

VisiMix LAMINAR

# User's Guide

Simulation of Mixing-Related Processes  
for Chemical Engineers

Mixing in highly viscous Newtonian and non-Newtonian media

Macroscale blending and micromixing in high shear areas

*Jerusalem*

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VisiMix Ltd., P. O. Box 45170 Har Hotzyim Jerusalem 91450 Israel  
Tel. 972-2-5870123 Fax 972-2-5870206 E-mail: [info@visimix.com](mailto:info@visimix.com)

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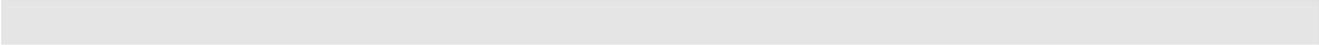
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## SECTION 1. INTRODUCTION

### 1.1. Welcome to VisiMix LAMINAR

Welcome to VisiMix LAMINAR, an upgraded VisiMix version for calculations of mixing in Newtonian and non-Newtonian media in LAMINAR and TRANSITIONAL FLOW REGIMES.

VisiMix LAMINAR is the first software covering calculations of macro-scale mixing (blending) and micro-mixing (high-shear treatment) of viscous liquids in the production of polymers, paints, coatings, detergent pastes, shampoos, food products, etc.

VisiMix LAMINAR is intended for process engineers, researchers, designers, R&D and production plant managers, i.e. for all professionals involved in treating or producing viscous liquid products. VisiMix LAMINAR contains database of rheological functions for some typical non-Newtonian media

VisiMix LAMINAR provides technical calculations of power, flow characteristics, shear stresses, stagnant zone formation, mixing, homogenizing, and heat transfer efficiency for Newtonian and non-Newtonian fluids in industrial and laboratory mixing equipment.

VisiMix LAMINAR calculates the flow and mixing parameters required for scaling-up and performs mathematical modeling of reactors and other process equipment operating in laminar and transitional mixing regimes.

VisiMix LAMINAR provides checking of mechanical reliability of mixing device;

VisiMix LAMINAR bridges the gap that separates day-to-day engineering practice from scientific achievements in the field of mixing and the high shear treatment of viscous Newtonian and non-Newtonian media.

***NOTE: If your version of VisiMix does not cover some features of interest to you, contact our technical support department for further information on these functions.***

**VisiMix helps:**

#### **Production Plant Engineers:**

- obtain complete information on the specific features and maximum potential of the equipment;
- find suitable regimes for alternative processing on the same equipment;
- find the best solutions to the existing mixing and heat transfer problems, and avoid new problems;
- find the most inexpensive ways to improve production processes based on the available technical means;
- check mechanical applicability of the mixing device for a new application or with a new impeller or drive velocity

**R&D and Pilot Plant Engineers:**

- ensure a high degree of media uniformity in laboratory equipment for process research;
- perform a more profound analysis of a process based on the data on flow parameters, local shear rates and the effective media viscosities in laboratory and pilot mixing equipment;
- select mixing regimes according to the desired degree of uniformity;
- reproduce the main features of production plant equipment on a laboratory or pilot plant scale (scaling down) and determine the scaling-up parameters;
- prepare the initial data for selecting or designing mixing equipment;

**Design Engineers:**

- perform technical calculations;
- avoid the formation of stagnant zones and choose optimal mixing devices;
- prepare the initial data for ordering the equipment;
- analyze and compare offers from different equipment suppliers;
- check mechanical applicability of the mixing devices offered by manufacturers

## SECTION 2. THEORETICAL BACKGROUND

**VisiMix LAMINAR** bridges the gap that separates engineering practice from achievements in the field of mixing and the high shear treatment of viscous Newtonian and non-Newtonian media. It provides chemical and process engineers with the ability to perform technical calculations based on the results of the most recent research, and on mathematical modeling of mixing processes.

**VisiMix LAMINAR** is based on fundamental equations of shear stress, mass and energy equilibrium, and the classic solutions to some of these equations. These results are used in conjunction with experimental information on mixing, and experimental correlations on flow resistance on tank walls and impeller blades flown over with laminar and turbulent flow.

The solution of these equations provides data on shear rates and shear stresses in critical areas of the tank volume (the zones near the impeller blades and near the tank wall) as a function of impeller geometry, rotational speed and properties of media. In addition, it provides information on the mixing intensity in different parts of the flow, as well as on the relative volumes of the zones of efficient mixing and the highest local shear stress.

At the next stage of calculations, this data is used for the approximate calculation of circulation flow in different points of the media. It serves as a basis for the development and application of stochastic models of mixing to obtain data on the frequencies of passages of different media fractions through the zones of efficient mixing and high shear stress. This important data allows you to understand, model, and scale-up mixing-dependent phenomena in laminar flow.

Calculations of the heat transfer from the laminar flow of agitated media are also based on calculated flow velocities. The mathematical models and the primary results of their application have been tested in the course of experimental research and verified by many years of industrial practice.

The main research data and mathematical models are described in the book *Mixing in Liquid Media* (by L. N. Braginsky, V. I. Begachev and V. M. Barabash, Chimia, Leningrad, Russia, 1984), and numerous publications in scientific journals.

### 2.1. Mixing in Laminar and Transitional Regimes. Physical Interpretation.

#### 2.1.1. Flow regime

Hydrodynamic flow regimes are determined based on the function FLOW RESISTANCE FACTOR vs. REYNOLDS NUMBER. It is understood that calculating resistance factors is based on the shear stress on the channel surface, or the local pressure drop on the obstacle (an object flowed over by the media, a turn or a narrow part of the channel, etc.). Calculation of the Reynolds number is based on the real or “equivalent” size of the channel or object, and on the real flow velocity. The following definitions are assumed:

A flow regime corresponding to an inverse proportion between the Resistance factor and the Reynolds number (Resistance factor = Constant / Reynolds number) is defined as a Laminar regime.

A flow regime corresponding to a weak dependence, or no dependence, of the Resistance factor on the Reynolds number (an exponential function with an exponent of  $-0.25 - 0$ ) is defined as a Turbulent regime.

A flow regime corresponding to the section of Resistance factor vs. Re number curve between the two extremes corresponding to Laminar and Turbulent regimes is defined as a Transitional regime.

It is clear that the Resistance factor vs. Re number function reflects the flow structure and the characteristics of the exchange of energy and mass in the flow.

In an agitated vessel, characteristics of flow structure and exchange are expressed by at least two different functions of the Resistance factor vs. Re number describing the flow resistance of the tank wall and of the impeller blades. In addition, VisiMix takes into account the additional flow resistance of baffles for baffled tanks (see NOTE).

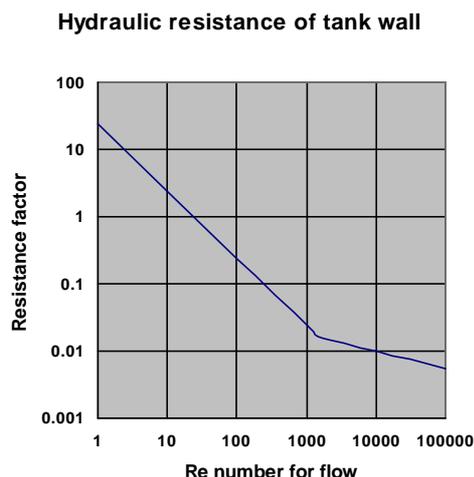
One of these functions (Figure 1) describes the shear stress on the tank wall as a function of average flow velocity. Its general character is typical for all kinds of channels, but the exact coordinates of the curve depend on the relative sizes of the tank and impeller. The Reynolds flow number for this function is based on the channel size, or tank radius, and on the average tangential velocity in the tank.

According to results reported in the literature, the Resistance factor for Re numbers of 1500 and less is inversely proportional to the Re number. Therefore, the flow regime corresponding to these conditions is considered Laminar.

The section of the curve corresponding to the higher Reynolds numbers is sloped at about  $-0.25$ , which corresponds to a Turbulent regime.

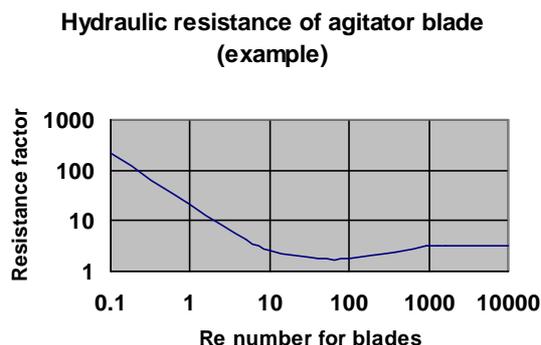
The second function (Figure 2) describes the flow resistance of the impeller blades flown over by the liquid media. The resistance factor of the blade is a function of the Re number for impeller blades expressed through the width of the blade and its relative velocity, i.e. the difference between the Tip velocity of impeller and the tangential velocity of the media. For low Re numbers (less than 1-5), the character of this function is strictly Laminar. At higher Re values, it becomes Transitional, and finally, Turbulent.

**NOTE: For baffled tanks, VisiMix LAMINAR takes into account the additional flow resistance of baffles. However, the effect of baffles in a laminar regime usually is not significant.**



**Figure 1.**

It must be noted that Transitional or Turbulent flow conditions around the blades sometimes co-exist with strictly Laminar values of Reynolds number for flow. The existence of different flow conditions causes a change in the slope of the experimental function Power number vs. Re number.



**Figure 2.**

In the range of Impeller Re numbers corresponding to the “minus one” slope of both functions, the Power number decreases in an inverse proportion to the Re number. In the range of higher Re numbers for the impeller blades, the slope decreases. In the range of a turbulent regime, for both resistance functions, only a weak dependence, if any, of the Power number on the Impeller Re number is observed. However, while the Re number for flow remains lower than 1500, the flow regime in the main part of a mixing tank is considered Laminar, even if a certain degree of turbulization may exist in the vicinity of the impeller blades.

On the other hand, it is obvious that at very high Re numbers, the laminar character of the flow is destroyed periodically by turbulent vortices. Due to such disturbances, a stepwise transition from laminar to turbulent mixing occurs, and the flow regime must be considered Transitional. The term Transitional regime of mixing, or Transitional flow regime is used here for flow Re numbers of 500 – 1500.

### 2.1.2. Interpretation of blending (macro-mixing) in laminar mixing regime

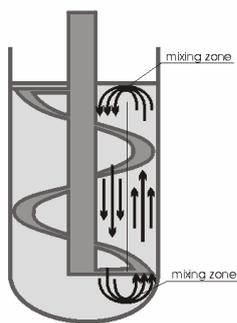
From the point of view of mixing, the total volume of the tank may be considered as consisting of zones with two different types of flow conditions.

In one part of the volume, stable state tangential and axial laminar motion occurs, and stable layers of media moving with different velocities are formed. The laminar flow regime is characterized by the stable motion of such layers of liquid, with no significant exchange of substance between them. Mixing in such flows occurs as a result of the deformation caused by the different velocities in the neighboring layers. This mechanism contributes to the blending since it ensures the redistribution of substances along the flow directions, but it does not cause inter-mixing of the layers.

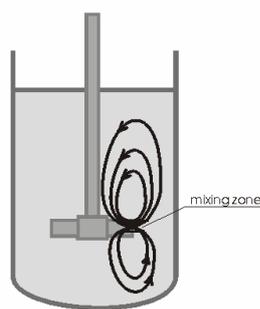
The stages of slow mixing due to deformation in tangential and axial flow alternate periodically with sharp changes in flow direction and structure followed by a fast random exchange of substance between the layers of media. This change of direction is a necessary condition for breaking the layers with different compositions, and consequently, for macro-scale homogenization of the media within the volume of the mixing zone.

The phenomena of fast exchange take place in certain parts of the flow, which we describe as zones of efficient mixing, or mixing zones. In tanks with Ribbon, Helical screw, or Anchor impellers, mixing zones are located around the turning points of the circulation flow close to the lower and upper edges of the impeller (Figure 3). In tanks with other impeller types, mixing zones are localized near the impeller blades (Figure 4). Passage of a portion of media through the mixing zone is described below as a mixing cycle.

Uniformity of a mixture is achieved when media from all points of the volume passes through the mixing zones. Due to non-uniform velocity distribution, the times needed for the liquid portions initially located in different points of the tank volume to reach the nearest mixing zone may differ by a few times, and the number of mixing cycles is thus a stochastic function of time.



**Figure 3.**



**Figure 4.**

The minimum number of mixing cycles required to achieve a certain predetermined technical result (a final degree of uniformity of viscous solution, distribution of temperature, selectivity of reaction, distribution of molecular mass in polymer production, etc.) depends on the process features and properties of the substances, for example, on the relation of densities and viscosities of components. However, for all processes, the degree of uniformity of a mixture in the tank is directly proportional to the average number of passages through the mixing zones,

and inversely proportional to the part of the media that has passed through a mixing zone less than a given number of times.

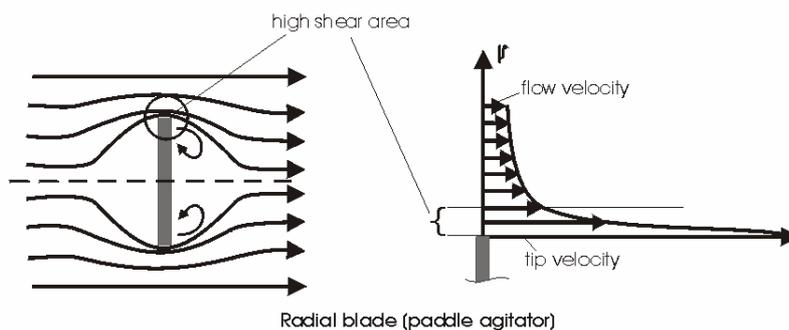
### 2.1.3. High shear treatment of media (micro-scale mixing)

A characteristic scale of the random exchange of a substance in the mixing zone described in the previous paragraph is by order of magnitude close to the size of the impeller blades, and can provide macro-scale mixing. Repeated passages of the media through these zones result in a stepwise decrease of the scale of non-uniformity down to the microscopic level, and further distribution proceeds due to diffusion.

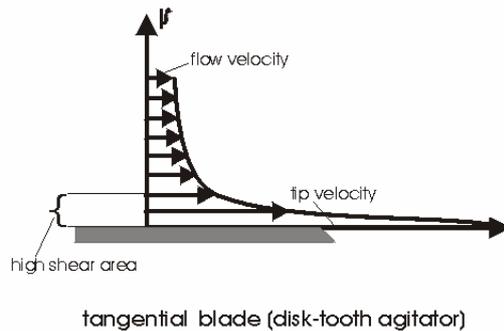
For a wide class of processes, more intensive treatment is necessary. For example, the manufacturing of multi-component and multiphase mixtures, such as paints, and cosmetics, requires a uniform distribution of various components, including powdered solids.

The solid material usually consists of very small (micron or sub-micron size) particles, which form big aggregates due to adhesive force. One of the main aims of mixing in such cases is the treatment of the media by extremely high shear stress. Such treatment helps to overcome adhesive forces, destroy aggregates, and achieve a high degree of uniformity on the microscopic level.

The most intensive treatment of the media takes place in high shear zones, which are formed in vicinity of the impeller blades due to big difference between velocities of the blade and the neighboring media (Figures 5, 6).



**Figure 5.**



**Figure 6.**

The destruction of aggregates and extremely “thin” micro-mixing are achieved only in these high shear zones (referred to below as Impeller shear zones), and the final result depends on the following parameters:

Shear rate, or shear stress near the impeller. For each chemical composition of a mixture, there is a certain critical value of shear stress required for the efficient destruction of aggregates and the homogenization of the mixture. The shear rate and, consequently, the shear stress on the impeller blades increase in a direct proportion to the rotational velocity of the impeller. Therefore, operations that require high shear treatment are usually performed in tanks with high-speed impellers.

The degree of treatment of media in the high shear zone. This is best characterized by the relative quantity of the media subject to high shear treatment for less than a certain predetermined period. This part of the media may naturally contain large aggregates or non-uniform inclusions. In most practical cases, high shear zones constitute a small part of the volume. Therefore, the final “untreated” part of the media is a stochastic function of the total relative volume of the high shear zone near the impeller blades. This part increases with the number of mixing cycles that occur during the process time. In some cases, macro-scale mixing (blending) may be incomplete because not all the media has passed through a mixing zone even once. This occurs if the distribution of axial velocity in the tank is highly non-uniform (see Circulation flow rate, p.61), and it is taken into account in estimation of the untreated part of the media.

#### 2.1.4. Formation of stagnant zones

If the Yield stress for the media does not equal zero, Shear stress on the wall may be lower than Yield stress. As a result, stagnant zones form on the periphery of the tank, and mixing is limited to a zone around the impeller. In such cases, VisiMix LAMINAR issues the message: “Formation of stagnant zones is expected. The configuration you have selected is not recommended...”, and does not perform calculations. You may get this message for zero values of Yield stress as well, if the velocities in the tank are negligibly small. The program provides approximate evaluation of stagnant zones volume as a function of mixing an properties of media (See Supplements).

To avoid stagnation, select a different impeller, or modify the mixing system in order to increase the impeller Torque. Another common technical solution is to use a Double-impeller system.

In order to get approximate information on Mixing power and other flow characteristics, such as the Circulation flow rate, the initial rheological curve must be replaced by an Approximate rheological function with Yield stress = 0. This function is also used for calculations of micro-scale mixing (High shear treatment) for tanks with Double-impeller systems.

Parameters of Approximate rheological function are found through the option Supplement. Approximation of rheology in the Calculate submenu, and entered in the input table Average properties of media as initial data for non-Newtonian media (see Approximation of rheology).

VisiMix is the first program that calculates the physically meaningful parameters for analysis and scaling-up of processes dependent on blending and high shear treatment of Newtonian and non-Newtonian media.

The program is applicable in a wide range of flow conditions, including the range of relatively high Reynolds numbers on the border of a turbulent flow regime. Obviously, at high Re numbers, the laminar character of the flow is distorted periodically by turbulent vortices. Due to such disturbances, a stepwise transition from laminar to turbulent mixing occurs. However, the exact course of the transition process is still unpredictable, and the program does not take into account these random macro- and micro-scale disturbances. Therefore, on threshold of laminar regime, certain differences in the parameter values calculated by VisiMix LAMINAR and VisiMix versions for Turbulent flow may be expected.

## SECTION 3. BUILT-IN DEMO PROJECTS

For your convenience, VisiMix LAMINAR contains eight built-in examples (projects) with a fixed set of initial data, each project corresponding to one or several VisiMix calculation options. For these projects, all relevant calculations have been performed.

The built-in demo projects (see the table below) offer calculation examples for the following:

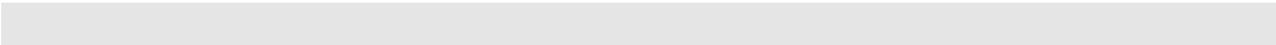
- mixing power (power01 and power02)
- blending (blending01 and blending02)
- heat transfer (ribheat01 and ribheat02)
- scaling-up (saw1-1 and saw2-1)

**Table 1. The List of Demo Projects in VisiMix LAMINAR**

Subject	Features	Project name	Input parameters	Relevant Output parameters (Calculate)		Recommended Help sections
				Menu section	Parameters	
Power consumption Circulation	3-stage impeller; Newtonian media	Power 01	Tank geometry Average properties of media	Flow characteristics  Power and forces	Scheme of main circulation cycles Impeller Re number Mixing power	Scheme of main circulation cycles
Power consumption Circulation Blending	Ribbon impeller  Non-Newtonian media	Power 02	Tank geometry  Average properties of media  Blending. Inlet and sensor positions	Flow characteristics  Power and forces  Blending	Scheme of main circulation cycles Impeller Re number Mixing power Unmixed part of media vs. time (%), final value Mean circulation time Mixing time Char. function of tracer distribution Dynamics of mixing/blending	Scheme of main circulation cycles Blending. Uniformity of mixing. Unmixed part of media - final value Simulation of macro-mixing

Blending  Mechanical calculations of shaft	2-stage impeller  Newtonian media	Blending 01	Tank geometry  Average properties of media  Blending. Inlet and sensor positions  Shaft design	Flow characteristics  Blending  Mechan. calculations of shafts	Scheme of main circulation cycles Impeller Re number Unmixed part of media vs. time (%), final value Mean circulation time Mixing time Characteristic function of tracer distribution Dynamics of mixing/blending	Scheme of main circulation cycles Blending. Uniformity of mixing. Unmixed part of media - final value Simulation of macro-mixing Mechanical calculations of shafts
Blending	3-stage impeller  Non-Newtonian media	blending 02	Tank geometry  Average properties of media  Blending. Inlet and sensor positions	Flow characteristics  Blending	Scheme of main circulation cycles Impeller Re number Unmixed part of media vs. time (%), final value Mean circ. time Mixing time Characteristic function of tracer distribution Dynamics of mixing/blending	Scheme of main circulation cycles Blending. Uniformity of mixing. Unmixed part of media - final value Simulation of macro-mixing
Heat transfer	Ribbon impeller  Newtonian media	ribheat01	Tank shell Jacket Average properties of media Heat transfer parameters	Heat transfer Liquid agent	Heat transfer coefficient, media side  Wall temperature, media side	Heat transfer
Heat transfer	Ribbon impeller  Non-Newtonian media	ribheat02	Tank shell Jacket Average properties of media Heat transfer parameters	Shear on the tank wall  Heat transfer  Liquid agent	Average shear rate near the tank wall Effective viscosity near the tank wall Heat transfer coefficient, media side Wall temperature, media side	Shear on the tank wall  Heat transfer

Homogenizing multiphase mixtures, destruction of aggregates of particles	Laboratory scale	saw1-1	Tank geometry  Average properties of media  Process duration	Shear rate near the impeller blades  Blending  Uniformity of mixing  High shear treatment Flow characteristics	Shear rate near the impeller blades Shear stress near the impeller blades Relative volume of impeller shear zone Unmixed part of media vs. time (%), final value Untreated fraction of media Tip velocity of impeller Re number for impeller blades	Mixing in laminar and transitional regimes. Physical interpretation  High shear treatment
Homogenizing multiphase mixtures, destruction of aggregates of particles (compare with Saw1-1)	Production scale	saw2-1	Tank geometry  Average properties of media  Process duration	Shear rate near the impeller blades  Blending. Uniformity of mixing.  High shear treatment  Flow characteristics	Shear rate near the impeller blades Shear stress near the impeller blades Relative volume of impeller shear zone Unmixed part of media vs. time (%), final value Untreated fract. of media Tip velocity of impeller Re number for impeller blades	Mixing in laminar and transitional regimes Physical interpretation High shear treatment



## SECTION 4. KEY PARAMETERS FOR EVALUATION AND SCALE-UP

VisiMix LAMINAR calculates key parameters needed for evaluation and scaling up of various processes involving the mixing of highly viscous media. Table 2 below will help you select the parameters important for your particular process based on known process characteristics.

**Table 2. Key Parameters for Evaluation and Scale-Up of Processes in Newtonian and Non-Newtonian Viscous Media**

Process	Characteristic product sample	Typical products	Phenomena controlling the process	VisiMix Parameters for evaluation and scaling-up
Batch mixing of viscous solutions	0.01 - 1 kg	Polymer solutions  Pastes of detergents	Uniformity of distribution of circulation flow Macroscale mixing	- Circulation flow rate - Mixing time - Dynamics of mixing/blending - Unmixed part of media, final value
Continuous flow mixing of viscous solutions	0.01 - 1 kg	Polymer solutions  Pastes of detergents	Uniformity of distribution of circulation flow Macroscale mixing	- Circulation flow rate - Mixing time - Dynamics of mixing/blending - Unmixed part of media - Characteristic function of tracer distribution
Homogenizing multi-component mixtures. Uniform distribution of small admixtures	0.1 - 50 g	Creams  Food products	Uniformity of distribution of circulation flow Macroscale mixing No. of mixing cycles	- Unmixed part of media vs. time - Unmixed part of media, final value - Dynamics of mixing/blending.
Homogenizing multiphase mixtures	5 - 0.1 g	Creams  Food products	Macroscale mixing Number of mixing cycles High shear treatment	- Unmixed part of media, final value - Dynamics of mixing/blending - Shear stress near the impeller blades - Untreated fraction of media
Destruction of aggregates. Ensuring microscale uniformity.	1 - 100 mg and less	Paints Coatings Medicines Ointments Foodstuffs	High shear treatment	- Shear stress near the impeller blades - Untreated fract. of media - Unmixed part of media, final value
Heat transfer		All	Shear rate near	- Heat transfer rate

		applications	the tank wall	
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#### 4.1. Selecting Mixing Equipment

VisiMix LAMINAR provides the data for:

- Predicting the degree of uniformity of mixing and the formation of stagnant zones;
- Analysis of mixing-dependent processes from the point of view of mixing and heat transfer;
- Scaling-up and scaling-down of processes and equipment;
- Checking the suitability of the equipment for a given production process;
- Comparing different designs of tanks, baffles, and impellers;
- Selecting the best ways of improving process regimes according to your technical possibilities;
- Selecting or designing new mixing units.

Several practical considerations of a general character that should be taken into account in selecting impellers for highly viscous, and especially non-Newtonian media, are given below.

To achieve efficient mixing, it is advisable to select impellers with larger tip diameters;

It is known that the most efficient mixing is achieved in tanks with Helical Ribbon, Helical Screw, and Anchor impellers; the height of the impellers (“h” in the input table of these impellers) must be about the same as the height of the media in the tank;

Anchor impellers provide lower circulation than Ribbon impellers;

For other impeller types, the Tip diameter must be at least half of the Tank diameter, and the distance between the impeller and either the surface of the media, or the tank bottom should not exceed the Tip diameter.

If the height of the media in the tank is greater than 1.5 times the tank diameter, the use of 2- or 3-stage impeller may be advisable;

The highest heat transfer rates are obtained by applications of scraper (sweeping-wall) impellers (see Supplements);

For processes that include emulsification, the destruction of solid particle aggregates, the homogenizing of multi-component mixtures, and some others, tooth-disk impellers are normally used. These impellers can be also used in tanks with additional low speed blades (see Double-impeller systems; see also Entering Initial Data for a New Project).

## SECTION 5. HOW TO INSTALL VISIMIX LAMINAR 2K7

Installation rules for the 'stand alone' and the network version of the program are different. Installation of each program has to be performed accordingly to the Installation instruction that is applied to the program CD.

## SECTION 6. STARTING VISIMIX

After installing **VisiMix LAMINAR**, the main menu appears on the screen (Figure 7). It has the following structure:

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



**Figure 7.**

### 6.1. Project

VisiMix performs mathematical modeling of processes in relation to a project - a single set of initial data, which includes the types and main dimensions of equipment as well as the physical properties of the media and regime parameters. 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.

To start VisiMix, select Project. When the Project submenu appears, you have two options: starting a new project or working with one of the projects you have previously stored in the system.

The program enables you to open several projects (up to four) which can be simultaneously displayed on the screen. However, you may modify initial data, create new output windows, or use any other functions only for the Current Project whose name appears in the text field at the bottom of the screen. To change the Current Project, use Project list option in View or Project list button in the upper screen bar. If windows related to several projects are displayed on the screen, you can also change the Current Project by double-clicking on the colored frame of the window related to the project you now want to become the current one.

## 6.2. Edit input

This option gives you access to all input tables related to the Current Project. Use it to selectively modify the initial data, for instance, Average density, Width of blades, or any other parameter by choosing the appropriate submenu item. You may also use the Edit option to enter initial data, although normally, the required initial data is automatically requested by VisiMix.

The Edit option has the following structure (Figure 8) briefly described below



**Figure 8.**

### **Tank:**

- Tank geometry: Main inside dimensions of the tank and volume of media
- Tank Shell: Tank shell characteristics for heat transfer calculations

### **Jacket:**

- General characteristics: Main data on various types of jackets, including number of jacket sections, their height, position and connection between the jackets
- Specific characteristics: Specific data for each jacket type - width of conventional jacket, diameter or half-pipe coil

**Impeller:** Characteristics and dimensions of the impeller

**Baffles:** Type, number, position and dimensions of baffles

### **Shaft:**

- Shaft design: Shaft type and dimensions
- Shaft material and impeller mass: Properties of the shaft materials and impeller mass
- Impellers data for mechanical calculations.

### **Properties & Regime:**

- Average properties of media - Average density and viscosity, or rheological parameters for non-Newtonian media, used for hydrodynamic calculations
- Upper limit of shear rate – maximum value of shear rate measured in the course of rheological studies

**Blending.** Inlet/sensor position – positions of inlet tube and sensor in the tank

**Process duration** – the expected or required duration of the mixing operation

### **Heat transfer:**

- Media temperature - average temperature of media in the tank
- Heating vaporous agent - Heating steam pressure or data for another condensing heating agent.
- Heating/cooling liquid agent - Liquid heat transfer agent, its flow rate and initial temperature.
- Heat transfer properties of the media - Physical properties of the media required for heat transfer calculations.

**NOTE: When entering initial data through the Edit option, you may sometimes obtain a different input table from the one you have selected. This means that you must first complete the table invoked by VisiMix, and then the table you have originally selected will be invoked automatically.**

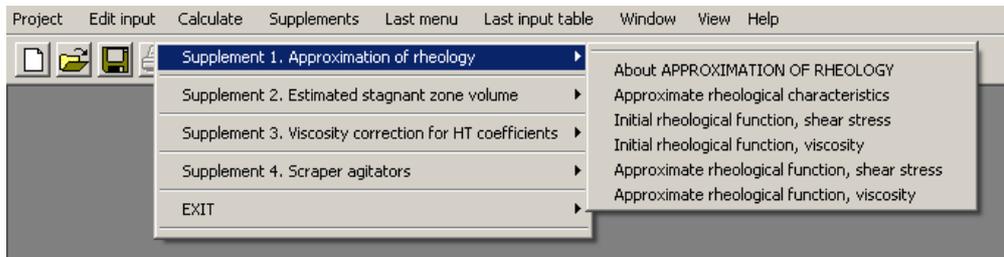
### 6.3. Calculate

Use this option to perform the calculations. The Calculate submenu provides access to modeling in relation to all mixing problems and output parameters. For a detailed description see Section 9.

### 6.4. Supplements.

This menu option opens access to a few additional VisiMix functions (Fig.9):

**Supplement 1.** Approximation of rheology – Replacement of a real rheological function including a final value of Yield stress with approximating exponential curve (Yield stress=0) in limits defined by User. The replacement function is used for approximate calculations (see Section 9).



**Figure 9.**

### 6.5. Last menu

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

#### **Example:**

You have clicked on Mixing power in the Power and forces submenu and obtained an output. In order to obtain another output parameter, for instance, Power number, you do not need to return to the Calculate menu. Simply click on Last menu - Power number to obtain your output.

### 6.5. 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 heat transfer rates and select the best vaporous heat transfer agent, you can change the input after each calculation by selecting Last input table only, without going through the long procedure of addressing Edit – Properties & Regime - Heat Transfer. This option is activated after you have first accessed an input table through the Edit option, or the quick access buttons in the upper screen bar.

### 6.6. Window

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

## 6.7. View

This option contains the following functions:

- Toolbars
- Initial data explorer
- Project list
- Drawing of apparatus

### 6.7.1. Toolbars

This option allows you to display or remove the main toolbar located in the upper screen bar

### 6.7.2. Initial data explorer

This option shows a list of initial data for the current project, including equipment data (tank, impeller, shaft and baffle), and properties & regime parameters (see the description of the Edit input option above). This option is also accessible from a quick access button in the upper screen bar. To modify any of the initial data using the initial data explorer, select the required item, and press the Edit button at the bottom of the screen. The appropriate input screen will be invoked.

### 6.7.3. 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.

### 6.7.4. Drawing of apparatus

This option shows the diagram of the mixing system for the current project, with main dimensions. This diagram automatically appears on the screen after all basic initial data for a new project has been entered, or when an existing project is opened. It is also accessible from a quick access button in the upper screen bar.

## 6.8. 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 7. STARTING A NEW PROJECT OR OPENING AN EXISTING ONE

Select Project. The following submenu appears:

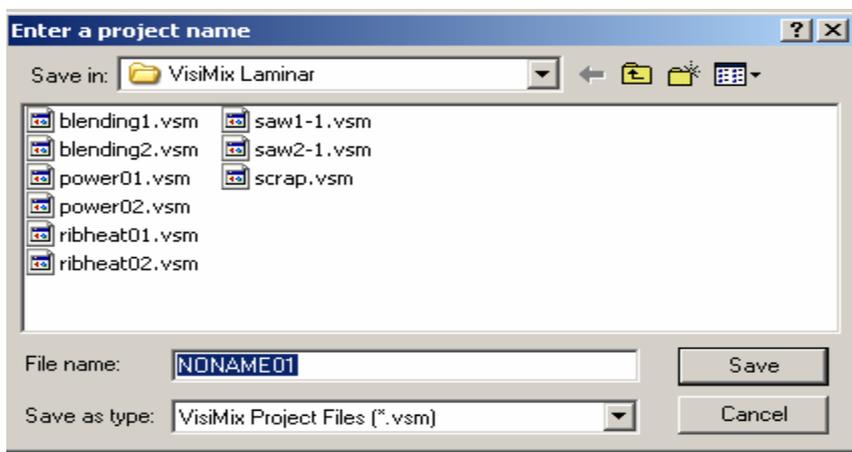
- New
- Open
- Close
- Clone
- Project comments
- Save
- Save as
- Report
- Print
- [Recent projects]
- Exit

### 7.1. New

To start a new project:

1. Select New from the Project menu.
2. When the new project dialogue appears (Figure 10), 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.

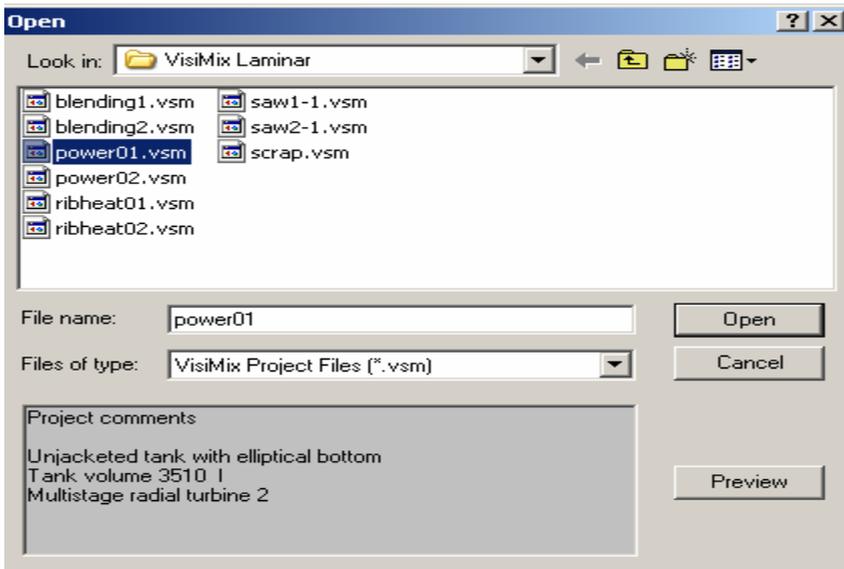


**Figure 10.**

### 7.2. Open

To open an existing project:

Select Open from the Project menu. The Open dialogue appears (Figure 11). From the file browser screen select the desired project and click OK.



**Figure 11.**

The system displays a diagram of the apparatus and its main dimensions. Use the Edit option or the quick access buttons in the upper screen bar to check and modify initial data for your equipment (Tank, Baffles and Impeller). For media properties and regime characteristics, use Edit option only (Properties & Regime).

### **7.3. Close**

Use this option to close and save the current project.

### **7.4. 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.

### **7.5. 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.

### **7.6. 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.

### **7.7. Save as**

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

### **7.8. Report**

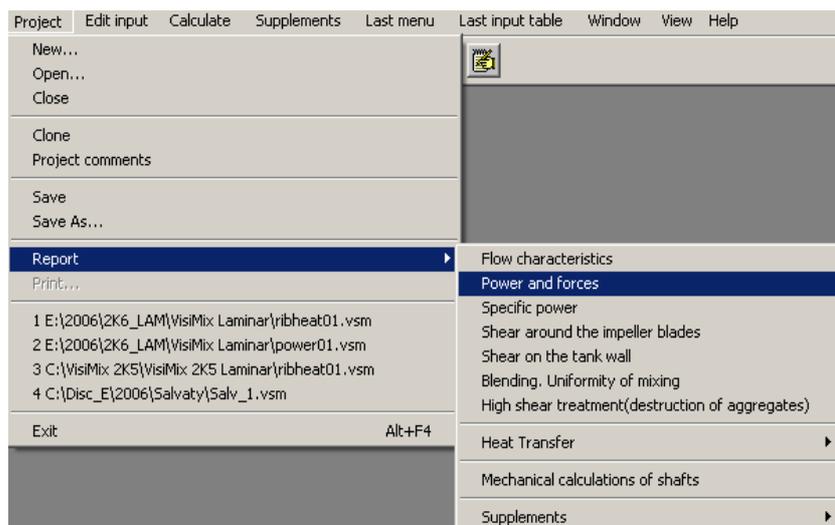
Use this option to accumulate the initial data and calculated results in a file of standard HTML format.

Selecting Report at any stage of working on a current project invokes a submenu, which is identical to the Calculate submenu (Figure 12). Choose any item you are interested in, and supply additional data if requested by VisiMix. When the required initial data is entered, VisiMix asks you to enter a name for the report. Enter the report name, and VisiMix will create a report

including relevant initial data and the results of the calculations. On completing the report, VisiMix issues an appropriate message.

You may create one or more reports for your project.

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. This enables you to plot and process your data.



**Figure 12.**

### 7.9. 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 (tank, impeller, baffles, average properties of media, and so on) are printed from the corresponding input data tables.

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

### 7.10. Exit

Use this option to close opened projects and quit VisiMix.

## SECTION 8. ENTERING INITIAL DATA FOR A NEW PROJECT

After you enter the name of a new project and click OK, VisiMix 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.

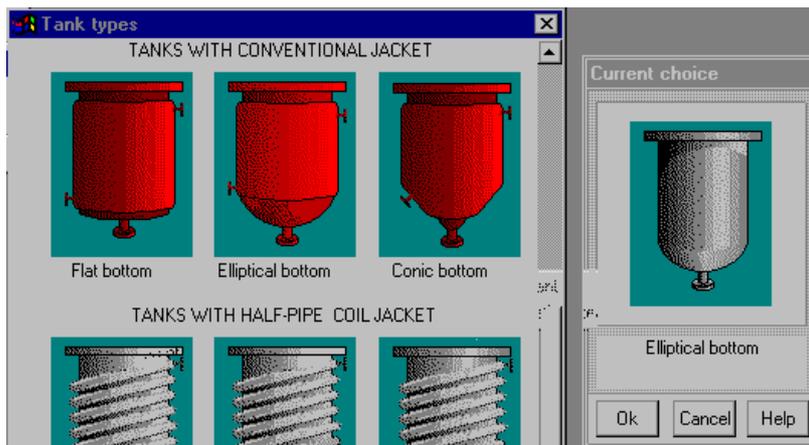
Whenever you choose an item for simulation from the Calculate submenu, VisiMix will request additional data required for modeling or for calculating the selected parameter. You do not need to enter any additional data unless VisiMix requests it. The data you have entered are stored in the system, and when addressing any further parameters of the output submenus, you will be asked to enter only that data which is required for defining your particular parameter, and which has not been entered previously.

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

VisiMix 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, contradicts previously entered data, or is beyond VisiMix 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.

### 8.1. 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) and type of a heat transfer device (no heat transfer device, conventional jacket or half-pipe coil jacket) appears (Figure 13).



**Figure 13.**

The jacket may consist of one or two sections connected in series or in parallel. Choose a tank 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.

**NOTE: If you do not plan to perform heat transfer calculations in the current project, do not select a jacketed/insulated tank, even if your tank has a heat transfer device. Select an equivalent unjacketed tank instead. If you select a tank with a heat transfer device, you will be asked to supply all its parameters.**

When the scheme of the selected tank appears (Figure 13), supply the requested values of tank parameters by completing the table of dimensions.

TANK WITH ELLIPTICAL BOTTOM	
Inside diameter	1600 mm
Total tank height	4300 mm
Total volume	8378 l
Level of media	3864 mm
Volume of media	7500 l

Diagram labels:  $\varnothing 1600$ , 4300

Buttons: OK, Cancel, Choose new tank, Print, Help

**Figure 13.**

### 8.1.1. Tank with flat bottom

Supply the internal dimensions of the selected flat-bottomed tank. Enter the Inside diameter and either the Total tank height, or Total volume, and the second parameter will be entered automatically. The same applies to the Level of media and Volume of media. 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 will then be displayed.

### 8.1.2. Tank with elliptical bottom

Supply the internal dimensions of the selected tank with an elliptical bottom. This option may also be used for calculating tanks with a spherical bottom, as the influence of the difference in geometry proves to be insignificant for the process modeling.

Enter the Inside diameter and either the Total tank height, or Total volume, and the other parameter will be entered automatically. The same applies to the Level of media and Volume of media. After the table has been completed, click anywhere on the field of 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 will then be displayed.

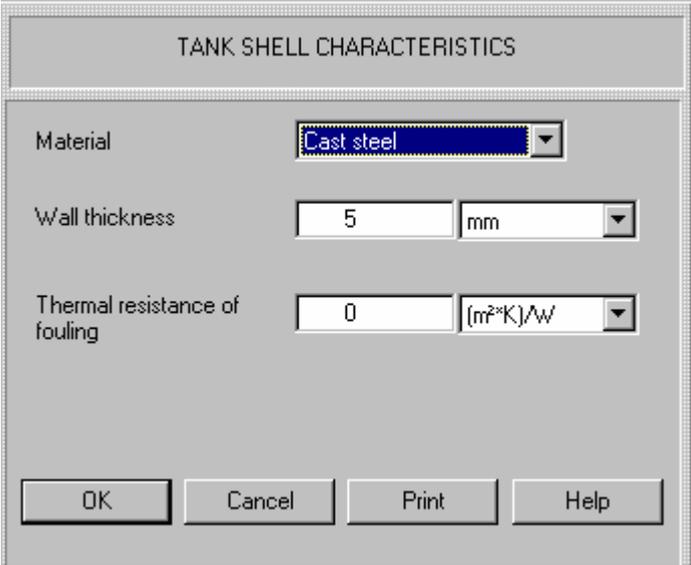
### 8.1.3. Tank with conic bottom

Supply the internal dimensions of the selected tank with a conic bottom. The Cone angle is usually 45-60 degrees. The maximum Height of cone is controlled by the program as a function of the Inside diameter and the Cone angle.

Enter the Inside diameter, cone dimensions, and either the Height of Cylindrical Part, or Total volume, and the other parameter will be entered automatically. The same applies to the Level of media and Volume of media. After the table has been completed, click anywhere on the field of 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 will then be displayed.

### 8.1.4. Tank shell characteristics

You will be asked to fill in this table (Figure 14), if you have selected a tank with a heat transfer device (HTD) for the current project.



TANK SHELL CHARACTERISTICS	
Material	Cast steel
Wall thickness	5 mm
Thermal resistance of fouling	0 (m²*K)/W

OK Cancel Print Help

**Figure 14.**

**Material.** Select the desired tank material. All the required data for the selected material will be supplied by the program.

**Wall thickness.** This parameter is required for calculating the wall thermal resistance. If you do not know the exact figure, enter an estimate; for steel tanks it is usually 5-9 mm.

You may not enter a wall thickness lower than 1.5 mm.

**Thermal resistance of fouling.** Fouling of the heat transfer area may occur both on the jacket and on the media side of the tank wall. Thermal resistance of fouling depends on the kind of heat transfer agent (HTA) and the properties of the media, and is estimated according to available practical data.

Some typical values for deposit layers not exceeding a thickness of 0.5 mm on the surface of stainless steel plates are given in Appendix 1. Enter the estimated value, or zero if there is no fouling. In the case of fouling on both sides of the wall, enter the sum of the estimated values of the corresponding thermal resistance values for each side.

### 8.1.5. Tank heat transfer data. General.

You will be asked to fill in this table (Figure 15) if you have selected a tank with a heat transfer device (HTD) for the current project. A diagram of a tank with a Half-pipe coil jacket (HC) or Conventional Jacket (CJ) will appear, according to the selected Tank type and dimensions. The program covers a wide variety of HTD designs.

The screenshot shows a software dialog box titled "TANK HEAT TRANSFER DATA. GENERAL". It features a "Help" button in the top right corner. The main area contains several input fields and dropdown menus. Under "Jacket covers bottom", the value "YES" is selected. "Number of jacket sections" is set to "1". The "Lower section" group includes "Distance from bottom" (empty), "Height, Hlow" (2000 mm), and "Heat transfer area, according to drawings" (0 sq.m). The "Upper section" group includes "Distance between two sections" (empty), "Height, Hup" (empty), "Heat transfer area, according to drawings" (empty), and "Connection of jackets" (empty). A diagram on the right shows a tank with a jacket, with dimensions: diameter 1400, jacket height 2400, and lower section height Hlow. At the bottom are "OK", "Cancel", and "Print" buttons.

Figure 15.

**Jacket covers bottom.** If you choose YES, the heat transfer area of the bottom will be assumed to equal 2/3 of its total area. In most cases, the heat transfer area of the bottom part of the HTD constitutes only a small part of the entire heat-transfer area.

**Number of jacket sections.** You may perform calculations for jackets consisting of one or two separate sections. If you choose "1", the program will assume your tank has lower jacket only. In this case, parameters relating to the upper jacket section will appear in inactive script.

**Heat transfer area.** Enter the exact values of the HT area for each jacket section, if known. If this value is unknown, enter zero, and the program will calculate the HT area according to your input.

**Connection of jackets.** For a 2-sectioned jacket, specify if the sections are connected in series, or in parallel. For liquid heat transfer agents (LA), VisiMix assumes that the inlet tube is located in the lower cross-section, and the outlet is in the upper cross-section. The jacket sections are assumed to be connected in series, if the Lower section outlet is connected to the Upper section inlet. For condensing vaporous heat transfer agents (VA), the inlet tube is supposed to be located in the upper cross-section, and the outlet - in the lower cross-section of each jacket section. The jacket sections are assumed to be connected in series, if the Upper section outlet is connected to the Lower section inlet.

### 8.1.6. Tank jacket. Specific characteristics.

Half-pipe coil jacket. Specific characteristics.

Half- You will be asked to fill in this table (Figure 16) after you have selected a tank with a pipe coil HTD and completed the TANK HEAT TRANSFER GENERAL DATA input table. The entire table appears in active script if a 2-section jacket has been selected. For a single-section jacket, only the Lower section boxes are active.

**Pipe diameter.** Enter the inside diameter of the Half-pipe coil jacket.

**Distance between coils.** Enter the distance between the axes of the adjacent half-pipe turns as shown in the diagram.

**Number of starts.** Enter the number of starts of the Half-pipe coil (1 or more, according to the tank design).

**NOTE:** If you have a 2-section jacket and attempt to exit the table without entering data for both jacket sections, VisiMix issues an appropriate message.

### Conventional jacket. Specific characteristics.

You will be asked to fill in this table (Figure 17) after you have selected a tank with a conventional jacket and completed the TANK HEAT TRANSFER GENERAL DATA input table.

The entire table appears in active script if a 2-section jacket has been selected. For a single-section jacket, only the Lower section boxes are active.

HALF-PIPE COIL JACKET. SPECIFIC CHARACTERISTICS.

Lower section

Pipe diameter, lower section, d  mm

Distance between coils, l  mm

Number of starts

Upper section

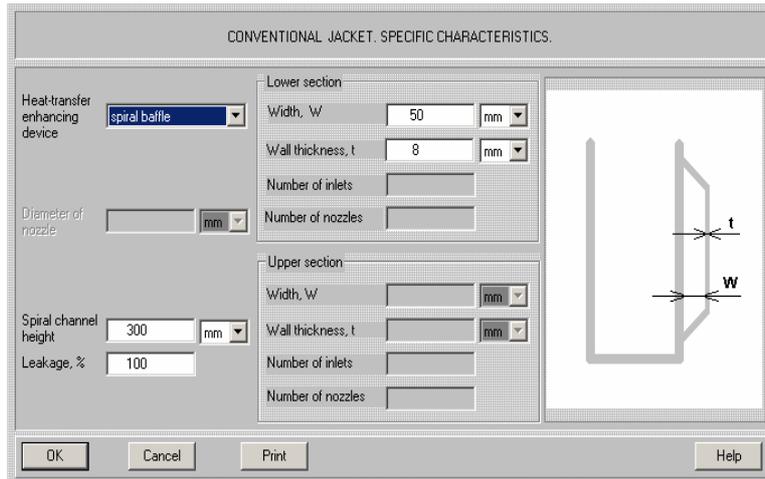
Pipe diameter, upper section, d  mm

Distance between coils, l  mm

Number of starts

OK Cancel Print Help

**Figure 16.**



**Figure 17.**

**Width, W.** Enter the width of the channel inside the jacket, i.e. half of the difference between the inside diameter of the jacket and the outside diameter of the tank.

**Wall thickness, t.** Enter the thickness of the jacket wall.

In addition to the jacket dimensions, the parameters of devices used for improving the jacket heat transfer, such as agitation nozzles and spiral baffles, are entered in this table.

**Heat-transfer enhancing device.** Select “agitation nozzles” or “spiral baffle” for an appropriate heat-transfer enhancing device. Select “absent” if your jacket has no heat-transfer enhancing device.

Agitation nozzles are mainly used in glass-lined equipment. Their main effect is to impose a spiral flow pattern tangential to the jacket wall by momentum exchange between the high-velocity tangential stream leaving the nozzle and the jacket fluid. This momentum exchange results in “swirl velocities” in the range of 0.3-1.2 m/s, which is high enough to cause turbulent flow [Donald H. Bollinger, Assessing Heat Transfer in Process Vessel Jackets, Chemical Engineering, September 20, 1982, pp. 95-100]. VisiMix takes into account both agitation nozzles, which create a spiral tangential flow, and additional inlets that may be located on the jacket surface.

**NOTE: The flow rate through all inlets is assumed to be the same.**

The following parameters are entered for the jackets with agitation nozzles:

- Diameter of nozzle. Enter the throat diameter of the agitation nozzle.
- Number of inlets. Enter the total number of inlets for the jacket, including agitation nozzles.
- Number of nozzles. Enter the number of agitation nozzles in the jacket (2-3 agitation nozzles are recommended).

Agitation nozzles produce jacket heat-transfer coefficients two or three times higher than those in conventional jackets without nozzles, however, more pumping energy is required to overcome nozzle pressure drop.

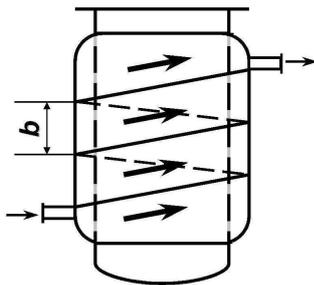
A spiral baffle consists of a metal strip spirally wound around a vessel wall from jacket entrance to exit. This strip directs the flow in a spiral path to obtain fluid velocities, typically in the range of 0.3-1.2 m/s. The baffle is manufactured in such a way that a gap is often left between the baffle and the jacket wall. This gap is a second path for the fluid from the jacket inlet to outlet, perpendicular to the desired path along the baffle. The fluid that leaks, i.e. bypasses the spiral baffle through this gap, does not contribute directly to heat transfer at the vessel wall. In general, leakage flow amounts to one-third to one-half of the total flow circulated to a spirally baffled jacket.

Compared to agitation nozzles, spiral baffles require a higher flow rate of the heat transfer agent, but result in much less of the pressure drop, to ensure the same heat-transfer rates. Spirally baffled jackets, therefore, require only a part of the energy (typically, not more than about 40%) needed by jackets with agitation nozzles.

The following parameters are entered for the spiral baffle:

**Spiral channel height,  $b$ .** Enter the distance between the adjacent spiral turns for the baffle (see the diagram below).

**Leakage, %.** Enter the estimated part of the heat transfer fluid that bypasses the spiral baffle through the gap between the baffle and the jacket wall.



Conventional jacket with spiral baffling

### Embossed and dimpled jackets. Specific characteristics.

You will be asked to fill this table (Figure 18) after you have selected a tank with embossed or dimpled jacket and completed TANK HEAT TRANSFER GENERAL DATA input table. Embossed and dimpled jackets ensure better heat exchange and higher efficiency than conventional jackets. Tanks with embossed or dimpled jackets are manufactured using a special double-layer metal plate, which is preliminarily embossed or dimpled.

**Plate type.** Enter the jacket type – embossed or dimpled.

- **Embossed.** This type of plate is made by (1) contact welding of two metal sheets of different thickness so that welded spots are formed at regular spacing from each other and (2) by hydraulic or pneumatic pressure, so that the thicker plate remains flat, and the thinner one is inflated. As a result, a channel of a variable cross-section is formed. The maximum height of the channel is in the range of 3-15 mm. Any material compatible with resistance welding may be used.

- Dimpled: fabricated by welding a pre-deformed metal sheet to a flat plate, so as to obtain a channel of a variable cross-section between the plates, the maximum channel height usually varying from 3 to 15 mm, as for embossed plates.

A diagram corresponding to your choice appears on the screen. Enter the dimensions as shown in the diagram:

- Plate thickness,  $t$ .
- Pillow height,  $w$ .
- Spot diameter,  $d$ .
- Spot spacing,  $l$ .

All geometrically possible values are allowed.

EMBOSED / DIMPLED JACKET. SPECIFIC CHARACTERISTICS.

Plate type:

Plate thickness,  $t$ :  mm

Pillow height,  $w$ :  mm

Spot diameter,  $d$ :  mm

Spot spacing,  $l$ :  mm

Flow obstruction factor, lower section:

Flow obstruction factor, upper section:

Buttons: OK, Cancel, Print, Help

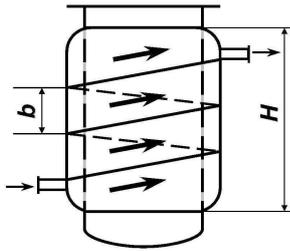
**Figure 18.**

Embossed and dimpled jackets are sometimes equipped with spiral, horizontal, or vertical baffles for further intensification of the heat transfer. In this case, you are requested to enter an additional parameter, Flow obstruction factor, FOF which characterizes the decrease in the flow cross-section due to the heat-transfer enhancing device.

If your embossed/dimpled jacket has no heat-transfer enhancing device, enter “1” for the Flow obstruction factor.

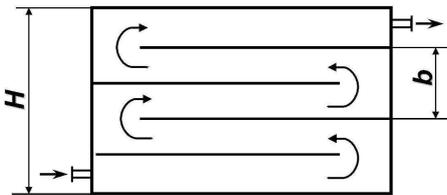
**Flow obstruction factor, FOF.** Enter the ratio of the flow area in the baffled channel to the unbaffled flow area. This coefficient shows the narrowing of the channel and, accordingly, the increase in the flow velocity.

For the spiral baffling of the jacket shown in the diagram below,  
 $FOF = H/b$ .



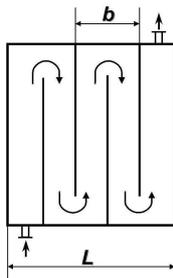
Embossed/dimpled jacket with spiral baffling

For the horizontal baffling shown in the diagram below,  $FOF = 2H/b$ .



Embossed/dimpled jacket with horizontal baffling

For the vertical baffling shown in the diagram below,  $FOF = L/b$ .



Embossed/dimpled jacket with vertical baffling

In the case of series connection of the internal heat transfer devices,  
 $FOF = n$ , where  $n$  is number of plates constituting the heat-transfer device.

In all other cases, the FOF value must be selected empirically, based on general engineering considerations.

## 8.2. Baffles

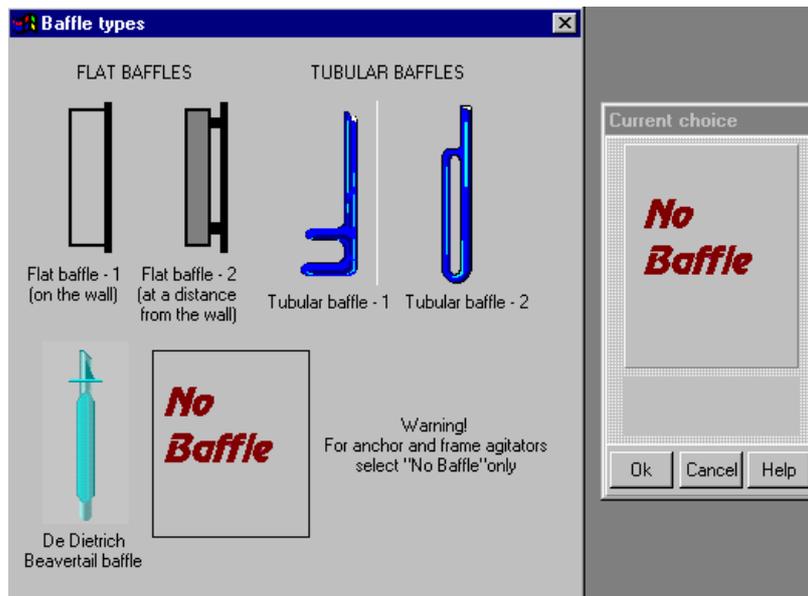
Mixing of high viscosity media in laminar regime is usually performed in unbaffled tanks, since the effect of baffles in laminar flow conditions is negative. However, baffled tanks are sometimes used for mixing in 'transitional' regime.

Some mixing operations are performed in tanks with Double-impeller systems, i.e., mixing systems consisting of two different impellers, for instance, a low velocity anchor impeller and a high velocity tooth-disk impeller. To calculate power and mixing characteristics for the high velocity impellers in such configurations, the blades of the low speed anchor must be entered as baffles of the same dimensions.

The procedure for selecting the baffle type and entering baffle data is similar to the one used for tanks.

The VisiMix selection of baffles (Figure 19) includes flat baffles used in steel tanks, and tubular baffles used mainly in glass-lined equipment.

**NOTE: The case of baffled tanks with Anchor/Frame impellers is not covered by the current VisiMix version since it is of little practical interest.**

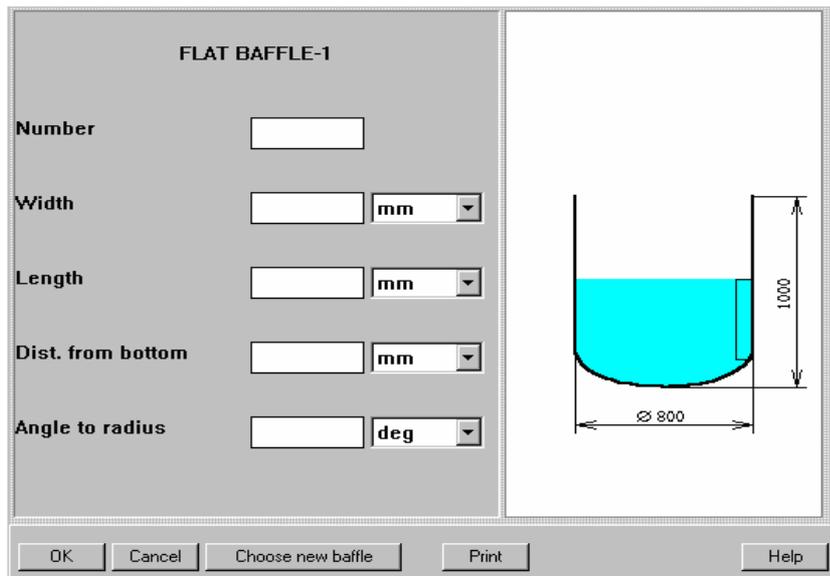


**Figure 19.**

### 8.2.1. Flat baffle-1 and Flat baffle-2

Use these input tables (Figure 20) for entering the characteristics of flat baffles. Flat baffle-1 corresponds to a flat baffle on the wall, Flat baffle-2 corresponds to a baffle at a distance from the wall. The distance between Flat baffle-2 and the tank wall is usually about 1/3 – 1/4 of the baffle width.

**NOTE: For radially installed baffles (both flat and tubular), the Angle to radius is zero.**



**Figure 20.**

### 8.2.2. Tubular baffle-1 and tubular baffle-2

These baffles have a tubular or flattened tubular cross-section. They are used mainly in glass-lined mixing tanks. The Tube diameter is usually about 1/10 of the tank radius.

### 8.2.3. Beavertail baffle

This is the most common baffle type used in De Dietrich glass-lined equipment. You may use this option for simulation of inlet/outlet tubes fixed inside the tank.

## 8.3. Impeller

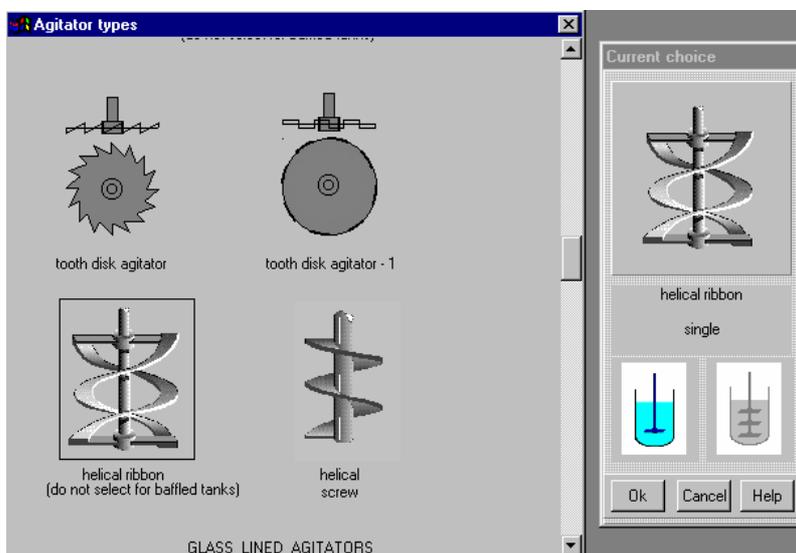
The procedure for selecting the impeller type and entering impeller data is similar to the one used for tanks and baffles. VisiMix LAMINAR impeller selection is shown in Figure 21.

The blue color in this graphic menu corresponds to glass-lined impellers characterized by their smooth surface and the streamlined configuration of the blades.

When choosing an impeller for your mixing system, you should take into account the following considerations:

- 1) Helical ribbon, Helical screw, and sometimes Anchor/Frame impellers are considered the best choice for the efficient mixing of highly viscous media in a laminar regime. However, other impeller types, particularly in 2- or 3-stage systems, can also be quite efficient.
- 2) Mixing and homogenization of multi-component mixtures (paints, coatings, etc.), which includes the destruction of small solid particle aggregates and micro-mixing, is usually performed with Tooth-disk impellers. Sometimes these impellers are used together with low speed anchors with blades placed close to the tank wall (Double-impeller systems).

You may choose impellers of most typical designs, both steel and glass-lined. After you have selected the impeller type, you can choose either a “single” or a “multistage” system by clicking on the appropriate diagram in the Current choice window in the impeller screen. It is assumed that a multistage system consists of two or three identical impellers.



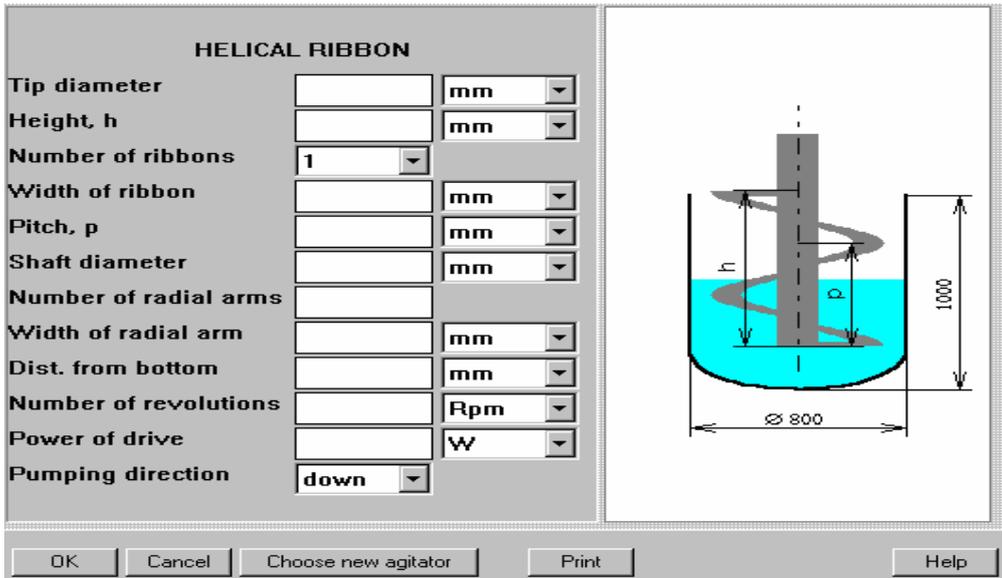
**Figure 21.**

**NOTE: VisiMix LAMINAR can be used for most common impeller designs. If you want to perform calculations for an impeller, which is not shown in the IMPELLER TYPES screen, contact VisiMix technical support.**

When the scheme of the selected impeller appears (Figure 22), supply the requested impeller parameters.

The most common pumping direction for impellers is down. For single-stage impellers, VisiMix allows for selecting pumping direction. For multistage impellers, Pumping direction cannot be selected and is always down.

**NOTE: When entering impeller data for a multistage system, take into account that the software will disregard the upper impeller if it is placed too close to the surface or above the surface.**



**Figure 22.**

### 8.3.1. Anchor, frame

Compared to the Anchor impeller, the Frame impeller has an additional horizontal bar. This bar is used to prevent the winding of the impeller vertical arms. Its effect on the power and mixing process in turbulent regime is negligible. The Tip diameter of Anchor and Frame impellers is usually about 0.8 to 0.95 of the tank's inside diameter, and the Width of blades ("arms") is about 0.07 to 0.1 of the Tip diameter. The height of the arms should be approximately the same as the height of the media in the tank.

In tanks used for the production of paints, coating, etc. ("dissolvers"), Anchor impellers are sometimes used with high speed impellers with small tip diameters (see Double-impeller systems).

**Note.** *Decrease of distance between the wall and anchor arm to less than 0.05 of the tank diameter results usually in reduction of inside circulation.*

### 8.3.2. DeDietrich impeller

The blades of this glass-lined impeller are made of slightly flattened and curved tubes. The geometric proportions of the impeller are set by the manufacturer; therefore, the only variables are the Tip diameter, and the parameters describing the position of impeller in the tank, i.e. the Distance from bottom, and the Distance between stages for multistage systems. For the mixing of viscous media, the Tip diameter is usually 0.5 to 0.7 of the tank diameter.

### 8.3.3. DeDietrich GlasLock with Variable Flat Blades

De Dietrich glass-lined GlasLock impellers are used for various unit operations, including blending, mixing, homogenization, gas dispersion, suspension, heat transfer, crystallization, etc. They are designed with individually adjustable and removable blades, and can be used in both single and multistage applications.

#### **8.3.4. DeDietrich GlasLock with Flat Blades**

The typical pitch angles of GlasLock impellers with flat blades are 30, 45, 60 and 90 degrees. The width of the blades is usually about 0.1 to 0.2 of the Tip diameter, the length of the blades is 0.1 to 0.25 of the Tip diameter. The standard number of blades is three.

#### **8.3.5. De Dietrich GlasLock with Hydrofoil Blades**

GlasLock impellers with hydrofoil blades ensure low power consumption and a high pumping capacity. They are used for suspension processes, heat transfer, and chemical reactions. The standard number of blades is three. The geometric proportions of the impeller are fixed by the manufacturer; therefore, the only variables are Pitch angle, Tip diameter and the parameters describing the position of the impeller in the tank, i.e. the Distance from bottom, and the Distance between stages for multistage systems.

#### **8.3.6. De Dietrich GlasLock with Breaker Bar Blades**

GlasLock impellers with Breaker Bar Blades are mainly used for viscous products. The standard pitch angles are 45 and 90 degrees, the standard number of blades is two. For the mixing of viscous media, the Tip diameter is usually 0.5 to 0.8 of the tank diameter.

#### **8.3.7. Glass-lined paddle and impeller impellers**

This option can be used for glass lined impellers of different design and dimensions, including those manufactured by Pfaudler, Tycoon, etc. It may also be used for polymer-lined impellers. Glass lining technology requires a streamlined configuration for all the elements of the impellers; therefore, the impeller blades are usually manufactured of flattened tubes.

#### **8.3.8. Paddle**

For paddle impellers, the Tip diameter is usually 0.4 to 0.65 of the tank diameter. The number of blades is usually 2 - 6; the width of the blades is 0.1 to 0.2 of the Tip diameter. These impellers are often used in laboratory equipment, including magnetic mixers.

#### **8.3.9. Pitch paddle.**

A standard Pitch-paddle impeller has 3 or 4 blades and Pitch angle of 45 degrees, width of blades – 0.1 – 0.2 of the Tip diameter.. The Tip diameter is usually 0.5 to 0.7 of the tank diameter. The program allows for choosing arbitrary impeller geometry. However, more than eight blades, and a blade width greater than 0.3 of the Tip diameter are not recommended.

#### **8.3.10. Disk turbine**

The most typical design of a disk turbine is a “Rushton turbine” with the following geometry: a pitch angle of 90 degrees, six blades; a disk diameter that is 0.75 of the Tip diameter; a blade width that is 0.2 of the Tip diameter and a blade length that is 0.25 of the

Tip diameter. Tip diameter of Disk turbine impeller is usually less than 0.4 of the Tank diameter.

### **8.3.11. Lightnin A310**

The blades of this impeller have a special hydrofoil configuration developed by the manufacturer in order to reduce energy losses. The pitch angle and geometric proportions of the impeller are fixed by the manufacturer; therefore, the only variables are the Tip diameter and the parameters describing the impeller position: the Distance from bottom, and the Distance between stages for multistage systems.

### **8.3.12. Propeller**

The propeller impeller in the current version of VisiMix corresponds to a “marine screw” with a Pitch = 1.0 (a blade angle of about 26 degrees). The Tip diameter is usually 1/4 - 1/3 of the tank diameter. The most common pumping direction is down.

### **8.3.13. Tooth-disk impellers**

These impellers are used mainly for the preparation and homogenization of multi-component mixtures, such as paints, coatings, etc. They are driven by high speed drives with rotational velocities from about 150 up to several thousand rpm; their tip velocity is usually 5-15 m/s or greater. Typically, the number of blades is 18 to 36. The program verifies your input and corrects the data based on the impeller geometry.

very The mixtures processed with Tooth-disk impellers are usually multi-component and multiphase mixtures containing a powdered solid phase. This solid material consists of small (micron or sub-micron size) particles that may form big aggregates due to adhesive force. These impellers are mainly used for the treatment of the media by extremely high shear stress. Such treatment helps to overcome adhesive forces, destroy the aggregates, and achieve a high degree of uniformity on a microscopic level (complete micro-mixing of the media, see also Section 2, High shear treatment).

One of the necessary conditions for successful high-shear operation is the complete and thorough mixing and homogenizing of the media on a macro-scale level (blending).

In some cases, particularly for highly non-Newtonian media, it is hard to ensure sufficiently fast and uniform blending. In such cases, a Tooth-disk impeller may be used together with another impeller, characterized by a large tip diameter and low rotational velocity (see Double-impeller systems, par. 8.3.17).

### **8.3.14. Helical ribbon**

Impellers of this type are considered an efficient tool for mixing viscous media, especially media with non-Newtonian properties. The Tip diameter of the impeller is usually between 0.8 and 0.95 of tank diameter; the width of the blades is 0.08 to 0.12 of the Tip diameter, the pitch of the ribbon is 0.5 to 2.0 of the Tip diameter. The height of the ribbon must be about the same as the height of the media in the tank.

The models used in VisiMix are based on the assumption that the height of the liquid below and above the impeller does not exceed 0.7 of the Tip diameter of the impeller. It is also assumed that the radial arms are designed as sloped plates with a pitch angle of 45 degrees, opposed to the pitch of the ribbon: for down-pumping ribbon, radial arms are pitched up.

**NOTE: If this is not the case, or if the radial arms are designed as pipes, the calculated circulation flow rate may be overestimated by 5-10%. To avoid overestimation, enter "0" for "Number of radial arms" when calculating circulation and high shear treatment.**

### 8.3.15. Helical screw

Helical screw impellers are considered an efficient tool for mixing viscous media, especially media with non-Newtonian properties. The Tip diameter of the impeller is usually between 0.4 and 0.65 of the tank diameter, and the pitch of the screw is 0.5 to 2.0 of the Tip diameter. The height of the impeller, "h" must be about the same as the height of the media in the tank.

### 8.3.16. Radial turbine

This option can be used for the calculations for a number of impellers produced by different manufacturers. For instance, for approximate simulation of a Intermig impeller, select Radial turbine 2 and enter:

Pitch angle,  $\phi_i = 26$  degrees,  
Width of blades,  $W = 0.1$  Tip diameter;  
Length of blades,  $L = 0.1$  Tip diameter.

### 8.3.17. Double-impeller system

For better mixing of multi-component mixtures (paints, etc., see Section 2, High shear treatment), high-speed Tooth-disk impellers are often used in combination with low-speed anchor impellers, or with additional low-speed vertical or helical blades installed close to the tank wall. Such configuration is referred to here as Double-impeller system. These systems are also efficient when a Tooth-disk impeller alone cannot prevent the formation of stagnant zones and ensure the complete involvement of non-Newtonian media in axial circulation (see Section 2, Formation of stagnant zones).

Calculation of mixing in such tanks is performed in two steps.

- The first step - Macro-scale mixing (blending) tank power characteristics for the low speed blades - is performed through input tables for Anchor or Helical screw impellers, disregarding the high-speed impeller.
- The second step – the calculation of power and shear characteristics of the high-speed impeller - is performed for a baffled tank, in which the size and position of the baffles must correspond to the geometry of the low-speed blades.

Calculations of flow passages through a mixing zone, and of High-shear treatment must be performed using Double-impeller options in the corresponding submenus.

While performing calculations for the high-speed impeller, you may receive a warning message informing you of the formation of stagnant zones. If you still want to perform the calculations, use the option Supplement. Approximation of rheology in the Calculate menu to calculate approximate rheological characteristics and repeat calculations with adjusted rheological parameters for non-Newtonian media (see Formation of stagnant zones, p. 11 and Approximation of rheology, p. 89).

***NOTE: The message “Formation of stagnant zones is expected” is a sign of unsatisfactory mixing. However, efficient mixing can still be achieved if a Double impeller system is used and if there is no warning message when calculating the low-speed impeller based on initial rheological function.***

#### 8.4. Shaft

Data in this part of the program are used for checking the suitability of the shaft based on the calculation of the critical frequency of shaft vibrations and maximum torsion stresses in dangerous cross-sections.

Calculations are based on the shaft sizes as preliminarily estimated and entered (see below). If the results of the calculations do not confirm the shaft reliability, the program issues appropriate messages. In this case, you should modify your input, e.g., increase the cross-section of the shaft section mentioned in the message, reduce the number of revolutions, etc.

The maximum torque of the selected impellers drive is used as initial data for Torsion stress calculation. For this reason, the mechanical calculations are always performed after the calculations of the hydrodynamics. The program automatically performs a preliminary check-up of the selected drive. If the drive does not correspond to the requirements described above, the program issues appropriate messages.

The program allows for two shafts schemes that differ by position of bearings with respect to the impellers:

Console shafts – bearings are placed on the end of shaft opposite to the impellers. Usually the bearings are fixed on the tank cover (head) or on a special construction over the level of media. Impellers are fixed on the ‘console’ end of the shaft that is submerged in liquid media. However, the program can be applied for ‘bottom entering’ or ‘side entering’ shafts.

Beam shafts – bearings are placed on both ends of the shaft, and impellers are fixed between the bearings. Such shafts are described also as ‘shafts with end bearing’ or ‘shafts with submerged bearing’.

All shaft sections are assumed to be made of the same metal with identical mechanical properties. Calculations can also be performed for glass-lined shafts and shafts with other coatings. However, applicability of the VisiMix suitability criteria is not guaranteed for these cases.

Calculations are performed for shafts with two to five impellers fixed on different distances from the bearings.

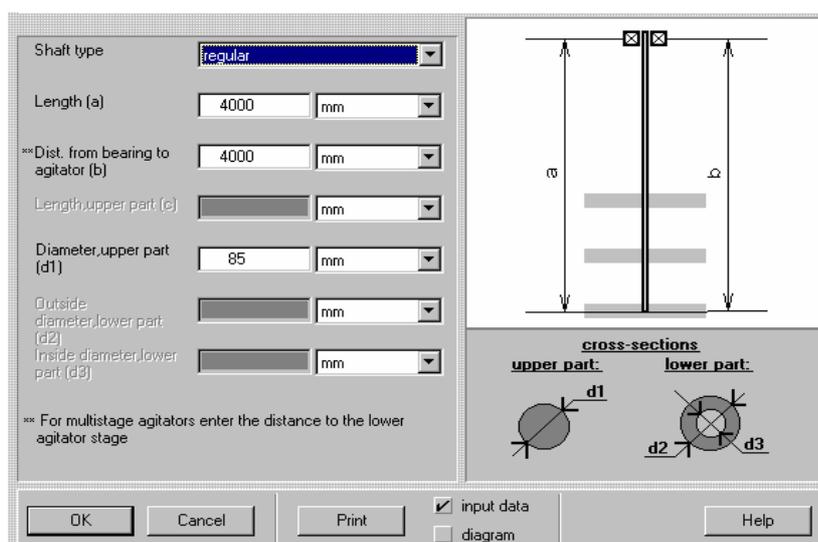
### 8.4.1. Shaft design

Four types of shafts are considered:

- A solid stiff console shaft with a constant diameter (console regular);
- A stiff console shaft consisting of two parts of different diameters (console combined);
- A solid stiff beam shaft with a constant diameter (beam regular);
- A stiff beam shaft consisting of two parts of different diameters (beam combined);

A built-up shaft with stiff couplings is regarded as a single item.

The term “stiff shaft” means that the rotational frequency of the shaft is less than the shaft’s critical (resonance) frequency of vibrations.



**Figure 23.**

Length (a). This parameter is related to the ‘loaded’ part of the shaft. For console shafts you enter length of the console, i.e. distance between the cross-section of the lower bearing and the end of the shaft. For beam shafts distance between bearings is entered.

A built-up shaft with stiff couplings is regarded as a single item.

Distance between bearings (b) is entered for console shafts only. Influence of this parameters for the regular shafts is not significant. If the distance is unknown, enter 0. In this case the program performs calculations for  $b = a/4$ , that corresponds in the most cases to the maximum reservation.

Upper part (length, diameter). For a combined shaft, the upper section is the section between the cross-section of the bearing and the cross-section corresponding to the change of the shaft diameter. For a regular shaft, the whole shaft is considered as the upper section.

Diameter between bearings (d0) is required for combined console shafts only. If this diameter is unknown, you are asked to enter 0 for approximate calculation. In this case the d0 is assumed to be equal to diameter of the upper shaft section ( $d0 = d$ ).

Lower part (outside and inside diameters). For a shaft with a solid lower section, enter “0” as an inside diameter.

#### 8.4.2. Shaft material.

Enter the properties of the shaft material: Density, Yield strength, Young’s modulus of elasticity (Figure 24).

Some typical values of Yield strength and Young’s modulus of elasticity for a number of commonly used materials is presented in the table (given according to Mechanics of Materials, SI Metric Edition, F. P. Beer, E. R. Johnston, Jr., McGraw-Hill, 1985, and Mixing in the Process Industries, Second Edition, N. Harnby, M. F. Edwards, A. W. Nienow, Butterworth - Heinemann, 1992).

The image shows a dialog box titled "SHAFT MATERIAL". It has four rows of input fields, each with a label on the left and a text box on the right with a unit dropdown menu. The first row is "Density" with the value "7850" and unit "kg/cub.m". The second row is "Yield strength in tension" with the value "3e+08" and unit "N/sq.m". The third row is "Young's modulus of elasticity" with the value "1.93e+11" and unit "N/sq.m". The fourth row is "Pull-out factor" with the value "2". At the bottom of the dialog box are four buttons: "OK", "Cancel", "Print", and "Help".

**Figure 24.**

The actual values of these properties depend on shaft shape and dimensions, heat treatment and composition of the material.

Density for different steels lies in the range 7700 - 8000 kg/m<sup>3</sup>

For Titanium, the density is 4500 kg/m<sup>3</sup>.

Yield strength and Young’s modulus of elasticity

Material	Properties			
	Yield strength		Young modulus of elasticity	
	N/sq. m	psi	N/sq. m	psi
Structural steel	2.6 E+8	3.77 E+4	2 E+11	2.9 E+7
High strength low alloyed steel	3.5 E+8	5.08 E+4	2 E+11	2.9 E+7
Quenched and tempered alloyed steel	7 E+8	1.02 E+5	2 E+11	2.9 E+7

Stainless cold-rolled steel	5÷11 E+8	7.25÷16 E+4	1.93 E+11	2.8 E+7
Stainless annealed steel	2.05÷2.75 E+8	2.97÷3.99 E+4	1.93 E+11	2.8 E+7
Titanium	5.15 E+8	7.47 E+4	1.03 E+11	1.49 E+7

### 8.4.3. Impellers data for mechanical calculations.

**Mass of impellers.** The mass of each impeller has to be entered accordingly to its position on the shaft. The numbers of impellers in this table corresponds to their numbers in the Mixing device input table.

**Figure 25.**

Distance from bearing to impeller . For console shafts enter the distance from the central cross-section of the impeller placed close to the lower end of the shaft to the cross-section of the lower bearing. For beam shafts the distance from this impeller to the upper bearing is entered. Positions of other Impellers are defined by the program accordingly to the previous inputs.

## 8.5. Properties & Regime

### 8.5.1. Average properties of media

Calculations of flow and mixing parameters in VisiMix LAMINAR are based on a universal rheological model shown in this input table (Figure 26). If you describe the behavior of your media with a different model, we recommend approximating the rheological function with the equations adduced here.

**Figure 26.**

Physical properties of the media entered in this input table are used both for calculations of flow characteristics, and for calculations of

Heat transfer. Therefore, the viscosity of the media must correspond to the Temperature of media (see Properties & Regime, Heat transfer, Temperature of media).

For non-Newtonian media, the rheological constants must be measured in the range of shear rates calculated by the program (see Shear rate near the impeller blades and Average shear rate near the tank wall).

If the Yield stress for the media does not equal 0, Average shear stress near the tank wall may happen to be lower than the Yield stress. This causes the formation of a stagnant zone on the tank periphery, so that the mixing is limited to a mixing zone around the impeller. In this case, VisiMix issues an appropriate warning and does not perform calculations. To avoid such situations, increase the impeller torque by modifying/replacing the impeller, or use a Double-impeller system.

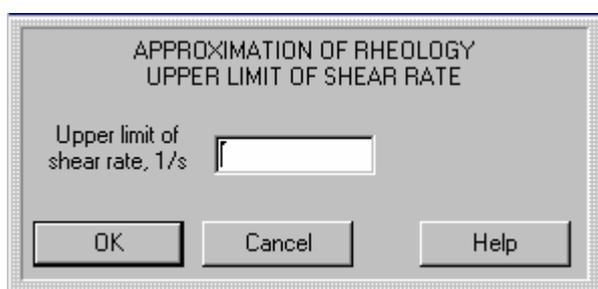
To obtain approximate information on the Mixing power and other flow characteristics, such as Circulation flow rate, the initial rheological curve must be replaced with an Approximate rheological function with the Yield stress = 0. This function is used also for calculations of micro-scale mixing (High shear treatment) for tanks with Double-impeller system.

Parameters of Approximate rheological function are found through the option Supplement. Approximation of rheology in the Calculate submenu, and entered in the input table Average properties of media as initial data for non-Newtonian media (see Approximation of rheology, p. 89).

### 8.5.2. Upper limit for shear rate

Enter the shear rate value corresponding to the upper limit of shear rate according to your rheological measurements (Figure 27). This initial parameter is used in the supplementary sub-program Approximation of rheology (see Supplement 1).

In some cases, especially when the media is non-Newtonian and has a relatively high Yield stress value, it is impossible to find a satisfactory solution for flow velocities and circulation due to formation of stagnant zones in the tank. However, information on Mixing power and approximate estimate of the flow characteristics (in particular, Circulation flow rate) can be obtained if the initial rheological curve is replaced by an approximate function with Yield stress = 0. The data on Upper limit of shear rate is used for obtaining the best possible approximation within the limits corresponding to your experimental data on the media properties.

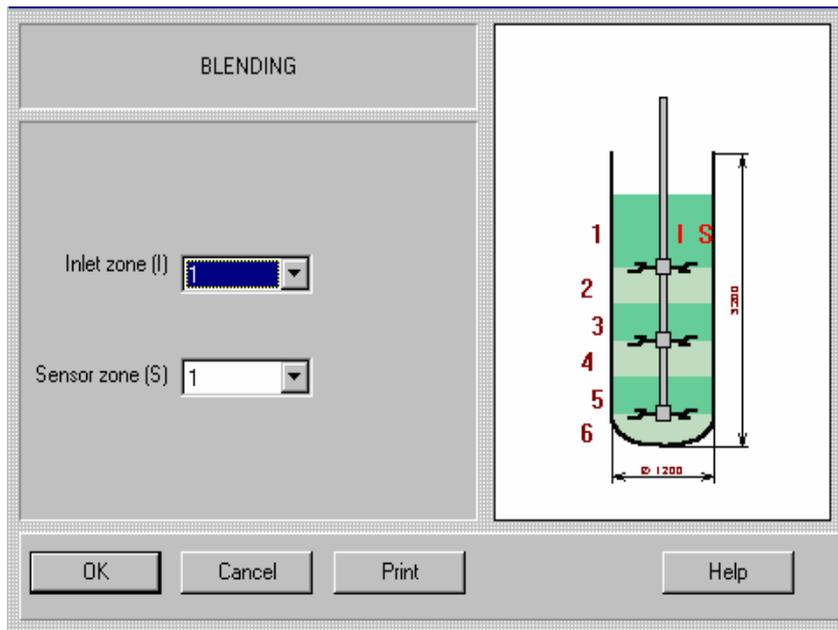


**Figure 27.**

### 8.5.3. Blending. Inlet/sensor position.

The character of transport and distribution of a tracer in the tank depends on the position of inlet with respect to the impeller. The readings of the measuring device, and their change in the course of the process, also depend on the position of the sensor in relation to the impellers and inlet.

Therefore, you are asked to approximate the inlet and sensor positions (Figure 28).

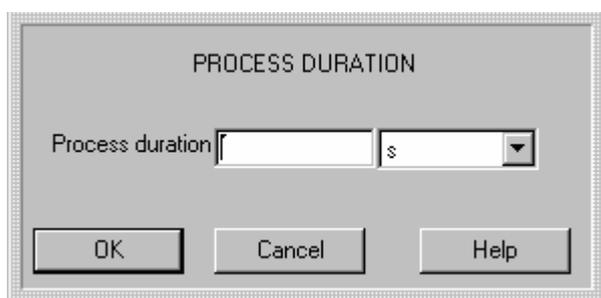


**Figure 28.**

Select zones where your inlet and sensor are located. Your input is used for calculating concentrations in the nearest mixing zones only, and therefore the exact positions of the inlet point and sensor inside the zones are not required.

#### 8.5.4. Process duration

You are asked to complete this table (Figure 29) when you first select Unmixed part of media (%), final value in the Calculate menu. Enter the expected or desired process duration. The program calculates the time in which about 90% of the media passes through the impeller area at least 5 times (see Dynamics of mixing/blending, p. 73). This is the minimum allowable value for Process duration. If you enter a lower value, the process will not be sufficient to ensure satisfactory mixing, and the program will default to the minimum allowable value. The maximum allowable value is 5000 times higher than this minimum value. If you enter a higher value, the entered process time will be unreasonably high, and the program will default to the allowable maximum.

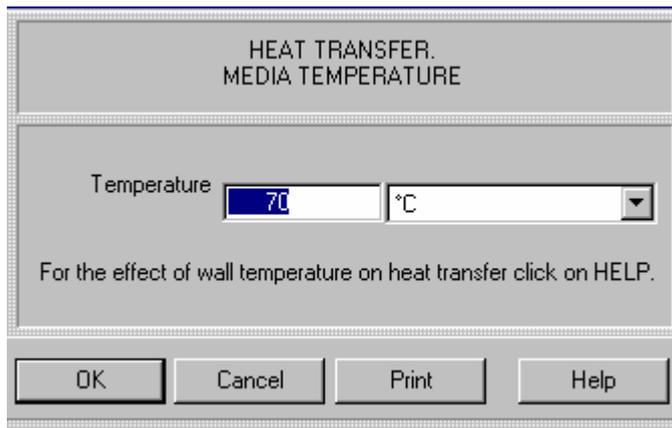


**Figure 29.**

#### 8.5.5. Heat transfer

##### **Media temperature.**

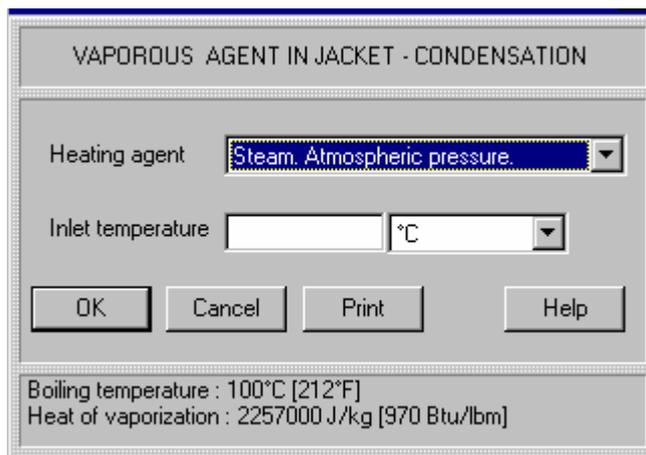
Enter the average temperature of the media in the tank (Figure 30). VisiMix LAMINAR performs heat transfer calculations for fixed temperature regime only.



**Figure 30.**

### Heating vaporous agent.

The program allows for modeling heat transfer for tanks with a number of widely used vaporous heating agents (VA). Choose the required heating agent and pressure (Figure 31). The values of Boiling temperature and Heat of vaporization for the selected agent are shown in the lower part of the table. Enter the Inlet temperature of the selected agent in accordance with this data.



**Figure 31.**

### Heating/cooling liquid agent

The program performs heat transfer calculations and modeling for tanks with most commonly used heating/cooling agents. Choose the Heating/cooling agent and enter Inlet temperature and Inlet flow rate, lower jacket section (Figure 32). Enter Inlet flow rate, upper jacket section if you have selected a 2-section jacket with the sections connected “in parallel” for the current project. The practical range of operating temperatures and the properties of the selected agent are shown in the lower part of the table.

**NOTE: The liquid agent velocity in inlet/outlet pipes of the jacket does not usually exceed 5 m/s.**

HEATING / COOLING LIQUID AGENT IN JACKET.

Heating/cooling agent: Water

Inlet temperature: 25 °C

Flow rate of heat transfer agent in lower jacket: 3 cub.m/h

Flow rate of heat transfer agent in upper jacket: cub.m/s

Operating temperature range: 5 - 204°C [41 - 400°F]

Properties of the agent

density...1000 kg/m<sup>3</sup> [62.4 lbm/ft<sup>3</sup>]  
 specific heat...4190 J/(kg\*K) [1.01 Btu/(lbm\*°F)]  
 thermal conductivity...0.603 W/m\*K [0.348 (Btu\*ft)/(h\*ft<sup>2</sup>\*°F)]  
 dynamic viscosity at 100°C(212°F)...0.000284 Pa\*sec [0.284 cP]

**Figure 32.**

**Heat-transfer properties of the media**

VisiMix LAMINAR performs heat transfer calculations for fixed temperature regime only. Enter the Specific heat and Heat conductivity of the media for this temperature (Figure

33).

HEAT TRANSFER PROPERTIES OF THE MEDIA

Specific heat: 4000 J/(kg\*K)

Heat conductivity: 0.31 W/(m\*K)

**Figure 33.**

The existing correlations for predicting the change of viscosity as a function of temperature are not reliable enough when applied to high viscosity media. The dependence of the rheological parameters of non-Newtonian media on temperature is even more complicated. Therefore, calculation of the media-side heat-transfer coefficients does not include the Sieder and Tate correction factor.

If the temperature function of the viscosity is known, media-side heat-transfer coefficients calculated by VisiMix LAMINAR may be adjusted using the relation (Viscosity at the

Wall temperature, media side/Viscosity at the Temperature of media). For cooling, this relation must be used with an exponent of 0.1; for heating, use an exponent of 0.14.

## SECTION 9. MENU CALCULATE. OUTPUT PARAMETERS.

This option enables the user to perform calculations and modeling in relation to various mixing problems. Each of the Calculate submenus (Figure 34) contains several commands (options). Selecting any of these brings up the appropriate output window.

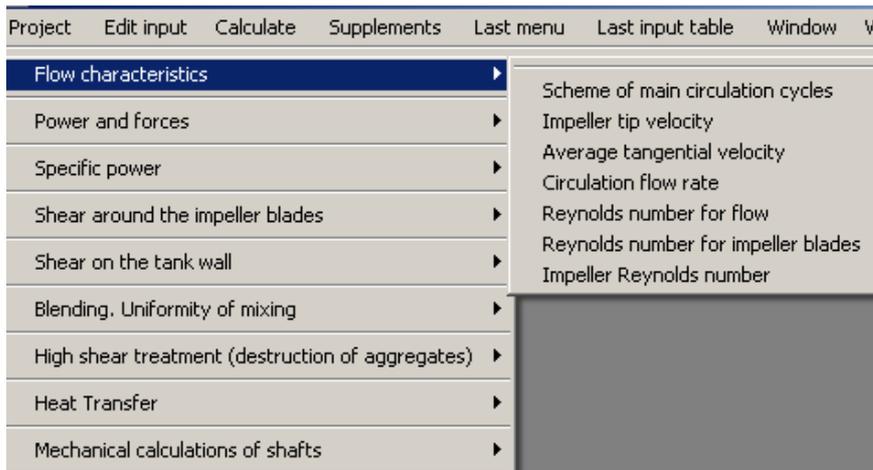
To determine the suitability of the equipment and its most important characteristics, select Flow characteristics in the Calculate submenu. A table of the most important data appears. For more detailed information, turn to other questions in the same submenu.



**Figure 34.**

### 9.1. FLOW CHARACTERISTICS

The Flow characteristics submenu is shown in Figure 35. This option provides calculated characteristics of the flow.



**Figure 35.**

#### 9.1.1. Scheme of main circulation cycles

This diagram corresponds to the main cycles of circulation formed in the tank. The number and position of cycles depend on the type, number, and position of the impellers. The distance between the schematic “flow line” and the nearest impeller corresponds to the

coordinate where local radial velocity approximately equals the mean value of radial velocity for a given cycle. Thus, larger distances correspond to greater involvement of the media in axial circulation through the impeller, and consequently, to better mixing. Small circulation cycles concentrated very close to the impeller indicate that circulation is limited to the impeller area, and the rest of the media in the tank is not involved in the circulation. This situation corresponds to stagnation in the bulk of the volume, and, accordingly, to low values of the Index of uniformity of flow distribution in the tank volume (see Circulation flow rate below). The reliable simulation of mixing in this case is impossible. Therefore, VisiMix will not calculate some parameters in the Blending option in the Calculate submenu, and will issue an appropriate message.

### **9.1.2. Tip velocity of impeller**

The tip velocity of the impeller is the linear velocity of the edge of the impeller blade. This parameter is given for reference.

### **9.1.3. Average tangential velocity**

In a laminar regime, the radial profile of tangential velocity varies along the tank axis and depends on the distance from the impeller. Average tangential velocity is calculated as integral along both radial and axial directions. This value is used in calculations of hydraulic resistance on the tank wall (see POWER AND FORCES below), heat transfer, etc.

### **9.1.4. Circulation flow rate**

This parameter describes the total flow rate of media through the impellers. Unlike circulation in a turbulent mixing regime, circulation in laminar flow is not uniformly distributed in the tank volume, and a part of circulation flow rate corresponds to “short circuited” circulation around the blades. The degree of non- uniformity of the circulation is described by Index of uniformity of flow distribution in the tank volume. The higher this index is, the higher the uniformity of the flow distribution, and the smaller the “short circuited” part of the flow. Higher values of the Index correspond to better mixing. Values lower than 0.2 are a sign of poor mixing, when almost all circulation is short-circuited in a small area near the impeller (see Scheme of main circulation cycles, p. 60). In this situation, calculations of Blending will not be reliable, and VisiMix will not calculate the Mixing time and the Characteristic function of tracer distribution in the Blending option. An attempt to select one of these parameters for calculation will invoke an appropriate message.

### **9.1.5. Re number for flow**

This parameter is based on the Average tangential velocity and tank radius. It characterizes the degree of turbulization of the flow, and determines the hydraulic resistance of the tank wall. The upper limit of a laminar flow regime for the agitated media corresponds to the values of Re number for flow in the range of 1000 - 1500. VisiMix LAMINAR performs calculations for  $Re < 1500$ .

### 9.1.6. Re number for impeller blades

The Re number for impeller blades is based on the Width of blade and on the characteristic relative velocity of the blade, which equals the difference between the Tip velocity of impeller and tangential velocity at the same radius. This parameter characterizes the flow regime near the impeller blades; it is used for calculations of torque and local shear rate on the blades. Values lower than 1 - 5 correspond to a purely laminar flow regime, values higher than 150 correspond to a turbulent regime of flow over the blades.

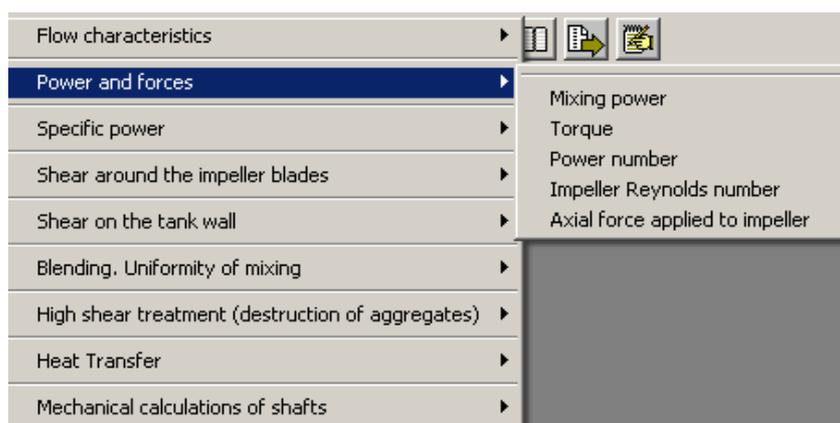
### 9.1.7. Impeller Re number

The Re number for impeller is a standard Reynolds number normally used for impellers. It is based on the Tip diameter of the impeller, its rotational velocity, and the kinematic viscosity of the media. For non-Newtonian media, it is based on the Effective viscosity near the impeller blades. This parameter is given for reference purposes only, and is not used for calculations.

## 9.2. POWER AND FORCES

The Power and forces submenu is shown in Figure 36.

Calculation of the power consumption of impellers is based on the equation of momentum equilibrium. The torque on the impeller blades must be balanced with a sum of two moments of hydraulic resistance: the moment created by the tangential shear stress on the wall, and the moment created by the flow over fixed internal devices (baffles, tubes, etc.). All three moments are functions of the tangential component of flow velocity. The equation is solved using experimental correlations for flow resistance of the tank wall, impeller blades, and submerged devices, to obtain the values of Torque and Mixing power. The Power number is calculated according to a standard formula. Calculation of the Axial force applied to impeller is based on the Torque and Pitch angle of the impeller blades.



**Figure 36.**

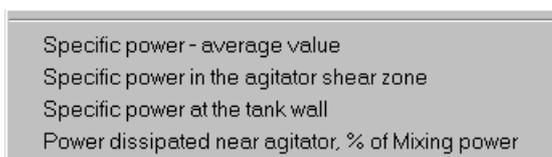
The function Resistance factor of the blade vs. Re number used in equations of momentum equilibrium is non-linear. A combination of this function with the rheological function of the media, which is also non-linear, sometimes results in several solutions for the equations of the momentum equilibrium. Multiple solutions, and multiple values of tangential velocity, shear rates, effective viscosity, and torque are obtained in a narrow range of Re numbers corresponding to the

upper limit of transitional regime for impeller blades. This phenomenon of hydrodynamic instability is not exceptional, and may occur in practice. However, so far it has not been either confirmed or disproved experimentally. In such cases, the program returns the maximum and the minimum values of Mixing power, Torque, Power number, and Impeller Re number. All calculations of mixing are performed based on the minimum value of the shear rate near the impeller blades.

It is advisable, if possible, to modify the parameters of the mixing system so as to avoid the range of Re numbers corresponding to multiple solutions.

### 9.3. SPECIFIC POWER

This submenu is shown in Figure 37.



**Figure 37.**

#### 9.3.1. Specific power - average value

The average specific power per 1 kg of media is calculated as Mixing power divided by Volume of media and Average density of media.

#### 9.3.2. Specific power in the impeller shear zone

The estimation of the Specific power in a high shear zone near the impeller blades is based on the calculated values of the Shear rate near the impeller blades and the Kinematic viscosity of media. For non-Newtonian media, the Effective viscosity near the impeller blades is used.

#### 9.3.3. Specific power at the tank wall

The estimation of Specific power in a boundary layer on the tank wall is based on the calculated values of the Average shear rate near the tank wall and Kinematic viscosity of media. For non-Newtonian media, the Effective viscosity near the tank wall is used.

#### 9.3.4. Power dissipated near the impeller, % of Mixing power

Calculation of this parameter is based on the calculated values of Specific power in the impeller shear zone. It serves as an indication of non-uniform power distribution in the tank and depends on the type and dimensions of the impeller.

### 9.4. SHEAR AROUND THE IMPELLER BLADES

This submenu is shown in Figure 38.

Shear rate near the agitator blades  
Shear stress near the agitator blades  
Effective viscosity near the agitator blades  
Relative volume of agitator shear zone

**Figure 38.**

#### **9.4.1. Shear rate near the impeller blades**

Calculation of this parameter is based on experimental correlations for the hydraulic resistance factor for the impeller blade, which is a function of Re number for impeller blades. This value is directly proportional to the Tip velocity of impeller and inversely proportional to the Width of blade. In a transitional regime, the shear rate increases with the increase in Re number for impeller blades.

#### **9.4.2. Shear stress near the impeller blades**

This parameter is calculated based on the Shear rate near the impeller blades and media viscosity. For non-Newtonian media, the Effective viscosity near the impeller blades is used.

#### **9.4.3. Effective viscosity near the impeller blades**

This parameter is calculated for non-Newtonian media based on the rheological model shown in the Average properties of media input table, and the constants you entered in this table. The calculations are performed for the value of the shear rate estimated as the Shear rate near the impeller blades.

For Newtonian fluids, the Effective viscosity near the impeller blades is constant and equals the Dynamic viscosity of the media.

#### **9.4.4. Relative volume of impeller shear zone**

A maximum estimate of the volume of the high shear zone near the impeller blades is based on the calculated values of the Specific power in the impeller shear zone and the Power dissipated near impeller.

### **9.5. SHEAR ON THE TANK WALL**

This submenu is shown in Figure 39.

Average shear rate near the tank wall  
Average shear stress near the tank wall  
Effective viscosity near the tank wall

**Figure 39.**

#### **9.5.1. Average shear rate near the tank wall**

This parameter is calculated based on the Average shear stress near the tank wall and the Dynamic viscosity, or rheological data entered in the Average properties of media input table.

### 9.5.2. Average shear stress near the tank wall

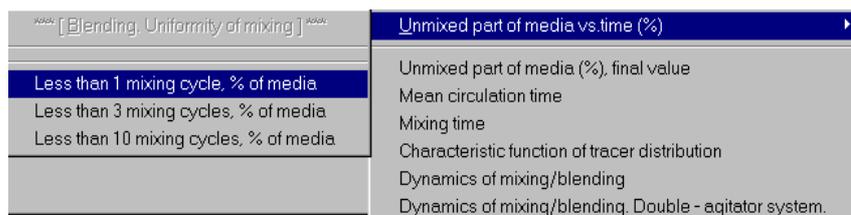
This parameter is calculated using the calculated value of the moment of the hydraulic resistance of the tank wall. It is used for shear rate and heat transfer calculations.

### 9.5.3. Effective viscosity near the tank wall

Calculation of this parameter is based on the Average shear rate near the tank wall and rheological data entered in the Average properties of media input table. For Newtonian media, the Effective viscosity near the tank wall equals the Dynamic viscosity.

## 9.6. BLENDING. UNIFORMITY OF MIXING.

This submenu is shown in Figure 40.



**Figure 40.**

A laminar flow regime is characterized by the stable motion of neighboring layers of liquid without a significant exchange of substance between these layers. Mixing in this flow regime occurs as a result of the deformation and thinning of the layers, and is a very slow process. In agitated vessels, the stage of slow deformation in tangential, and axial flow alternates periodically with a sharp change in flow direction and structure. This change of direction is followed by a fast random exchange of substance between the layers of the media, and, consequently, by macro-scale homogenization of the media within the neighboring layers. In addition, the flow disturbance results in the exchange of substance between zones corresponding to neighboring circulation cycles (see Scheme of main circulation cycles above), and is an essential constituent of mixing.

The phenomenon of the random exchange takes place in certain parts of the flow, which are described as “zones of efficient mixing”, or mixing zones. In tanks with Ribbon, Helical screw, or Anchor impellers, mixing zones are placed around the turning points of the circulation flow in the lower and upper cross-sections of the tank. In tanks with other impeller types, mixing zones are localized around the impellers. A single passage of a portion of media through a mixing zone is described below as a mixing cycle.

Uniformity of mixture is achieved as a result of the passage of media from all parts of the tank through the mixing zones. Due to non-uniform velocity distribution, the time necessary for liquid portions initially placed in different points of the tank to reach the nearest mixing zone, may vary by several times. The number of mixing cycles for a sample of media is a stochastic function of time.

The average number of mixing cycles required to achieve a predetermined technical result (a final degree of uniformity of viscous solution, distribution of temperature, selectivity of reaction, distribution of molecular mass, etc.) depends on process features and properties of the substances, for example, on the relation of densities and viscosities of components. However, the degree of uniformity of mixture in the tank is directly proportional to the average number of passages through the mixing zone, and inversely proportional to the fraction of media that passed through the mixing zone less than a certain required number of times.

In some situations, when circulation in the tank is limited to a small area near the impeller (“short-circuited”), and the rest of the media in the tank is stagnant, reliable simulation of mixing is impossible. In these cases, VisiMix does not calculate some parameters in the Blending option in the Calculate submenu, and issues an appropriate message. This situation corresponds to low values of Index of uniformity of flow distribution in the tank volume (see Circulation flow rate and Scheme of main circulation cycles above).

### **Simulation of macro-mixing.**

Let us assume that a small quantity of a substance (tracer) is injected instantly into a certain point inside the volume of media. This substance is a solution of a tracer in a solvent, which is soluble in the agitated media. The solvent does not differ from the media by density and viscosity. The final concentration of the tracer in the tank is assumed to equal 1.0.

The tracer is assumed to be injected into one of the mixing zones in accordance with the inlet position which is specified by you in the input table Blending. Inlet/sensor position. Let us also assume that the sensor monitors the change in the tracer concentration in the mixing zone in accordance with your input.

VisiMix follows the passage of the media from all points of the tank volume through the mixing zones. In addition, it simulates the change in tracer concentration in all mixing zones. The results of the simulation for the sensor position you entered are presented as graphs and diagrams.

The Mixing time table presents the maximum values of mixing time required to achieve a given degree of uniformity in all parts of the tank volume. The degree of uniformity is evaluated quantitatively based on the maximum value of the deviation between the local concentrations of the tracer in all mixing zones, and the average concentration value.

VisiMix only performs simulation of blending (macro-mixing) in those cases, when all the media in the tank is involved in tangential motion and circulation through the mixing zones. When the media is non-Newtonian, in particular, when it is characterized by a finite value of Yield stress (see Average properties of media, p. 51), this condition is not always satisfied. In such cases, the program issues a warning about incomplete mixing and the formation of stagnant zones. To avoid such conditions, change the impeller geometry to increase the Torque (by increasing the Tip diameter of impeller, Number of impellers, or Width of blades).

#### **9.6.1. Unmixed part of media vs. time (%)**

The Unmixed part of media is understood as part of the total media in the tank that at any given moment has passed less than a certain number of mixing cycles. VisiMix shows graphs of the Unmixed part of media vs. time (%) for 1, 3 and 10 mixing cycles.

The flow velocity distribution in tanks with a laminar mixing regime is non-uniform. Unlike conditions in a turbulent regime, there is no intensive random exchange between zones located at different distances from the impeller. Therefore, for part of the media in the tank, the frequency of circulation through the mixing zones is very low, and the media may remain unmixed for a relatively long time. As the degree of uniformity in the circulation flow in the tank (see Circulation flow rate above) goes lower, the amount of unmixed media increases.

The minimum number of mixing cycles required to achieve a predetermined technical result (a final degree of uniformity of viscous solution, distribution of temperature, selectivity of reaction, distribution of molecular mass, etc.) depends on process features and properties of the substances, for example, on the relation of densities and viscosities of components. However, the degree of uniformity of mixture in the tank is directly proportional to the average number of passages through the mixing zone, and inversely proportional to the fraction of media that passed through a mixing zone less than a given number of times.

#### **9.6.2. Unmixed part of media (%), final value**

This parameter is calculated as part of the media that has not passed a single mixing cycle in the time specified in the Process duration input table. This part of the media is small compared to the total volume of media, but its value may be important for estimating the quality of some products. For your convenience, the Process duration value is also shown in this output table.

#### **9.6.3. Mean circulation time**

This parameter is calculated based on the Volume of media and the Circulation flow rate. Its value is inversely proportional to the mean frequency of mixing cycles and provides a general evaluation of mixing efficiency. If its calculated value exceeds 72 hours, the mixing is considered too slow to be practical. In such cases, VisiMix issues an appropriate message, and does not proceed with calculations.

Mixing efficiency may be increased by increasing the number of impeller blades or the Tip diameter of the impeller, by using multi-stage impellers, or by introducing any other changes resulting in the increase of Torque, or Axial force applied to impeller.

#### **9.6.4. Mixing time**

This table shows the results of the simulation of a mixing process. The required duration of the mixing process depends on the desired degree of non-uniformity of the final mixture, i.e.  $\pm 10\%$ ,  $5\%$ , or  $2\%$  of the final change in concentration.

The process conditions are as follows:

- a tracing fluid is injected into the tank according to the input in Blending. Inlet/sensor position;
- the injection is performed instantly, or in a very short time;
- the volume of the injected portion of the tracer is small in comparison to the Volume of media in the tank;
- the physical properties of the tracing fluid are identical to the properties of the media in the tank;
- the values presented in the table correspond to the mixing time needed to achieve the required concentration in all mixing zones.

In some situations, when circulation in the tank is short-circuited in a small area near the impeller, and the rest of the media in the tank is stagnant, reliable simulation of mixing is impossible. In these cases, VisiMix does not calculate Mixing time, and issues an appropriate message (see Circulation flow rate, p. 61 and Scheme of main circulation cycles, p. 60).

#### **9.6.5. Characteristic function of tracer distribution**

This graph shows the results of the simulation of mixing corresponding to the following conditions:

- a tracing fluid is injected into the tank according to the input in Blending. Inlet/sensor position;
- the injection is performed instantly, or in a very short time;
- the volume of the injected portion of the tracer is small in comparison to the Volume of media in the tank;
- the physical properties of the tracing fluid are identical to the properties of the media in the tank.

The curve in the graph reproduces the readings of the sensor located according to Blending. Inlet/sensor position input table.

In some situations, when circulation in the tank is short-circuited in a small area near the impeller, and the rest of the media in the tank is stagnant, reliable simulation of mixing is impossible. In these cases, VisiMix does not calculate Characteristic function of tracer distribution, and issues an appropriate message (see Circulation flow rate and Scheme of main circulation cycles).

#### **9.6.6. Dynamics of mixing/blending**

This diagram (Figure 41) illustrates the dynamics of the gradual involvement of media from different zones of the tank into circulation through the mixing zones, and the decrease in the unmixed fraction of the media in the course of the mixing process.

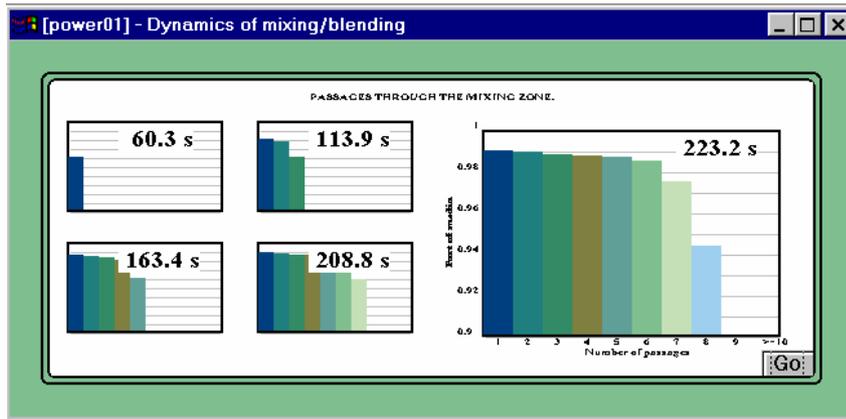


Figure 41.

### 9.6.7. Dynamics of mixing/blending. Double-impeller system.

This diagram is similar to the one shown in Figure 39. It illustrates blending in tanks with a double-impeller system consisting of a low-speed anchor or ribbon impeller placed near the tank wall, and an additional high-speed smaller impeller (see Double-impeller system). Such systems are mainly used for the production of paints. The diagram shows the gradual involvement of media from different zones of the tank in circulation through the mixing zones of the high-speed impeller. Due to the effect of the low-speed impeller with a large Tip diameter, Mixing time in such tanks is relatively short. Therefore, after a short period of mixing, the position of any given portion of media in the tank, and the probability for this portion to pass through the mixing zone of the high-speed impeller, become independent of its initial position. As a result, the flow distribution in the tank volume is much more uniform than in single-impeller systems (see also BLENDING. Uniformity of mixing and Dynamics of mixing/blending).

**NOTE: In Double-impeller systems, anchor/frame, ribbon, and screw impellers are not used as internal high-speed impellers.**

### 9.7. HIGH SHEAR TREATMENT (DESTRUCTION OF AGGREGATES)

This submenu is shown in Figure 42.

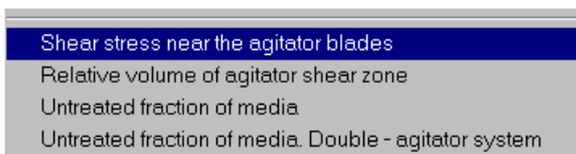


Figure 42.

A highly intensive treatment of media takes place in high shear zones, which are formed in the vicinity of impeller blades as a result of the big difference between the velocities of the blades and the neighboring media.

The destruction of aggregates and extremely “thin” micro-mixing of the media occur in these high shear zones only, referred to below as Impeller shear zones. The final results depend on the following two parameters: shear rate, or shear stress near the impeller, and the degree of treatment in the high shear zone.

### 9.7.1. Shear stress near the impeller blades

For every mixture's chemical composition, there is a certain critical value of shear stress, which is necessary for the efficient destruction of aggregates and homogenization of the mixture. The shear rate on the impeller blades increases in a direct proportion to the number of revolutions. Therefore, operations that require high shear treatment are usually performed in tanks with high-speed impellers.

### 9.7.2. Relative volume of impeller shear zone

The degree of treatment in the high shear zone is best characterized by the relative quantity of the media subject to high shear treatment for less than a certain predetermined period. This part of the media may naturally contain large aggregates or non-uniform inclusions.

In most practical cases, high shear zones constitute a small part of the mixing zones described above. Therefore, the final "untreated" part of the media is a stochastic function of the total relative volume of the high shear zone, and increases with a number of mixing cycles of the media during the process time. In some cases, macro-scale mixing (blending) may be incomplete because not all the media has passed through a mixing zone even once. This occurs if distribution of axial velocity in the tank is highly non-uniform (see Circulation flow rate), and it is taken into account in the estimation of the untreated part of the media.

### 9.7.3. Untreated fraction of media

This parameter represents the relative media quantity, which underwent high shear treatment less than 1 - 5 times during the time entered in Process duration input table. The figures in this output table indicate the degree of treatment of media in the high shear zone, and can be used as scaling-up parameters (see MIXING IN LAMINAR AND TRANSITIONAL REGIMES. Physical interpretation). For your convenience, the Process duration value is also shown in this output table.

The untreated part of the media is estimated as a stochastic function of the Relative volume of impeller shear zone. It increases with the number of mixing cycles of the media that take place in the process time.

In some cases, macro-scale mixing (blending) of the media is incomplete because not all the media has passed through the mixing zone even once. This happens if the distribution of axial velocity in the tank is too non-uniform (see Circulation flow rate), and it is taken into account in estimating the untreated part of media.

### 9.7.4. Untreated fraction of media. Double - impeller system.

This table is related to a mixing process in a tank with a double-impeller system consisting of a low-speed anchor or ribbon impeller placed near the tank wall, and an additional high-speed smaller impeller (see Double-impeller system). Such systems are mainly used for the production of paints; as high-speed impellers, tooth-disk impellers are normally used.

This parameter represents the relative media quantity, which underwent the high shear treatment less than 1 - 5 times during the time entered in the Process duration input table. The figures in this table indicate the degree of media treatment in the high shear zone, and they can be used as scaling-up parameters (see MIXING IN LAMINAR AND TRANSITIONAL REGIMES. Physical interpretation). For your convenience, the Process duration value is also shown in this output table.

The untreated part of the media is estimated as a stochastic function of the Relative volume of impeller shear zone. It increases with the number of mixing cycles of the media that take place in the process time.

In some cases, macro-scale mixing (blending) of the media is incomplete because not all the media has passed through the mixing zone even once. Due to the effect of the low-speed impeller with a large Tip diameter, the Mixing time in such tanks is relatively short. Therefore, after a short period of mixing, the position of any given portion of media in the tank, and the probability for this portion to pass through the mixing zone of the high-speed impeller become independent of its initial position. As a result, the flow distribution in the tank volume is more uniform, and the time required for the same degree of high-shear treatment in the Impeller shear zone is shorter than in a single-impeller system.

## 9.8 HEAT TRANSFER

### 9.8.1. Introduction

**VisiMix LAMINAR** performs the calculation for heat flux and heat-transfer coefficients for a fixed temperature of the media; media-side heat-transfer coefficients, jacket-side heat-transfer coefficients, and thermal resistance of the tank wall are taken into account.

Calculation of heat transfer is based on the Leveq model of heat transfer in a fully developed laminar boundary layer. For interpretation of the calculated results, the following specific features of heat transfer to a flow of highly viscous media must be taken into account:

In tanks with low mixing intensity, temperature distribution in the boundary layer becomes very close to a steady state distribution due to a low flow velocity of the media. Applying the Leveq model to such conditions would result in underestimation of heat-transfer coefficients. To avoid this, VisiMix also calculates also heat-transfer coefficients corresponding to the steady state temperature boundary layer, and returns the higher of the two values.

The existing correlations for predicting the change in the viscosity as a function of the temperature are not reliable enough when they are applied to high viscosity media. The problem is even more complicated when the temperature-dependence of the rheological parameters of non-Newtonian media is considered. Therefore, calculations of media-side heat-transfer coefficients do not include the Sieder and Tate correction factor.

If the temperature function of the media's viscosity is known, media-side heat-transfer coefficients calculated by the current version of VisiMix may be adjusted using the

following relation: Viscosity at the wall temperature, media side/Viscosity at the temperature of media (See Supplement 3).

### **Heat transfer devices (HTD)**

Calculations are performed for tanks with two types of external heat-transfer devices: conventional jackets and half-pipe coil jackets. Both may consist of one section (if there is one section only, the program regards it as “Lower”) or two separate sections (“Lower” and “Upper”).

The position of the sections, their dimensions and heat transfer areas may vary. The Lower section may cover the tank bottom.

### **Connection of two jacket sections**

The sections may be connected in series and in parallel.

#### **Connection in parallel:**

The liquid heat transfer agent (LA) inlets are placed in the lower cross-section of each section; the outlets are in the upper cross-section of each section. The inlet temperature of LA is the same for both sections; LA flow rates are estimated and entered by you independently.

Condensing (vaporous) heat transfer agent (VA) - steam, Dowtherm vapor, etc. -- inlets are placed in the upper cross-section of each section; the outlets of condensate are in the lower cross-section of each section. The inlet temperature and the pressure of vaporous agents (VA) are the same for both sections.

#### **Connection in series:**

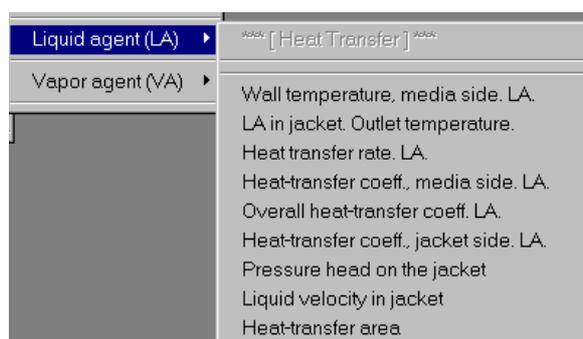
The liquid heat transfer agent (LA) inlet is placed in the lower cross-section of the lower section; the LA outlet is placed in the upper cross-section of the lower section; the inlet of the upper section placed in its lower cross-section is connected to the outlet of the lower section; the outlet of the LA is placed in the upper cross-section of the upper jacket section. The flow rate of LA in both jacket sections is the same. The inlet temperature of LA for the lower section is entered by you, the inlet temperature for the upper section is assumed to be equal to the temperature of LA on the outlet of the lower section.

Condensing (vaporous) heat transfer agent (VA) - steam, Dowtherm vapor, etc. - inlets are placed in the upper cross-section of the upper section, the outlet of condensate and steam (vapor) of the upper section is placed in its lower cross-section and connected to the inlet pipe placed in the upper cross-section of the lower section. The outlet of condensate is placed in the lower cross-section of the lower section. Steam (vapor) pressure in both sections is assumed to be the same; the inlet temperature for the lower section is assumed to be equal to saturation temperature.

## Heat transfer agents - (HTA)

- VisiMix performs heat transfer calculations in heat transfer devices for two kinds of HTA liquid agents (LA) and condensing steam or organic vapors (VA). There is no need to enter the physical properties of HTA; select an appropriate agent and enter the inlet conditions: inlet temperature for LA, inlet temperature and pressure for VA. The required properties of HTA are retrieved by the program from its database. The program includes also subprograms for approximate calculations of temperature dependent physical properties of HTA.

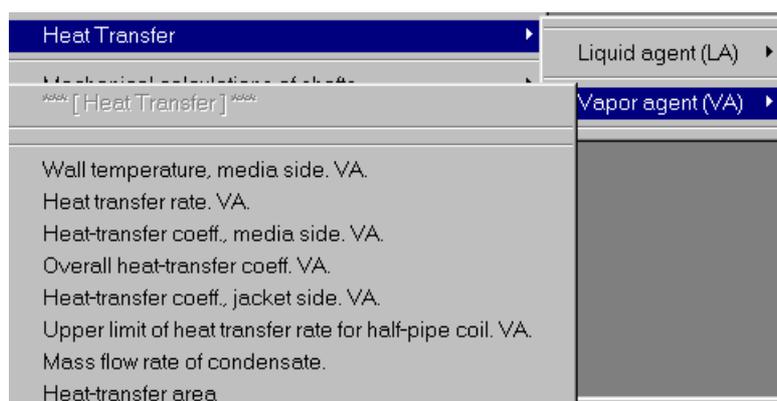
The Heat Transfer submenus are shown in Figures 43 (liquid heat-transfer agent, LA) and 44 (vaporous heat-transfer agent, VA).



**Figure 43.**

### 9.8.2. Wall temperature, media side

This parameter is calculated as the average temperature of the tank wall at the media side. In the case of fouling, the Wall temperature should be understood as the temperature of the media-side surface of the fouling layer. In cases where the media is sensitive to super-heating or super-cooling, check the Wall temperature.



**Figure 44.**

### 9.8.3. LA in jacket. Outlet temperature

This parameter represents the temperature of the liquid heat-transfer agent at the outlet of the lower and upper jacket sections, and is calculated for tanks with liquid heating/cooling agents (LA).

#### **9.8.4. Heat transfer rate**

This parameter represents the total heat transfer rate between the media and the heat transfer agent for both jacket sections. Positive values of the Heat transfer rate correspond to the heat flow from the media to the heat transfer agent (HTA); negative values of the Heat transfer rate correspond to the heat flow from the HTA to the media.

#### **9.8.5. Heat transfer coefficient, media side**

Calculation of this parameter is based on the Leveq model of heat transfer in a fully developed laminar boundary layer. For interpretation of the calculated results, the following specific features of heat transfer to a flow of highly viscous media must be taken into account:

In tanks with low mixing intensity, temperature distribution in the boundary layer becomes very close to a steady state distribution due to the low flow velocity of the media. Applying the Leveq model to such conditions would result in underestimating heat-transfer coefficients. To avoid this, VisiMix also calculates heat-transfer coefficients corresponding to the steady state temperature boundary layer, and returns the higher of the two values.

The existing correlations for predicting the change in the viscosity as a function of temperature are not reliable enough when they are applied to high viscosity media. The problem is even more complicated when the temperature-dependence of the rheological parameters of non-Newtonian media is considered. Therefore, calculations of media-side heat-transfer coefficients do not include the Sieder and Tate correction factor.

If the temperature function of the media viscosity is known, media-side heat-transfer coefficients calculated by the current version of VisiMix may be adjusted using the following relation: Viscosity at the wall temperature, media side / Viscosity at the temperature of media (See Supplement 3).

#### **9.8.6. Overall heat transfer coefficient**

This parameter is calculated for each jacket section separately. The calculation is based on the values of the Heat transfer coefficient, media side, Heat transfer coefficient, jacket side, and on the thermal resistance of the tank wall. Evaluation of the wall thermal resistance is based on your input of the tank Material and Wall thickness (see Tank shell characteristics). Thermal resistance of fouling is added accordingly to your input in this table.

#### **9.8.7. Heat transfer coefficient, jacket side**

This parameter is calculated separately for each jacket section with respect to the current temperature of the Heat transfer agent and the temperature of the wall at the jacket side. Calculation is based on well-known and tested empirical correlations.

#### 9.8.8. Pressure head on the jacket

This parameter is calculated for tanks with liquid heating/cooling agents (LA), for lower and upper jacket sections. The displayed value corresponds to the maximum flow resistance, i.e. to the lowest possible temperature of the heat-transfer agent in the jacket.

#### 9.8.9. Upper limit of heat transfer rate for half-pipe coil

This parameter is calculated for tanks with Half-pipe coil jackets heated by a condensing vaporous agent (VA) only. It is generally known that excessively high condensation rate results in a high volume flow rate of the condensate, and may cause “flooding” of the half-pipe coil jacket. The program estimates the maximum value of the heat transfer rate, which will not cause flooding. Calculations are based on empirical correlations verified during a long period of practical use.

The Upper limit of heat transfer rate for a given tank can be increased by connecting the two half-pipe coil sections in-parallel and increasing the Number of starts of the half-pipe coil (see Edit, Jacket).

#### 9.8.10. Mass flow rate of condensate

This parameter is calculated for tanks heated with a condensing vaporous agent (VA) based on the calculated value of the Heat transfer rate.

#### 9.8.11. Heat transfer area

This output table contains two parameters – the Heat transfer area and the Active heat transfer area. Both are calculated for the lower and upper jacket sections. The Heat transfer area is the jacketed part of the tank wall surface, including the jacketed part of the bottom for the lower section. For a single-jacketed device, the Heat transfer area for upper section is zero. Heat transfer area values in this table are those you entered in the input table TANK HEAT TRANSFER DATA. GENERAL, or those values calculated by VisiMix if no such data was entered.

Heat transfer calculations are based on the Active heat transfer area, which is the area of the submerged part of the Heat transfer area. This parameter is calculated by VisiMix based on the volume of media in the tank.

### 9.9. MECHANICAL CALCULATIONS OF SHAFTS

#### Calculated parameters and suitability criteria

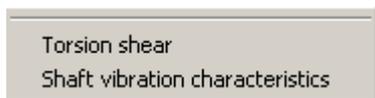
The program performs two sets of calculations:

- **Maximum torsional shear stress.** The torque applied to the shaft is assumed to correspond to the maximum value of the driving momentum due to motor acceleration, i.e. 2.5 times higher than the motor rated torque. These calculations are performed for the upper cross-sections of

the upper and lower stages of the shaft. A single-stage shaft (**regular**) is regarded as the upper stage of a 2-stage shaft with a zero length for the lower stage. The shaft is considered to be strong enough if the calculated stress value is equal or higher than 0.577 of the yield strength of the shaft material.

- **Critical frequency of vibrations.** The shaft is considered to be stiff and reliable if the rotational frequency is less than 70% of the calculated critical (resonance) velocity. According to many years' practical experience, this condition is fully reliable for mixing in homogeneous liquids, as well as in liquid-liquid and liquid-solid systems. For gas-liquid systems, the impeller rotational frequency must be about 60% of the critical frequency. To avoid additional sources of vibrations, two more conditions are recommended:
  - the product of the rotational frequency of the shaft and the number of blades must not equal the critical frequency of the shaft, and
  - the number of baffles in the tank must not be equal to the number of impeller's blades. In tanks with an even number of baffles, it is advisable to use impellers with an odd number of blades.

The menu of **Mechanical calculations of shafts** is shown in Figure 45.



**Figure 45.**

The following output parameters are provided in **Torsion shear** table.

#### **9.9.1. Allowable shear stress**

**Allowable shear stress** is equal to 0.577 of the yield strength of the material you entered .

#### **9.9.2. Maximum shear stress in upper shaft section**

This parameter is the maximum torsion shear stress in the upper cross-section of the shaft (cross-section of the lower bearing for single- and two-stage shafts) resulting from the maximum driving momentum due to the motor acceleration. The shaft is considered to be strong enough if the calculated stress value is equal or higher than 0.577 of the yield strength of the material (see Shaft design).

#### **9.9.3. Maximum shear stress in lower shaft section**

This value is calculated as a torsion shear stress in the upper cross-section of the lower section of two-stage shafts (see above). For single-stage shafts, this parameter is not taken into account.

#### **9.9.4. Maximum shear stress in the shaft section between bearings.**

This value is calculated for console shafts only. It is related to the Diameter of shaft between bearings (d0).

The following output parameters are found in **Shaft vibration characteristics** table.

### 9.9.5. Critical frequency of vibrations

The critical frequency of vibrations is the main calculated parameter in the **SHAFT VIBRATIONS CHARACTERISTICS** output table. It is the critical (resonance) frequency of the shaft vibrations. This value must not be close to the rotational frequency of the shaft.

The shaft is considered as **stiff** if the rotational frequency is less than 70% of the calculated critical (resonance) velocity. Based on many years' practical experience, this condition is fully reliable for mixing in homogeneous liquids, as well as in liquid-liquid and liquid-solid systems. For gas-liquid systems, the impeller rotational frequency must be about 60% of the critical frequency. To avoid additional sources of vibrations, two more conditions are recommended:

- the product of the shaft rotational frequency and the number of blades must not equal the critical frequency of the shaft, and
- the number of baffles in the tank must not be equal to the number of impeller's blades. In tanks with an even number of baffles, it is advisable to use impellers with an odd number of blades.

### 9.9.6. Rotational frequency

Rotational frequency is the rotational velocity of the shaft, rps.

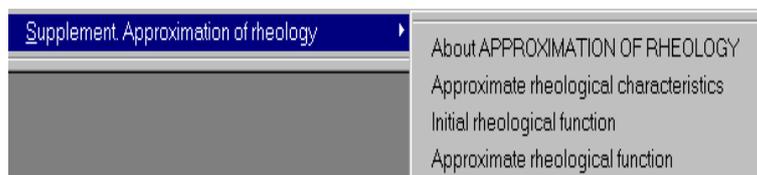
### 9.9.7. Rotational to critical frequency ratio

This parameter is calculated as a ratio of the shaft's rotational velocity and its critical frequency, and is included for your convenience.

The shaft is considered as **stiff** if the ratio is lower than 0.7. For mixing in gas-liquid systems the ratios lower than 0.6 are recommended.

## 9.10. SUPPLEMENT 1. APPROXIMATION OF RHEOLOGY.

This submenu is shown in Figure 46.



**Figure 46.**

In some cases, especially for non-Newtonian media with a relatively high Yield stress value, it is impossible to find a satisfactory solution for flow velocities and circulation due to the formation of stagnant zones in the tank. In such cases, **VisiMix LAMINAR** warns you of the formation of stagnant zones, and does not perform calculations.

However, **VisiMix LAMINAR** may still be used for some mixing calculations in such media, i. e. for estimating Mixing power, Circulation flow rate, and especially for calculating the parameters of micro-mixing (High shear treatment) in tanks with Double-impeller systems. To perform these calculations, we recommend replacing the initial rheological curve with an approximate rheological function with a Yield stress = 0.

This supplementary program helps you find the best parameters of Approximate rheological function based on the condition of the minimum square root deviation between the two functions in the range between “0” and your input of the Upper limit of shear rate.

These parameters are shown in the output table Approximate rheological characteristics. The quality of the approximation can be evaluated through the options Initial rheological function and Approximate rheological function.

In order to perform approximate calculations, enter output parameters from the table Approximate rheological characteristics into input table Average properties of media.

***NOTE: The message “Formation of stagnant zones is expected” is a sign of unsatisfactory mixing. However, efficient mixing can still be achieved if a Double impeller system is used, and there is no warning message when calculating the low-speed impeller based on initial rheological function.***

#### **9.10.1. About APPROXIMATION OF RHEOLOGY**

Use this Supplement for calculations of non-Newtonian media with a relatively high Yield stress value, when stagnant zones are formed in the tank. For more details, see Formation of stagnant zones, Section 2).

#### **9.10.2. Approximate rheological characteristics**

This table shows the result of approximating the initial rheological function by an approximate function with Yield stress = 0. For approximate calculations, enter these parameters in the input table Average properties of media.

#### **9.10.3. Initial rheological function**

This graph shows the function of the media rheology corresponding to the initial data you entered in the input table Average properties of media.

#### **9.10.4. Approximate rheological function**

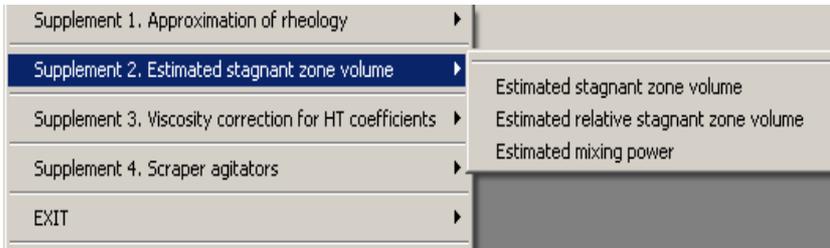
This graph shows the function of the media rheology corresponding to the parameters of rheology shown in the output table Approximate rheological characteristics.

### **9.11. SUPPLEMENT 2. Estimated stagnant zone volume.**

The necessary condition for motion of media can be formulated as follows : local shear stress must be equal or higher then the Yield stress of the media.

In some cases, especially when mixing media is a non-Newtonian media with a relatively high Yield stress value, this condition is not satisfied, and zones without flow are formed.

Formation of such stagnant zones has negative influence on mixing uniformity, It creates also some problems for mathematical modeling - it is impossible to find a satisfactory solution for flow velocities and circulation due to formation of stagnant zones in the tank. In such cases, **VisiMix LAMINAR** warns the user of the formation of stagnant zones, and does not perform calculations. It is possible, however, to evaluate approximately a distance from the tank wall that corresponds to the Shear stress – Yield stress equilibrium. Results of approximate modeling of such conditions are obtained by addressing the Supplement 2 (Figure 47).



**Figure 47.**

The part of tank volume in which the Shear stress is below the Yield stress is defined as a stagnant zone. Estimation of Mixing power is based on the entered Yield stress

#### **9.11.1. Estimated stagnant zone volume.**

VisiMix program defines reduction of shear rate and shear stress along the distance from impeller. As a result, a surface is formed that confines the volume with local shear stress over the Yield stress. The part of volume located outside of this threshold is defined as the Stagnant zone volume.

#### **9.11.2. Estimated relative stagnant zone volume.**

It is defined as quotient of the Estimated stagnant zone and Volume of media

#### **9.11.3. Estimated mixing power.**

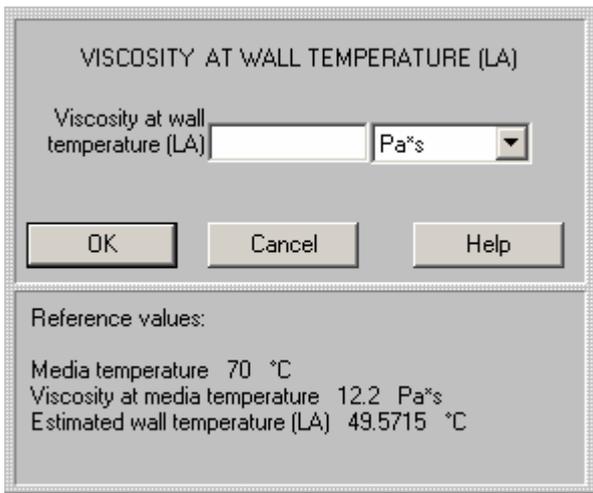
Estimation of mixing power is based on the entered Yield stress value and calculated radius of the stagnant zone threshold.

### **9.12. SUPPLEMENT 3. Viscosity correction for Heat Transfer coefficients.**

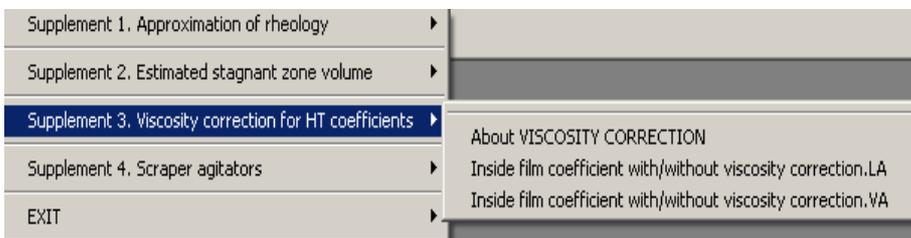
Coefficient of heat transfer from wall to agitated media is dependent on the wall temperature. This dependence is taken into account using viscosity of the media corresponding to the wall temperature:

$$K = K_o (\mu / \mu_0)^{0.14}$$

where  $K$  is inside film heat transfer coefficient calculated by the program for the average media temperature,  $\mu$  and  $\mu_0$  – viscosity values at the wall and media temperatures, respectively. The estimated value of wall temperature is printed in the Input screen below the corresponding input table (Figure 48). These values are defined with regard to kind of heat transfer agent in the tank jacket (Figure 49)



**Figure 48.**



**Figure 49.**

The functions Viscosity – Temperature for different liquids are highly individual. For this reason in order to adjust the heat transfer calculation the viscosity value has to be entered by the User.

### 9.13. SUPPLEMENT 4. Screper agitators.

Impellers with scrapers are used in tanks and reactors that require intensive heat transfer to or from high viscosity media. Their application is typical for polymerization equipment, and also for mixing tanks that are used in production of pastes, creams and other high viscosity mixtures with non-Newtonian properties.

The scrapers are fixed to horizontal hands. Accordingly to the calculations and experimental results, in mixers of technically reasonable design influence of the hands on mixing is negligible. It can be checked by comparing of the power values calculated for scrapers and for horizontal hands without scrapers

Intensive heat transfer to the tank wall that is swept with scrapers occurs due to periodic replacement of a boundary liquid film that is in thermal equilibrium with the wall ( $T_{\text{film}} = T_{\text{wall}}$ ) by a ‘new’ layer with different temperature. If turbulent mixing in the tank is intensive enough, this temperature is equal or nearly equal to the average temperature of the media. Calculation of Media-side heat transfer coefficients for such conditions is based on the well known theoretical solution for non-stationary heat conductivity in a semi-infinite body. Close to the lower limit of turbulent regime the radial turbulent mixing between periphery and bulk part of the tank volume is not so good, and it results in decrease of the heat transfer rate.

**NOTE: Even small distance between the scraper and the tank wall can cause a significant reduction of heat transfer rate.**

### **Entering initial data for a new Project.**

- Enter the Project name and select a Tank as described in par. 5.1 and 6.1.
- Select 'No baffle' option in the Baffle selection table.
- After obtaining impeller selection table click 'Cancel'.
- Enter Average properties of media as described in par. 6.5.1.
- Select Supplements> Screper agitators>Screper agitator. INPUT and fill the input table
- Select and click the menu options corresponding to the purpose of calculations.

If you select Heat transfer option for the first time, the program will display a table for input of Heat transfer properties of media.

### **Editing the initial data.**

Editing of the initial data for Supplements is performed using the Menu icon Initial Data explorer. The Last input table option can be also used.

### **Returning from Supplements to the main part of the program.**

In order to return from Supplements to the main part of the program click EXIT in the Supplements-Screper agitators menu.

***NOTE: The Screper agitators can be used only in tanks without baffles. If the Supplement is used for an existing Project that includes a tank with any type of baffles, a corresponding message arrives on the screen. If it happens, you have to return to the main program and select the No baffles conditions.***

**APPENDIX 1. THERMAL RESISTANCE OF FOULING FOR VARIOUS HEAT TRANSFER AGENTS AND MEDIA.**

Medium	Thermal resistance, m <sup>2</sup> *K/W
<b>WATER:</b>	
Distilled water	0.00004
Sea water	0.00011
Pure service water	0.00023
Polluted service water	0.00055
River water	0.00017
Hard water	0.00025
<b>O I L:</b>	
Motor oil	0.00086
Lubricating oil	0.0042
Quenching oil	0.001
Transformer oil	0.00015
Vegetable oil	0.00031
Fuel oil	0.0005
Petroleum	0.0002
<b>A C I D:</b>	
Hydrochloric acid	0.00005
Phosphoric acid	0.00005
Sulfuric acid	0.00005
Acetic acid	0.0005
<b>SOLUTIONS &amp; BRINES:</b>	
Aluminate solution	0.00015
Caustic solution	0.0002
Alkaline solution	0.0004
Salt solution	0.0002...0.0005
Ammoniac brine	0.0003

Medium	Thermal resistance, m <sup>2</sup> *K/W
MISCELLANEOUS:	
Scale	0.00033
Iron vitriol	0.001
Coke	0.00072
Gypsum	0.00083
Lime	0.00042
Organic heat-transfer media	0.0002
Polymer-forming liquids	0.00045
Rust	0.0005
Soot	0.01
Carbon bisulphide	0.0002
Refrigerant liquids	0.00007
Aromatic hydrocarbon	0.00018
Asphalt and residuum	0.0017

## APPENDIX 2. CONVERSION TABLES

### Conversion of US customary and commonly used units to SI units

Parameter	Value in US customary or commonly used units	Corresponding value in SI or technical metric units
<b>Linear sizes, Area, Volume</b>		
linear size	X in	25.4*X mm
	X ft	0.3048*X m
area	X sq. ft	0.0929*X sq.m
volume	X gal US	3.785*X liter, 0.003785*X cub. m
	X cub. ft	28.3*X liter, 0.0283*X cub. m
<b>Specific area</b>		
specific area	X sq. ft/cub. ft	3.2808*X sq. m/cub. m
<b>Mass, density</b>		
mass	X lbm	0.4536*X kg
	X lb. mol	0.4536*X kmol, 453.6*X mol
density	X lbm/cub. ft	16.02*X kg/cub m
	X lbm/gal US	119.8*X kg/cub m
<b>Viscosity</b>		
dynamic viscosity	X cP	0.001*X Pa*s
	X lbf*s/sq. ft	47.88*X Pa*s
kinematic viscosity	X cSt	1E-6*X sq.m/s
	X sq. ft/s	0.0929*X sq. m/s
<b>Surface tension</b>		
surface tension	X lbf/ft	14.59*X N/m
	X dyn/cm	0.001*X N/m
<b>Concentration</b>		
concentration	X lbm/1000 gal US	0.1198*X kg/cub m
concentr. (molar/volume)	X lb. mol/cub. ft	16.02*X kmol/cub. m
	X lb. mol/gal US	119.8*X kmol/cub. m

Parameter	Value in US customary or commonly used units	Corresponding value in SI or technical metric units
<b>Flow rate</b>		
flow rate - mass	X lbm/s	0.4536*X kg/s
	X lbm/min	0.007560*X kg/s
	X lbm/h	0.000126*X kg/s
		0.4356*X kg/h
flow rate - volume	X cub. ft/s	0.02832*X cub. m/s
	X cub. ft/min	0.000472*X cub. m/s, 1.699*X cub. m/h
	X cub. ft/h	0.02832*X cub. m/h
	X gal US/h	0.003785*X cub. m/h
	X gal US/min	0.2271*X cub. m/h, 6.308E-5*X cub. m/s
flow rate - molar	X lb. mol/s	453.6*X mol/s, 0.4536*X kmol/s
	X lb. mol/min	7.560*X mol/s, 0.007560*X kmol/s
<b>Velocity</b>		
velocity	X ft/s	0.3048*X m/s
	X in/s	0.0254*X m/s
<b>Force</b>		
force	X lbf	4.448*X N
<b>Shear stress</b>		
shear stress	X lbf/sq. in	6895*X Pa
	X lbf/sq. ft	47.88*X Pa
<b>Torque</b>		
bending momentum, torque	X lbf*ft	1.356*X N*m
	X lbf*in	0.113*X N*m
<b>Energy, Power</b>		
energy	X lbf*ft	1.355*X J
	X B.t.u.	1.055*X kJ, 1055*X J
power	X B.t.u./s	1055*X W
	X hp	746*X W, 0.746*X kW

Parameter	Value in US customary or commonly used units	Corresponding value in SI or technical metric units
<b>Specific power, turbulent dissipation rate</b>		
specific power (turbulent dissipation rate)	X hp/cub. ft	26.33*X kW/cub. m
	X Btu/(cub. ft*s)	37.26*X kW/cub. m
	X lbf*ft/(lbm*s)	2.989*X W/kg
	X Btu/(lbm*s)	2326 X W/kg
<b>Specific reaction rate</b>		
specific reaction rate	X cub. ft/(lb.mol*s)	0.0624*X l/(mol*s)
	X cub. ft/(lb.mol*h)	1.734E-5*X l/(mol*s)
<b>Pressure</b>		
pressure	X psi	0.068*X Atm
	X mm H2O	9.806*X Pa
	X mm Hg	133.3*X Pa
	X lbf/sq. ft	47.88*X Pa
	X psi	6895*X Pa
	X psi	0.0672*X Pa

<b>Thermal Units</b>		
<b>Specific heat</b>		
specific heat	X Btu/(lbm*°F)	4187*X J/(kg*K)
	X cal/(kg*°C)	4.184*X J/(kg*K)
<b>Heat conductivity</b>		
heat conductivity	X Btu*ft/(h*sq.ft.*°F)	1.73*X W/(m*K)
	X Btu*in/(h*sq.ft.*°F)	0.1442*X W/(m*K)
	X cal*cm/(s*sq.cm*°C)	418.4*X W/(m*K)
	X kcal*m/(h*sq.m*°C)	1.162*X W/(m*K)
<b>Temperature</b>		
temperature	X °F	5/9*(X - 32) °C
	X °F	5/9*(X + 459.4) K
<b>Energy of activation</b>		
energy of activation	X Btu/(lb*mol)	2.326*X J/mol

Thermal Units		
Arrhenius constant		
Arrhenius constant	X cub. ft/(lb*mol*s)	0.06243*X cub. m/(Kmol*s)
	X cub. ft/(lb*mol*h)	1.734*10 <sup>-5</sup> *X cub. m/(Kmol*s)
Heat flux		
heat flux	X Btu/(h*sq.ft)	3.155*X W/sq.m
Thermal resistance		
thermal resistance	X °F *sq.ft*h/Btu	0.1761*X K*sq.m/W
Heat transfer coefficient		
heat transfer coefficient	X Btu/(s* sq. ft* °F)	2.044*10 <sup>4</sup> *X W/(sq. m*K)
	X Btu/(h* sq. ft* °F)	5.678*X W/(sq. m*K)
	X kcal/(h*sq. m*°C)	1.162*X W/(sq. m*K)

### Conversion of SI units to US customary and commonly used units

Parameter	Value in SI or technical metric units	Corresponding value in US customary or commonly used units
Linear size, area, volume		
linear size	X mm	0.03937*X in
	X m	3.2808*X ft
area	X sq.m	10.76*X sq. ft
volume	X liter	0.03531*X cub. ft, 0.2642*X gal US
	X cub. m	35.31*X cub. ft, 264.2*X gal US
Specific area		
specific area	X sq.m/cub. m	0.3048*X sq. ft/cub. ft
		0.0254*X sq. in/cub. in
Mass, Density		
mass	X kg	2.205*X lbm
	X mol	0.002205*X lb. mol
	X kmol	2.205*X lb. mol
density	X kg/cub. m	0.06243*X lbm/cub. ft
		0.008345*X lbm/gal US

Parameter	Value in SI or technical metric units	Corresponding value in US customary or commonly used units
<b>Viscosity</b>		
dynamic viscosity	X Pa*s	1000*X cP, 0.02089*X lbf*s/sq. ft
	X cP	2.089E-5*X lbf*s/sq. ft
kinematic viscosity	X sq.m/s	1E6*X cSt, 10.76*X sq. ft/s
	X cSt	1.076E-5*X sq. ft/s
<b>Surface tension</b>		
surface tension	X N/m	1000*X dyn/cm, 0.0685*X lbf/ft
<b>Concentration</b>		
concentration mass/volume)	X kg/cub. m	0.06243*X lbm/cub. ft
		8.345*X lbm/1000 gal US
concentration (molar/volume)	X kmol/cub. m ( mol/liter )	0.06243*X lb. mol/cub. ft 0.008345*X lb. mol/gal US
<b>Flow rate</b>		
flow rate - mass	X kg/s	2.205*X lbm/s, 132.3*X lbm/min
flow rate - volume	X cub. m/s	35.31*X cub. ft/s, 2119*X cub. ft/min
	X cub. m/h	35.31*X cub. ft/h
		0.5886*X cub. ft/min
		4.403*X gal US/min
flow rate - molar	X mol/s	0.002205*X lb. mol/s
	X kmol/s	2.205*X lb. mol/s
<b>Velocity</b>		
velocity	X m/s	3.2808*X ft/s, 39.37*X in/s
<b>Force</b>		
force	X N	0.2248*X lbf
<b>Shear stress</b>		
shear stress	X Pa	0.000145*X lbf/sq. in 0.02089*X lbf/sq. ft

Parameter	Value in SI or technical metric units	Corresponding value in US customary or commonly used units
Torque		
bending momentum, torque	X N*m	0.738*X lbf*ft, 8.851*X lbf*in
Energy, Power		
energy	X kJ	0.9478*X Btu
	X J	0.738*X lbf*ft
power	X W	0.0009478*X Btu/s
		0.00134*X hp
	X kW	1.34*X hp
		0.9478*X Btu/s
Specific power, turbulent dissipation rate		
specific power (turbulent dissipation rate)	X kW/cub. m	0.03797*X hp/cub. ft, 0.0268*X Btu/(cub. ft*s)
	X W/kg	0.3346*X lbf.ft/(lbm*s)
		0.0004299*X Btu/(lbm*s)
Specific reaction rate		
specific reaction rate	X l/(mol*s)	16.02*X cub. ft/(lb.mol*s)
		57666*X cub. ft/(lb.mol*h)
Pressure		
pressure	X Pa	0.9869*10 <sup>-6</sup> *X atm
	X atm	14.696* X lbf/sq. in (psi)
	X Pa	0.102*X mm H2O
	X Pa	0.0075*X mm Hg
	X atm	1.01325*X bar
	X Pa	10*X dyn/sq. cm

Thermal Units		
Parameter	Value in SI or technical metric units	Corresponding value in US customary and commonly used units
Specific heat		
specific heat	X J/(kg*K)	0.0002388*X Btu/(lbm*°F)
	X J/(kg*K)	0.239*X cal/(kg*°C)
Heat conductivity		
heat conductivity	X W/(m*K)	0.578*X Btu*ft/(h*sq.ft.* °F)
	X W/(m*K)	6.933*X Btu*in/(h*sq.ft.* °F)
	X W/(m*K)	0.00239*X cal*cm/(s*sq.cm*°C)
	X W/(m*K)	0.8604*X kcal*m/(h*sq.m*°C)
Temperature		
temperature	X °C	9/5*X + 32 °F
	X K	9/5*X - 459.4 °F
Energy of activation		
energy of activation	X J/mol	0.4298*X Btu/(lb*mol)
Arrhenius constant		
Arrhenius constant	X cub. m/(Kmol*s)	0.01602*X cub. ft/(lb*mol*s)
	X cub. m/(Kmol*s)	57.67*10 <sup>3</sup> *X cub. ft/(lb*mol*h)
Heat flux		
heat flux	X W/sq.m	0.317*X Btu/(h*sq.ft)
Thermal resistance		
thermal resistance	X K*sq.m/W	5.678*X °F *sq.ft*h/Btu
Heat transfer coefficient		
heat transfer coefficient	X W/(sq. m*K)	0.8924*10 <sup>-5</sup> *X Btu/(s* sq. ft* °F)
	X W/(sq. m*K)	0.1761*X Btu/(h* sq. ft* °F)
	X W/(sq. m*K)	0.8606*X kcal/(h*sq. m*°C)