VISIMIX LAMINAR.
BLENDING OF NON-NEWTONIAN LIQUID. POWER. CIRCULATION. MIXING TIME.

Subject of the example – application of program VisiMix Laminar for analysis and improvement of process characteristics of existing mixing tank.

We are going to get quantitative evaluation of the mixing regime, evaluate circulation, mixing time and homogenizing efficiency and to check if it is po95ssible to improve the process using accessible technical means.

The general sequence of operations:
- create a new project file,
- select the corresponding equipment from the VisiMix graphical menus,
- enter the initial data requested by the program,
- and then select the parameters for calculations from the **Calculate** menu.

Characteristics of equipment and media.

Tank. A tank with an elliptical bottom with a 2-stage Intermig impeller. The system has the following parameters:

Tank inside diameter	1200 mm
Tank height	3200 mm
Tip diameter of impeller	720 mm

Baffles: There are 4 flat baffles inside the tank, with a width of 120 mm, length of 2700 mm, installed normally to the wall at a distance of 30 mm from the wall and 400 mm from the bottom.

Media: The tank is used for mixing a non-Newtonian media with the following characteristics:

Density	1130 kg/cub.m
Rheology function:	

Shear stress = 6 + 10.2 (Shear rate)$^{0.68}$

1. Opening the project and entering the design data and properties of media.

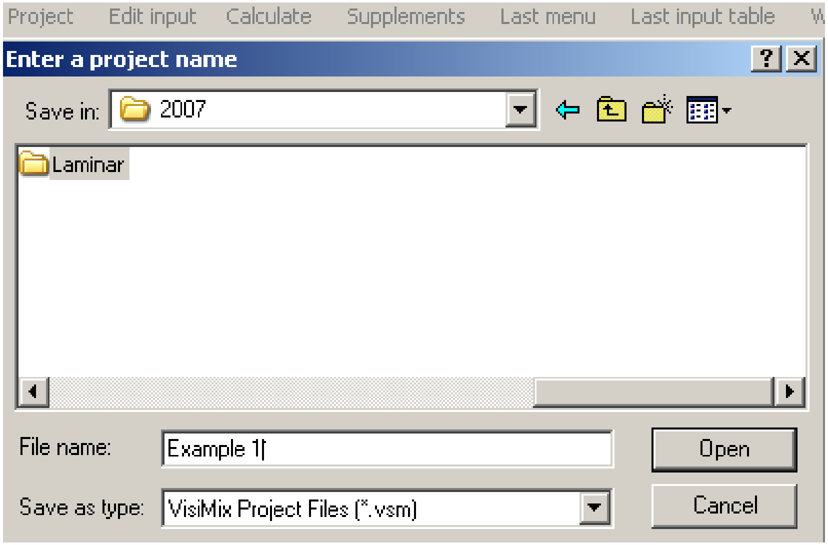


Figure 1. Opening of a new project and entering the project name.

After the project is opened, VisiMix **Tank types** graphical menu appears (Figure 2). The selected tank appears in the **Current choice** window on the right (Figure 2). Click **OK** confirms your choice.

The **Tank** input table appears and has to be (Figure 3). The diagram in the screen changes to reflect the input.

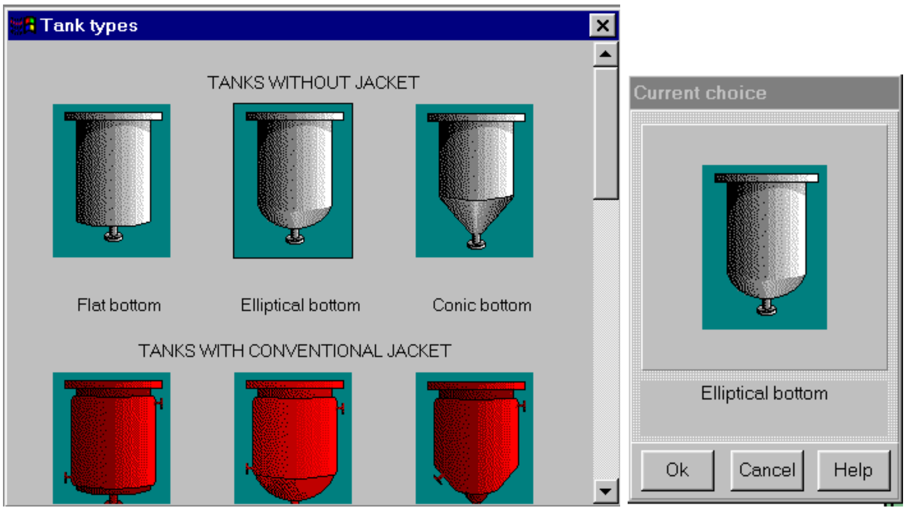


Figure 2. Selecting an unjacketed tank with elliptical bottom.

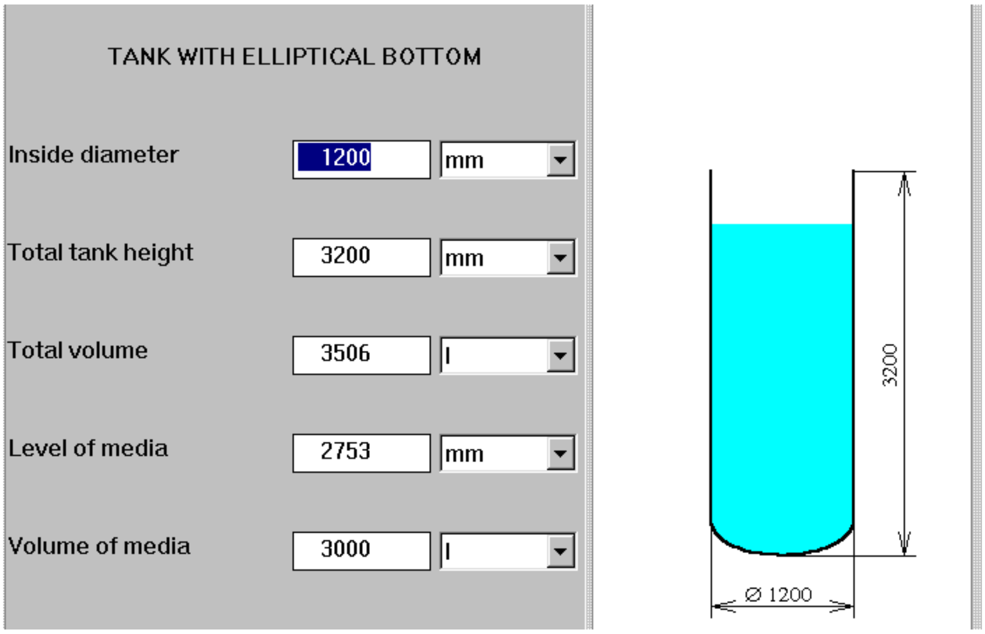


Figure 3. Entering the tank dimensions.

The next step – selecting and entering the baffles – is shown in the Figures 4 and 5.

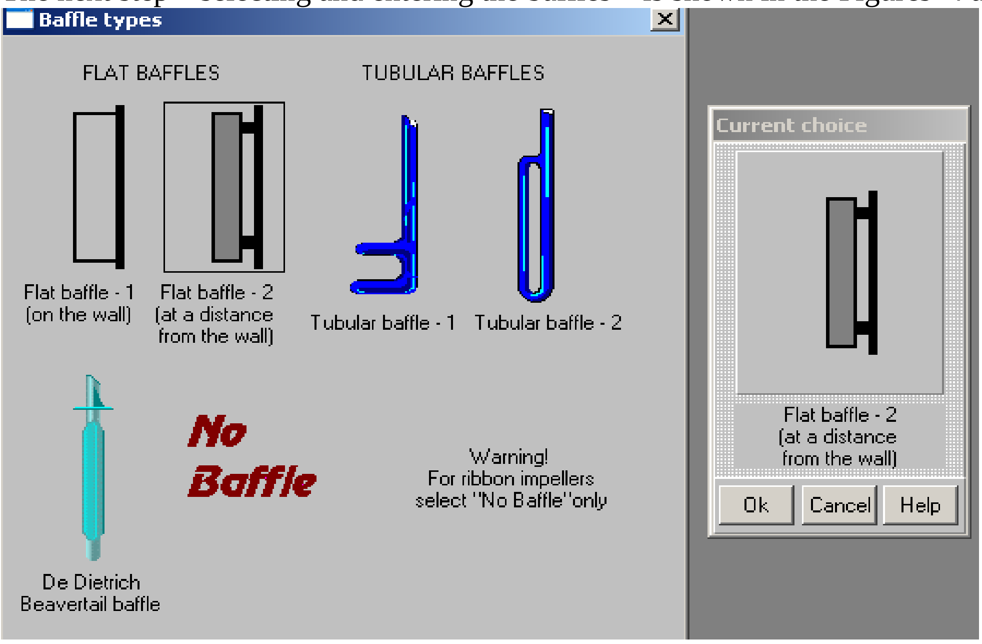


Figure 4. Selecting the baffle type.

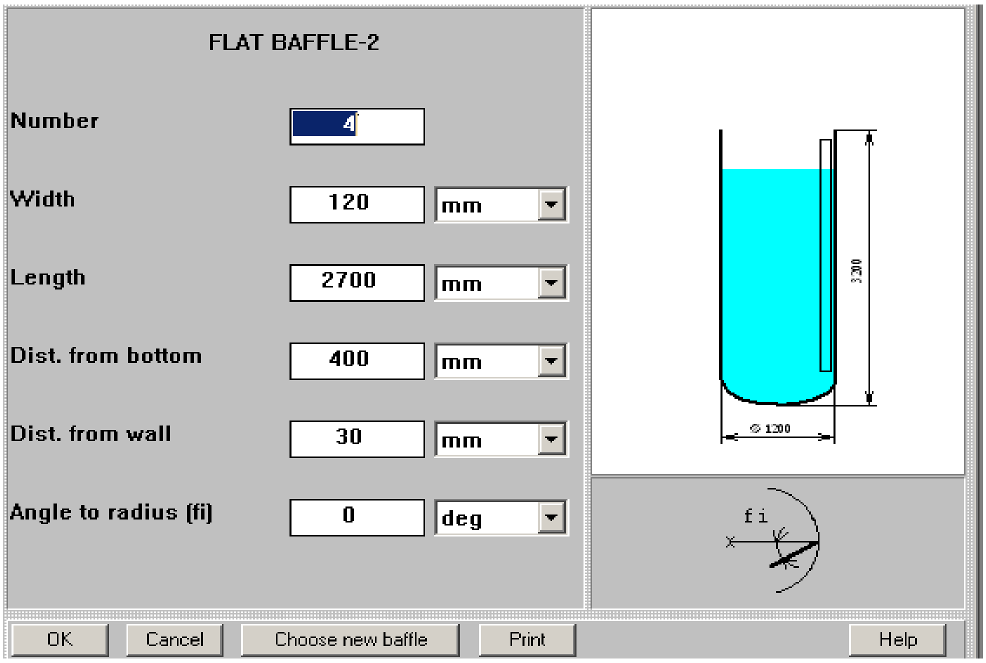


Figure 5. Entering dimensions of baffles.

After clicking OK, the **Impeller types** graphical menu appears (Figure 6).

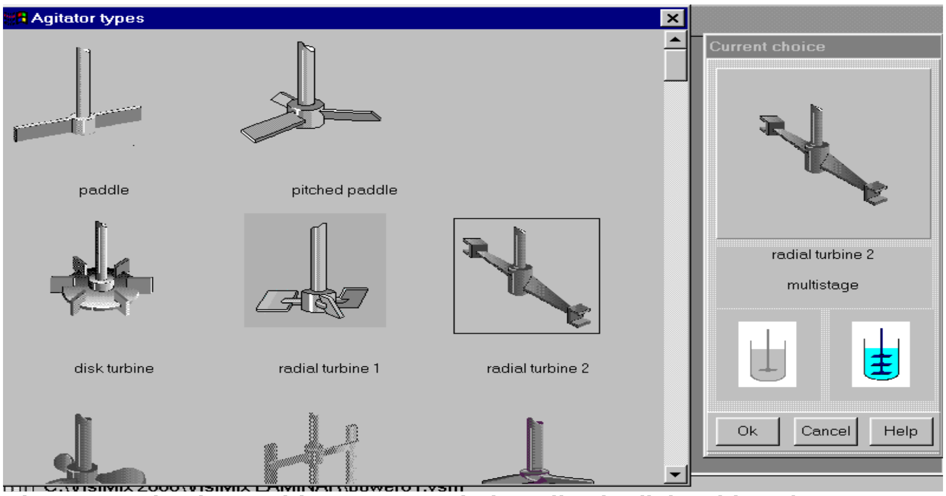


Figure 6. Selecting multistage Intermig impeller (radial turbine 2).

Our case corresponds to a multistage impeller of the type **radial turbine 2**. After selecting **multistage,** the corresponding impeller input table appears. Detailed instructions for entering data of this particularimpeller are found by click on Help button. We enter the impeller parameters accordingly to these data (Figure 7) and click OK. The **Average properties of media** input table appears (Figure 8).

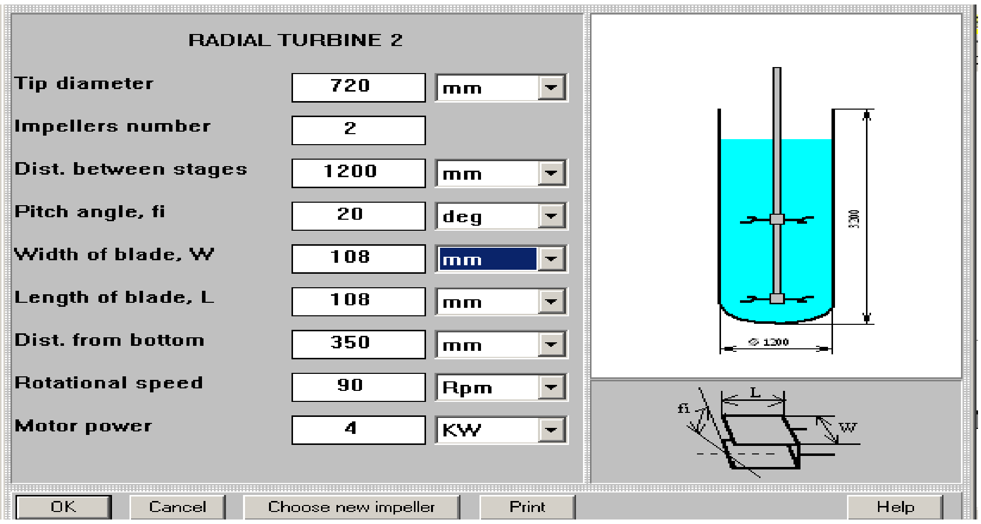


Figure 7. Entering the impeller data.

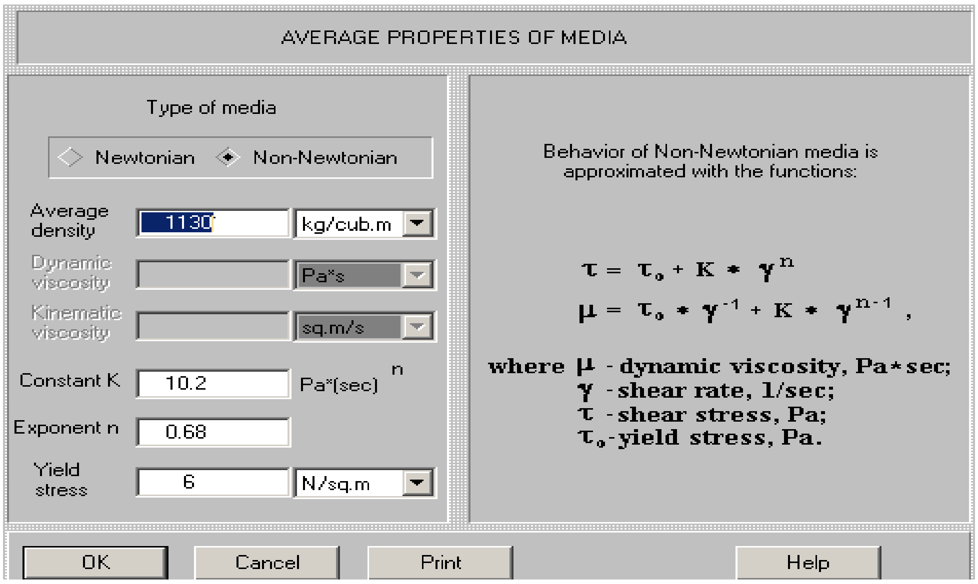


Figure 8. Entering average properties for the media.

To fill the above table, we select the non-**Newtonian** option and enter the rheological constants presented above. After all the data are entered, the final diagram of the tank appears (Figure 9).

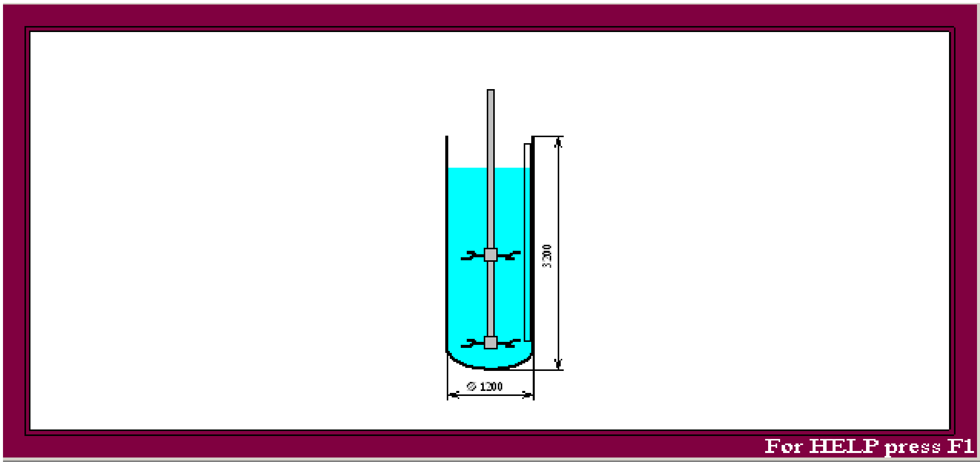


Figure 9. Diagram of the mixing unit.

2. Calculation of power and general mixing characteristics.

All VisiMix calculation menus are contained in the **Calculate** option in the main menu.

The first parameter we want to calculate is the **Mixing power**. Select **Power and forces** in the **Calculate** menu and click on the **Mixing power** (Figure 10).

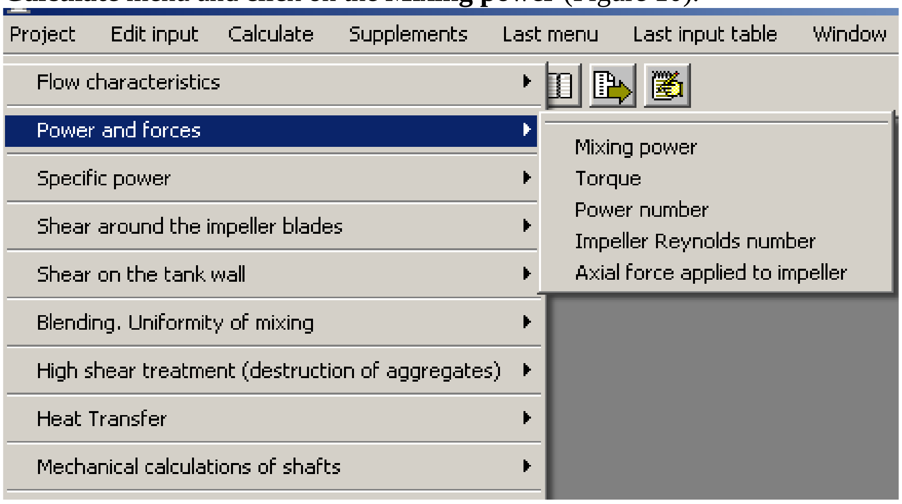
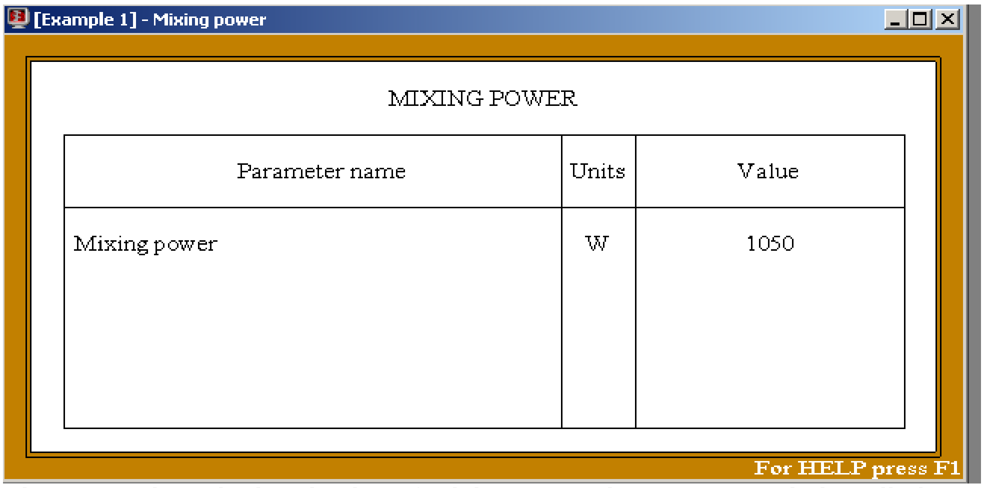


Figure 10. Calculating the mixing power.

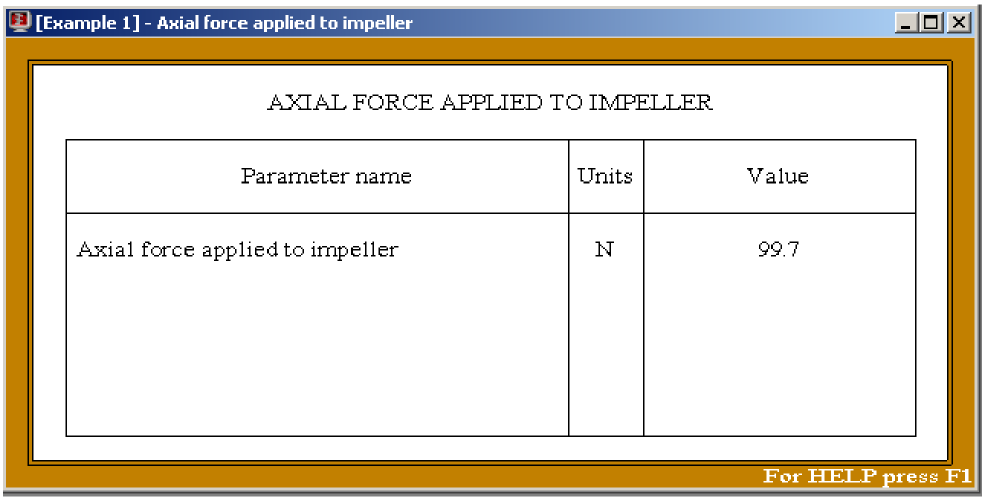
The program starts the calculations, and almost immediately the appropriate output window appears (Figure 11).



Parameter name	Units	Value
Mixing power	W	1050

Figure 11. The calculated value of mixing power (2-stage Intermig impeller).

You can now address other questions in the same menu, for instance, **Axial force applied to impeller**. The calculated value is shown in Figure 12. It is about 10 kg – i.e. low enough.



Parameter name	Units	Value
Axial force applied to impeller	N	99.7

Figure 12. The calculated value of the axial force applied to impeller.

Now we are going to use VisiMix to define the flow regime. The hydrodynamic regimes of flows are normally characterized by the Reynolds numbers. VisiMix calculates three different Reynolds numbers:

- **Reynolds number for flow**
- **Re number for impeller blades**
- **Impeller Reynolds number**

The **Reynolds number for flow** calculated by VisiMix is based on the average flow velocity and characterizes the flow regime in the bulk of volume. The **Re number for impeller blades** is based on the velocity of the flow past the blade and the blade width, and characterizes the mixing conditions in the immediate vicinity of the blade.
The mentioned velocity values are defined by program as a result of solution for flow velocity distribution.

The **Impeller Reynolds number** is based on the impeller diameter and rotational velocity of the impeller. This expression is formal and does not include any characteristics of flow velocity. In VisiMix it is not used, it is calculated for reference purposes only. Until recently, this was the only **Re** number that was used by engineers, because the other two values could not be calculated.

To calculate the Reynolds numbers, select **Flow characteristics** in the **Calculate** and click on the appropriate parameters (Figure 13).

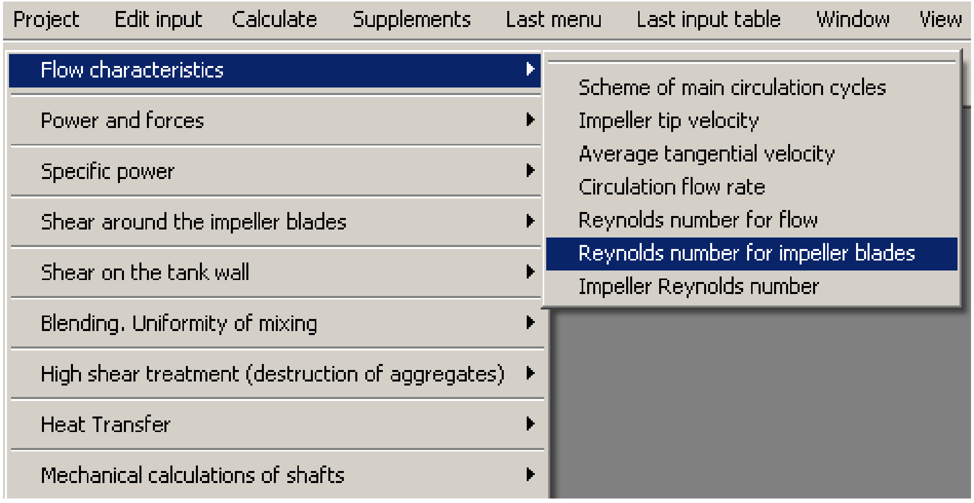


Figure 13. Calculating the Reynolds number.

The appropriate output windows are shown in Figure 14.

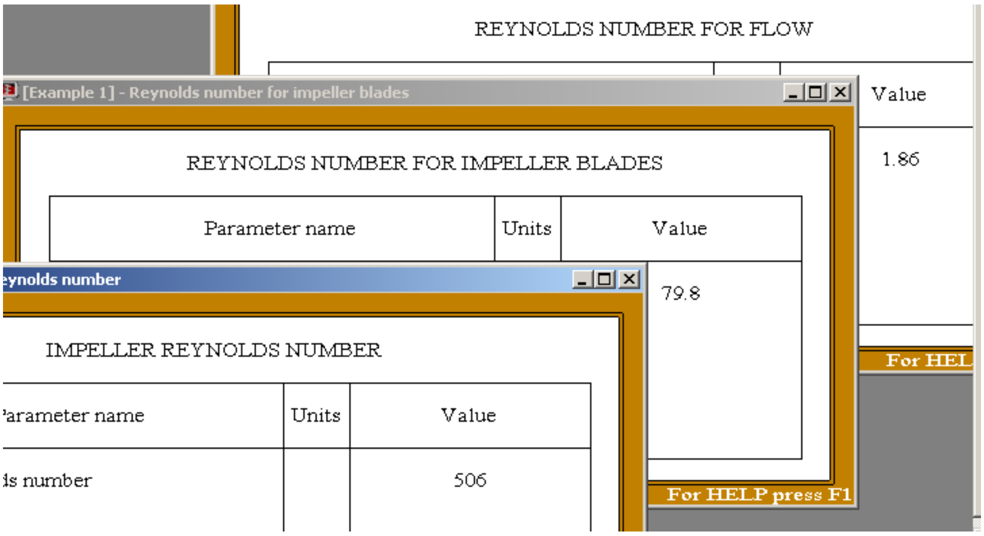


Figure 14. The calculated values for the characteristic Reynolds numbers.

You can see that both in the bulk of volume and near the blades the flow regime is strictly laminar, while flowing over the blades may be considered as turbulent (the critical values of **Re number** for flowing over the bodies are about 20 - 50).

For a laminar flow regime, one of the most important characteristics of mixing is the **Circulation flow rate**. This parameter is accessed through the **Flow characteristics** option (Figure 13), the calculated value arrives in a form presented in the Figure 16. The another output parameter presented in this window **-Mean circulation time is** accessed through the sub-menu **Blending. Uniformity of mixing** (Figure 15).

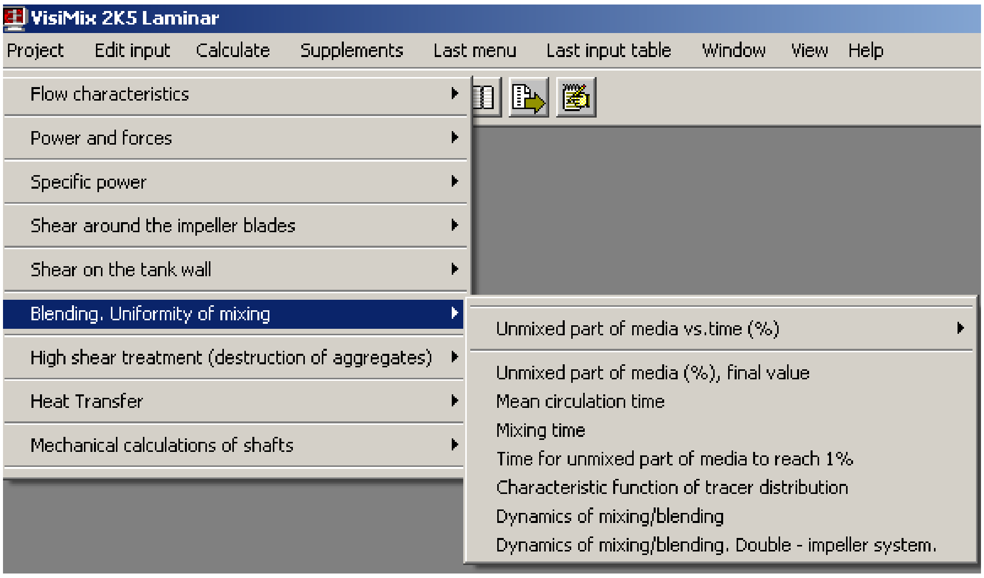


Figure 15. Calculating the Mean circulation time.

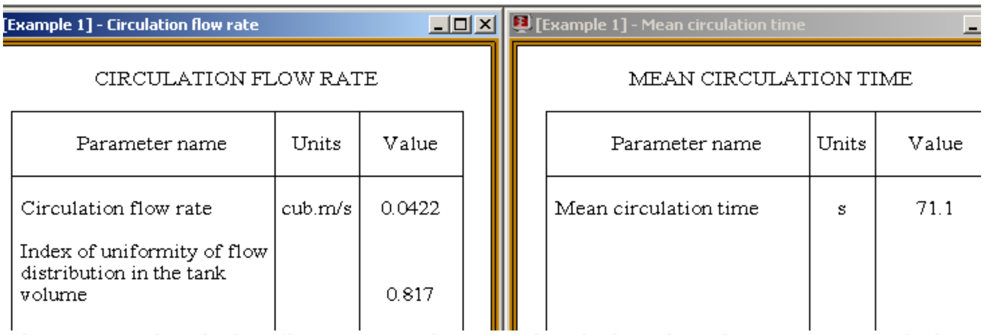


Figure 16. Circulation flow rate and Mean circulation time (2-stage Intermig impeller).

You see that the **Circulation flow rate** is about 40 l/s, and the **Mean circulation time** is relatively short. This means that the circulation in the system is quite intensive. Note another parameter in the **Circulation flow rate** table: **Index of uniformity of flow distribution in the tank volume**. What does this parameter mean?

In **Help – Contents - Output parameters – Flow characteristics - Circulation flow rate** you will find: " 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 signs of poor mixing, when almost all circulation is short-circuited in a small area near the impeller." It is illustrated by the **Scheme of main circulation cycles**, which is another parameter in the **Flow characteristics** option. This scheme is shown in Figure 17.

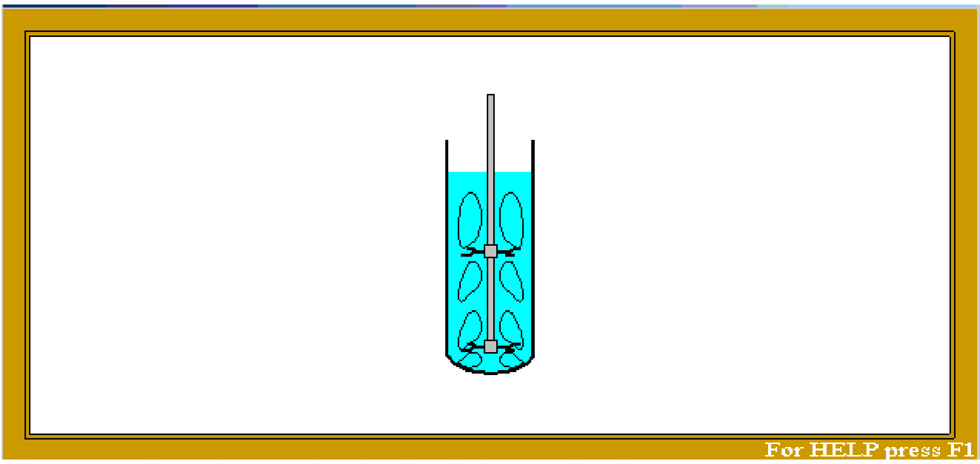


Figure 17. The scheme of main circulation cycles (2-stage Intermig impeller).

It shows that in our case the entire volume of the tank is involved in circulation. However, this does not always happen, and it depends on the equipment design and properties of media.

3. Macroscale mixing – blending.

Now let us address the main question of interest to us, which is the **Mixing time**. Select the **Mixing time** in the **Blending. Uniformity of mixing** option (Figure 15).

Additional data is needed to calculate the mixing time. VisiMix invokes an appropriate input table (Figure 1-18), and you are requested to enter the inlet zone location since the mixing time naturally depends on the point where the admixture is added. In this table, you are also asked to indicate the sensor position in the tank. If the sensor is absent – enter any position.
Click OK, and in a few seconds the appropriate output window appears (Figure 19).

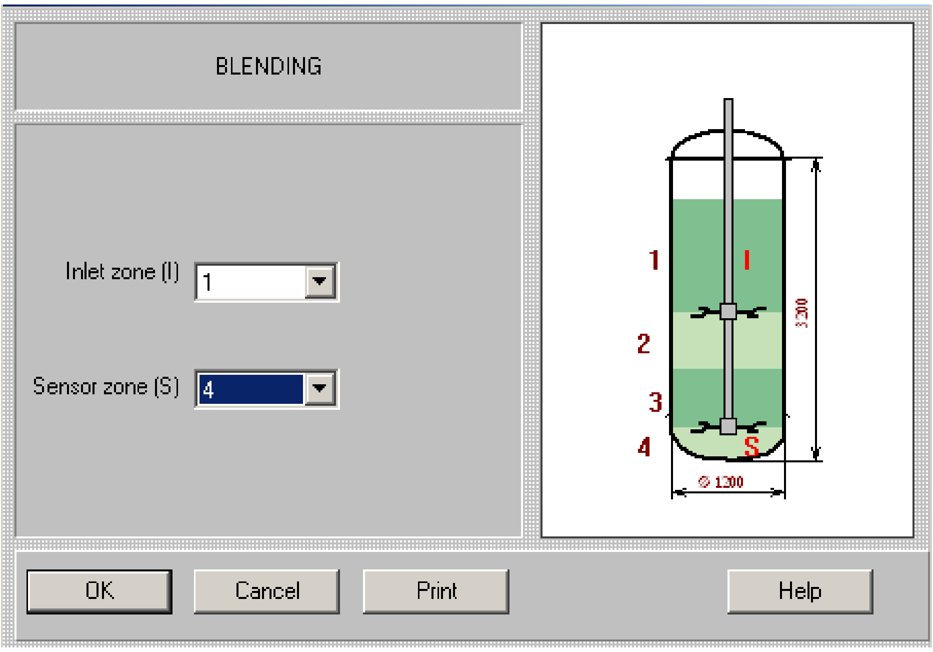


Figure 18. Entering the location of the inlet and sensor zones.

MIXING TIME

Parameter name	Units	Value
Mixing time necessary to attain 10% non-uniformity	s	1330
Mixing time necessary to attain 5% non-uniformity	s	1670
Mixing time necessary to attain 2% non-uniformity	s	2110

For HELP press F1

Figure 19. The calculated values for the mixing time (2-stage Intermig impeller).

In this table you see three different values of the mixing time, depending on the degree of uniformity achieved. In order to calculate the next parameter – **Unmixed part of media** (see the same menu), the program will ask us to enter additionally the real (or preferred) mixing duration (see Figure 20).

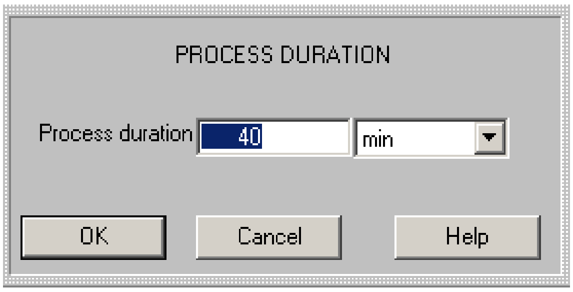


Figure 20. Entering the expected mixing duration.

UNMIXED PART OF MEDIA (%), FINAL VALUE

Parameter name	Units	Value
Process duration	s	2400
Unmixed part of media (%), final value		0.274

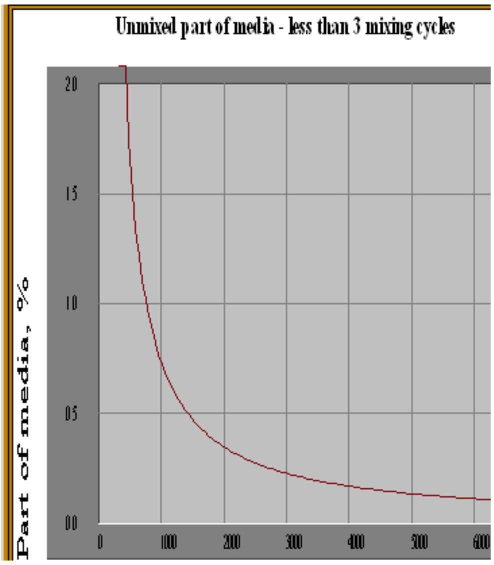


Figure 21. Dynamics of blending and completeness of mixing.

4. Homogenization.

If the raw materials include a powder, one of the main requirements can often consists in destruction of the aggregates of solid particles and homogenizing of the mixture. The homogenizing occurs due to effect of a relatively high shear that is created in zones around the impeller blades. In order to calculate local shear characteristics in this area, we will use the menu section **Shear around impeller blades** (Figures 22,23) , and for mathematical modeling of dynamics of high shear treatment of media - the menu section **High shear treatment** (Figures 24,25).

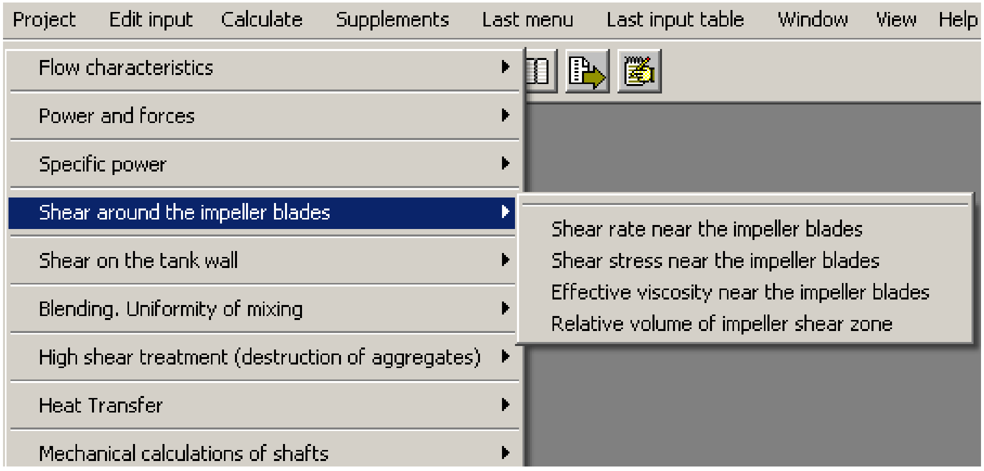


Figure 22. Menu section for calculation of maximum shear.

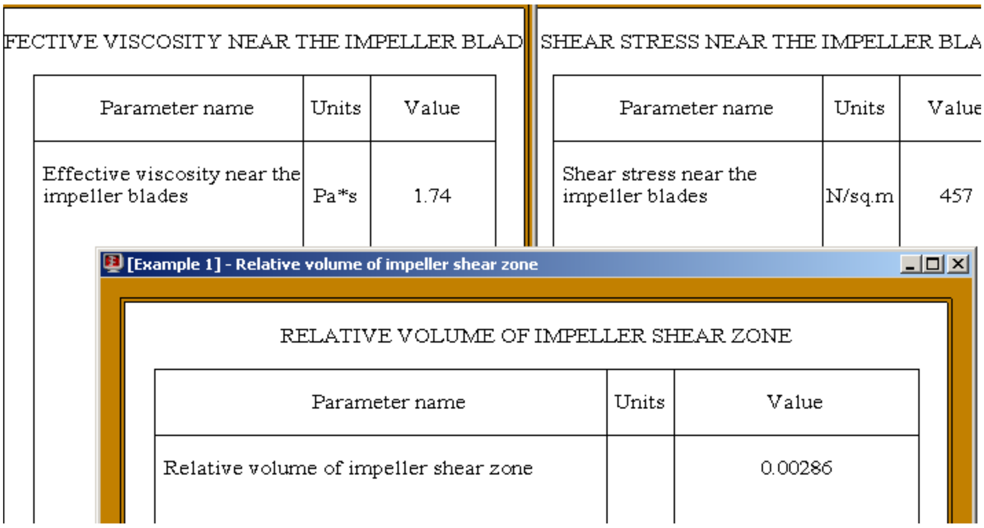


Figure 23. Calculated parameters of the maximum shear zones.

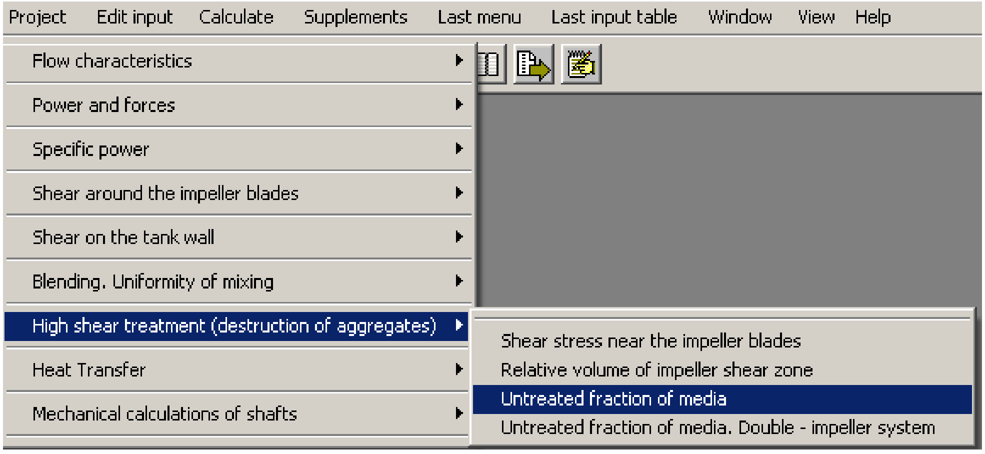
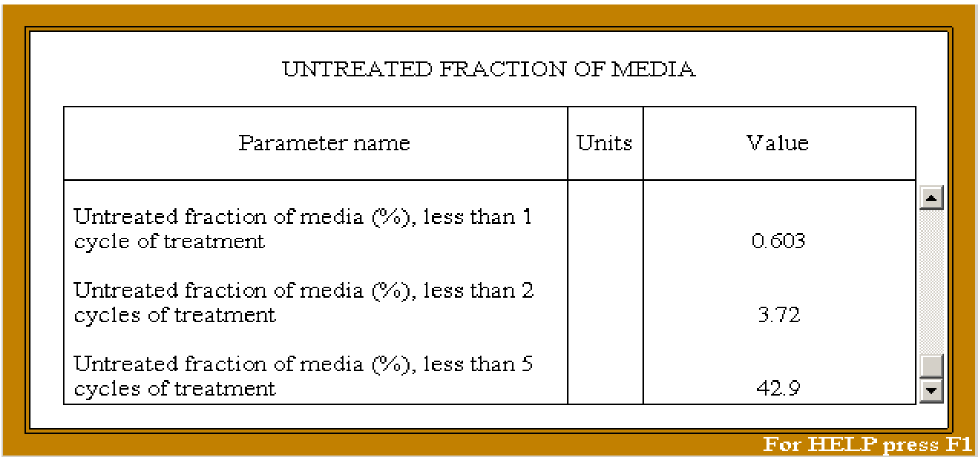


Figure 24. Menu section for modeling of high shear theatment.



UNTREATED FRACTION OF MEDIA

Parameter name	Units	Value
Untreated fraction of media (%), less than 1 cycle of treatment		0.603
Untreated fraction of media (%), less than 2 cycles of treatment		3.72
Untreated fraction of media (%), less than 5 cycles of treatment		42.9

For HELP press F1

Figure 25. Statistical evaluation of completeness of high shear treatment of mixture in tank with 2-stage impeller.

Results of calculations presented above show that power of drive is not used completely. So, our last step of calculation – to check a possibility to improve the mixing parameters of the tank without change of drive. One of simple ways to do it – install additional impeller of the same design. In order to do it, we return to the initial data. via **Edit input>Impeller** and change **Impellers number** and **Distance between impellers** in the Impeller input table (Figure 26).

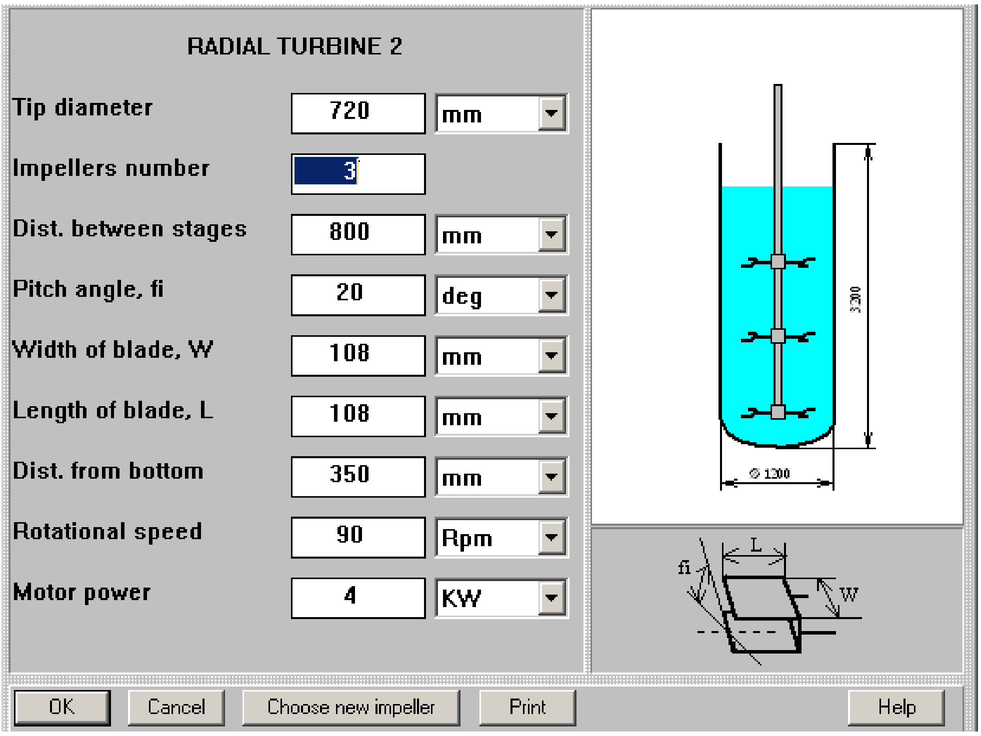


Figure 26. Entering the additional impeller.

Accordingly to the results of calculations, the additional impeller allows to decrease **Process duration** from 40 to 30 min (Figure 27) along with some improvement of mixing completeness (Figures 28,29). Increase of power consumption due to introduction of the third impeller is expected, but the **Mixing power** does not exceed the safe limits (Figure 30).

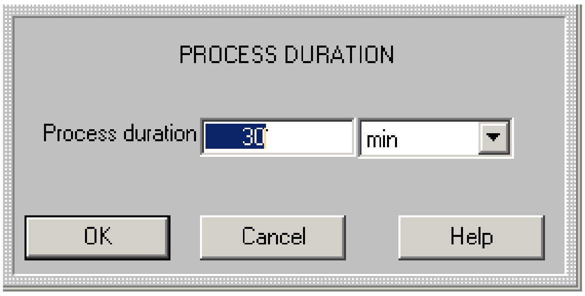


Figure 27. Entering reduced process duration for tank with 3 impellers.

MIXING TIME

Parameter name	Units	Value
Mixing time necessary to attain 10% non-uniformity	s	1230
Mixing time necessary to attain 5% non-uniformity	s	1520
Mixing time necessary to attain 2% non-uniformity	s	1900

UNMIXED PART OF MEDIA (%), FINAL VAI

Parameter name	Units	Value
Process duration	s	1800
Unmixed part of media (%), final value		0.122

Figure 28. Completeness of mixing in tank with 3-stage impeller.

UNTREATED FRACTION OF MEDIA

Parameter name	Units	Value
Untreated fraction of media (%), less than 1 cycle of treatment		0.000672
Untreated fraction of media (%), less than 2 cycles of treatment		0.00875
Untreated fraction of media (%), less than 5 cycles of treatment		0.833

For HELP press F1

***Figure 29.* High shear treatment of suspension in tank with 3-stage impeller.**

MIXING POWER

Parameter name	Units	Value
Mixing power	W	1520

For HELP press F1

Figure 30. Power consumption of 3-stage impeller.