GAS SCRUBBING: MAKE A RIGHT CHOICE

"Reactor gas scrubbing is not merely about spraying suitable liquid in a tower or two, but requires careful consideration of type and combination of scrubbers, heat removal and material of construction. The PCB norms on air pollution are very stringent and challenging when it comes to scrubbing pure gas streams vented from the reactors. 99.9% of pure gas scrubbed is a million ppm before and after scrubbing! Nevertheless, a high removal efficiency is essential to make further dilution by air possible. Looking at scrubbing efficiencies of more than 99% requires expertise and not just the "neighbour do-we do" approach."

The most commonly encountered reactor vent gases in chemical process industries are HCl, Cl_2, SO_2, SO_3, H_2S, NH_3, HBr, NOx and Acid Mists, which either come out individually or as mixture, but generally without much inert gases or air. In aqueous solution based reaction or processes with ice or steam charging, water vapours to the extent of saturation limits may be encountered. The emission limits of most of these gases are less than 50 mg/Nm^3, meaning that for every Normal (At 25°C) cubic meter of air, only specified "milligram" gas can be emitted.

In terms of volumetric PPM (parts per million) levels, the standards get lowered by dividing mg/Nm3 values by a factor equivalent to Mol. Wt./24.5. In Gujarat, for example, GPCB emission limits for HCl, Cl_2 and SO_2 are 20 mg/Nm^3 (13.4 PPM), 9 mg/Nm^3 (3.1 PPM) and 40 mg/Nm^3 (15.3 PPM) resp.

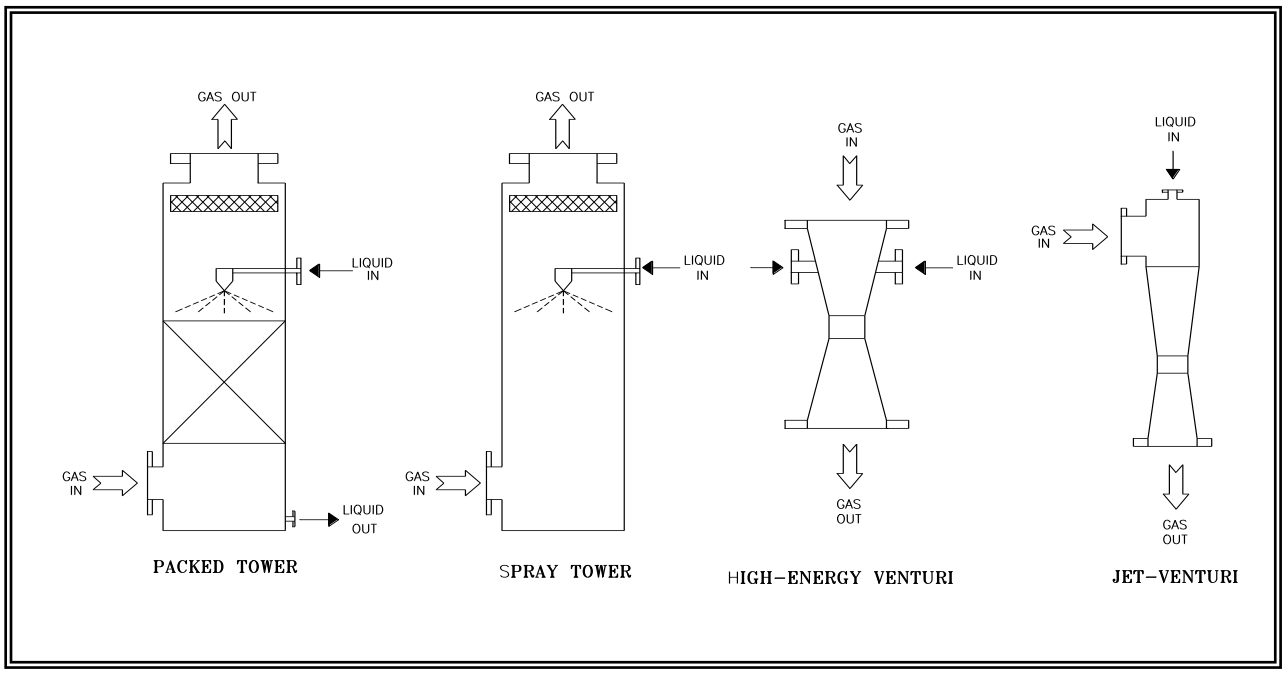
A pure gas stream vented out of the reactor would be 10^6 PPM in concentration, assuming there is no water vapour considering an example of 100 kg/hr pure HCl emission, a scrubbing system with 99.9% efficiency will still have 0.1 kg/hr pure HCl which would be 10^6 PPM gas at outlet, ignoring water-vapours. To meet the standards of 20 mg/Nm^3, 5000 Nm^3/hr air is still required to dilute 0.1 kg/hr HCl.

This example indicates necessity of high removal efficiency to meet the norms. With 90% efficiency, dilution air requirement would be 500000 Nm^3/hr and for 99% efficiency, it would be 50000 Nm^3/hr, both impractical to provide.

SCRUBBING EQUIPMENT:

The most commonly used scrubbers are Packed Towers, Spray Towers, Falling Film Absorbers and Venturi Scrubbers, while some proprietary variants are also available. All of these work on the principle of increased mass-transfer by increasing the interactive surface area between gas and liquid. Specially designed packings like Raschig Rings, Pall Rings and Tellerettes are dumped randomly in Packed Towers to promote formation of liquid film as it trickles down the tower. In Falling Film Absorbers, the equipment operates at a designed circulation rate to promote formation of liquid film in vertical tubes. In Spray Towers and Venturi Scrubbers, the interactive surface area is increased by spraying the liquid in the form

of droplets. Of all these, Packed Towers and Venturi Scrubbers are discussed in details for their high efficiency and unique advantages respectively in versatile applications.



Normally, all Packed Towers for pure gas/mixture scrubbing applications are designed for counter current operation with liquid sprayed on up-flowing gas. Provision of specially designed packings with high specific surface area (surface area per unit volume) gives very high removal efficiencies in practical tower heights. For the same performance, a spray tower system would require 2 –4 times the height or multiple stages.

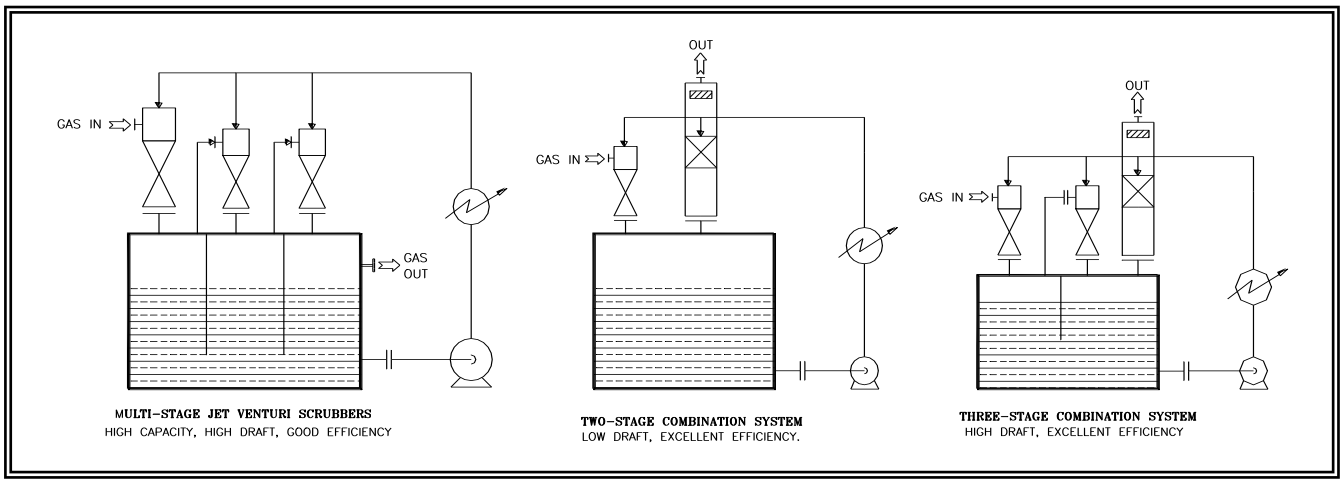
Key design parameters in case of a Packed Tower are the gas and liquid velocities through the tower and the percent flooding corresponding to these velocities. The tower diameter is determined based on gas and liquid rates and type and size of packings since the gas-liquid velocities are critical, Packed Towers have limitation on turn-down possibilities. Generally, gas flow variation in a Packed Tower should not be more than 1:4. For pure gas streams with a design removal efficiency of 99%, this variation is 1:100 between bottom and top of the tower. In such cases, the actual removal efficiency reduces drastically and part of the gas escapes without coming in contact with liquid. Multi-stage Tower Scrubber configuration minimizes the effect of gas flow variation.

Venturi Scrubbers

The conventional high-energy venturi scrubbers which utilize gas velocities to shear the water spray into fine droplets are suitable for scrubbing particulates but exhibit poor gas removal efficiencies. These type generally operate at a lower liquid-to-gas ratio and high pressure drops. High-energy Venturi Scrubbers are not suitable for pure gas scrubbing.

A variant of conventional Venturi Scrubber with principles of vacuum ejectors has been developed and called Jet-Venturi or Ejector-Venturi Scrubber. This is an excellent device for scrubbing reactor gases and performs dual function of gas scrubbing and creating necessary draft to handle the system pressure drop. This features helps to eliminate blowers which are highly maintenance-prone equipments in corrosive environment. The Jet-Venturi operates at very high liquid-to-gas ratio and the liquid is sprayed through spray nozzles creating a special spray pattern.

Jet-Venturi Scrubbers give moderate removal efficiencies and serve best as initial stages of a multi-stage scrubbing system. A three – stage system with only Jet-Venturi Scrubbers can give more than 95% removal efficiency for gases like HCl, HBr and SO_2 using dilute caustic solution as liquid. For higher efficiency, a single Packed Tower as the last stage is generally adequate. Since there is no turn-down limitation in gas flow entering the Jet-Venturies the performance is not affected much. Initial stage Jet-Venturies also serve as a cushion for subsequent Packed Tower in terms of dampening gas flow rate fluctuations.



SCRUBBING EFFICIENCIES FOR VARIOUS EQUIPMENT:

Sr	Gas	Liquid	Single Stage Jet Venturi	Single Stage Packed Tower	Multi Stage Jet Venturi	Multi Stage Combination
1.	HCl	Water	80-85 %	95% +	90% +	99.9%+
		Caustic	85-90%	95% +	90-95%	99.9%+
2.	SO_2 SO_3 HBr	Caustic	80-85%	95% +	90-95%	99.9%+
3.	NH_3	Water	60-70%	95% +	70-80%	99.9% +
4.	NO_X	Water	40-60%	50-60%	50-60%	80% +(With Air)
		Caustic	30-40%	40-50%	40-50%	70% + (With Air)

HEAT REMOVAL:

Most of the gas absorption and neutralization processes are highly exothermic in nature. Heat of reaction is quite significant for scrubbing applications involving pure or rich gas streams. Heat removal is generally done by providing a cooler in liquid recirculation line. For clear liquids, plate-type heat exchangers are

most economical and are available in SS-316 and titanium. For HCl Recovery applications, graphite block-type heat exchangers are a good choice, while glass shell & tube heat exchangers can also be used.

HEAT GENERATION ON SCRUBBING:

Gas – Liquid	Heat Generation kcal/kg Gas	Gas- Liquid	Heat Generation kcal/kg Gas
HCl – Water	490	H_2S – Caustic	375
HCl – Caustic	850	HF– Caustic	1350
SO_2 – Caustic	580	NH_3 – Water	490
SO_2 – Water	160	NH_3 – Sulphuric	1200
SO_2 – Soda Ash	170	NO_2 – Water	210
Cl2 – Caustic	350	NO_2 – Caustic	400

MATERIAL OF CONSTRUCTION:

Compatibility of equipment material with the gas mixture, scrubbing liquid and products of absorption and neutralization is a key factor determining life and performance of the equipment. HDPE is most widely used for Towers and Circulation Tanks but has lower temperature resistance and is highly prone to leaking at joints because of difference in structure of moulded plastic and welded plastic. Fibreglass Reinforced Plastic (FRP) equipment have excellent strength but most of the resins are susceptible to attack by solvents, even in traces. Poly Propylene with fibreglass backing solves the problem of solvent attack while providing required strength. SS316L can be used for gases for SO_2, H_2S and NH_3. Mild steel can be used for NH_3 – Water System. Graphite is an excellent material for HCl recovery applications.

Material selection should be done based on corrosion charts supplied by material manufacturers. Material of pumps, heat-exchangers and piping should also be selected carefully based on scrubbing liquid and products of scrubbing.