2.1 The vessel geometry

The most commonly adopted geometry of a stirred gas-liquid contactor is an upright cylinder, which may have a flat bottom and open top in most mixing laboratory scale vessels, it normally has hemi-elliptical end plates at both ends in plant scale vessels to meet process and structure requirement as process equipment. In mixing studies, the standard configuration as shown in Fig. 2.1-1 has been widely adopted because that a great number of empirical correlations are available to estimate its hydrodynamics as well as other transport characteristics.

Fig. 2.1-1 Standard configuration of a stirred vessel with single Rushton turbine impeller.
For a pilot scale or small process proposes, a jacketed vessel equipped with single or dual impeller vessel is used quite often. Figures 2.1-2, and 3 depict examples of laboratory and pilot plant scale fermenters. For plant scale or large volume gas-liquid contactors, a multiple impellers design with higher aspect ratio as shown in Fig. 2.1-4 is employed to ensure better gas utilization and to reduce the structure cost. The recommended aspect ratio of the cylinder is known as 2.0~3.0, if the ratio exceeds this limit, it may cause vibration of the shaft which is harmful to the driving unit and sealing device. Internal heat exchange elements such as internal coil or baffle coil as shown in Fig. 2.1-4 is often used in large diameter tanks to replace the jacket to meet structure requirement.
2.2 The impeller

The roles of impeller in mechanical stirred gas-liquid contactors are:
(1) To disperse gas into bubbles (discontinuous phase) for creating more interfacial area;
(2) To pump liquid which can generate circulation of fluids to accelerate mixing;
(3) To create high shear and turbulence for promoting micro-mixing or transfer process;
(4) To re-circulate bubbles and extend the residence time of gas within the system.

A proper design and selection of impeller for the system is most critical for the gas-liquid contactors to have good hydrodynamics condition and well gas dispersion performance. Figure 2.2-1 shows the various impellers, which are commonly used in stirred gas-liquid contactors. They are further classified into radial flow (a, b and c) and axial flow (d, e, and f) impellers, depending on flow direction of the discharge stream from the impeller.

![Impellers](image_url)

**Fig. 2.2-1 Different types of impeller used for gas-liquid system**

Among these disk turbines, the straight blade disk turbine (Fig. 2.2-1a Rushton turbine) was acknowledged to be one of the most efficient design for gas dispersion purpose. Because it can generate higher shear and strong trailing vortices, which can disperse the sparged gas without itself becoming flooded. Recent studies indicated that the Scaba turbine (Fig. 2.2-1d, also known as Smith turbine) can offer less power reduction due to aeration and also give higher gas handling capacity at same energy dissipation density. For more viscous liquids, or to accelerate liquid mixing, a pitched blade paddle impeller (as shown in Fig. 2.2-2) is often installed as the upper impeller to obtain higher liquid circulation.
The ideal size of the impeller for gas dispersion impeller is suggested to be one third to one half of the vessel diameter and the lowest impeller is generally located one impeller diameter above the bottom of the vessel. For tall vessels, a multiple impellers arrangement as shown in Fig. 2.1-4 is employed to allow complete dispersion of gas and optimal mixing of components within the system. In this case, the distance between impellers, at least a 1.5 impeller diameter is recommended to acquire a better performance.

The height of the lowest impeller from the bottom (denote as c in Fig. 2.1-1) is depended on the type of the impeller characteristic. For axial flow impeller, such as pitched blade turbine or pitched paddle impeller, at least 0.5D distance from the bottom is needed to have proper flow pattern of fluid flow. For radial flow type impeller, a minimum clearance of 0.5D is required as shown in Fig. 2.2-3.
2.3 The gas sparger

It was often considered that the type of gas sparger can directly affect the initial size of the dispersed bubbles before the mechanism of gas dispersion of the impeller was well understood. Three basic types of gas sparger were used, namely, the porous sparger, the orifice or ring perforated sparger (as shown in Fig. 2.3-1a) and nozzle sparger (as shown in Fig. 2.3-1b, and c). The porous sparger has been used primarily in a non-agitation system, since it has a higher pressure loss, and the holes are tended to be clogged by dirt, this type of sparger is rarely used in large scale equipment. In laboratory or pilot scale gas-liquid contactors, perforated ring sparger is widely applied. The perforated ring is normally arranged below the impeller in the size of approximately three-quarters of the impeller diameter. The diameter of the holes should be at least 2-3 mm to avoid clogging and at least several downward facing larger holes are needed to drain for avoiding blockage of the holes by sediments. For plant scale gas-liquid contactors, the single or multi-nozzle sparger is popularly used because of its simple structure and low pressure loss. The position of the nozzle should be located centrally below the impeller or located at side balanced places with a guided ring. For the cases in which no contamination problem exists, the self-induced type sparger design such as Woldhof type sparger (as shown in Fig. 2.3-1d) is used for sparging gas and also circulating liquid.

![Fig. 2.3 Various types of gas sparger](image)

2.4 Baffle

An unbaffled vessel containing low viscosity liquid tends to swirl and generates undesirable vortex as shown in Fig. 2.4-1a. This undesirable swirling flow causes not only severe reduction in mixing efficiency, but also leads the dispersed bubbles to swirl to center core due to its centrifugal effect. These actions cause a severe surface aeration for the unbaffled system. To eliminate this swirling flow in a cylindrical vessel, installation of four
0.08T-0.1T width baffles as shown in Fig. 2.4-1b is recommended. The baffles promote up and down flow, which accelerates the liquid mixing of the entire system, however, it also increases the power drawn by impellers. The term, “complete baffled” refers to the installation of proper number of baffles such that the power consumption of impeller reaches at plateau or a maximum level. For cylindrical vessel which its diameter is less than 3 m, four baffles with 0.08T-0.1T width are sufficient to give a complete baffled condition. For larger diameter vessel, more than four baffles may be required to attain a satisfied condition. Figure 2.4-2 illustrates various ways to install the baffles. Vertical baffles at wall as shown in Fig. 2.4-2a is very common for low or moderate low viscosity liquids. To prevent the existence of the stagnant region behind the baffles, baffles can be set away a clearance from tank wall as shown in Fig. 2.4-2b. An inclined baffle (as shown in Fig. 2.4-2c) is adopted for higher viscous liquid cases. The height of baffle is usually mostly top to bottom, but it may submerges beneath the free surface around 0.1T as shown in Fig. 2.4-3, if the process needs some degree of swirling induction.

Fig. 2.4-1 Flow patterns in baffled and unaffled stirred vessels
For gas-liquid systems height and location of the baffles might severely affect the motion and distribution of the dispersed bubbles within the vessel as shown in Fig. 2.4.4.
In a plant scale vessels, the baffles also may serve as heat transfer surface as Fig. 2.4-5. However, one should bear in mind that excess baffling may cause localizing flow which results in poor mixing of the system.

2.5 Stablizing devices

To prevent vibration of the rotating shaft which causes extra loading on supporting bearing and sealing, bottom bearing as shown in Fig. 2.5-1 is oftlen recommended. In some cases, stablizing fin or ring as shown in Fig. 2.5-2 is attached beneath the impeller. By choosing the mass of the ring or fins, one can shift the critical rotational speed which can prevent further damage of supporting bearing and sealing.

Fig. 2.5-1 End bearing

(a) end bearing

(b) stabilizer ring

(c) stabilizer fin

Fig. 2.5-2 Type of Stabilizer fins