

A New Gas Dispersion Impeller with Vertically Asymmetric Blades



André Bakker

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Abstract

For several decades the so-called Rushton turbine was the standard impeller for gas dispersion applications. It features six flat blades mounted on a disk. John M. Smith and coworkers introduced the concept of using concave blades. They explained the improved performance of the concave blades compared to flat blades in terms of reduced cavity formation behind the blades. Impellers with a semi-circular blade shape are now common in the industry. Relatively recent, new blade designs with a deeper concavity have been proposed by other researchers. Under most conditions with these deeper blades the gas is being dispersed from the inside of the blade, instead of from large cavities behind the blade.

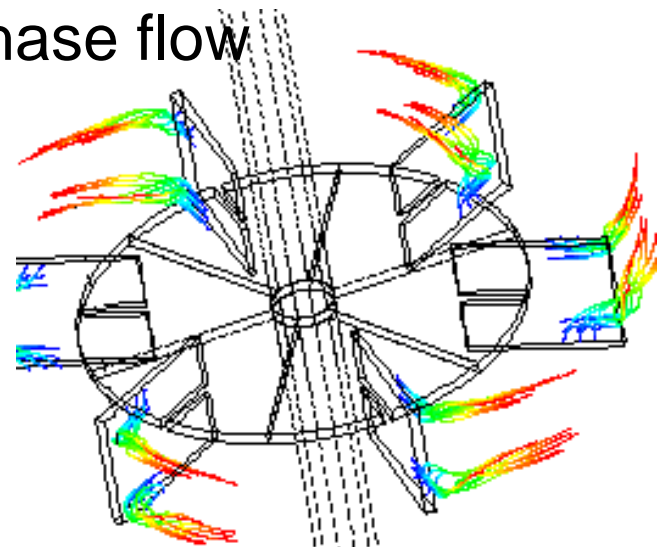
All of the disk-style gas dispersion impellers studied in the literature so far have blades that are symmetric with respect to the plane of the disk. This is not necessarily optimal, as the gas usually enters from the bottom, causing a distinctly asymmetric flow pattern. This paper discusses the performance of a new gas dispersion impeller with vertically asymmetric blades. The new impeller is designed to accommodate the different flow conditions above and below the impeller disk. The blade shape was optimized in a comparative study of more than twenty different geometries.

This paper discusses the performance of a gas dispersion impeller with blades that are vertically asymmetric; i.e. the blade shape above the disk is different from the shape below the disk. It is shown that this impeller has a gassed power curve that is flatter than that of other impellers. Furthermore, it can disperse more gas before flooding than the impellers with symmetric blades. Both experimental data and the results of advanced CFD simulations using FLUENT 5 will be discussed.

Gas Dispersion Impellers: 1950's

◆ Rushton Turbine

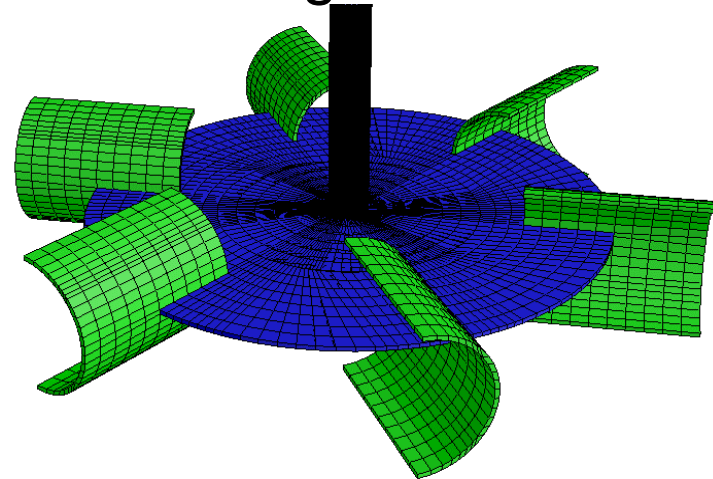
- Radial flow impeller
- Six flat blades on a disk
- Suitable for gas dispersion and liquid-liquid dispersion
- Turbulent power number range: 4.5-6.2
- Trailing vortices in single-phase flow
- Cavitation in gas-liquid flow



Gas Dispersion Impellers: 1980's

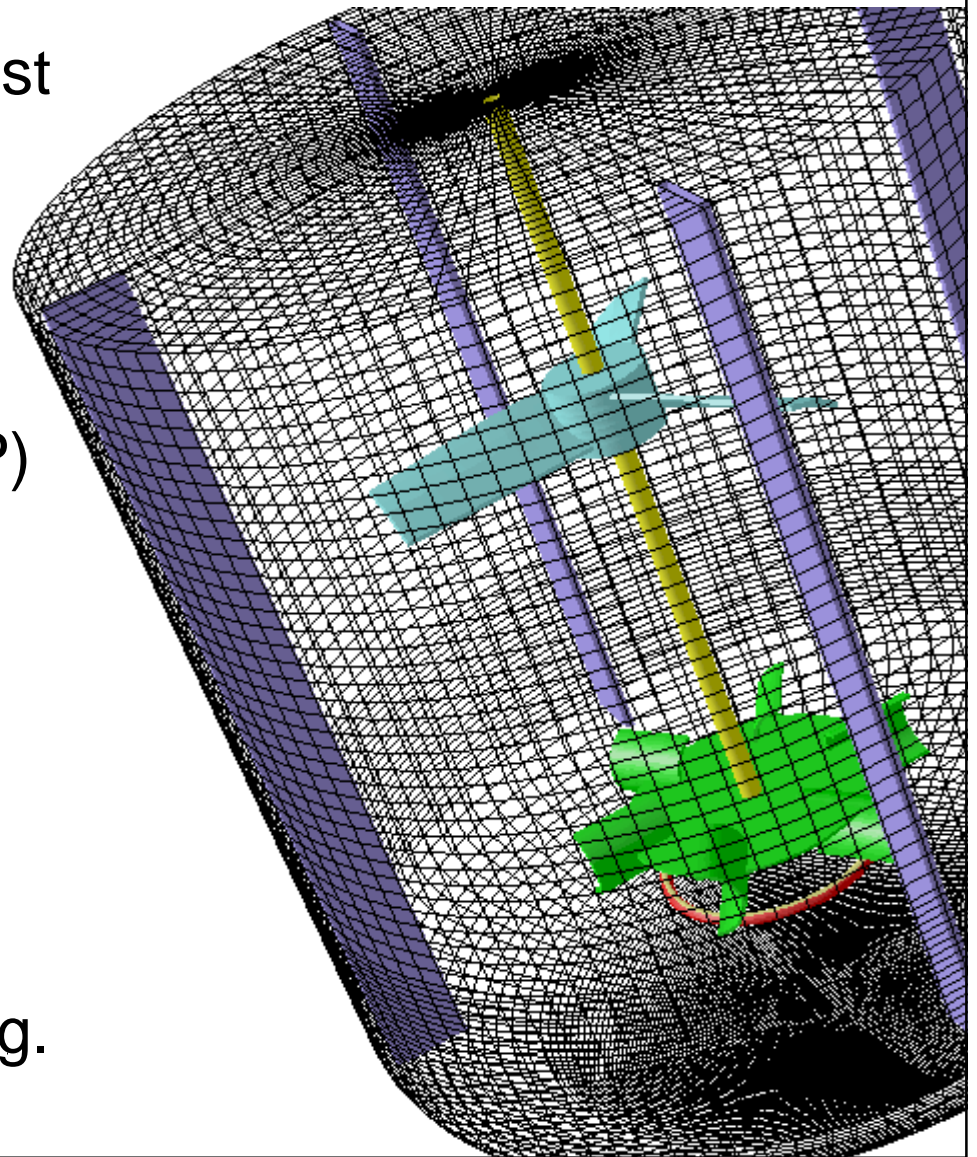
◆ Chemineer CD-6

- Radial flow impeller with six concave blades on a disk.
- Design based on prior research by Smith and co-workers.
- Lightnin R130, Philadelphia's "Smith Turbine."
- Turbulent power number range: 2.8-3.2.



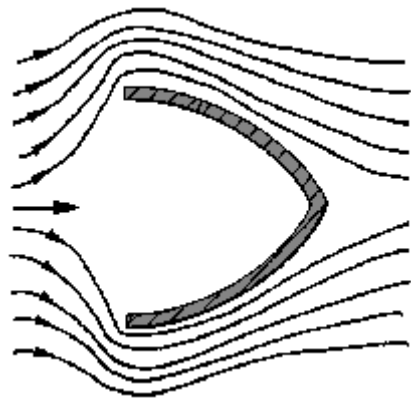
Multiple Impeller Systems - 1980's

- CD-6/HE-3 systems most widely used system in large scale fermenters. HE-3 can be either down or up pumping. Over 100,000 kW (130,000 HP) installed.
- Systems with solely down pumping axial flow impellers were not successful. Solely up pumping impellers work better than down pumping.

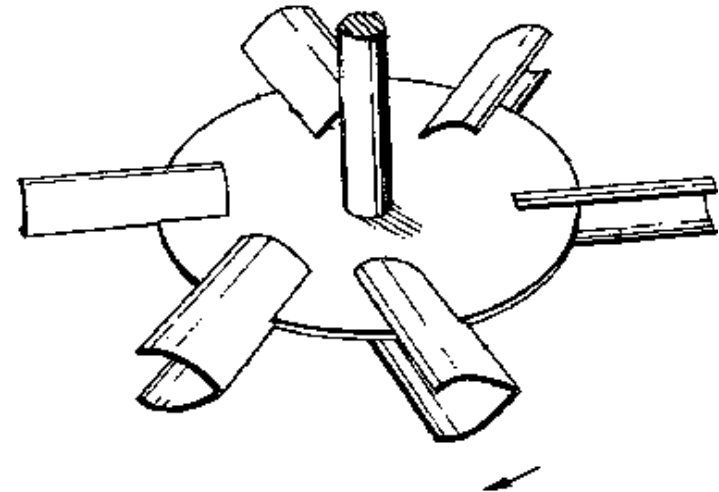


Gas Dispersion Impellers: 1988-1993

- ◆ Proprietary Scaba and ICI Impellers
 - Deeper concave blades
 - Sharp back edge of blade
 - With and without disks



US Patent 4,779,990 (1988)

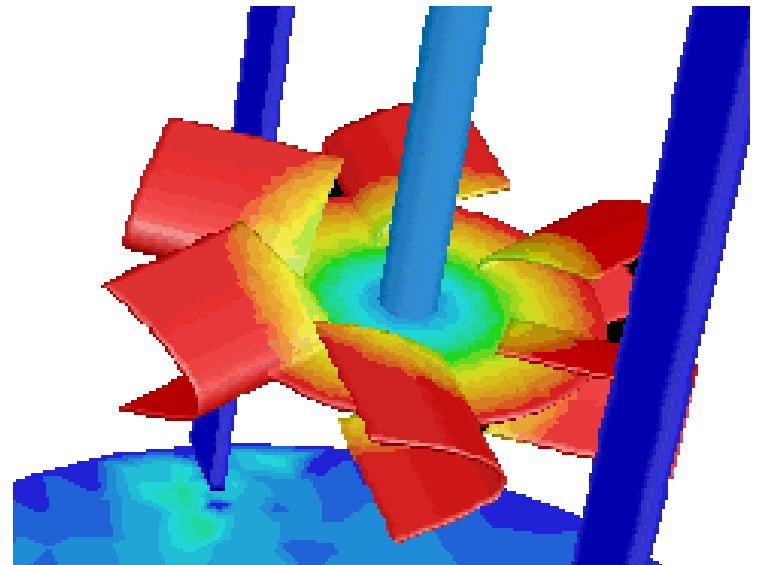


US Patent 5,198,156 (1993)

Gas Dispersion Impellers: 1998

◆ Chemineer BT-6

- Asymmetric blade technology: Gas flow is asymmetric so why would blade shape be symmetric?
- Blade curvature is different on top and bottom and the blade is longer on top.
- Rising gas is captured by longer upper portion of blade and dispersed from inside the deep blades.



BT-6 Performance Characteristics

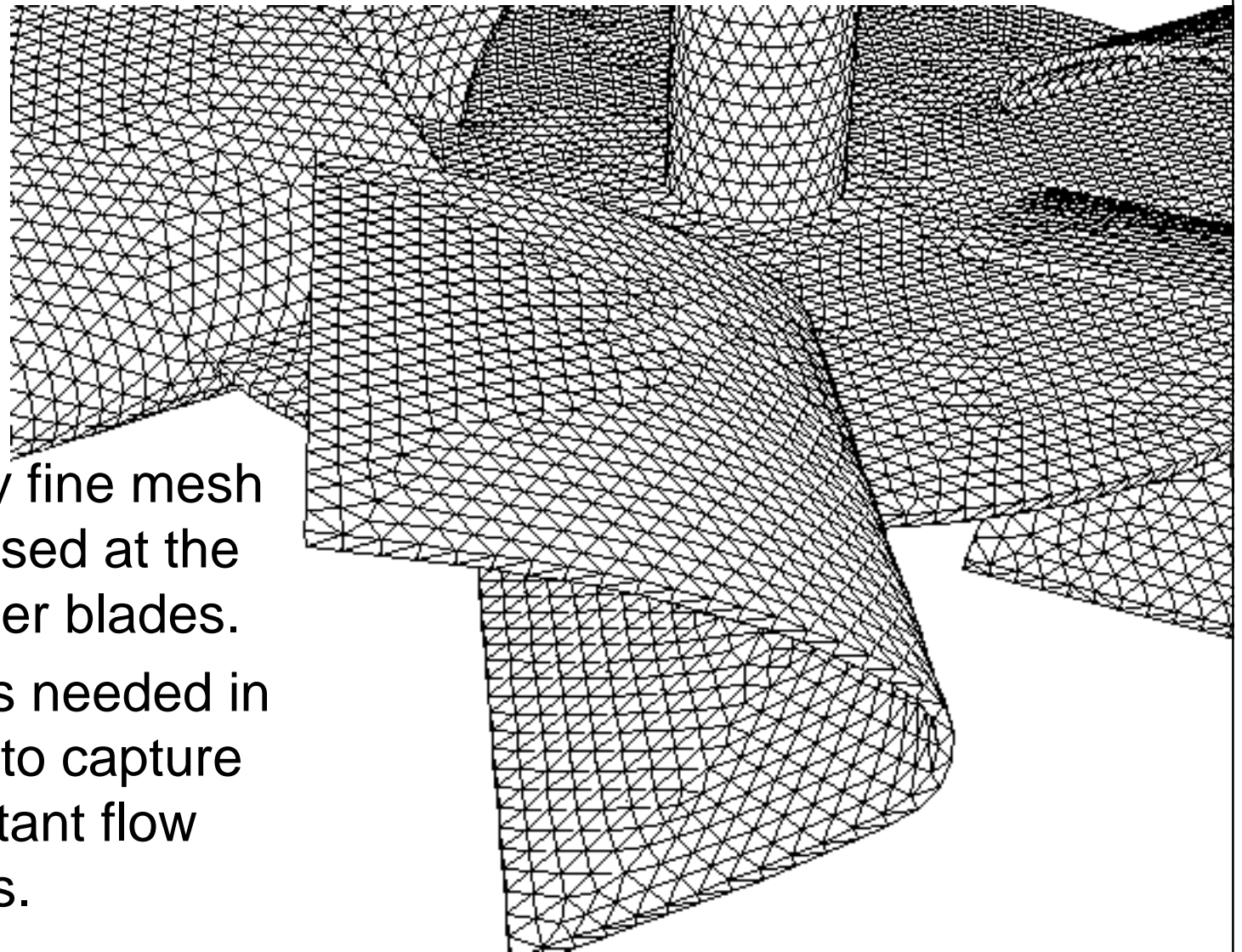
- ◆ Low turbulent power number $Po = 2.3$.
- ◆ Power number is constant for impeller Reynolds numbers greater than 1,000.
- ◆ Flat power draw curve under gassed conditions.
- ◆ Superior gas dispersion capabilities.

Single-Phase Flow Pattern

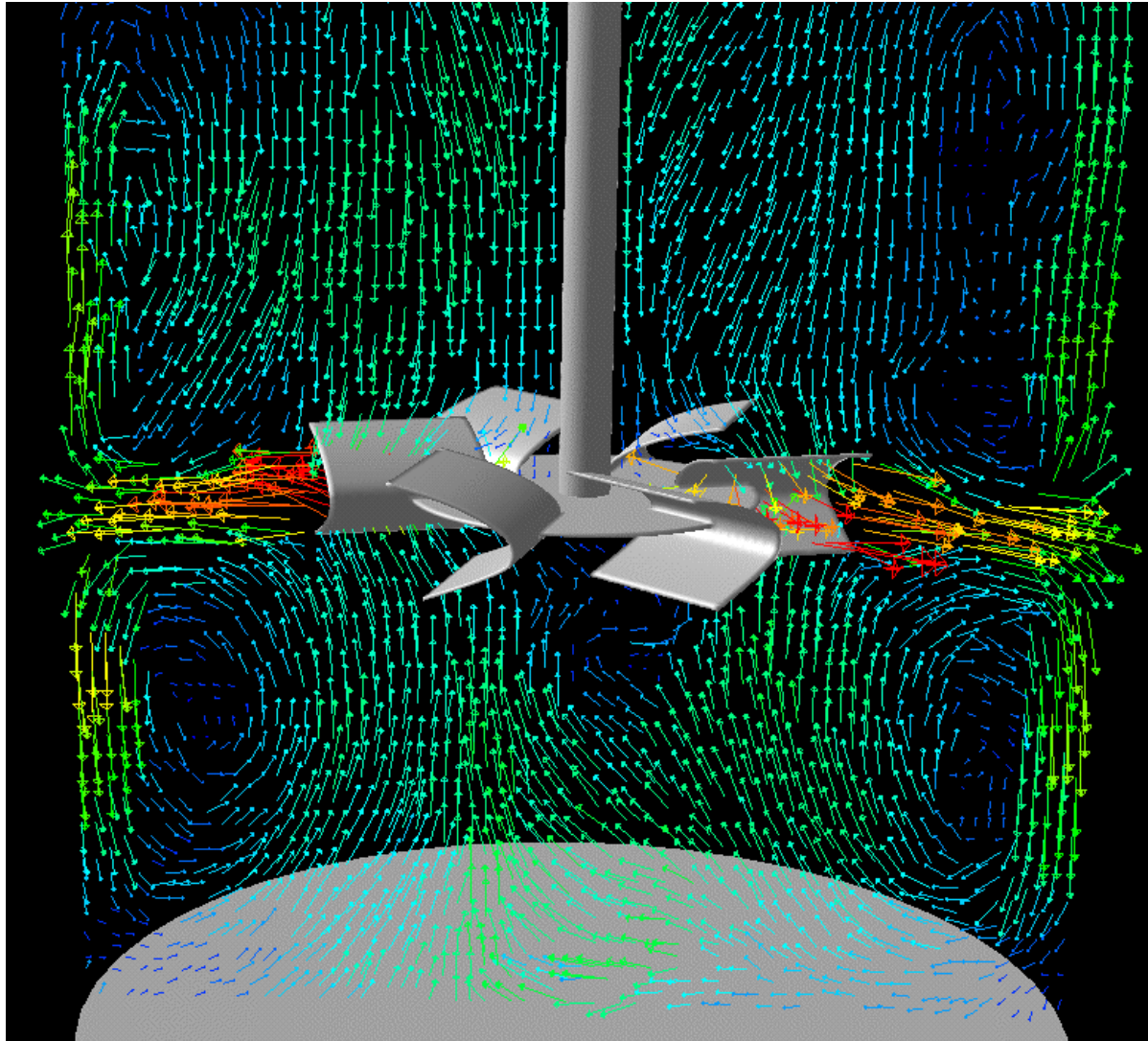
- ◆ Studied extensively using the Fluent 5 unstructured CFD solver.
- ◆ Unstructured tetrahedral meshes with up to 500,000 nodes, created using Gambit.
- ◆ Sliding mesh models.
- ◆ Both RANS and LES turbulence models used.

Impeller Grid

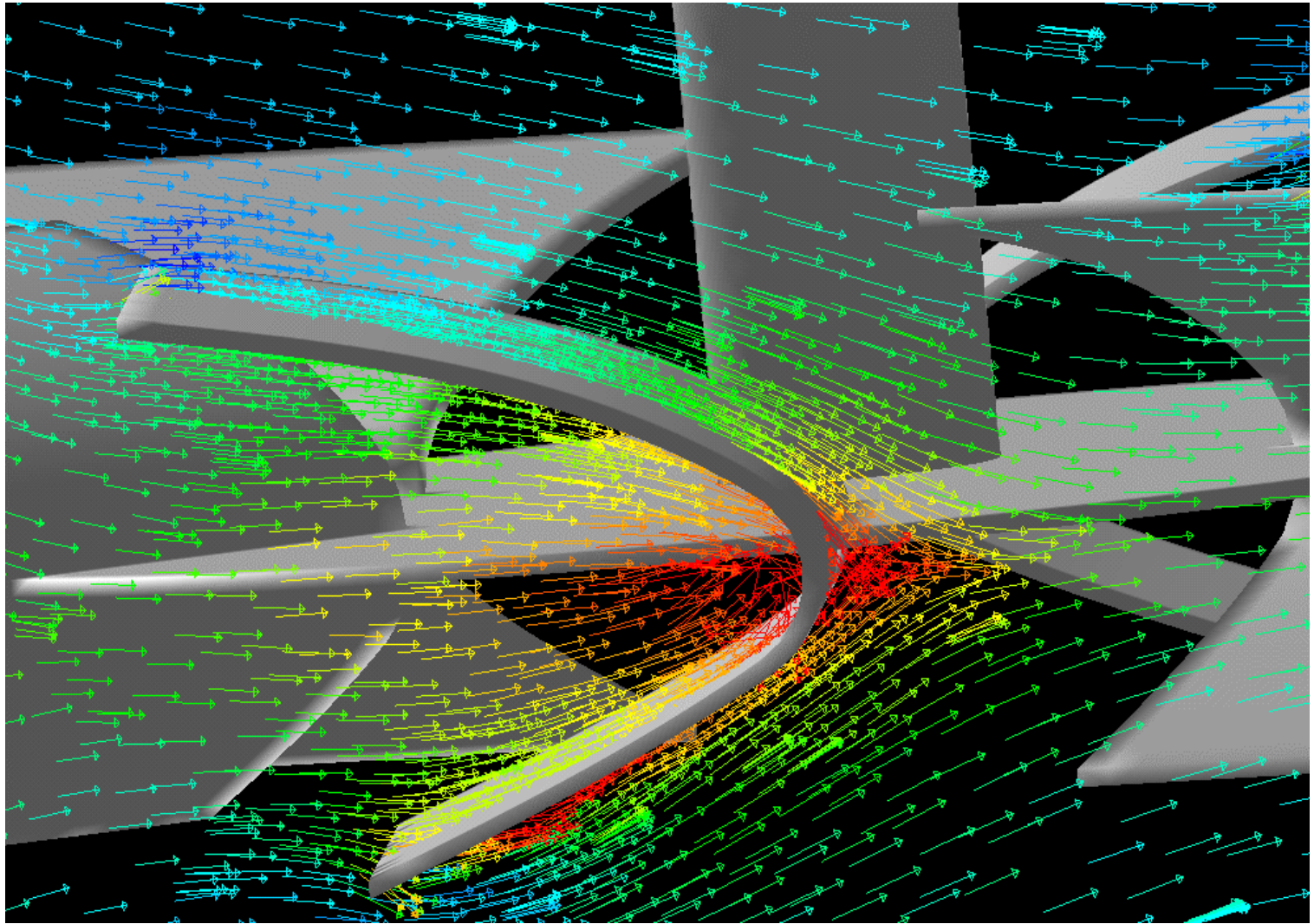
- ◆ A very fine mesh was used at the impeller blades.
- ◆ This is needed in order to capture important flow details.



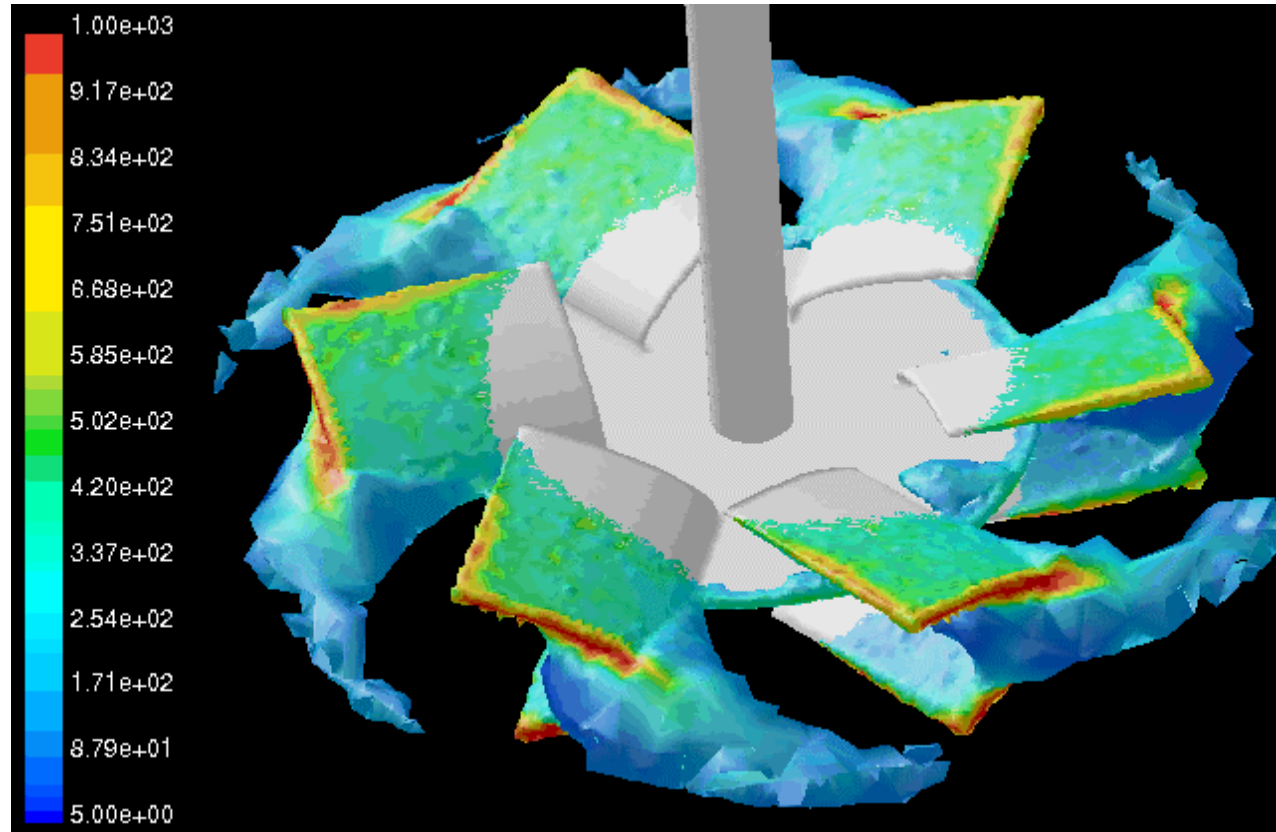
Flow Pattern in Vessel



Flow Around Impeller Blades

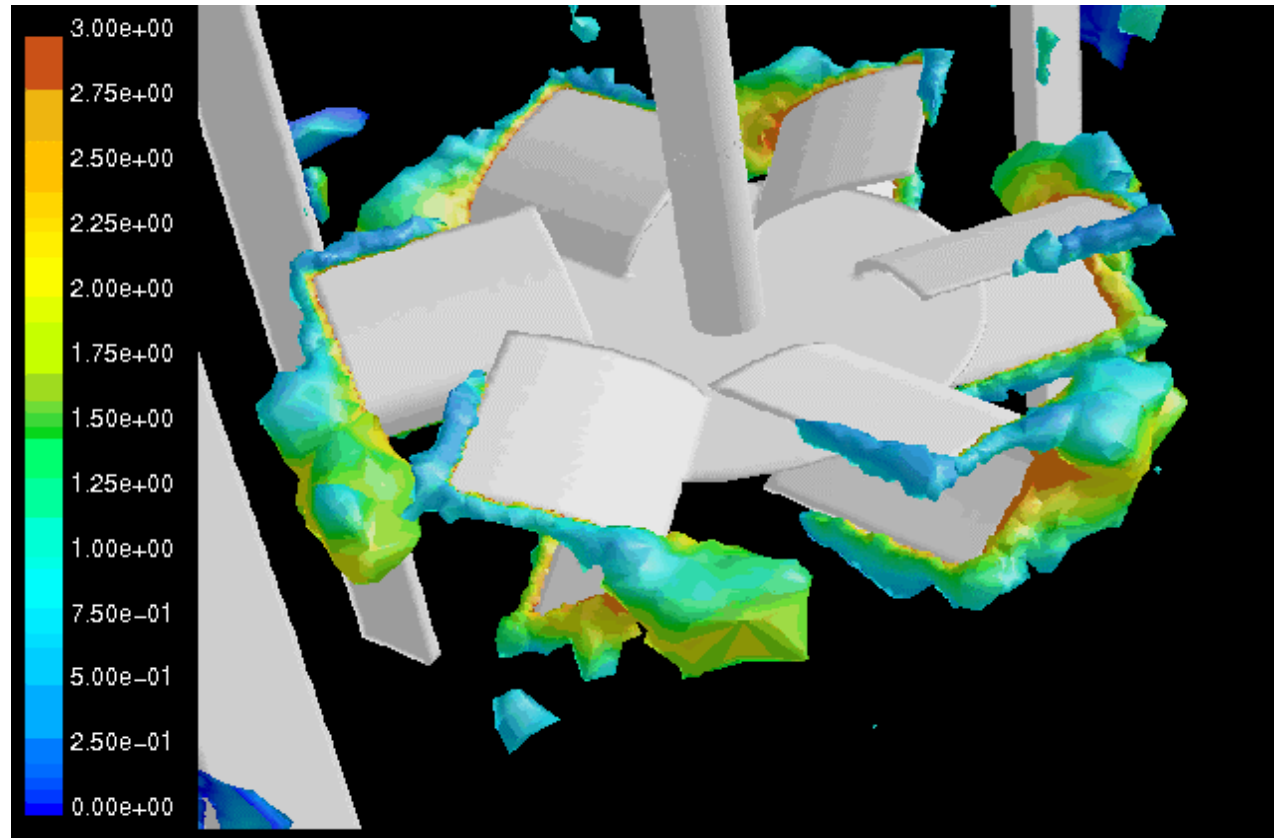


Impeller Flow Pattern



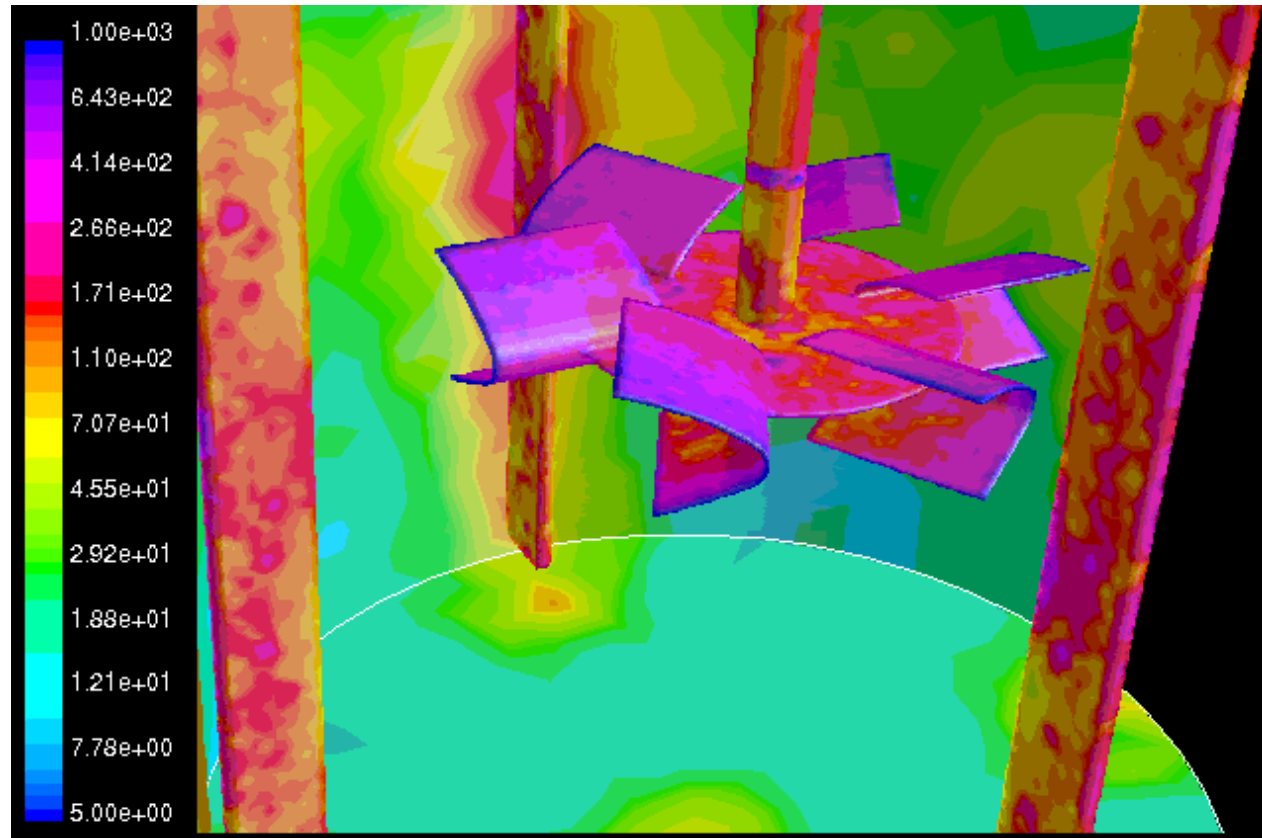
Vorticity magnitude on a surface of constant velocity (1.875 m/s).

Turbulence in Impeller Region



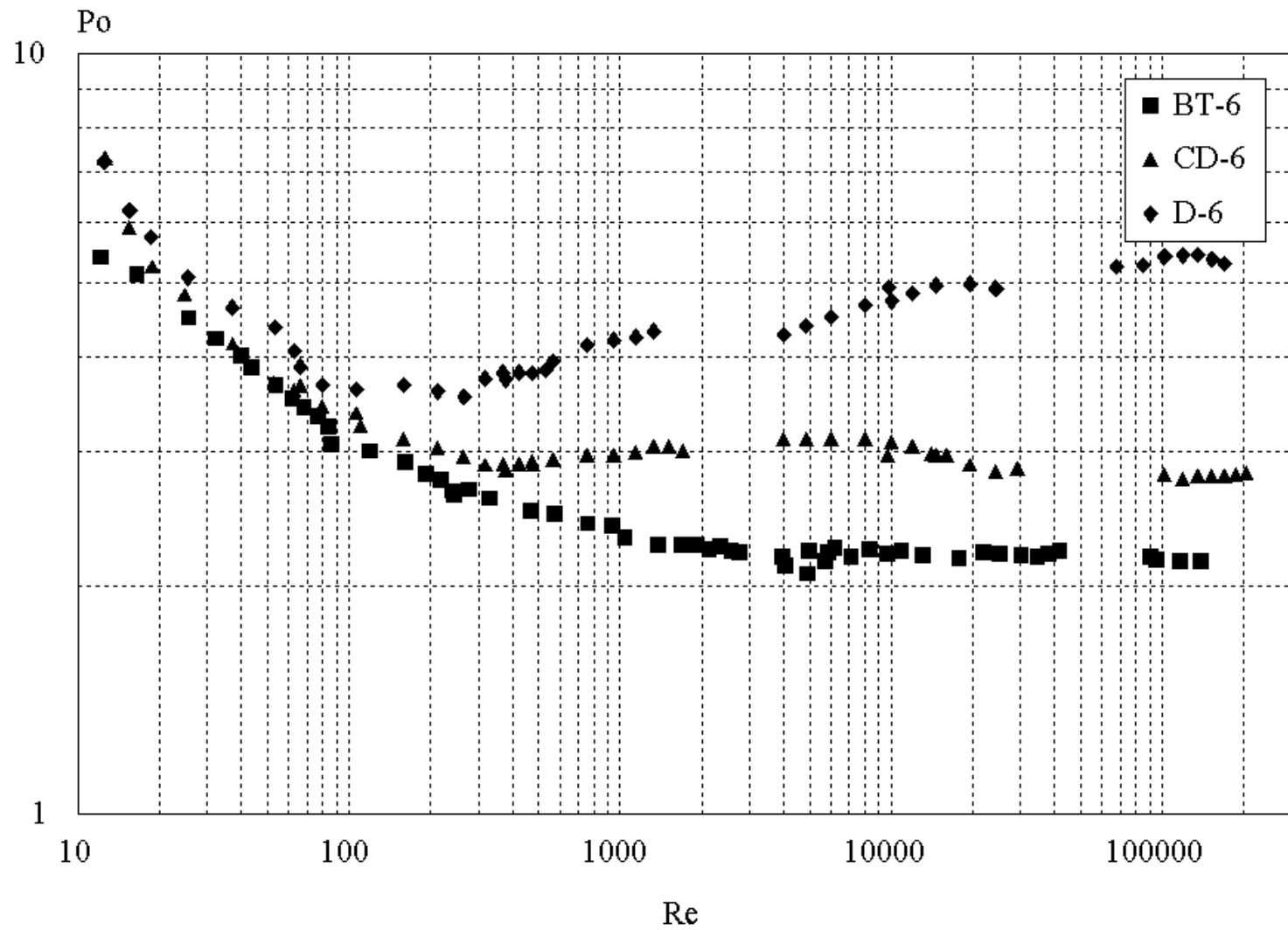
Velocity magnitude on a surface of constant turbulent kinetic energy (0.1 m²/s²).

Vorticity Magnitude

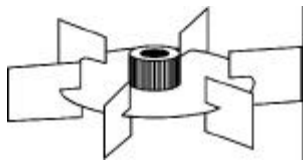


Vorticity magnitude on the impeller, tank wall, and baffles.

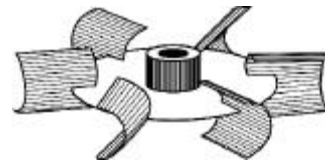
Ungassed Power Number Comparison



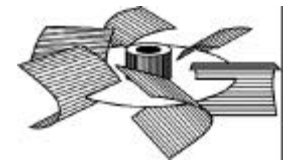
Gas Dispersion Retrofit Comparison



Rushton



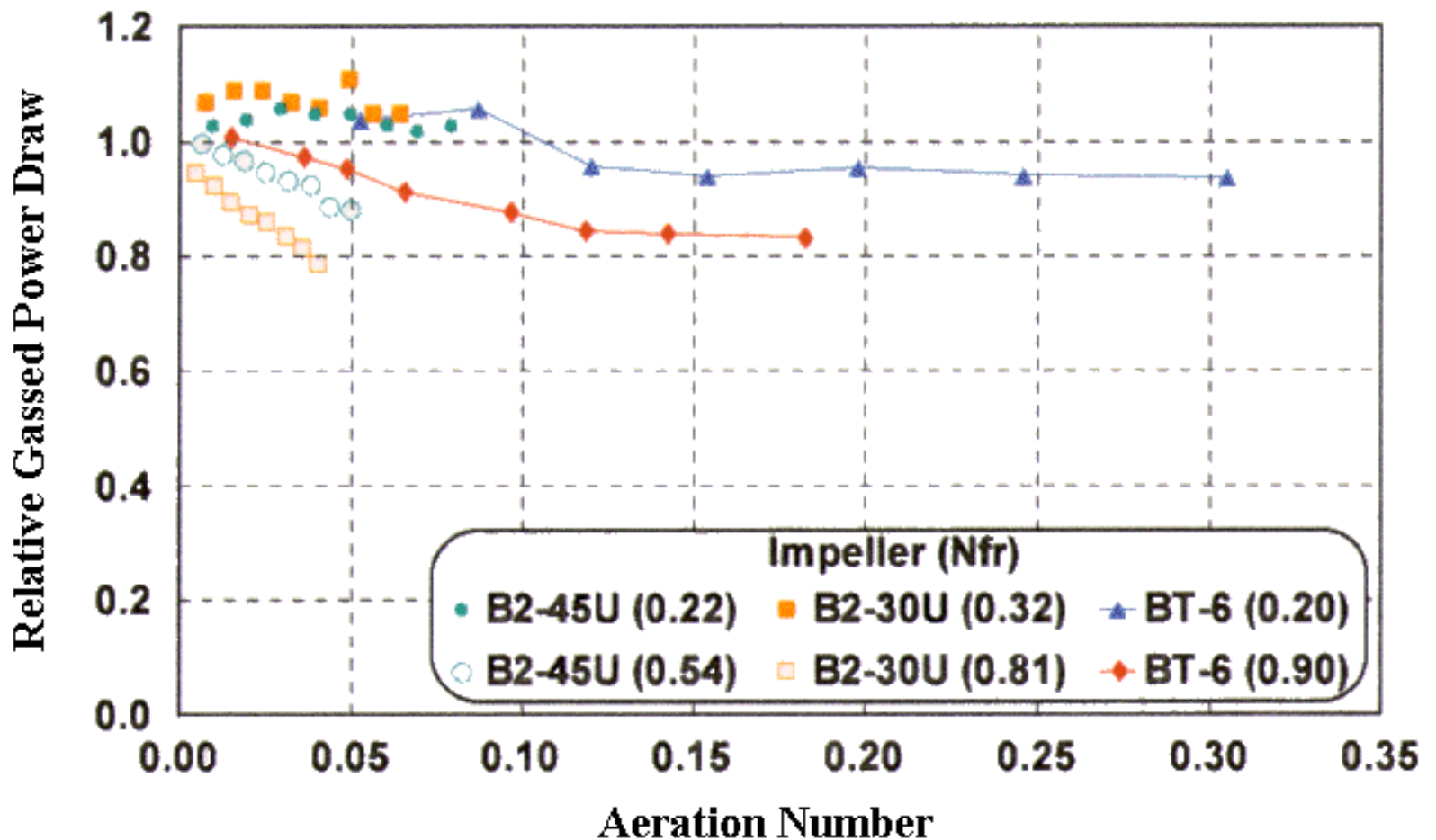
CD-6



BT-6

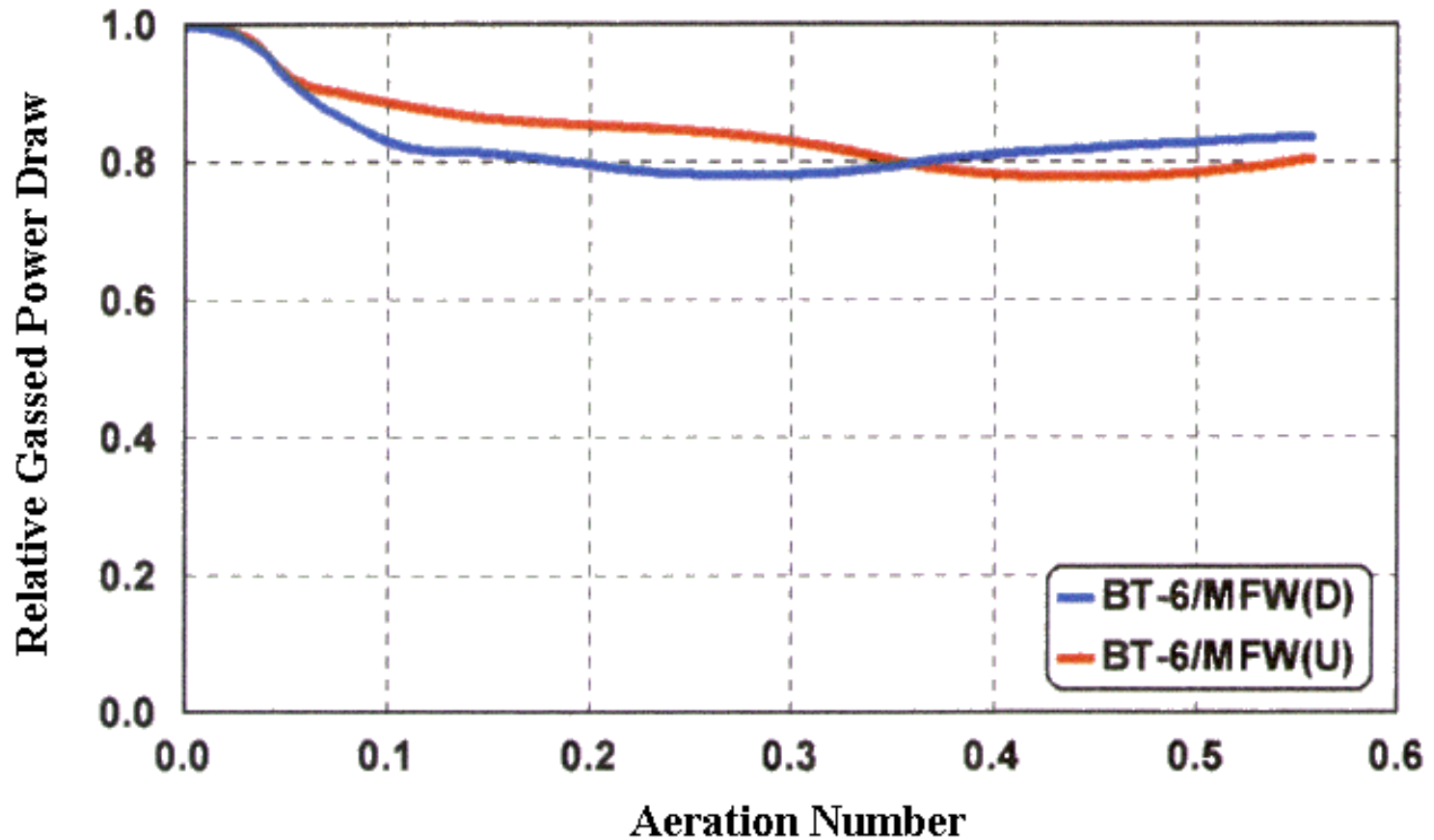
Gas flow rate 13 vvm ($v_{sg}=0.1\text{m/s}$).

Comparison With Up-Pumping Hydrofoil



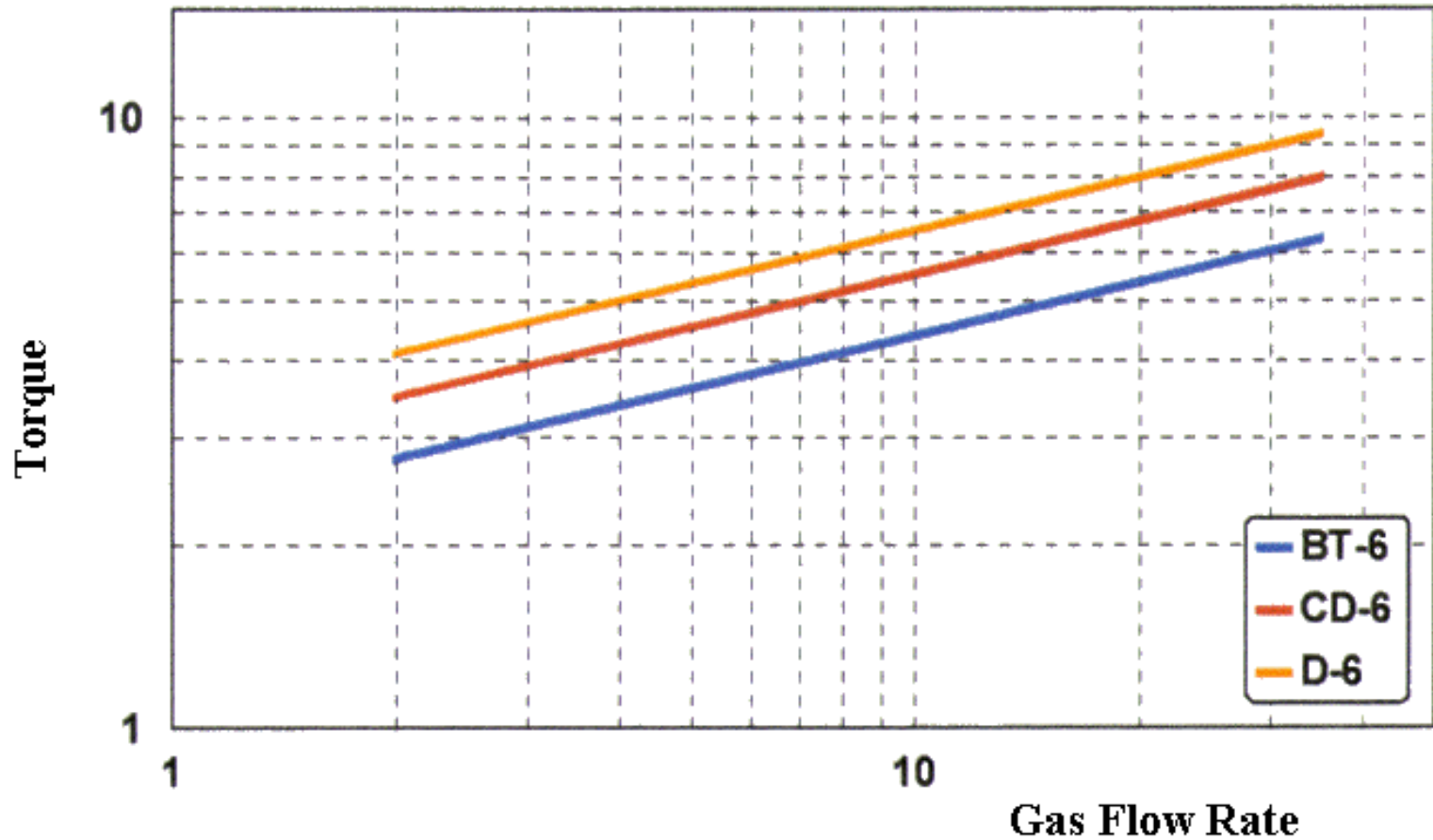
APV-B2 up-pumping wide blade hydrofoil data from:
Hari-Prajitno et al., CJChE, December 1998

BT-6/Maxflo Multiple Impeller Systems

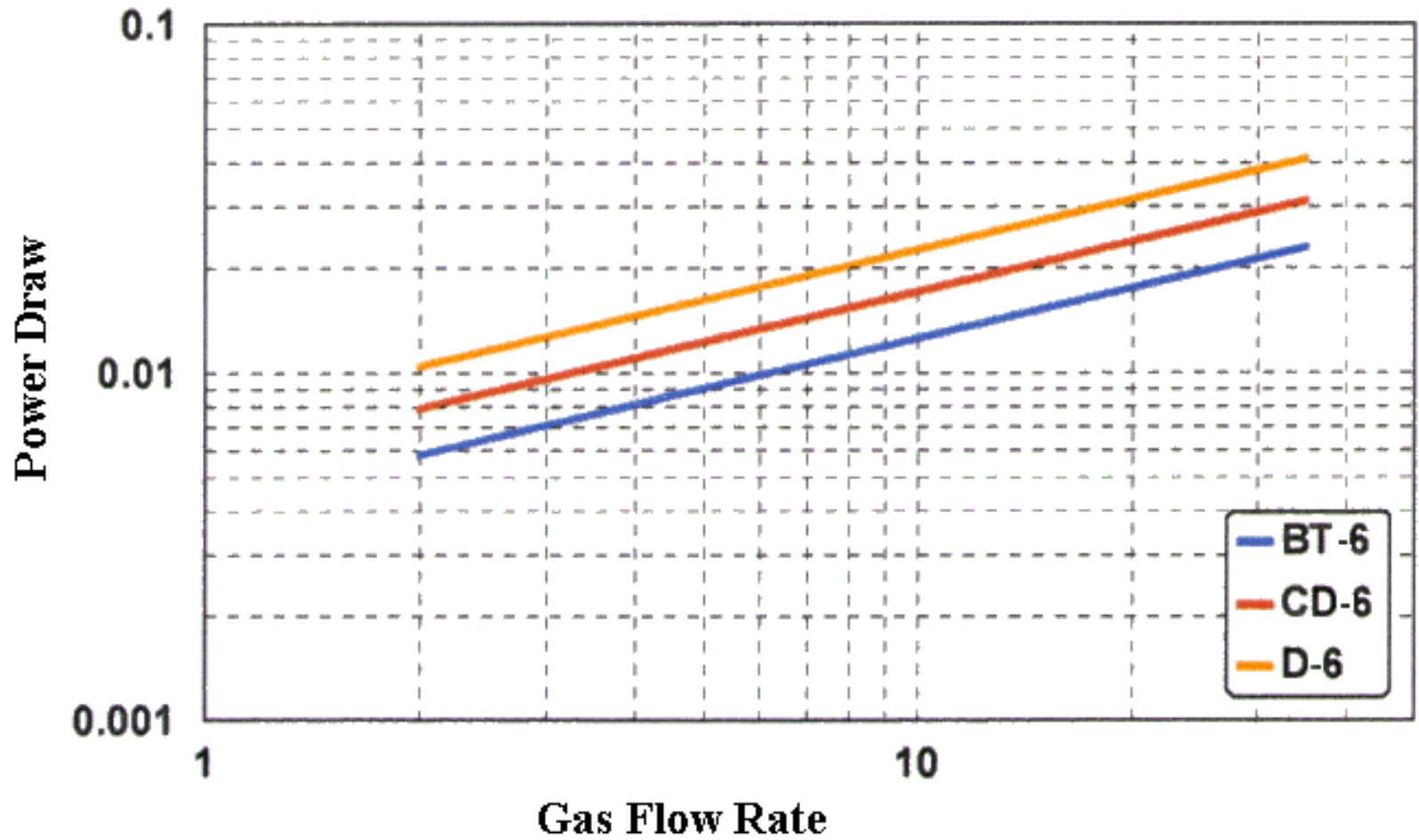


Froude Number = 0.3; D = down pumping; U = up pumping; equal power split)

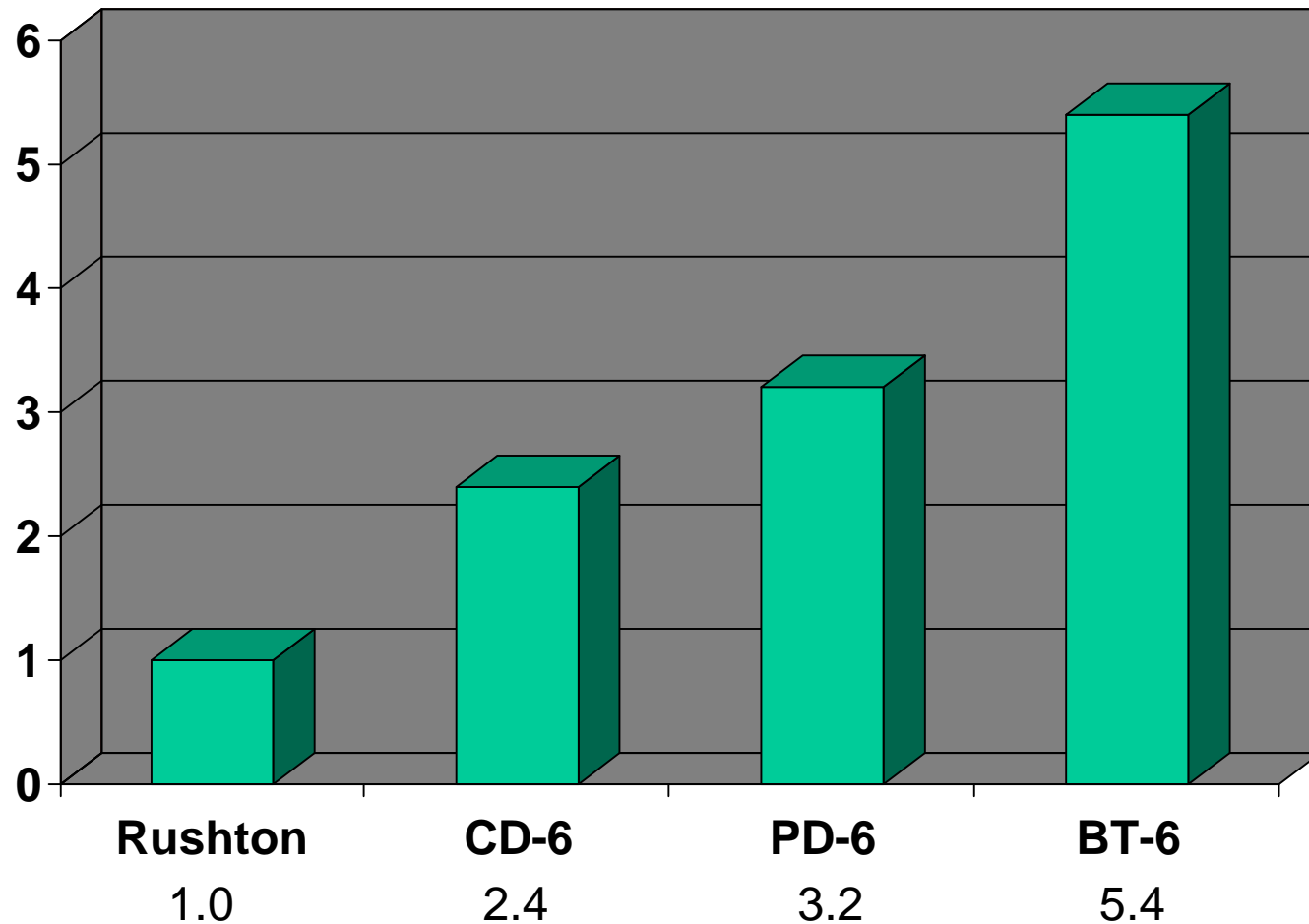
Torque Required for Complete Dispersion



Power Required for Complete Dispersion

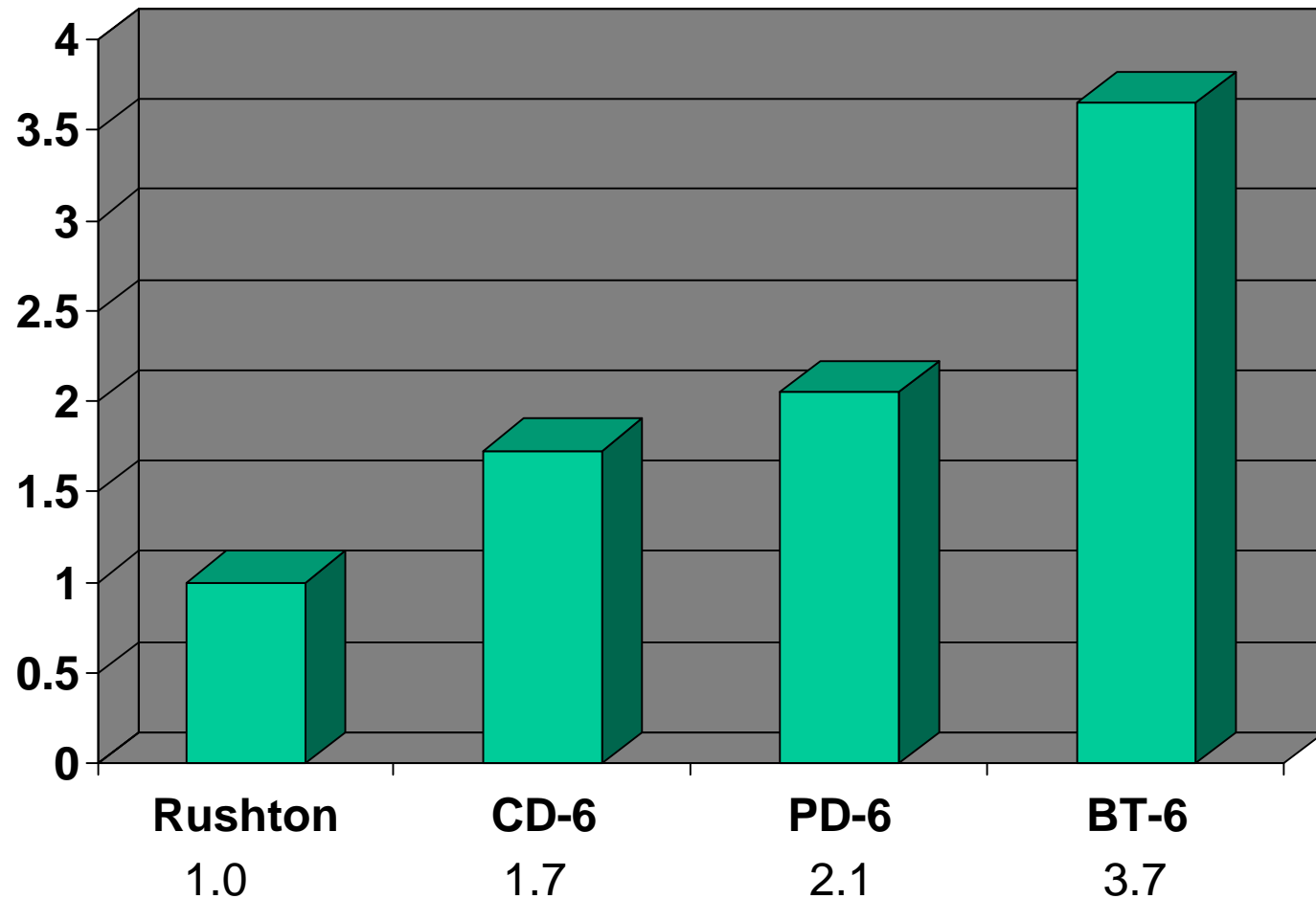


Relative Gas Dispersion Capability



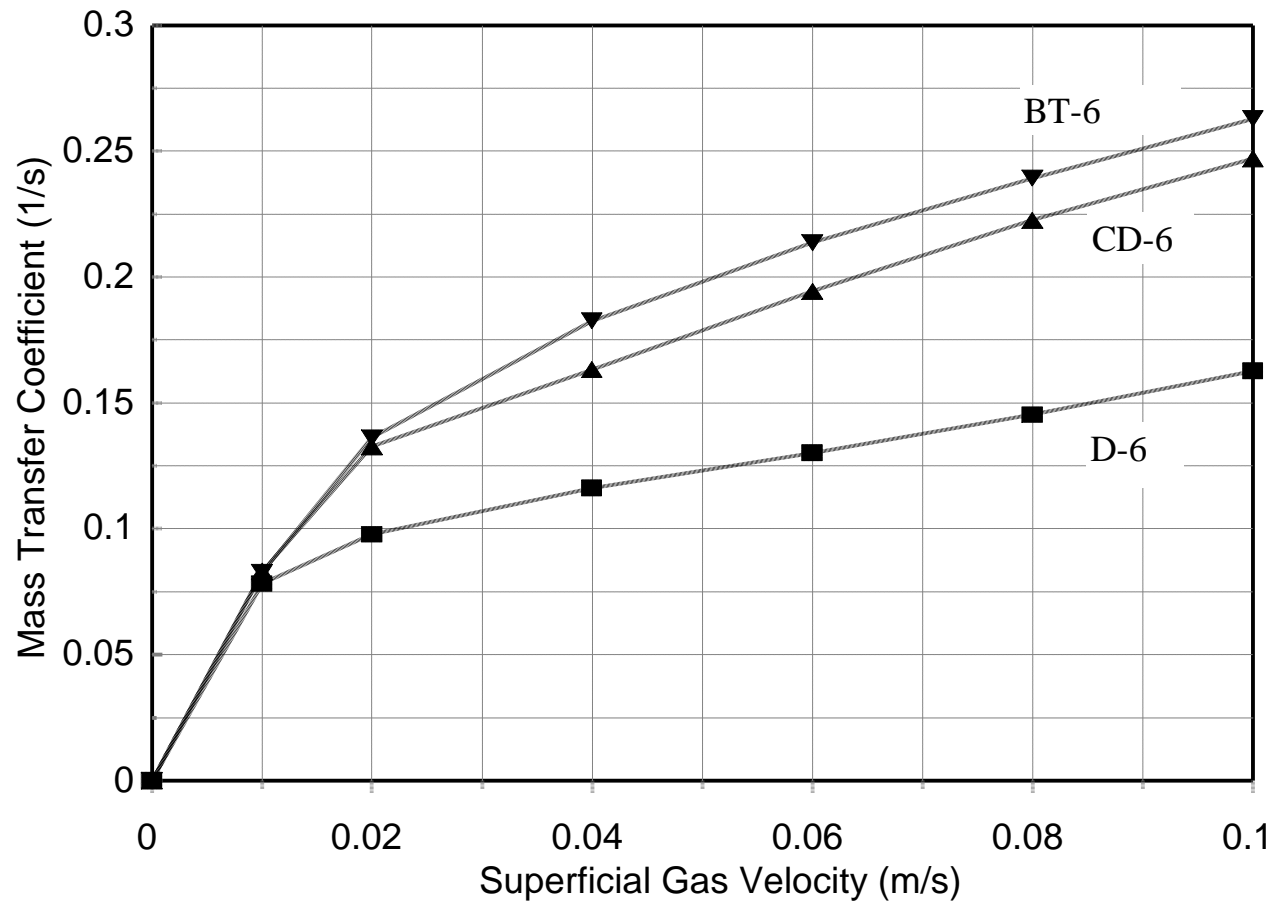
Retrofit comparison. Average of all available data.
The PD-6 is a concave blade impeller with deep symmetric blades.

Relative Gas Dispersion Capability



Constant D/T comparison. Average of all available data.
The PD-6 is a concave blade impeller with deep symmetric blades.

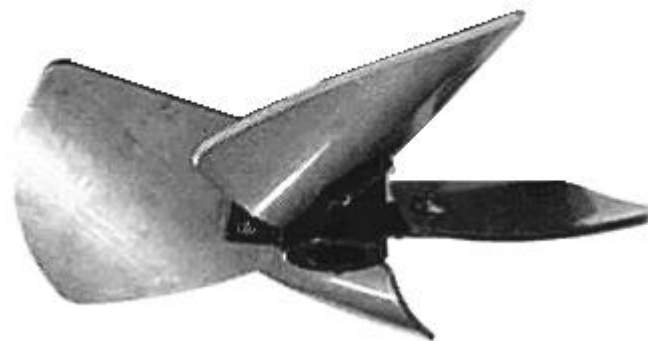
Mass Transfer Coefficient



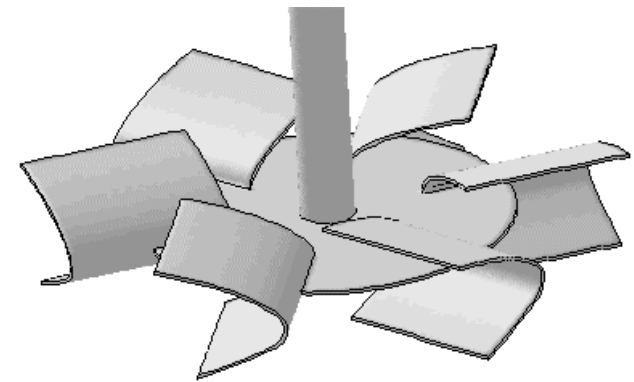
Retrofit comparison.
 k_a at $P_u/V = 2.2 \text{ kW/m}^3$

BT-6 Installation Examples

- ◆ Numerous successful industrial installations:
 - BT-6 with down-pumping HE-3 impellers in 750 kW (1000HP) fermenters.
 - BT-6 with up-pumping Maxflo-Y impellers in 162 kW (215HP) fermenters.
 - Multiple BT-6 impeller systems in gassed staged columns.
 - BT-6/PBT combinations in hydrogenators.



Maxflo-Y



BT-6

Conclusion

- ◆ The Chemineer BT-6 is the latest innovation in radial flow gas dispersion impeller technology.
- ◆ Experimental data was gathered with high gas flow rates in tanks with diameters up to 1.53m:
 - The patented impeller disperses more gas than all other designs.
 - The effect of gas flow rate on power draw is reduced compared to all preceding designs.
- ◆ The flow pattern was studied in detail using the FLUENT 5 unstructured CFD solver.
- ◆ Currently, installations range up to 750kW (1000HP).