Stacks Design Considerations

Composites USA
A Critical Process Systems Company

Proper stack design begins with an understanding of the process exhaust stream (volume, corrosiveness, temperature, flammability), local environmental requirements (height requirements, sampling requirements), local and regional building code requirements (height requirements, wind, seismic, snow loads), and desired geometry (gas entry, base configuration, lateral support).

The strength to weight and corrosion resistance of fiberglass reinforced plastic make it an ideal material of construction up to the temperature limits of the resin (250 – 350^{o}F depending on resin and service).

In general, the stack must first be designed for the process, and then designed mechanically and for accessory requirements. The process will dictate location and size. The mechanical analysis will take into account loads contributed by the stack dead weight, seismic and wind loads, buckling and bending moments, guy wire compression and temperature gradients to name a few. A brief discussion follows:

Location: The location and height of the stack is greatly influenced by the location, size, and configuration of the surrounding buildings and topography.

Airflow over a building creates a positive pressure zone on the upstream side of the building and a negative pressure zone or cavity on the roof and downstream side. Although the contour of these zones remains relatively stable as the wind velocity changes, the contour zone and cavity envelopes can be erratic in shape due to wind turbulence.

High stack discharge velocity and temperature increase flume height and thus effective stack height. This in turn aids in dispersion of stack contaminants, reducing ground level concentrations. The effective stack height is the sum of the actual stack height, the plume rise due to the exhaust velocity, and the buoyancy rise, which is a function of the temperature of the exit gases and the atmospheric conditions.

Wind flow over stacks creates negative zones and eddies behind the stack in the same manner as airflow around buildings. Low stack discharge velocities permit the effluent to be drawn into the stack eddy zone and may cause down wash. This reduces the effective stack height and may cause the effluent to enter the building cavity, even though the discharge may be well above this cavity.

The stack to wind velocity ratio should be at least 1.5 to 1. Under these conditions, the effluent will break cleanly from the stack, down wash will be eliminated, and the effective stack height will be maximized. In most cases, a stack discharge velocity of 3,000-4,000 feet per minute will provide good performance.

The guidelines above are satisfactory for most cases. However, federal, state and local environmental and zoning agencies may dictate stack height and location. In some cases the Federal Aviation Agency (FAA) regulations will govern some aspects of stack location or configuration.

Wind & Seismic Loads: Wind and seismic design loads are normally governed by the applicable local building codes (BOCA, SBBC, or ICBO in the U.S.). These form the basis for the mechanical designs, which follow.   The deflection at the top of the cantilever is limited to length (inches) / 180 per recommendations of the SPI. This is usually confirmed by finite element analysis of the stack so local reactions and bending movements can be determined.

Stack Lateral Support: Stacks may be designed either free standing, with all lateral support provided by the main stack support (ie. base flange or lugs) and stack shell, or with a combination of base and side lateral support. Side lateral support may consist of guy wires, hard connections to buildings or structural steel, or some other similar method. Use of lateral supports can often simplify the design of the stack and stack base, but this is not always the case. An analysis of the design conditions and stack geometry will often need to be done with and without lateral support to determine the most economical overall approach.

External stiffeners may need to be added to the shell to help resist buckling. An analysis of all forces acting on the stack will determine these requirements. Guy wires when used are recommended as stainless steel aircraft cable, set at an angle of 45^o.

Stack Base: Exhaust stacks are manufactured in a wide variety of configurations and supported in just as many ways. Stacks may be open with bottom entry, or closed bottom with side inlet. The stack may be designed for support at the base or along the sidewall, depending upon the stack size and physical constraints of the installation.

If an open bottom design is chosen, the choice usually comes down to supply with either a flange or a plain (raw) end. If a flange style is chosen, it could be possible to support the stack off the flange. Open base stacks are generally chosen where short stack sections are required to mount directly off the top of a piece of equipment, such as a fume scrubber, or off the discharge of a vertical discharge fan.

Closed base stacks may be supplied with mounting lugs similar to those supplied on process tanks, or with flanged bases. Flanged bases, in turn, may be supplied as stand-alone drilled flanges, as gusseted flanges, or as double flanged bases with gussets.

In all cases, the stack base will be designed for the appropriate number and size of hold down bolts by first calculating the maximum overturning load. Using this value in combination with the stack diameter, the load-carrying requirement for each bolt can be determined. Iterations may be performed with varying numbers of hold down bolts to achieve an optimum balance of size vs. numbers of bolts, and spacing on the concrete pads. In all calculations, no value is assigned to the bolts in compression on the downstream side of the neutral axis (opposite the wind). The entire load is divided among the bolts considered to be in tension.

In a similar manner, the base flange or hold down lugs are designed to satisfy the appropriate tension or compression loads imposed by the wind loads specified. Calculations for base flange thickness are modeled on relationships and equations specified in ASME RTP-1, ASME Section X, and other relevant codes.

Stack Sampling: Sampling ports are quite often installed on stacks to provide measurements for mandated emission testing. Two ports, installed at 90^o to each other, are located eight to ten stack diameters above bends or inlets, and at least two stack diameters below stack exits. Sample ports can be any size, but are typically 3" or 4" diameter with flanged or threaded ends, with blind flanges or plugs as appropriate.

Access Platforms: Access to sampling ports can be off adjacent building steel, if available, or off a platform and ladder supplied and installed with the stack. Platforms are designed per the requirements of OSHA and building codes. Three rail (top, mid, toe) systems with a minimum 3'-0" wide grating platforms are typically supplied. Support clips off the stack are designed and reinforced for loads imposed. Access to the platform can be by a ladder, caged per requirements, supported off the stack . Materials of construction for ladders and platform systems can be fiberglass (as shown), steel or alloy.

Corrosion Requirements: Stack materials of construction need to be evaluated for long term performance with the anticipated corrosive contaminants at temperature. Generally speaking, most fiberglass resin materials used for tanks and piping will perform very well for stacks as well. Additional guidance in this area can be obtained from any of several published corrosion tables, or by contacting Composites USA.

Flammability: All stacks should be manufactured using fire retardant materials. Many fiberglass materials have been tested and classified per the ASTM E-84 tunnel test. Many resins have successfully demonstrated a Class 1 flame resistance (measuring <25 with red oak =100 and concrete = 0) by the measurements of this test. Every effort should be made to use one of these resins.

Consideration should be given to the installation of a liquid flush or sprinkler system, particularly if there is a tendency to build up large cake or dust deposits in the stack, if oxidizing substances such as sodium chlorate or potassium permanganate can be deposited on the wall, or if process upsets can produce a gas stream that is potentially combustible.

Electrical Conductivity & Lightening Protection: Lightning bolts seek the path of least resistance. Depending upon the stack size and location, a lightening protection system might be considered. If a lightening protection system is desired, the points, conductors, fasteners, air terminals, joints and ground can be factory supplied and installed by Composites USA.

Aircraft Warning: For tall stacks, aircraft warning and or lighting may be required or advisable. These may be supplied and installed at Composites USA in full accordance with FAA requirements. Lighting systems, where supplied, are provided with manual or electric cabling and winch systems to allow servicing from ground level.

Condensate Handling & Maintenance: Stack gases are very often saturated vapors. It is not unusual for stack gases to cool and condense these vapors into a liquid condensate while operating. In addition, driving rains can often allow water into the stack from above. For both these reasons, drain connections are usually installed in closed bottom stacks. In addition, some stacks incorporate a sloped bottom, similar to those on some storage tanks, to facilitate full drainage.

Access to the base of the stack for periodic inspections and maintenance is recommended. Inspection ports can take the form of flanged and bolted manways, or flush mounted covers with hinged and lockable doors.

Rain caps of various styles are often incorporated to minimize liquid entering the stack (rain, snow). In addition to rain caps, drip rings are sometimes incorporated to catch and channel any stack condensation down to the base of the stack - and out of the plume.

Finally, where considered necessary, stack back draft dampers may be installed to prevent unwanted air from being drawn from outside through non-operational fans or process equipment.