Successful submersible mixing

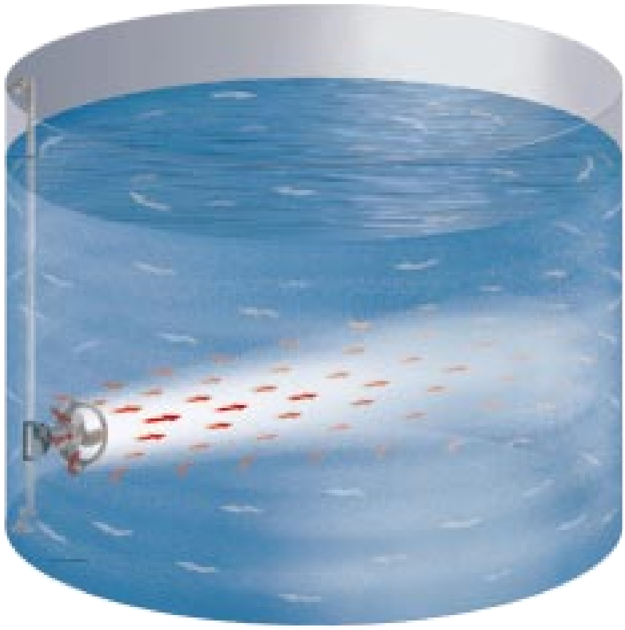
in principles and practice

Flygt

ITT Industries
Engineered for life

The last thing you need is a mixer

Most ITT Flygt customers aren't looking to buy a specific mixer. Instead, they'll ask for a cost-efficient mixing solution that facilitates or improves their process – from enhancing a biological process to simply keeping a tank bottom clear of sediment. Providing knowledge about applications and fluid dynamics is therefore as important as offering high-quality products.



The freedom in positioning and orientation is utilized to obtain a strong bulk flow. This is highly beneficial for instance in the blending of large volumes.

Start with turbulence and bulk flow

All mixing duties require varying degrees of both small-scale turbulence and bulk flow. For most mixing duties there is abundant turbulence in the tank and it is the strength of the overall bulk flow that controls the efficiency of the mixing. This is valid for mixing duties such as:

- Solids suspension
- Blending
- Destratification
- Liquid circulation

Measuring how well you're mixing

Operators and engineers often believe that mixing performance is difficult to specify and check. In some cases, poor mixing won't become evident for several years after start-up, so, for added reassurance, we offer several different methods of verifying mixing results.

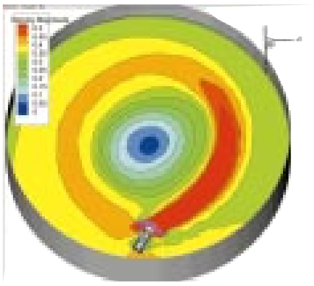
Tried and tested methods

To measure the total amount of suspended solids, ITT Flygt has developed a fast, accurate method. This relies on the fact that liquid pressure at a certain depth increases with the mass concentration of suspended solids.

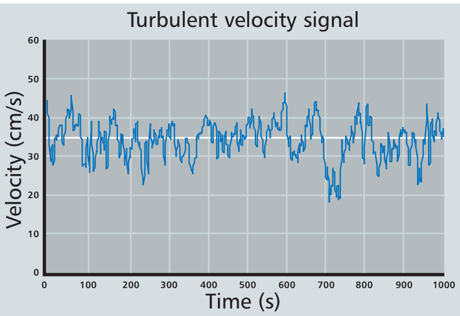
Another well-proven method is the measurement of fluid velocity. Although this is an indirect measure of mixing results, required values of velocities are well established and accepted for several applications. A key advantage is the fact that velocities can be both clearly specified and precisely measured.

Measurement of liquid velocities using an acoustic doppler velocity probe (ADV) connected to a PC.

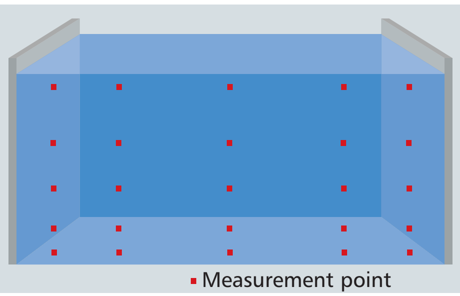
A probe with handheld computer for on-line measurement of biofloc concentration.



Different bottom shear stresses represented by different colors are useful in helping to avoid sedimentation.



The signal must be collected over a sufficiently long time period, typically a minimum of 2 mins.



A Gaussian Quadrature scheme of measure-ment points increases accuracy in average values.

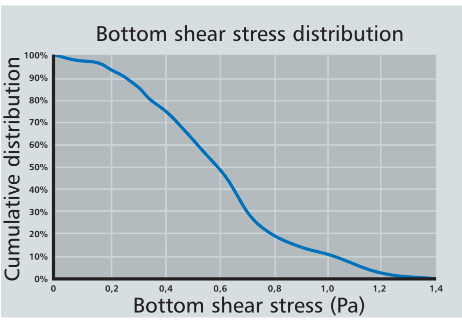


Illustration of the fraction of the bottom area where a given shear stress, or higher, is attained.

The best place to test

Knowledge of how to collect and assess data is equally as important as selecting the measurement equipment.

Fluctuations over time are always present in a mixed-liquid volume, so measurement times must be long enough to attain relevant data. Defining the required sampling frequency and measurement time can be quickly achieved by analysing the signal in a PC program.

Selection of measurement points is another important factor in order to obtain relevant and accurate results. The Gaussian Quadrature scheme of measurement points, and different weighting of those points, delivers more accuracy than a traditional, even distribution.

Using computers to gain optimum results

With the development of computer-processing capacity, the use of CFD (Computational Fluid Dynamics) has become an increasingly powerful tool in all disciplines of fluid dynamics. This is also true for the development of mixing know-how.

The overall flow pattern in a tank, generated by a submerged jet from a mixer, can be modelled with high precision. Parameters such as bottom shear stress distribution, average velocity and velocity distribution can be obtained and processed in various ways. This is invaluable in applications such as solids suspension, where bottom shear stress describes how well sediment is resuspended at different parts of the tank bottom.

Proving your design at the planning stage

Using CFD means that a lot of data and integrated parameters can be obtained early in the planning stage of a mixing application. ITT Flygt can help customers and other partners in obtaining such analyses.

ITT Flygt CFD report.

What are you mixing?

Information about the physical and chemical properties of the liquid content is important when making a thorough selection of mixing equipment. Knowing the internal friction in the liquid is of particular importance. The higher the internal friction, the "thicker" the liquid appears. Two major parameters which are used to describe internal friction are *viscosity* and *yield stress*.

Simple Newtonian liquids

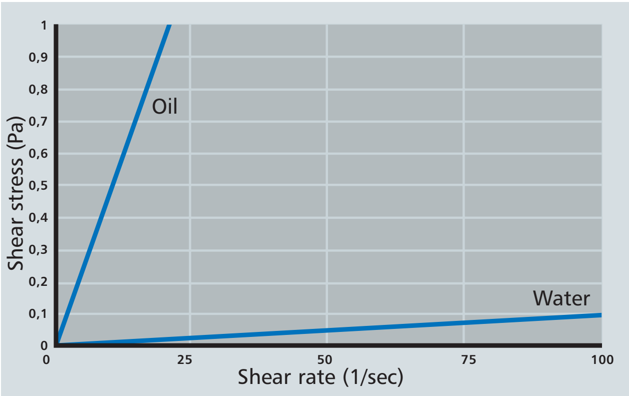
The internal friction of a liquid is generally illustrated in a rheogram. For simple liquids, like water, the internal friction is directly proportional to the shearing rate between liquid layers. Such liquids are called Newtonian liquids and the slope of the line expresses their *viscosity*.

ITT Flygt can assist in making rheology tests for liquids with unknown

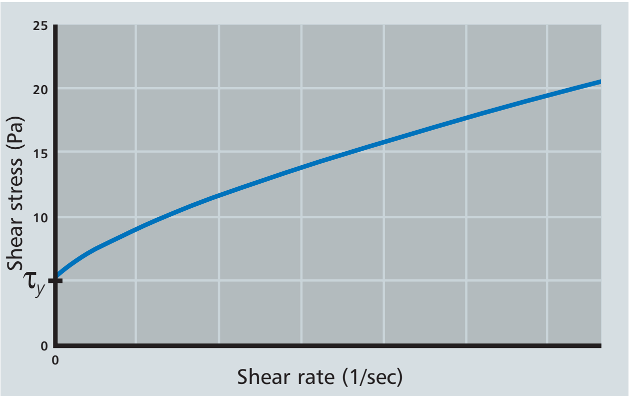
More complex liquid behavior

Many liquids behave in ways that differ from those of Newtonian liquids, and this is particularly true with suspensions of particles, fibers or bioflocs. At certain concentrations the suspended solids actually start interfering with each other, thereby increasing the internal friction of the mixture.

Suspensions of solids often have an internal friction that causes yield stress. This is a threshold friction that must be overcome before the liquid starts to move. Paper pulp, biological sludge and yoghurt are examples of liquids with yield stress.

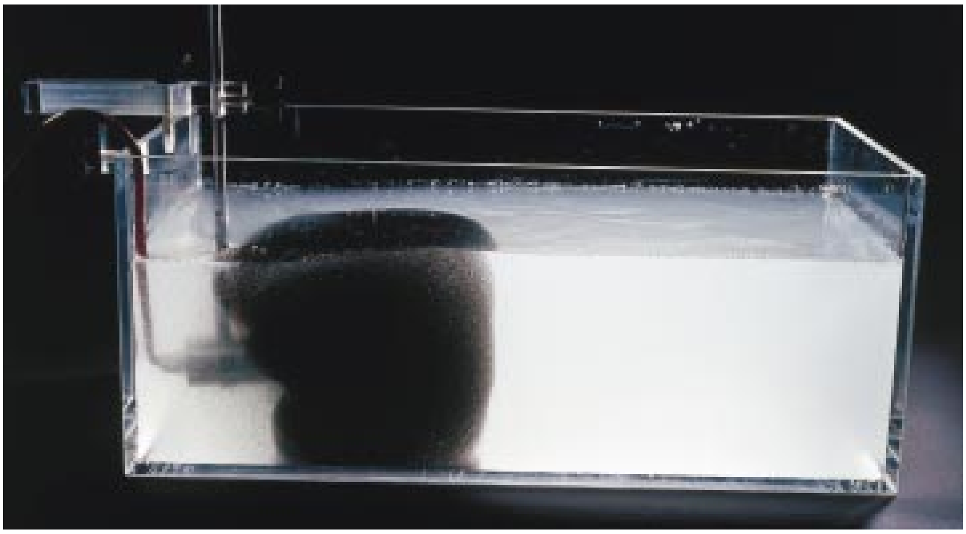


A rheogram for water and for motor oil. Both are Newtonian liquids, however with a great difference in viscosity (see table).



A rheogram of a liquid showing a typical yield stress(τ_y). This threshold friction must be overcome before the liquid starts to move.

Liquid	Temperature (°C/°F)	Viscosity (cP=mPas)
Gasoline	(16°C / 60°F)	0.31
Fresh water	(55°C / 130°F)	0.55
Fresh water	(16°C / 60°F)	1.1
Olive oil	(55°C / 130°F)	22
Olive oil	(38°C / 100°F)	40
Motor oil	(55°C / 130°F)	48
Motor oil	(16°C / 60°F)	460
Shampoo	(20°C / 68°F)	5000
Syrup	(8°C / 46°F)	8000



Insufficient mixing capacity in a yield stress liquid results in movement being restricted to the area surrounding the propeller (the dark area).

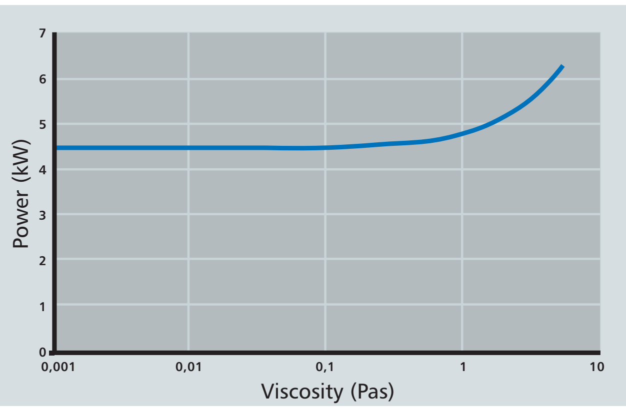
Influencing mixer sizing

• Viscosity
As viscosity goes up, the overall bulk flow rate in a tank is reduced because of the increased friction between the tank wall and the liquid. At the same time, small-scale turbulence is also reduced. In applications such as liquid blending, this calls for higher mixer capacity to be installed in order to obtain a given result. However, in solids suspension applications, a high viscosity is sometimes beneficial since settling velocities of particles are reduced.

Power consumption of a mixer is constant until the viscosity is so high that the flow around the propeller is no longer fully turbulent.

• Yield stress
For installations in liquids with yield stress, the mixer capacity must be selected so that the threshold value to get the liquid to move is overcome in all of the volume, not just in the space around the mixer. Unlike Newtonian liquids, inadequate mixer capacity in a yield stress liquid will result in completely dead zones where no mixing action takes place.

• Density
A high liquid density gives the mixer jet a higher momentum. This makes overcoming yield stress and high viscosity easier, and therefore is beneficial for the mixing result. On the other hand, the power consumption of a mixer is directly proportional to the liquid density, so motor capacity often has to be increased to avoid overloading.



The power consumption of a Flygt 4660 mixer is not influenced by increased viscosity until the flow around the propeller ceases to be fully turbulent.

Liquid	Yield stress(Pa)
Biosludge 4%	3-10
Manure 10%	3-7
Drilling mud	10-30
Paper pulp 4% (sample)	30
Yoghurt	3-20
Mustard 25˚C	5-55
Tomato ketchup 25˚C	5-25
Bentonite slurry 3%	8
Bentonite slurry 6%	60
Chocolate mousse	50-70

Examples of yield stresses. Concentrations and additives often have substantial influence.

How to select the right mixer for the task?

A crucial step in the process of defining a proper mixing solution is the selection of an appropriate mixer size. Information on the following key parameters is required:

Mixing duty and expected result
The expected result can be expressed in several different ways. For instance: in blending time, as a certain homogeneity to be maintained, or as liquid circulation rate. Old-fashioned specifications of required W/m^3 seldom take advantage of modern, efficient propellers and the opportunities provided by the optimal positioning of mixers.

Liquid characteristics
Liquid characteristics such as density, viscosity and yield stress all influence the mixer solution. Liquids are often known from previous experience, but collecting a sample for testing is sometimes the best way to obtain accurate information for proper mixer sizing.

Tank geometry
In addition to tank geometry, flow obstacles such as pipes, columns and inflows to the tank should also be taken into account.

Installation restrictions
Submersible mixers have the advantage of great freedom in positioning and orientation, and this should be utilized to make best use of the mixer jet momentum. Any restrictions as to where the mixer can be installed will therefore be important to know.

The result of the selection process must be a mixer selection that ensures the expected result with minimum investment and running costs.

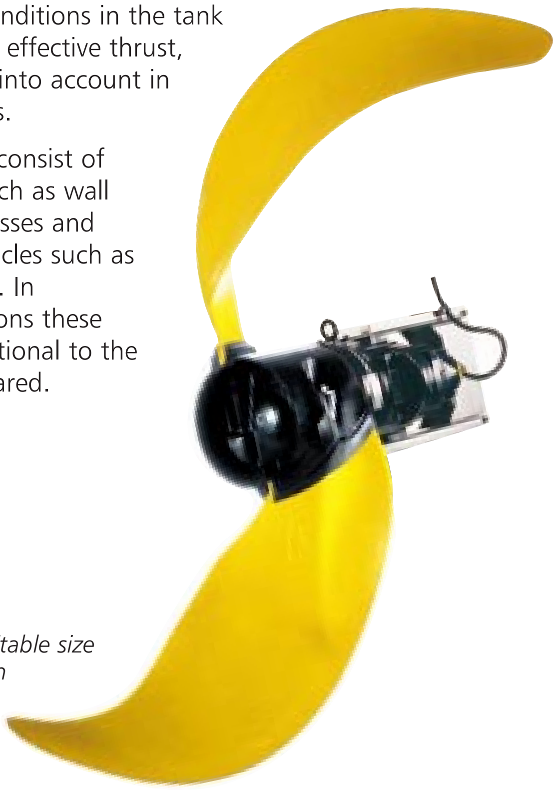
Calculate the required mixer thrust
For many common applications, the mixing result is controlled by the strength of the overall bulk flow. Small-scale turbulence is generally abundant in the tank.

Applied with minimum hydraulic losses, a mixer jet can perform proper mixing of large volumes.

In a mixed tank, a bulk flow is established in the equilibrium between the mixer thrust and the total flow losses. Put simply, this is Newton’s second law of motion applied to a liquid volume (for liquids, this law is commonly expressed as Navier-Stokes’ equations).

Mixer thrust is a well-tested product performance parameter under standard conditions. However, flow conditions in the tank can influence the effective thrust, and this is taken into account in the sizing process.

Total flow losses consist of several factors such as wall friction, corner losses and losses from obstacles such as columns or pipes. In turbulent conditions these losses are proportional to the flow velocity squared.



The selection of suitable size of mixer is crucial in defining a mixing solution.

Positioned for optimum mixing

The freedom in positioning and orientation is one of the key features of submersible mixers.

Freedom in positioning and orientation is one of the key features offered by submersible mixers. This makes it possible to achieve efficient mixing in any kind of tank shape.

The submerged mixer jet can be positioned to develop over a long distance and adapted to the shape of the tank. This ensures the creation of a maximum level of bulk flow, giving more efficient mixing with lower power consumption.

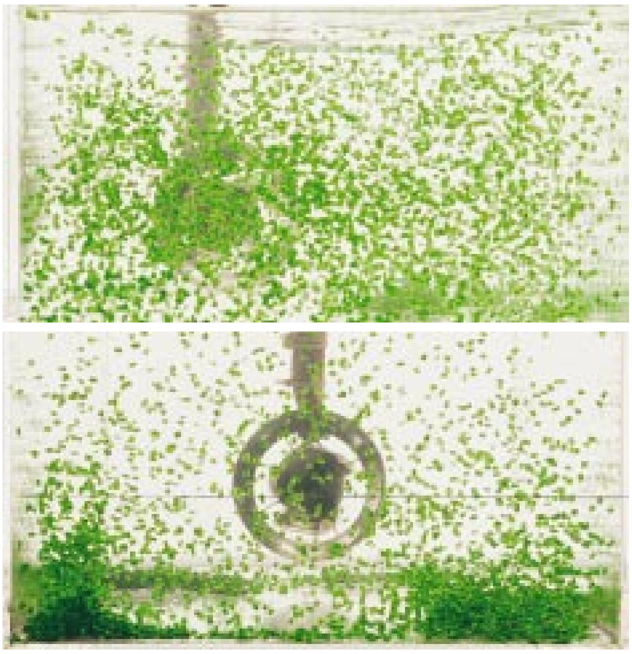
Correct positioning is actually one of the most effective means of obtaining successful and efficient mixing.

Jet-powered bulk flow
The jet generated by a submersible mixer entrains surrounding liquid as it moves along. The further the jet can develop without interruption, the higher the total flow rate becomes, and the stronger the bulk flow that is established in the tank. This bulk flow develops to become many times larger than the primary flow through the mixer propeller.

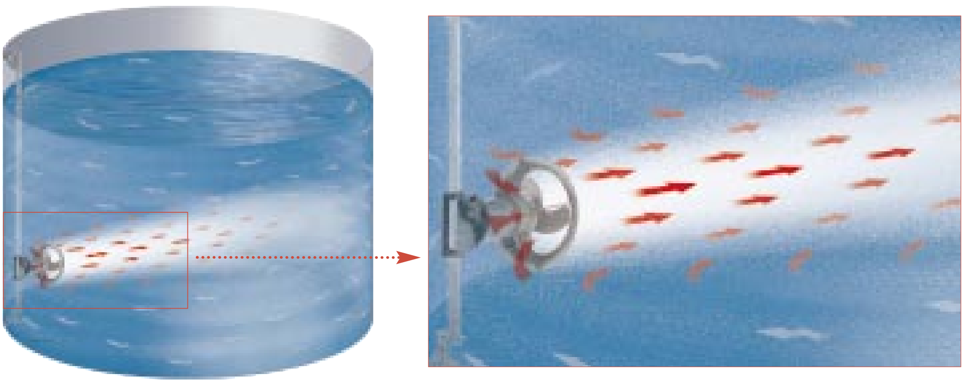
Maximum mixing, minimum investment
For bulk flow-controlled mixing duties – such as solids suspension and blending – there are two basic principles to consider in positioning:

- Allowing the jet to develop over a long distance
- Arranging the jet for smooth deflection to the tank boundaries

This will result in a maximum level of bulk flow and efficient mixing, while optimizing investment and running costs.



The importance of good mixer positioning: test results with the mixer in a good position (top), and in a less satisfactory position (bottom).



The primary flow of a submerged jet entrains surrounding liquid as it propagates. The overall bulk flow in a tank is often 15-20 times larger than the primary flow through the propeller.

ITT Flygt is the world's leading manufacturer and supplier of submersible fluid management systems. ITT Flygt submersible pumps, mixers and aeration systems are used in effluent treatment plants, collection systems and numerous other applications. We work closely with engineers, planners and consultants to ensure that our customers get the most from our systems. ITT Flygt is represented in over 130 countries and has 37 sales offices around the world.

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