Design recommendation for seawater flue gas desulfurization scrubber

The data below summarizes our revised results and design recommendations for this seawater FGD scrubbing application based on a warmer water temperature of 35°C. We should always design for the maximum water temperature (the warmest it will ever be) since the warmer the water, the less SO_2 vapor will dissolve in each liter, other things being equal. Because of the higher water flow rate needed at the warmer temperature, I had to increase the column diameter slightly. See design below.

DESIGN BASIS	
Dry Gas Mass Flow Rate:	600.813 Nm^3/s
Water Vapor Content:	11.725% (v/v)
Total Gas Flow Rate:	923.586 Am^3/s at 3.7 kPag
Gas Temperature:	80°C
Desired Outlet SOx Concentration:	< 97 g/s
DESIGN RECOMMENDATIONS	
Scrubbing Liquid:	Filtered Seawater once-through at 35°C
Seawater Total Alkalinity (as $CaCO_3$):	116.6 mg/L (2.332 mequiv/L)
Tower Diameter:	**20500 mm**
Packing Height:	4000 mm
Packing Type:	Q-PAC (glass-filled PP)
Mist Eliminator:	500 mm of #2 NUPAC
Demister Pressure Drop:	0.8 mbar
SO_2 Removal Efficiency:	> 96%
CALCULATED PERFORMANCE	
Sea Water Flow Rate:	**26,000 m^3/h**
Clean Packing Pressure Drop:	7.8 mbar
Liquid Hold-up:	10.10%
Approach to Flooding:	51% (at bottom)
Outlet Water Temperature:	39.2°C
Outlet Water pH:	~2.68
Outlet Gas Temperature:	35°C
Outlet Gas Flow Rate:	2,296,193 Nm^3/h

NOTE: The seawater flow rates were calculated based on water having a minimum seawater alkalinity of 116.6 mg/L (as $CaCO_3$) at 35°C. If the alkalinity is sometimes lower, the liquid flow will have to be increased to obtain the same SO_2 removal and vice versa. It would be prudent to design the system with some additional pump capacity in order to provide a margin of safety. (Pumps this large are probably going to need variable-speed drives, anyway.) The high flow capacity of Q-PAC will allow operators to turn up the water flow if needed without excessive pressure drop.

We expect very little sulfur trioxide (SO_3) to be removed by the scrubber. Sulfur trioxide will react with water vapor to form an aerosol, or fog, of sulfuric acid droplets. Those droplets of concentrated sulfuric acid will grow by absorbing more water vapor, especially as the gas gets completely saturated with water vapor in the scrubber. Some of the largest acid aerosol droplets will get knocked out in the scrubber, but we can't predict how much. It will depend on the aerosol droplet size distribution, which will be affected by the type of quench used and the distance (duct residence time) between the quench and the scrubber.

Aerosol droplets in the submicron size range cannot be removed by any random packing. Some customers maintain high removal efficiencies by capturing 99% of particles greater than 2 microns in size with a high-density composite mesh pad mist eliminator. The main drawback is that this mesh pad will add about 75~100 mm-H_2O to the pressure drop. Some customers choose to start with a dry layer (500mm) of #2 NUPAC as a demister with the ability to upgrade to a composite mesh pad if it proves necessary.

The Q-PAC media should be made of glass-filled polypropylene to provide adequate mechanical strength at elevated temperatures. The scrubber should be designed with a control system that prevents operators from starting the hot gas flow unless the packing is fully wetted and the gas is fully quenched. Under these conditions it will take approximately 20 seconds for water to flow through 4000 mm of packing. The control system should also automatically divert hot gas from the scrubber in the event of a loss of water flow.

The pressure gradient, compressive load and approach to flooding listed above refer to clean packing. Any tower with a potential for fouling by suspended solids that pass through the seawater strainers should be designed for a relatively low pressure drop. We have to expect that the pressure drop will creep up over time, thereby increasing the packing weight, pressure drop, and liquid holdup. Q-PAC with its high void fraction and high resistance to plugging will minimize the tendency for fouling.

Distribution of gas and liquid flows inside the scrubbing towers will be critically important. For example, if 60% of the gas flows up one half of the packed section while 40% flows up the other half, most of the gas will be scrubbed at an L/G ratio lower than calculated, and so the SO_2 removal from that portion of the gas will be significantly lower. We recommend using turning vanes or an extended inlet duct with an elbow to help evenly distribute the air.

It will also be important to use multi-beam gas-injection packing supports with high open area, which can drain a large amount of liquid without obstructing the gas flow. An ordinary bar-grid support would force gas and liquid to compete for the available open area, so a lot of liquid would tend to be held up on the horizontal grid surface. The packing support might become a "choke point"or "bottleneck",where flooding could occur even though the gas velocity is not high enough to flood the packing. The packing support should also be designed with a generous safety factor. Many of Lantec's customers routinely design packing supports for a worst-case liquid holdup of 0.20 m^3/m^3, even though the actual holdup is expected to be lower than that.

The warm seawater leaving these scrubbers will be extremely hazardous. Wherever it comes in contact with air, it can emit SO_2 in potentially lethal concentrations. Please make sure that the necessary safety precautions are taken for handling the effluent. The scrubber wastewater should be diluted with cooler, more alkaline water before it comes in contact with air and returned to the ocean.