

# VisiMix PL

## User's Guide

### Calculations for single direction Pipeline

Jerusalem



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## Section 1. Introduction.

### 1.1. Destination and the main features.

*Destination of the new program – prompt approximate evaluation of conducting capacity of simple pipelines for transfer of different liquids and highly viscous non-Newtonian materials from one production station to another within the plant.*

The program allows for modeling of single-direction pipelines for transferring of liquid material from vessels (mixing tanks or storages) to other stations inside the plant - to tanks, packaging machines or any other equipment units. Transportation of material can be performed by pump or/and by extra pressure in the storage. The pipeline may include a few elements - pipes, ruffled hoses, elbows, valves, reducers and expanders of different diameters. An example of pipeline with the accepted nomenclature is presented in the Fig.1, available types of fittings – in the par. 4.4.

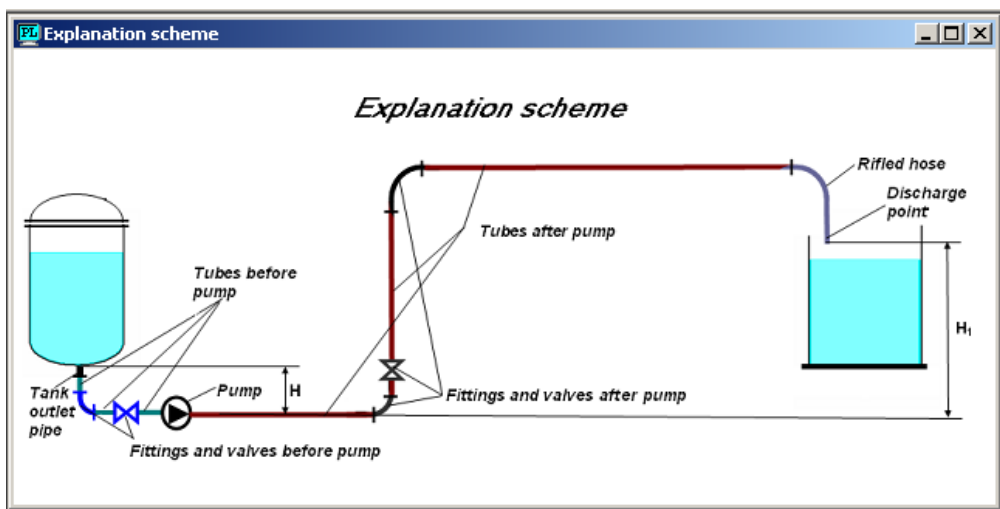


Fig.1.

The program provides calculations for flows of Newtonian liquids of different viscosity (from 1 to 1000000 cP), and also – non-Newtonian liquid materials (paints, shampoos, pastes, creams, etc) with rheology corresponding to Power law or Carreau rheological models.

The program is supplied with database of rheological constants for the most typical commercial non-Newtonian products. It includes also information on the most common standard dimensions of pipeline elements.

The program provides evaluation of:

- duration of complete transferring of liquid from the tank / storage
- dynamics of pumping and change of volume of liquid in the tank as a function of time
- flow resistance of pipeline as a function of time
- information on the flow- limiting pipe sections or fittings (bottlenecks)

### 1.2. Method of calculation.

*Calculation of flow resistance in the program is based on universally accepted methods.*

Flow resistance of a pipe section  $i$  is calculated as

$$\Delta P(i) = C_f(i) \rho \frac{V(i)^2}{2} \frac{L(i)}{D(i)}$$

and flow resistance of a fitting /valve  $i$  - as

$$\Delta P(i) = C_f(i) \rho \frac{V(i)^2}{2}$$

In these equations:  $\Delta P$  – flow resistance of (or pressure drop on) the element  $i$ ,

$L$  and  $D$  - length and internal diameter of the pipe section  $i$ ,

$V$  – mean flow velocity in the pipe section or fitting  $i$ ,

$C_f$  – flow resistance factor for the pipe section or fitting  $i$ ,

$\rho$  – density, kg/cub.m.

For smooth pipes flow resistance factors are calculated using the universally known equations: for laminar regime:

$$C_f(i) = 16 / \text{Re}(i)$$

and for turbulent regime

$$C_f(i) = 0.314 / \text{Re}(i)^{0.25}$$

For fittings and for rifflled hoses calculation of flow resistance factors is based on 2K model (see W.B. Hooper, The two-K method predicts head losses in pipe fittings, Chemical Engineering, Aug 1981, pp.96 - 100):

$$C_f(i) = \frac{K_1(i)}{\text{Re}(i)} + K_2(i)$$

In these equations

$$\text{Re}(i) = \frac{\rho V(i) D(i)}{\mu}$$

Here  $D(i)$  – inside diameter of the element  $i$ , m,

$V(i)$  – mean flow velocity in the element  $i$ , m/s,

$\mu$  - dynamic viscosity, Pa.s,

## Section 2. Starting VisiMix PL.

After installing **VisiMix PL**, the main menu appears on the screen (Figure 2). It has the following structure:

- Project**
- Edit Inputs**
- Calculate**
- Last menu**
- Last input table**
- Window**
- View**
- Help**

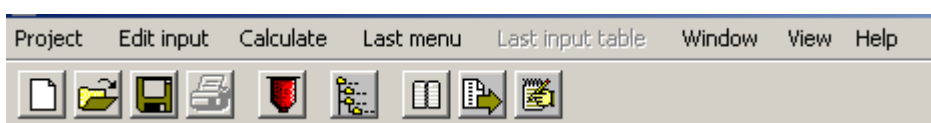


Figure 2.

### 2.1. Project

The program performs calculations in relation to a **Project** - a single set of initial data, which includes the types and main dimensions of pipeline elements and physical properties of the media. The project is identified by its name. All input and output windows corresponding to the same project are displayed in frames of the same color.

The program enables you to open several projects (up to four) which can be simultaneously displayed on the screen.

### 2.2. Edit input

This option gives you access to all input tables related to the current project. Use it to selectively modify the initial data.

You may also use the **Edit input** option to enter initial data while starting a new project, although normally the dialog boxes and tables of required initial data are automatically opened by the program.

### 2.3. Calculate

Use this option to perform the calculations. The **Calculate** submenu provides access to all Output parameters. For a detailed description see Section XXX.

### 2.4. Last menu

This convenient option enables you to directly invoke the **Calculate** submenu with which you last worked.

### 2.5. Last Input Table

This is another shortcut, which enables you to directly invoke the last input table with which you worked. For example, if you want to compare possible flow capacity of the pipeline with different types of valves, you can change the input after each calculation by selecting **Last input table** only, without going through the procedure of addressing **Edit**.

## **2.6. Window**

This option functions the same way it does in Microsoft Windows.

## **2.7. View**

This option contains the following functions:

**Initial data explorer**

**Project list**

### ***2.7.1. Initial data explorer***

This option shows a list of initial data for the current project, including pipeline elements and properties of media.

### ***2.7.2. Project list***

This option invokes the Project list dialogue, which contains a list of opened projects. In this dialogue, you can choose or change the current project. The name of the current project appears in the text field at the bottom of the screen. This option is also accessible from a quick access button in the upper screen bar.

## **2.8. Help**

This option functions the same way it does in Microsoft Windows. Press **F1** to invoke the **Help** section corresponding to the active window.

## Section 3. Starting a new project or opening an existing one

Select **Project**. The following submenu appears:

- New
- Open**
- Close
- Clone
- Project comments
- Save
- Save as
- Report
- Print
- [Recent projects]
- Exit

### 3.1. New

To start a new project:

1. Select **New** from the **Project** menu.
2. When the new project dialogue appears (Figure 3), enter a project name in the name field, then click **OK**.

This option is also accessible through a quick access button in the upper screen bar.

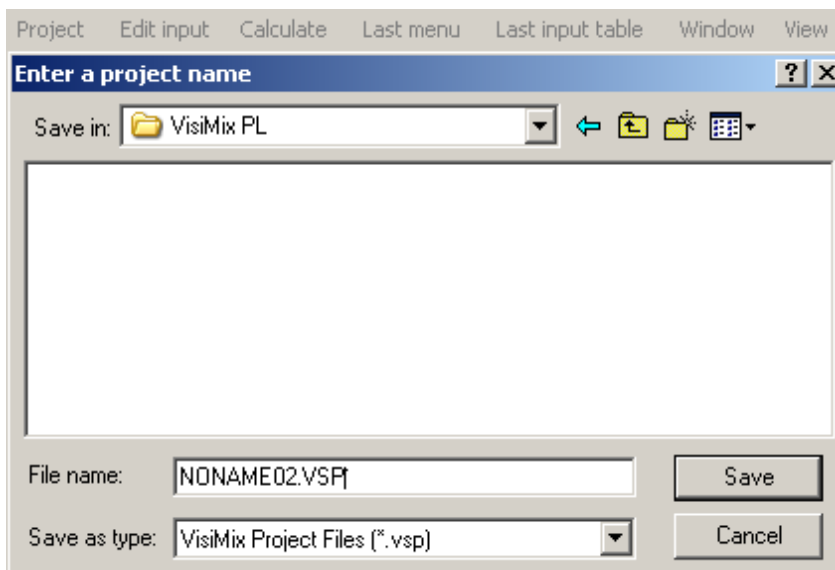


Figure 3.

### 3.2. Open

To open an existing project:

1. Select **Open** from the **Project** menu. The **Open** dialogue appears (Figure 4).
2. From the file browser screen select the desired project and click **OK**.

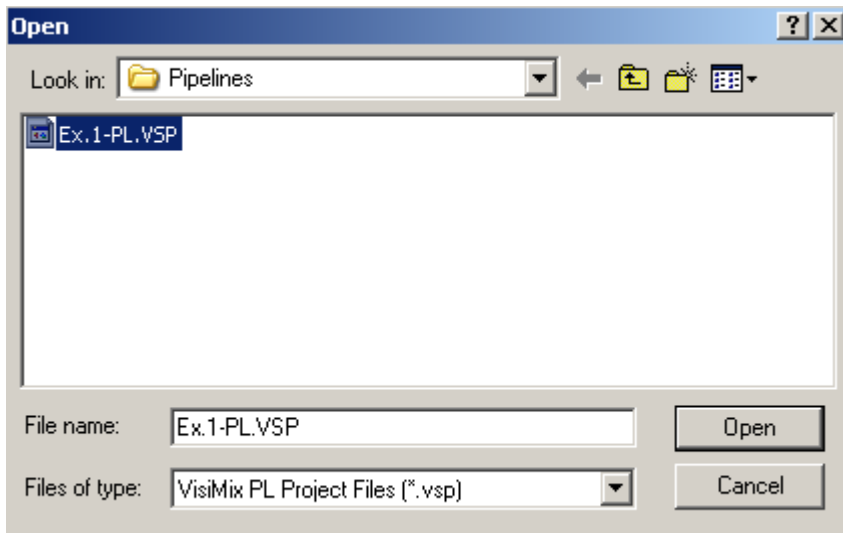


Figure 4.

### 3.3. Close

Use this option to close and save the current project.

### 3.4. Clone

Use this option to create up to four copies of you current project. It serves as a convenient tool for comparing different variants of the same basic project. This option is also accessible from a quick access button in the upper screen bar.

### 3.5. Project comments

Use this option to create or modify your comments to the project. This option is also accessible from a quick access button in the upper screen bar.

### 3.6. Save

Use this option to save all initial data for the current project. This option is also accessible from a quick access button in the upper screen bar.

### 3.7. Save as

Use this option to save the current project under a new name.

### 3.8. Report

Use this option to accumulate the initial data and calculated results in a file of standard HTML format.

Selecting **Report** at any stage of working on a current project invokes a submenu, which is identical to the **Calculate** submenu (see Section 5). Choose any item you are interested in. Being asked by the program to enter a name for the report, enter the name, and the program will create a report that includes relevant initial data and results of calculations. On completing the report, an appropriate message will be displayed.



The report is formed as a file with a **.htm** extension, and you may open, edit and print this file from Microsoft Internet Explorer or Microsoft Word (Microsoft Office 97 or higher). To work with your report files in Microsoft Word, make sure that the HTML converter option is on. The **Report** option presents all graphs, in addition to a graph form, in a standard tabular format.

### **3.9. Print**

Use this option to print the contents of the active output window. This option is also accessible through a quick access button in the upper screen bar.

Various groups of initial data are printed from the corresponding input data tables.

Each print-out also includes the complete information on the project and directory names.

### **3.10. Exit**

Use this option to close opened projects and quit VisiMix PL.

## Section 4. Entering Initial data for a New Project

After you enter the name of a new project and click OK, VisiMix PL requests the basic initial data required for all calculations by invoking the appropriate input tables. Supplying this data allows the program to start the calculations. You can use the **Calculate** function before all initial data is entered, but VisiMix will ask you to supply all parameter values first. The data you have entered are stored in the system, and when addressing any further parameters of the output submenus, you will not be asked to enter data once more.

Use the **Edit** option, or **Last Input Table** option to selectively modify your initial data.

The program provides possibility to enter initial data using different systems of units. In input tables selection of units for each parameter is performed by scrolling – see Figure 6.

**VisiMix PL** verifies the input. If your input contains inapplicable symbols, e.g. characters or punctuation marks instead of numbers, VisiMix issues a message indicating that one of the input values is incorrect. In this case you must click **OK** and correct the error. If your input is outside reasonable limits or is beyond VisiMix PL calculations range, VisiMix modifies the input, offering the nearest acceptable value to the one entered, and issues an appropriate message when necessary. In this case, you should check data before exiting the input table.

### ***ATTENTION!***

*The program does not perform comparison of different data and does not check their correspondence to one another (for example, inside diameters of pipes and fittings).*

### 4.1. Tank

After you enter the name of a new project and click **OK**, a selection of tanks differing by **bottom type** (flat, conic or elliptical) appears (Figure 5).

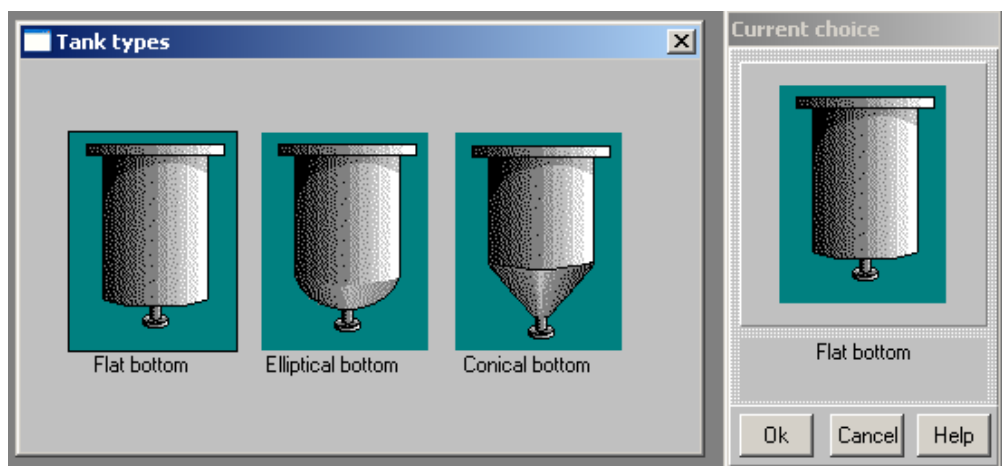


Figure 5.

Choose a tank type by clicking anywhere inside the selected drawing. The tank you have selected will appear in the **current choice** window on the right. Click **OK** to confirm your choice. When the scheme of the selected tank appears (Figure 6), supply the requested values of tank parameters. Take into account that the requested data are related to inside dimensions of the tank and outlet pipe.

It is possible to enter the **Inside diameter** and either the **Level of media** or **Volume of media**, and the second parameter will be entered automatically.

After the table has been completed, click anywhere on the field in the window, and the diagram on the screen will change to reflect your input. Click **OK** to confirm your input, and use the **Choose New Tank** button at the bottom of the screen to change the type of bottom. The tank types screen (Figure 5) will then be displayed.

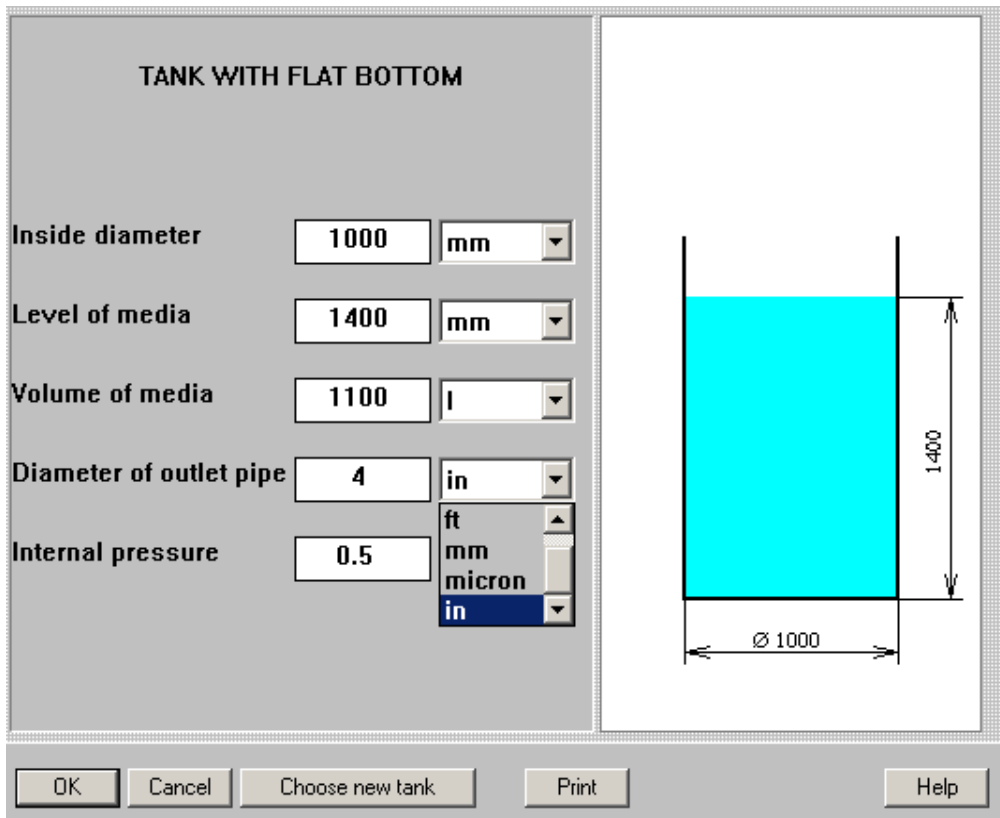


Figure 6.

#### 4.2. Pipeline characteristics.

This input table presented in the Figure 7 includes the general characteristics of the pipeline.

**Height of tank outlet (H).** Enter level of the tank outlet pipe in relation to position of the pump. H value may be positive or negative, but not lower than -10 m .

**Height of discharge point (H1).** Enter level of final point of the pipeline in relation to position of the pump. H1 value may be positive or negative.

**NOTE:** *Height of the pump position is assumed to be 0 m.*

**Diameter of discharge pipe.** Enter internal diameter of the pipeline discharge element (pipe, nozzle, etc.).

**External pressure in the discharge point.** If discharge point is above the liquid level inside a tank or storage, enter value of the pressure (positive or negative) in the tank. If the discharge point is below the liquid level, add hydraulic pressure of the liquid.

**Pump characteristics** are entered accordingly to the technical characteristics of the pump or safety valve. It is possible to enter desired flow rate as Pumping capacity, but it must not be higher than the maximum pumping capacity of the pump.

For the most of usual industrial pumps the suction head does not exceed 5-7 meter of water.

**NOTE:** *If transfer of liquid is performed without pump by extra pressure in the storage, '0' has to be entered as Pressure and Suction head, and desired flow rate – as Flow capacity of the pump.*

PIPELINE CHARACTERISTICS	
Height of tank outlet (H)	2 m
Height of discharge point (H1)	8 m
Diameter of discharge pipe	1.5 in
External pressure in outlet point	0 Bar
Pump characteristics	
Flow capacity	350 l/min
Pressure	8.6 Bar
Suction head (water)	6.9 m

OK Cancel Print Help

Figure 7.

### 4.3. Pipes and hoses.

The input system of the program allows for entering of two types of tubes – smooth pipes and rifflled pipes or hoses - of different diameters. In accordance with technical destination of the program, all tubes without ripples, including the plastic hoses, are entered as ‘**smooth**’, and all rifflled pipes and hoses – metallic and polymer – are entered as ‘**rifflled**’.

For each pipeline Project the program allows for entering pipe sections of different diameter and length. The sections positioned before and after pump are entered separately, but exact position of each section in relation to other sections and fittings is not taken into account.

In order to enter a section of tube placed **before pump** (Figure 8), press **Add** button.

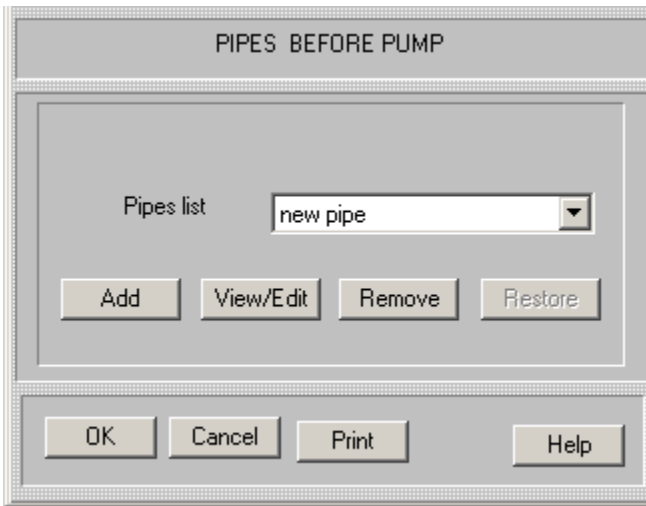


Figure 8.

Select **Smooth** or **Riffled** (Figure 9) and enter inside diameter and length of the tube section. The program allows for 6 sections of tube before and 6 sections of tube after the pump. It is recommended to add lengths of pipe sections of the same inside diameter and enter them as a single section.

Click **OK** to confirm the input.

To enter next section of pipe, scroll the dialog window and return to **New pipe** (Figure 10). Now click **Add** once more and enter the data as previously.

You can check your inputs by scrolling the dialog window (Figure 10) – select the corresponding section and click the **View/Edit** button. Numbers of sections correspond to order of entering. Maximum number of section is 6.

Use buttons **View / Edit** to check and edit your inputs, **Remove** to cancel the earlier input.

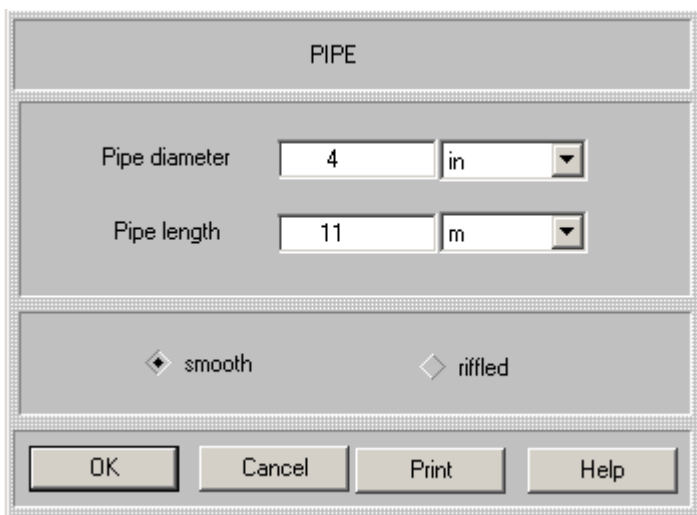


Figure 9.

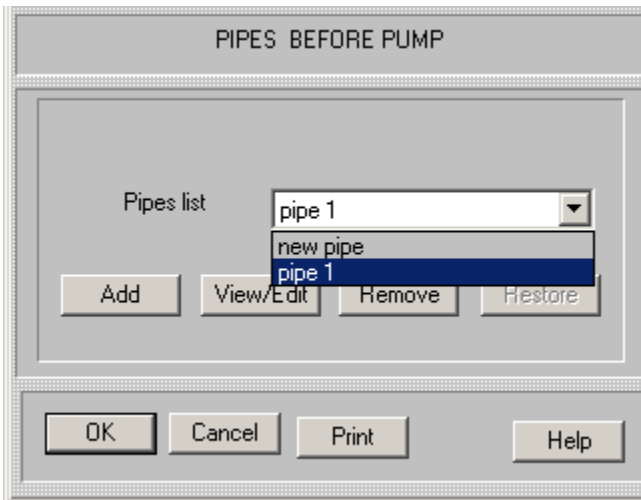


Figure 10.

The example above is related to entering of pipes **before pump**. Input of pipes **after pump** is performed in exactly the same way.

**ATTENTION:** For tables of standard diameters of steel and plastic pipes press **Help** or go to the main menu option **Diameters of pipes**.

#### 4.4. Fittings and valves.

The input system of the program allows for entering fittings and valves of a few the most frequently used types and configurations. For each Project the program allows for entering elements of different types and diameters. The elements positioned before and after pump are entered separately, but their exact position in relation to each other is not taken into account.

The input window for entering fittings and valves is displayed by the program after input of pipes is finished.

To enter a fitting or valve placed **before pump** (Figure 11):

- Click **Add** button.

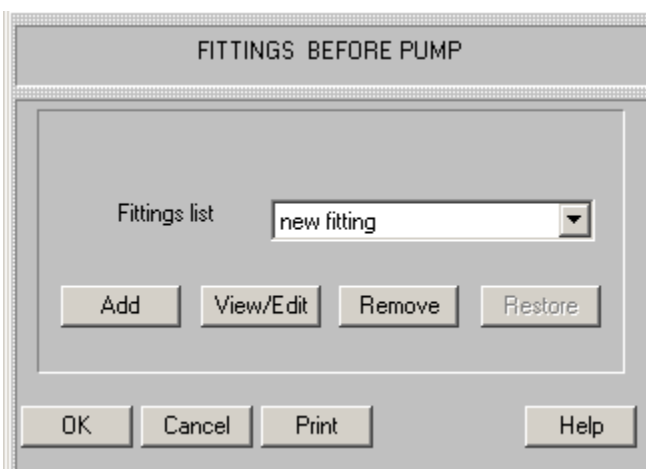


Figure 11.

- Select necessary fitting or valve from the graphic selection screen (Figure 12). To do it, click the corresponding icon, and the selected figure will arrive in the **Current choice** screen. Confirm selection with **OK**.

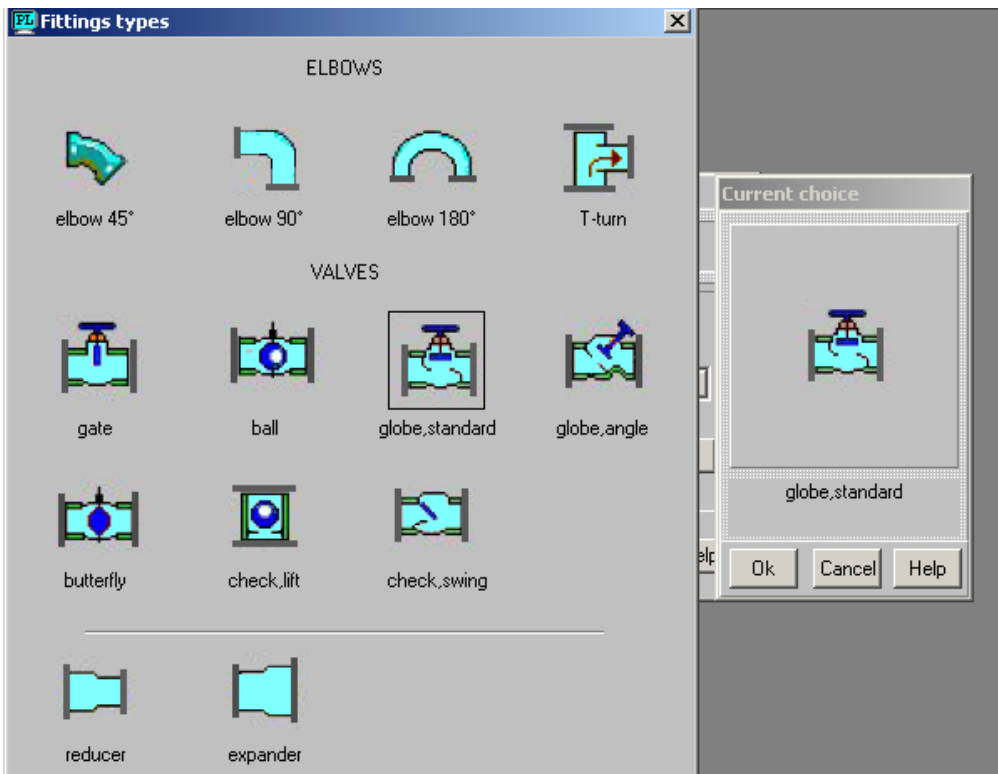


Figure 12.

- Enter data on the selected fitting accordingly to the program request. For Reducer you enter two diameters - **Big** and **Small** (Figure 13) , for any other fitting or valve – only the nominal diameter that is equal to diameter of the corresponding pipe (Figure 14). The maximum count (number) of identical fitting allowed by the program – three units.

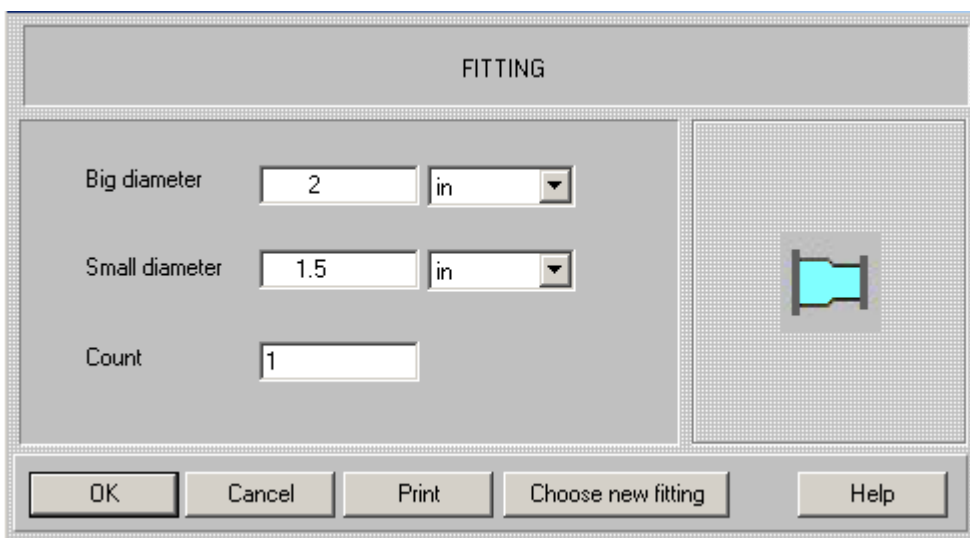


Figure 13.

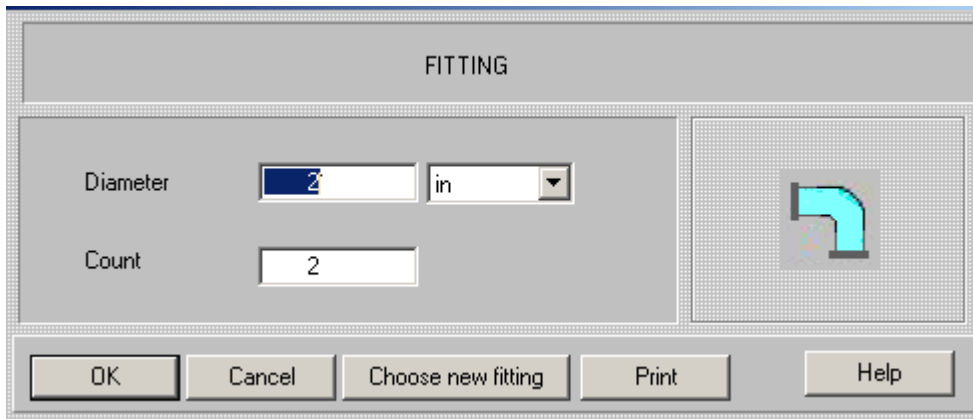


Figure 14.

- Confirm the input with **OK**.
- To enter fitting or valve of a different type or size, click **Add** (Figure 11) and repeat the actions.

Use buttons **View / Edit** to check and edit your inputs, **Remove** to cancel the earlier input and **Choose new fitting** to replace it with a new one.

The examples above are related to entering of fittings **before pump**. Input of fittings **after pump** is performed in exactly the same way.

**ATTENTION:** *Diameter of fittings is selected accordingly to nominal diameter of the corresponding pipe.*

#### **4.5. Average properties of media.**

Calculations of flow resistance of pipeline elements are based on average values of density and viscosity of media. If you are starting a new project, the program provides the input table 'Density and type of media' (Figure 15 ). It is necessary to enter average density of liquid and select one of the rheological types presented in the table. Equations defining the rheological behavior of the corresponding rheological types are presented in the input table.



DENSITY AND TYPE OF MEDIA

Average density  kg/cub.m

TYPE OF MEDIA

<input checked="" type="radio"/> Newtonian  $\tau = \mu * \gamma$	<input type="radio"/> Power-law non-Newtonian  $\tau = \tau_0 + K * \gamma^n$ $\mu = \tau_0 * \gamma^{-1} + K * \gamma^{n-1}$	<input type="radio"/> Carreau non-Newtonian  $\frac{\mu - \mu_{\min}}{\mu_{\max} - \mu_{\min}} = \left[ 1 + (\lambda * \gamma)^2 \right]^{\frac{n-1}{2}}$
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Figure 15.

Mark one of the points and click **OK**. A table of necessary parameters will be open by the program (Figures 16-18).

AVERAGE VISCOSITY OF MEDIA

Dynamic viscosity <input type="text" value="5"/> cP	$\tau = \mu * \gamma,$  <b>where</b> $\tau$ - shear stress, Pa; $\mu$ - dynamic viscosity, Pa*sec; $\gamma$ - shear rate, 1/sec;
Kinematic viscosity <input type="text" value="5e-06"/> sq.m/s	

Figure 16.

PARAMETERS OF RHEOLOGY  
POWER-LAW NON-NEWTONIAN

Constant K <input type="text"/> Pa*(sec) <sup>n</sup> Exponent n <input type="text"/> Yield stress <input type="text"/> N/sq.m	$\tau = \tau_0 + K * \gamma^n$ $\mu = \tau_0 * \gamma^{-1} + K * \gamma^{n-1}$ <p>where <math>\mu</math> - effective viscosity, Pa*sec;  <math>\gamma</math> - shear rate, 1/sec;  <math>\tau</math> - shear stress, Pa;  <math>\tau_0</math> - yield stress, Pa.</p>
<input type="button" value="OK"/> <input type="button" value="Cancel"/> <input type="button" value="Print"/>	<input type="button" value="Help"/>

Figure 17.

PARAMETERS OF RHEOLOGY  
CARREAU NON-NEWTONIAN

$\mu_{min}$ <input type="text"/> Pa*s $\mu_{max}$ <input type="text"/> Pa*s Constant $\lambda$ <input type="text"/> Exponent n <input type="text"/>	$\frac{\mu - \mu_{min}}{\mu_{max} - \mu_{min}} = \left[ 1 + (\lambda * \gamma)^2 \right]^{\frac{n-1}{2}}$ <p>where <math>\mu</math> - effective viscosity, Pa*sec;  <math>\mu_{min}</math> - min effective viscosity, Pa*sec;  <math>\mu_{max}</math> - max effective viscosity, Pa*sec;  <math>\lambda, n</math> - constants;  <math>\gamma</math> - shear rate, 1/sec;</p>
<input type="button" value="OK"/> <input type="button" value="Cancel"/> <input type="button" value="Print"/>	<input type="button" value="Help"/>

Figure 18.

#### 4.6. Rheological models handled by VisiMix programs.

##### Carreau rheological model.

Rheological properties of some non-Newtonian liquid are approximated with Carreau rheological model. Dependence between shear rate and viscosity is described with equation:

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

Here

- $\gamma$  - shear rate,
- $\mu$  - effective viscosity at shear rate  $\gamma$ ,
- $\mu_{min}$  - minimum viscosity, corresponding to  $\gamma = \infty$ ,
- $\mu_{max}$  - maximum viscosity, corresponding to  $\gamma = 0$ ,

n,  $\lambda$  – constants.

Parameters  $\mu_{\min}$ ,  $\mu_{\max}$ , n and  $\lambda$  are defined with measurements. A typical function corresponding to the Carreau model is shown below.

### Power-law rheological model.

VisiMix input system allows for entering of rheological constants for a few the most usual models – pseudo-plastic (Power-law) liquids and Bingham plastics – using the generalized description of the Power law model:

$$\tau = \tau_0 + K \gamma^n$$

or

$$\mu = (\tau_0 + K \gamma^n) / \gamma$$

Here  $\tau$  – shear stress, corresponding to the shear rate  $\gamma$ ,  
 $\tau_0$  – yield stress,  
K, n – constants.

These equations with  $n = 0$  correspond to the Bingham plastics.

Graphs of typical functions corresponding to the described rheological models are shown in the Figure 19.

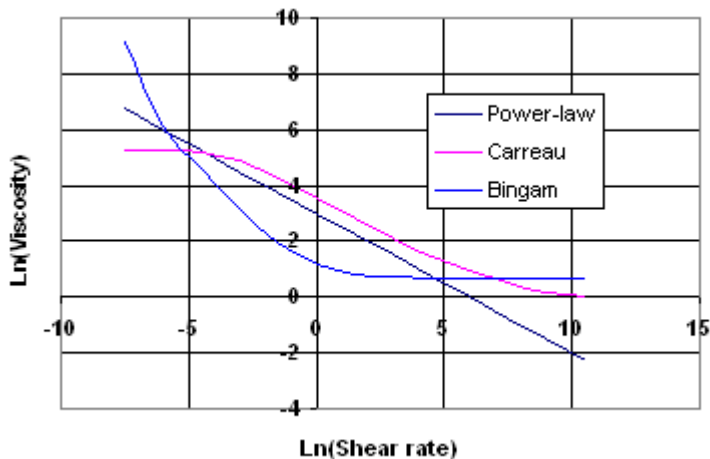


Figure 19.

### 4.7. Checking and changing parameters in the existing project.

Access to the entered initial data is possible via **Edit input** button. In order to facilitate the operation, the program is provided additionally with **Initial data explorer**. This option is

accessible from a quick access button in the upper screen bar. It shows a list of initial data for the current project, including all pipeline elements and properties of media (Figure 20).

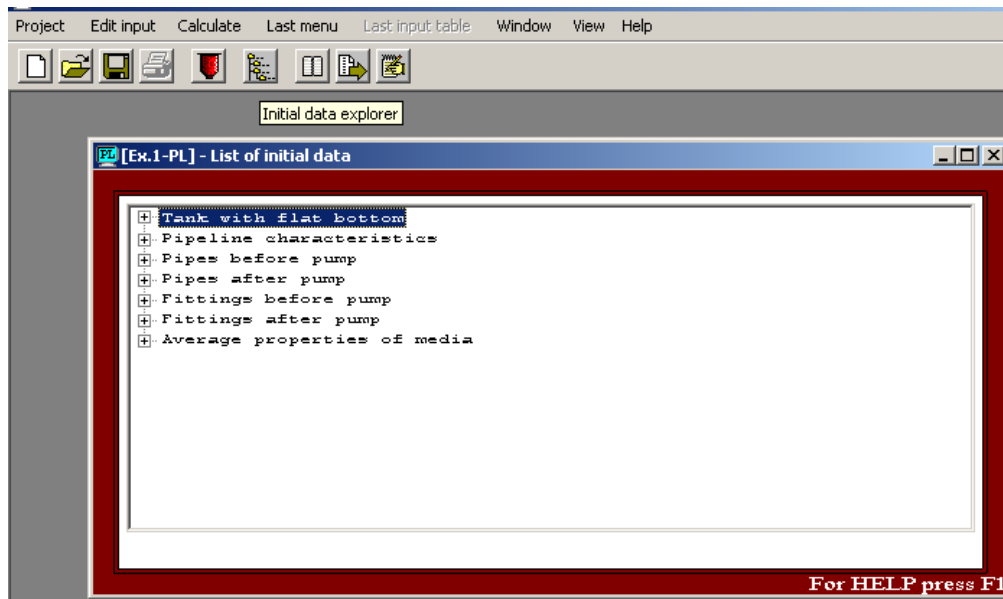


Figure 20.

## Section 5. Menu Calculate. Output parameters.

This option enables the user to perform calculations of hydraulic resistance and actual flow capacity of the pipeline. It provides also direct access to service sections of the program – databases of rheological constants of some non-Newtonian media and of standard dimensions of tubes. (Figure 21).

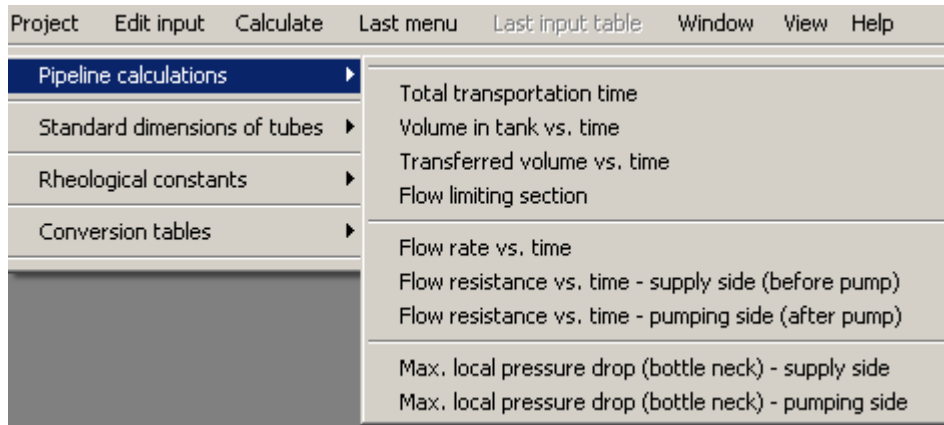


Figure 21.

### 5.1. Pipeline calculations.

This sub-menu (Figure 21) provides results of calculations for the selected pipeline and liquid. Independently of which of the **Calculate** options is selected, program performs calculations of all parameters included in the menu. If condition of complete transfer of liquid from the tank/storage is not satisfied, the program provides also warning messages. The most typical cases are described below:

1. Difference of pressure between inlet and outlet of pipeline is negative at the initial conditions. In this case the program finds that transportation is impossible, on the stage of checking the initial data. The program does not perform the calculations and informs the user on the arising problem – see Figure 22.

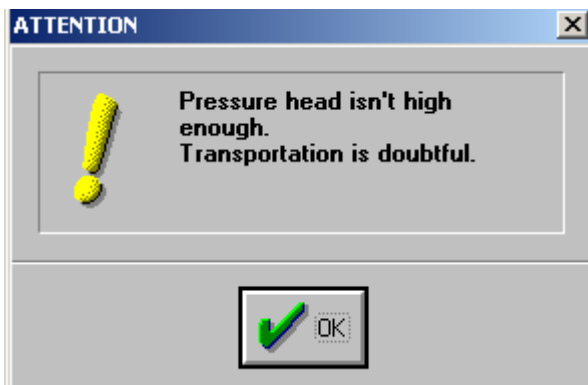


Figure 22.

- Initial level of liquid in the tank / storage is high enough to ensure 'positive' difference of pressure, but for the empty tank / storage the difference of pressure between inlet and outlet of pipeline is negative. In this case the program will show that transfer of liquid is interrupted on some level. The limiting part of the pipeline – before or after the pump – is defined in the message (Figure 23).

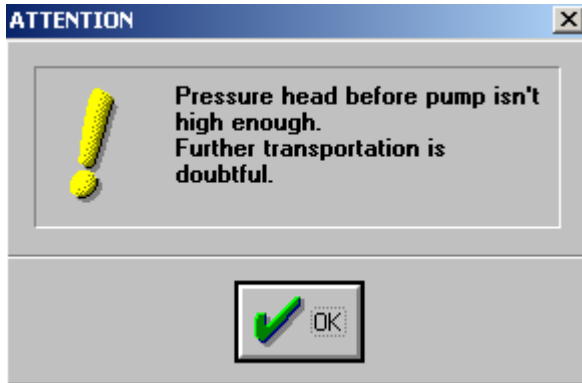


Figure 23.

- Difference of pressure between inlet and outlet of pipeline is positive, but for some reason – high viscosity of media or small cross-section of pipeline elements, low pressure of pump, etc. – flow rate of media is lower than 1/100 of the **Flow capacity** value in the project input. In this case the program interrupts calculation and provides the corresponding message (Figure 24).

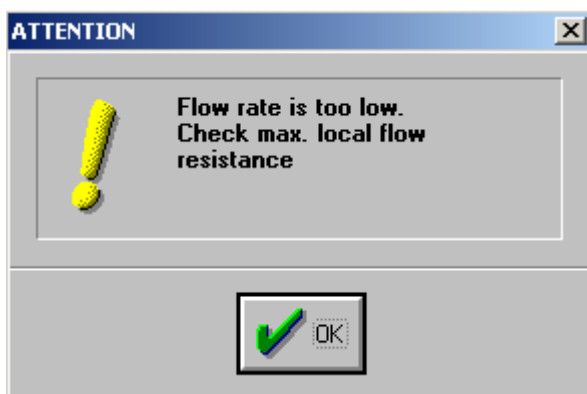


Figure 24.

### 5.1.1. Volume flow rate vs.time.

The basic part of calculations – calculation of instant values of volume flow rate of liquid as a function of current pressure head in the supply part of the line (before pump) and in the whole system. For user's convenience this function is transformed and presented in the form **Flow rate – Time**.

There are two possible configurations of this function corresponding to the different sets of conditions.

1. Difference of pressure between inlet and outlet of pipeline is high enough, and flow rate is controlled by pumping capacity of the pump or controller setup only. This case corresponds to constant flow rate value (Figure 25).

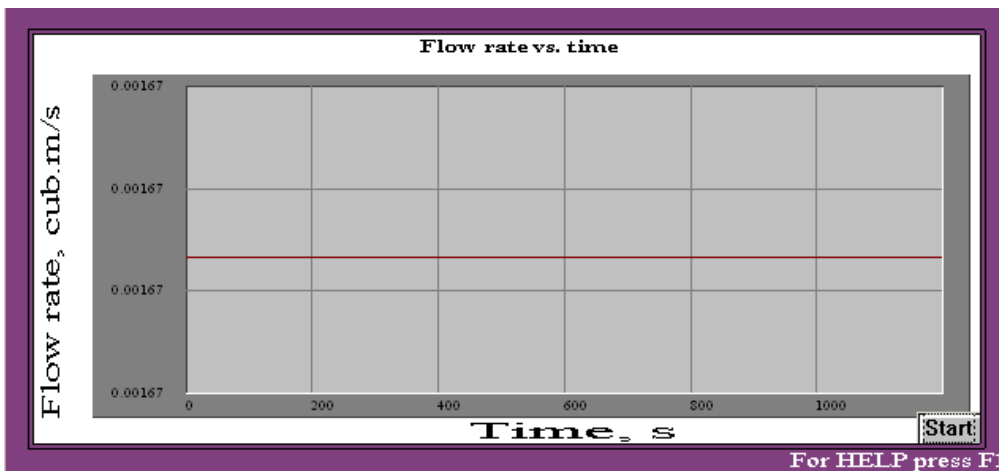


Figure 25.

2. Difference of pressure between inlet and outlet of pipeline is positive, but is not too high. Reduction of liquid level causes decrease of pressure head in supplying part of the pipeline, and as a result – reduction of flow rate (Figure 26).

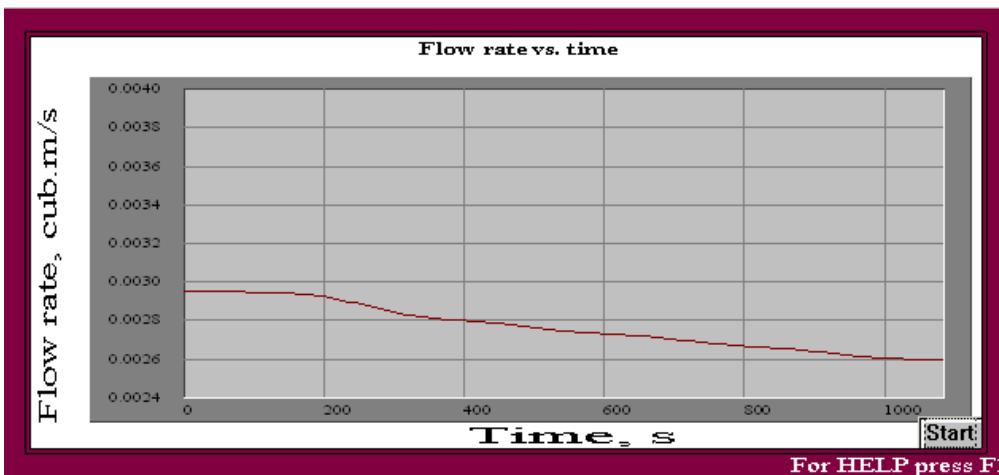


Figure 26.

If transportation of liquid is stopped for the reasons described in the paragraph 5.1, the flow rate is calculated till the interruption moment.

### **5.1.2. Total transportation time.**

The program defines duration of transfer of the liquid from the tank/storage (Figure 27). Usually it has to be duration of pumping necessary for complete transfer of media from the storage. If in some conditions only partial transfer of liquid is possible (see par.5.1), the program will display the calculated pumping duration and the message shown in the Figure 23.

TOTAL TRANSPORTATION TIME		
Parameter name	Units	Value
Total transportation time	s	1070

**For HELP press F1**

Figure 27

### **5.1.3. Flow limiting section**

This parameter is used when it is necessary to increase flow rate in the pipeline. The program defines automatically the section of the pipeline that is responsible for the upper limit of flow rate. The corresponding information occurs on the screen.

### **5.1.4. The Transferred volume**

The **Transferred volume** is defined by integrating of function Flow Rate vs. Time (par.5.1.1). The Volume in tank is defined as initial **Volume of media** minus **Transferred volume**.

### **5.1.5. Flow resistance vs.time – supplying side**

This parameter is defined as a sum of hydraulic resistance of all pipeline elements before the pump.

### **5.1.6. Flow resistance vs.time – pumping side**

This parameter is defined as a sum of hydraulic resistance of all pipeline elements after the pump.

### **5.1.7 Max. local pressure drop**

Max. local pressure drop (bottle neck) – supplying and pumping sides. The program provides data on the pipeline element with the maximum hydraulic resistance. It can happen that flow resistance of this element puts limitation on the maximum flow rate. The values correspond to the final moment of transportation process.

## **5.2. Standard dimensions of tubes.**

The program contains data on standard internal diameters of steel and plastic tubes, in English and Metric systems (Figure 28). Out of the wide range of standard sizes, the tubes widely used for transportation of liquid at low pressure are selected. Range of diameters – from 10 to 200 mm.



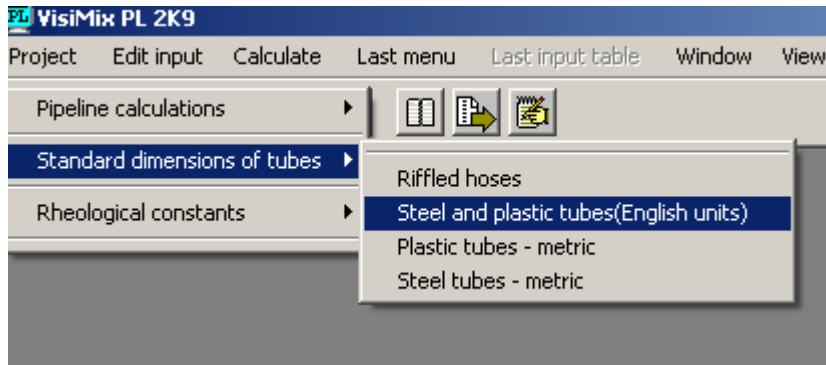


Figure 28.

### 5.3. Rheological constants.

Program contains data on rheological constants for some typical commercial non-Newtonian products (Figure 29). The constants have been defined with measurements in a wide range of shear rates (up to 10000 1/s) using rotational and capillary viscometers. Range of temperatures – from 20 to 50<sup>0</sup> C.

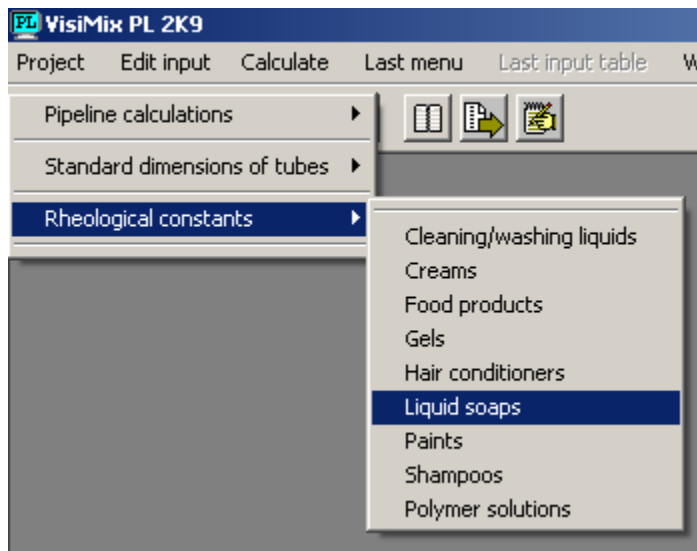


Figure 29.