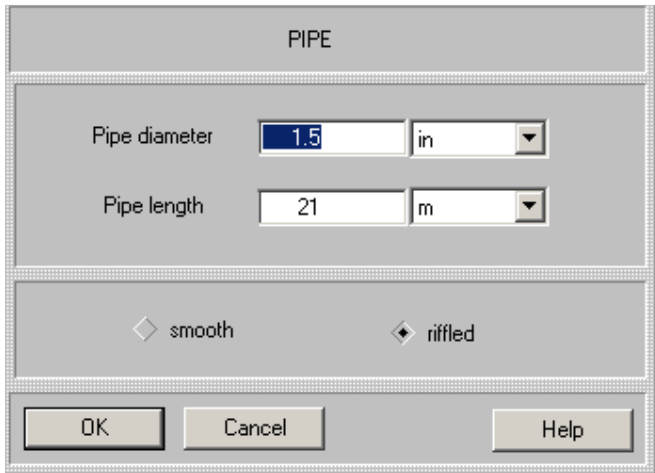


Figure 10.

After entering the last of the pipe section, close current dialog box by pressing **OK** (Figure 9). The input dialog box **FITTINGS BEFORE PUMP** is displayed automatically (Figure11). 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:

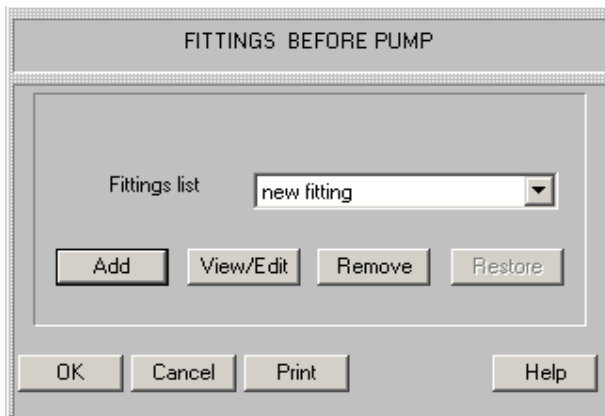


Figure 11.

Click **Add**, and the visual menu of fittings and valves will be displayed (Figure 12).

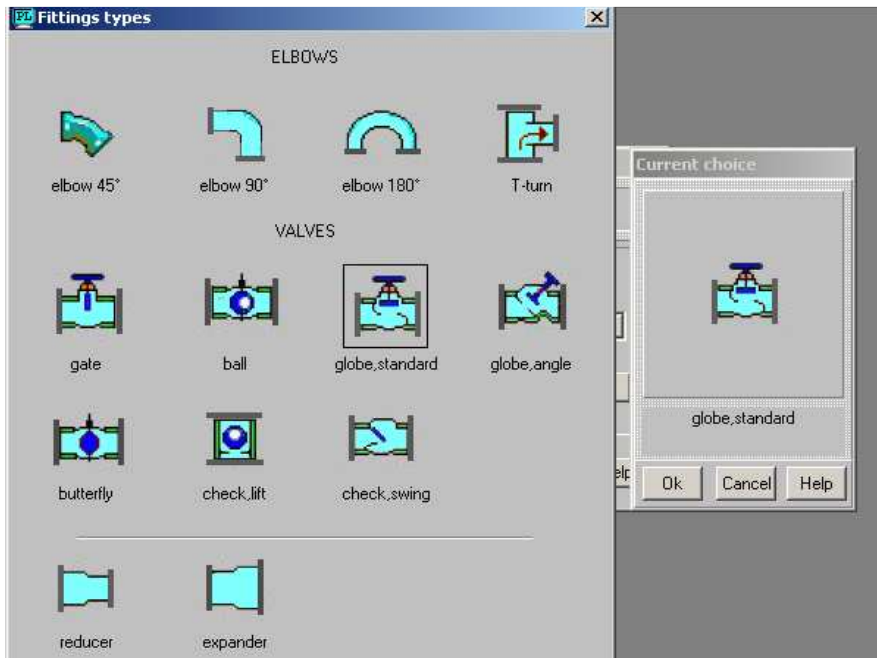


Figure 12.

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 13) and click **OK**.

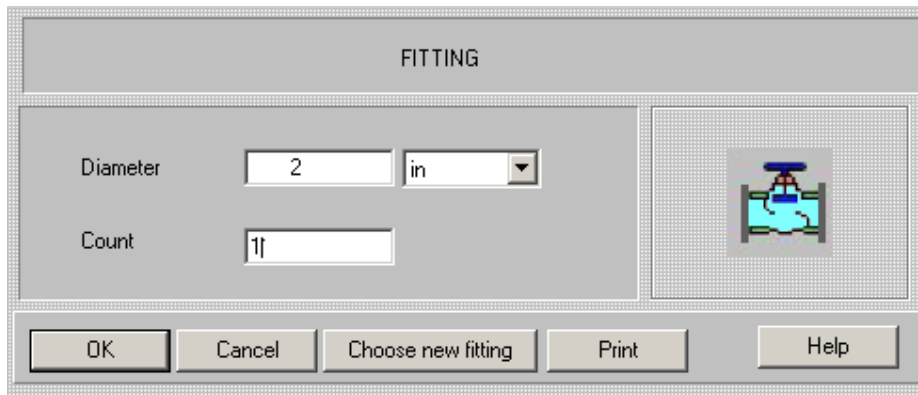


Figure 13.

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

After entering the last element before pump (Figure 14), close the current dialog box by pressing **OK** (Figure 15).

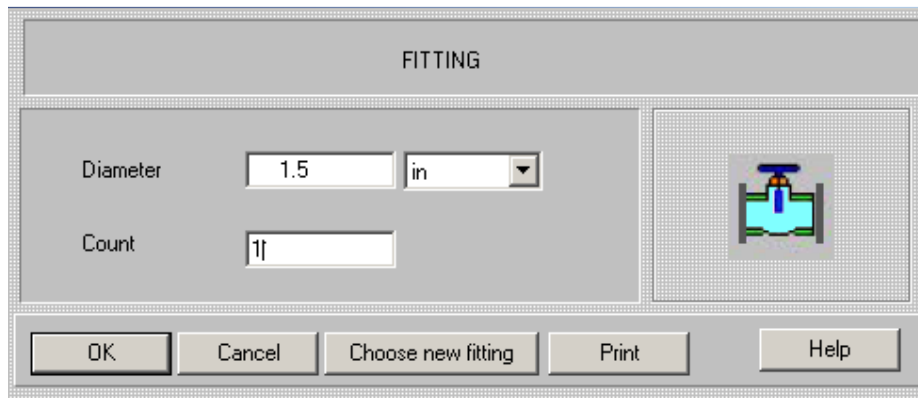


Figure 14.

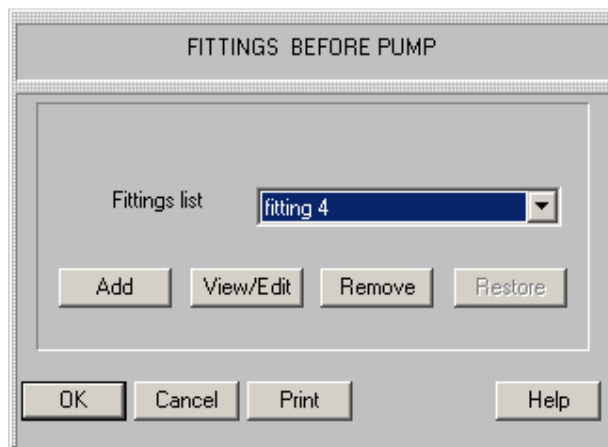


Figure 15.

Now the FITTINGS AFTER PUMP dialog box will be opened. Enter the corresponding elements (two 1 ½ in. valves, 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 above (Figure 16).

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 a non-Newtonian media are entered.

PIPELINE CHARACTERISTICS

Height of tank outlet (H)

Hight of discharge point (H1)

Diameter of discharge pipe

External pressure in outlet point

Pump characteristics

Flow capacity

Pressure

Suction head (water)

Figure 16.

DENSITY AND TYPE OF MEDIA

Average density

TYPE OF MEDIA

Newtonian
 $\tau = \mu * \gamma$

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

Carreau non-Newtonian:

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

Figure 17.

In our case rheological data for the shampoo are known and presented in the Table 4, so they can be entered immediately (Figure 18).

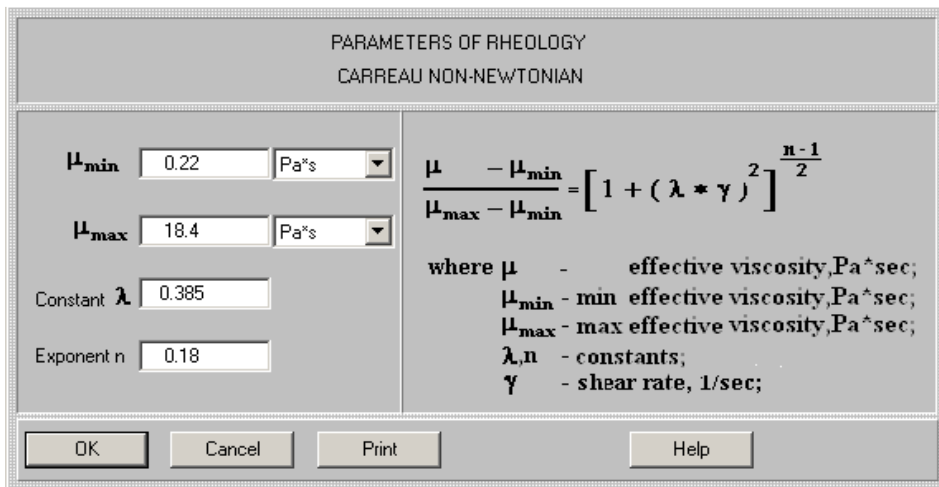


Figure 18.

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 19) and select name of the product, for example – **Shampoos**. A table of rheological data for different products of this type will be opened (Figure 20).

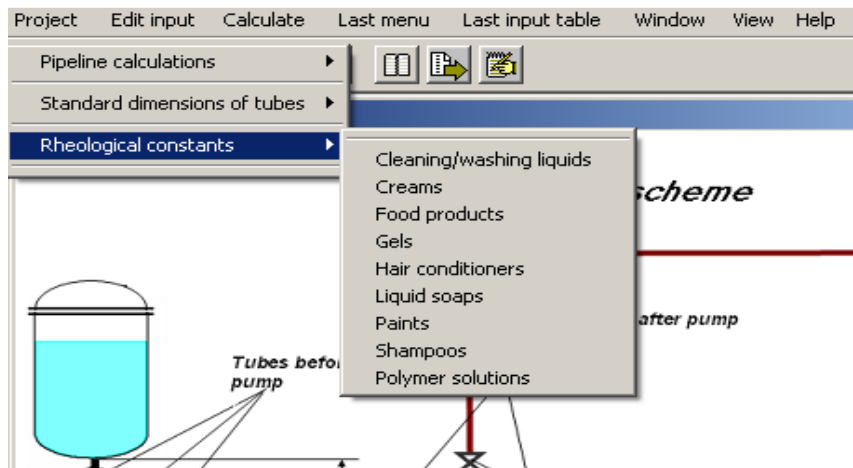
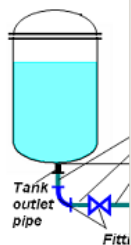


Figure 19.

Rheological constants Shampoos

Rheological model – power law



Material	Density, kg/cub.m	τ_0 , Pa	K	n	Shear rate min, 1/s	Shear rate max, 1/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, 1/s	Shear rate max, 1/s	Temper
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 20.

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 21).

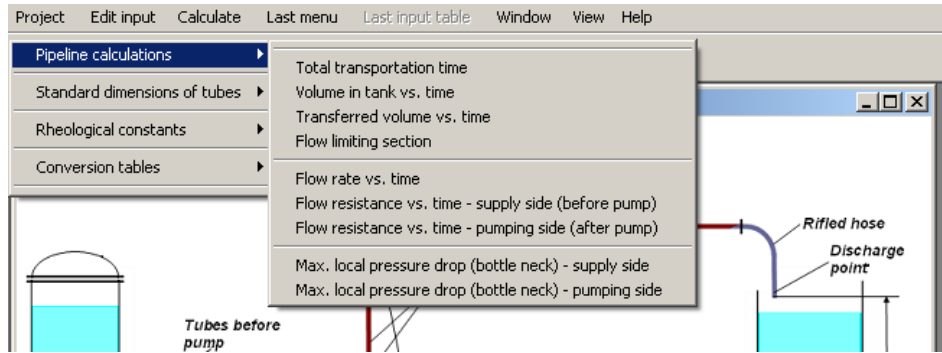


Figure 21.

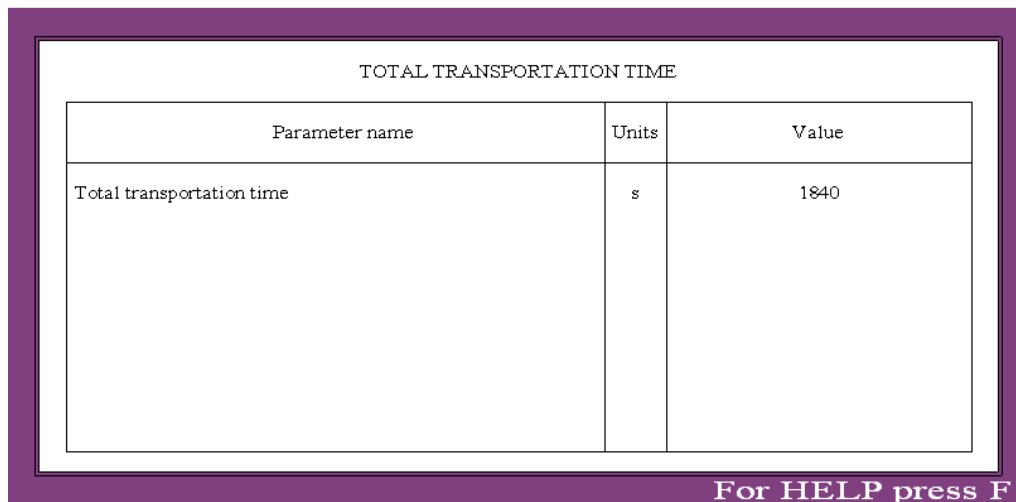


Figure 22.

Result of calculation arrives in a table form (Figure 22). The next step – calculation of pressure drop via **Last menu>Flow resistance vs. time – supply side** and **Last menu>Flow resistance vs. time – pumping side** (Figure 21). Results of calculations arrive as graphs (Figures 23 and 24).

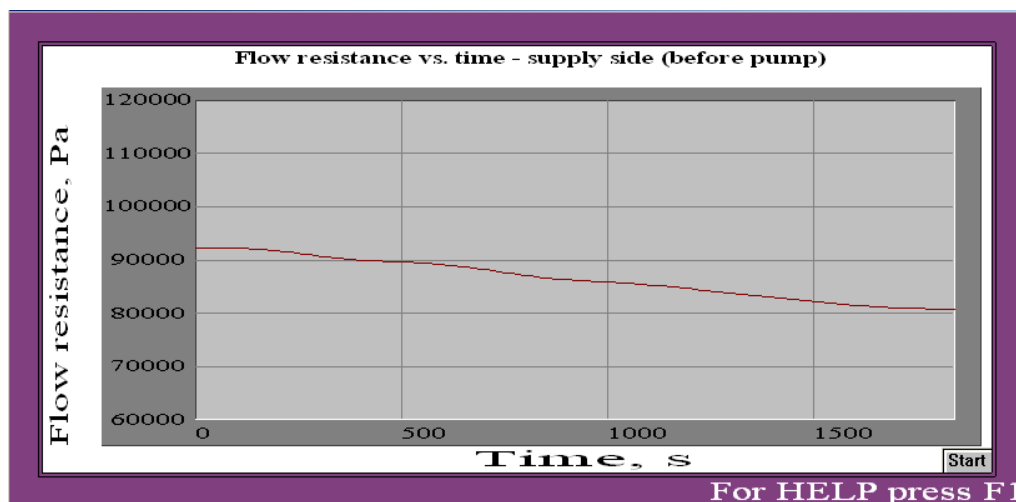


Figure 23.

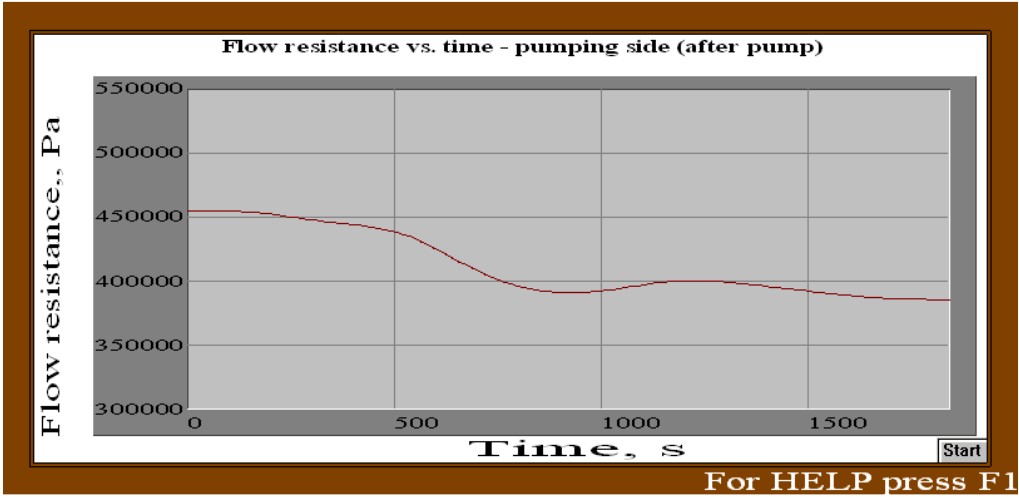


Figure 24.

4. Analysis of the results.

As follows from the data on Figure 22, transfer of shampoo can be performed within reasonable time – about 30 min. However, as it follows from the data of the Figure 24, the maximum pressure in the pipeline section after pump will be relatively high – about 4.5 Bar. Accordingly to handbook data, the maximum pressure in riffled PVC 1 ½ in hoses must not be higher then 3 Bar.

So, some changes of the system are necessary.

As the first step, in order to find the best way to reduce the pressure, click **Last menu** and select menu option **Max. local pressure drop (bottle neck) – pumping side.**

Result of calculation – table in the Figure 25 – shows that pressure in the pumping line is so high due to high hydraulic resistance of the hose. One of the obvious ways to reduce the pressure – to use a hose of bigger diameter.

Parameter name	Units	Value
Max. local pressure drop	N/sq.m	3.66e+05

Element pipe 1

For HELP press F1

Figure 25.

5. Correction of the input and calculations.

Standard diameters of rifflled hoses can be found in the database of the program VisiMix PL. Select **Calculate** in the main menu and click **Standard diameters of tubes>Rifflled hoses** (Figure 26). Accordingly to the displayed table (Figure 27), the next bigger diameter of hose – 2 in.

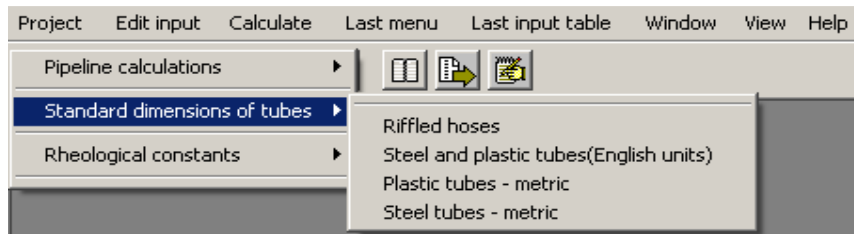


Figure 26.

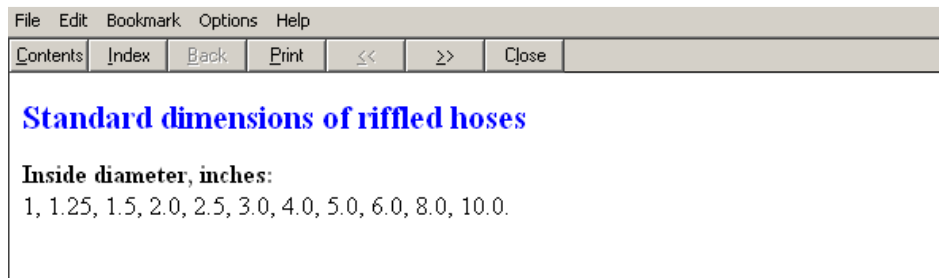


Figure 27.

So, let us enter the 2 in. hose instead the 1 ½ in. one. Click Edit>Pipes after pump (Figure 28). The corresponding dialog box arrives on the screen (see Figure 9).

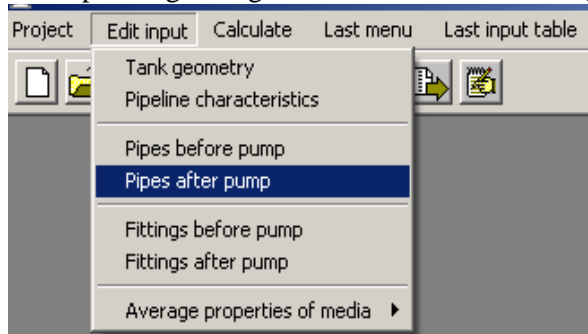


Figure 28.

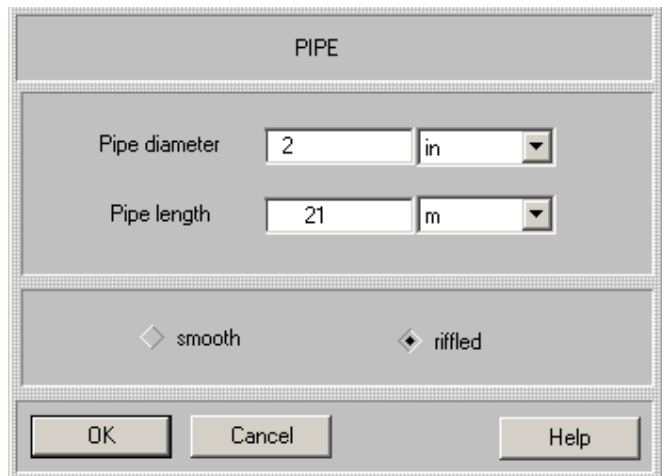


Figure 29.

Now find **Pipe 1** (by scrolling), click **View/Edit** and change 1.5 to 2 in. (Figure 29). Confirm change with **OK**, and close the dialog box with **OK**.

In order to connect the hose to the pump outlet and inlet tube of the feeding container (1 ½ in each), we have to enter additional elements – expander and reducer.

Click Edit input>Fittings after pump. The corresponding dialog box arrives on the screen (see Figure 30).

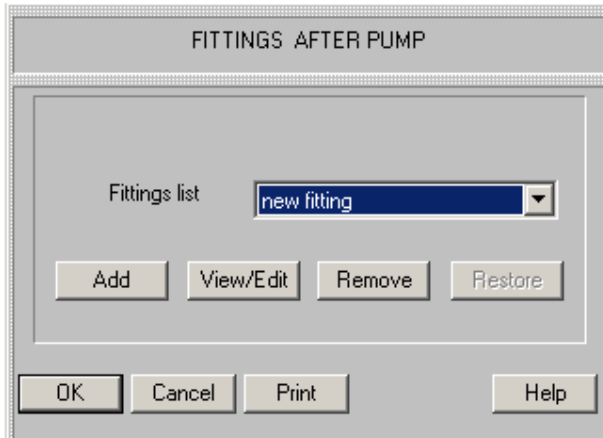


Figure 30.

Click Add, select **expander** in the visual menu (Figure 31) and enter the requested data (Figure 32).

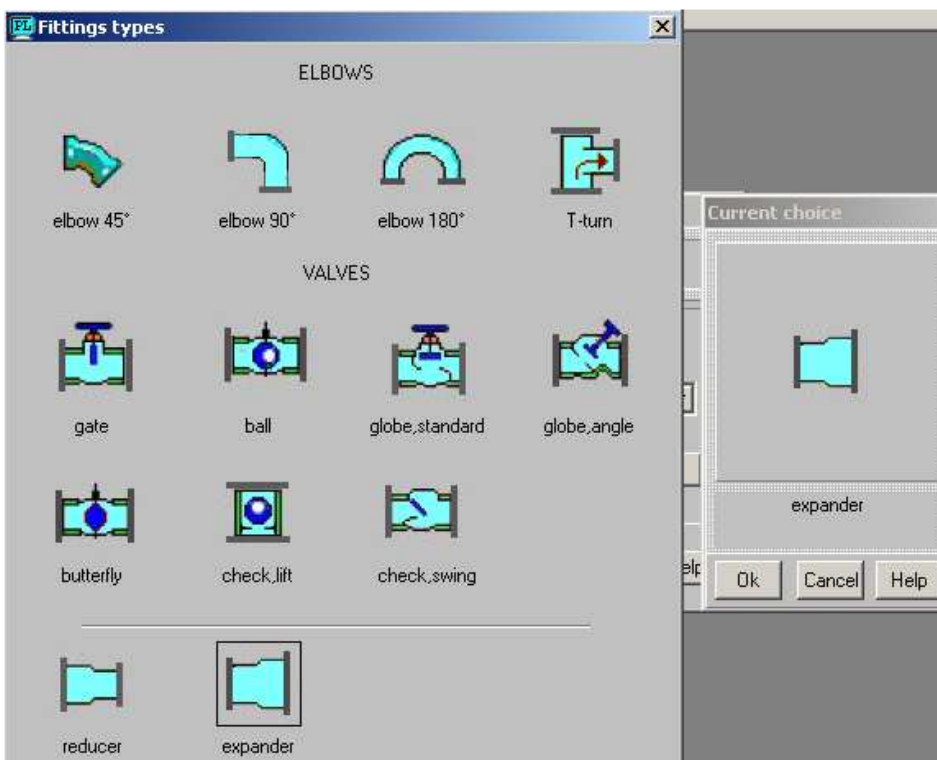


Figure 31.

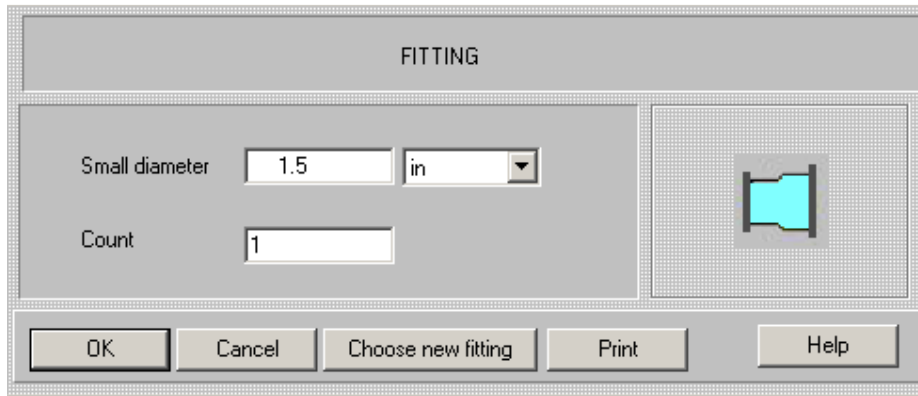


Figure 32.

Confirm the input with **OK**, and enter the next element – reducer (Figure 33).

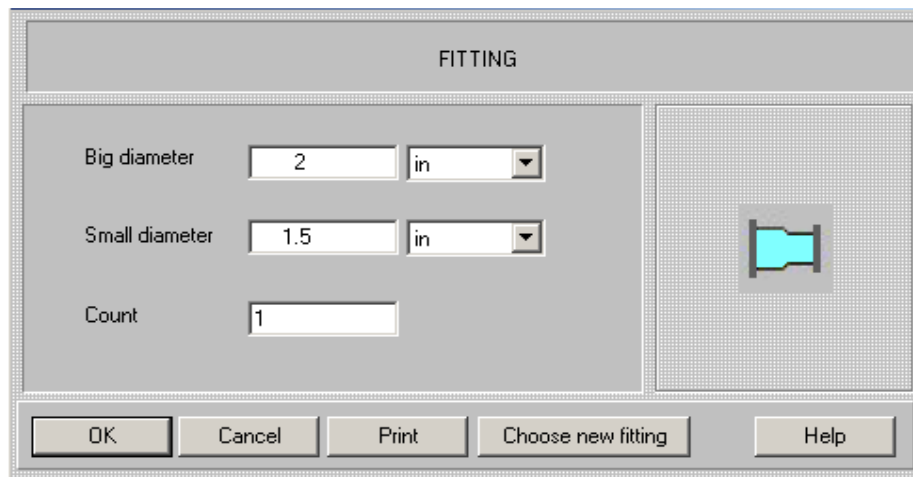


Figure 33.

After the input has been confirmed, the program repeats the calculations.

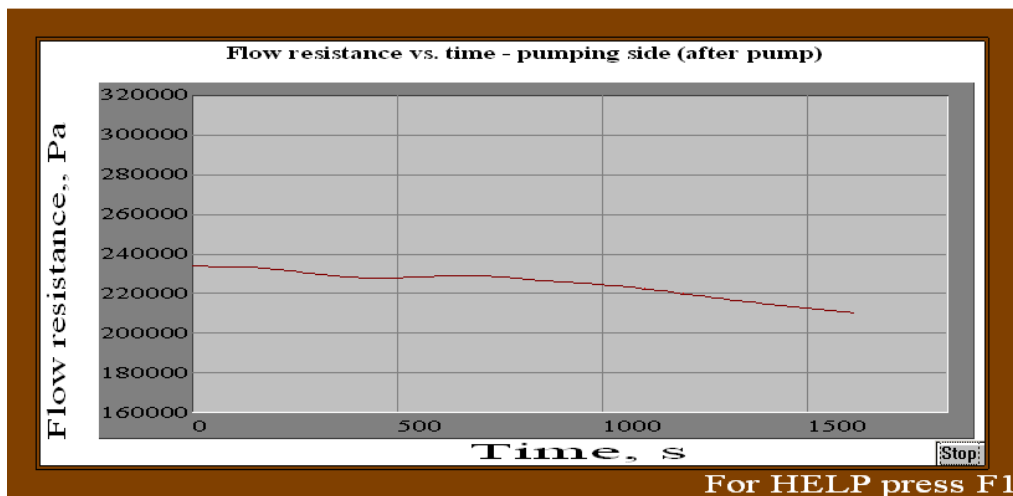


Figure 34.

As it follows from the results:

- Duration of transfer of the batch does not change, because the flow rate is limited by flow resistance of the supplying section of pipeline
- Maximum pressure in the pumping section of pipeline drops down to acceptable level.