# Attachment of Rooftop Equipment in High-Wind Regions

FEMA

## HURRICANE KATRINA RECOVERY ADVISORY

**Purpose:** To recommend practices for designing and installing rooftop equipment that will enhance wind resistance in high-wind regions.

**Note:** For attachment of lightning protection systems, see Hurricane Katrina Recovery Advisory on Rooftop Attachment of Lightning Protection Systems in High-Wind Regions.

## Key Issues

Rooftop equipment frequently becomes detached from rooftops during hurricanes. Water can enter the building at displaced equipment (see Figure 1); displaced equipment can puncture and tear roof coverings (thus allowing water to leak into the building). Equipment blown from a roof can damage buildings and injure people. Damaged equipment may no longer provide service to the building.

***Figure 1. This gooseneck was attached with only two small screws. A substantial amount of water was able to enter the building during the hurricane.***

## Construction Guidance

**Mechanical Penthouse:** By placing equipment in mechanical penthouses rather than being exposed on the roof, equipment within penthouses is shielded from high-wind loads and windborne debris (see Figure 2). Therefore, use of mechanical penthouses designed and constructed in accordance with a current building code are recommended, particularly for critical and essential facilities.

**Design Loads and Safety Factors:** Loads on rooftop equipment should be determined in accordance with the 2005 edition of ASCE 7.

Note: For guidance on load calculations, see "Calculating Wind Loads and Anchorage Requirements for Rooftop Equipment," ASHRAE Journal, volume 48, number 3, March 2006.

A minimum safety factor of 3 is recommended for critical and essential facilities, and a minimum safety factor of 2 is recommended for other buildings. Loads and resistance should also be calculated for heavy pieces of equipment (see Figure 2).

***Figure 2. This 30' x 10' x 8' 18,000-pound HVAC unit was attached to its curb with 16 straps (one screw per strap). Although the wind speeds were estimated to be only 85 to 95 miles per hour (3-second peak gust), it blew off the building.***

**Simplified Attachment Table:** To anchor fans, small HVAC units, and relief air hoods, the following minimum attachment schedule is recommended (see Table 1) (note: the attachment of the curb to the roof deck also needs to be designed to resist the design loads):

Table 1. Number of #12 Screws for Base Case Attachment of Rooftop Equipment

| Case No. | Curb Size and Equipment Type | Equipment Attachment | Fastener Factor for Each Side of Curb or Flange |
|---|---|---|---|
| 1 | 12”x 12” Curb with Gooseneck Relief Air Hood | Hood Screwed to Curb | 1.6 |
| 2 | 12”x 12” Gooseneck Relief Air Hood with Flange | Flange Screwed to 22 Gauge Steel Roof Deck | 2.8 |
| 3 | 12”x 12” Gooseneck Relief Air Hood with Flange | Flange Screwed to 15/32” OSB Roof Deck | 2.9 |
| 4 | 24”x 24” Curb with Gooseneck Relief Air Hood | Hood Screwed to Curb | 4.6 |
| 5 | 24”x 24” Gooseneck Relief Air Hood with Flange | Flange Screwed to 22 Gauge Steel Roof Deck | 8.1 |
| 6 | 24”x 24” Gooseneck Relief Air Hood with Flange | Flange Screwed to 15/32” OSB Roof Deck | 8.2 |
| 7 | 24”x 24” Curb with Exhaust Fan | Fan Screwed to Curb | 2.5 |
| 8 | 36”x 36” Curb with Exhaust Fan | Fan Screwed to Curb | 3.3 |
| 9 | 5’-9”x 3’- 8” Curb with 2’- 8” high HVAC Unit | HVAC Unit Screwed to Curb | 4.5* |
| 10 | 5’-9”x 3’- 8” Curb with 2’- 8” high Relief Air Hood | Hood Screwed to Curb | 35.6* |

**Notes to Table:**

1. The loads are based on the 2005 edition of ASCE 7. The resistance includes equipment weight.

2. The Base Case of the tabulated numbers of #12 screws (or ¼ pan-head screws for flange-attachment) is a 90-mph basic wind speed, 1.15 importance factor, 30’ building height, Exposure C, using a safety factor of 3.

3. For other basic wind speeds, or for an importance factor of 1, multiply the tabulated number of #12 screws by $\left(\frac{V_D^2 \times I}{90^2 \times 1.15}\right)$ to determine the required number of #12 screws or (¼ pan-head screws) required for the desired basic wind speed, $V_D$ (mph) and importance factor, I.

4. For other roof heights up to 200’, multiply the tabulated number of #12 screws by (1.00 + 0.003 [h - 30]) to determine the required number of #12 screws or ¼ pan-head screws for buildings between 30’ and 200’.

**Example A:** 24” x 24” exhaust fan screwed to curb (table row 7), Base Case conditions (see Note 1): 2.5 screws per side; therefore, round up and specify 3 screws per side.

**Example B:** 24” x 24” exhaust fan screwed to curb (table row 7), Base Case conditions, except 120 mph and importance factor of 1: $120^2 \times 1 \div 90^2 \times 1.15$ = 1.55 x 2.5 screws per side = 3.86 screws per side; therefore, round up and specify 4 screws per side.

**Example C:** 24” x 24” exhaust fan screwed to curb (table row 7), Base Case conditions, except 150’ roof height: 1.00 + 0.003 (150’ - 30’) = 1.00 + 0.36 = 1.36 x 2.5 screws per side = 3.4 screws per side; therefore, round down and specify 3 screws per side.

* This factor only applies to the long sides. At the short sides, use the fastener spacing used at the long sides.

**Fan Cowling Attachment:** Fans are frequently blown off their curbs because they are poorly attached. When fans are well attached, the cowlings frequently blow off (see Figure 3). Unless the fan manufacturer specifically engineered the cowling attachment to resist the design wind load, cable tie-downs (see Figure 4) are recommended to avoid cowling blow-off. For fan cowlings less than 4 feet in diameter, 1/8-inch diameter stainless steel cables are recommended.

***Figure 3. Cowlings blew off two of the three fans shown in this photo. Cowlings can tear roof membranes and break glazing.***

***Figure 4. To overcome blow-off of the fan cowling, this cowling was attached to the curb with cables.***

For larger cowlings, use 3/16-inch diameter cables. When the basic wind speed is 120 mph or less, specify two cables. Where the basic wind speed is greater than 120 mph, specify four cables. To minimize leakage potential at the anchor point, it is recommended that the cables be adequately anchored to the equipment curb (rather than anchored to the roof deck). The attachment of the curb itself also needs to be designed and specified.

**Ductwork:** To avoid wind and windborne debris damage to rooftop ductwork, it is recommended that ductwork not be installed on the roof (see Figure 5). If ductwork is installed on the roof, it is recommended that the gauge of the ducts and their attachment be sufficient to resist the design wind loads.

***Figure 5. Two large openings remained (circled area and inset to the right) after the ductwork on this roof blew away.***

**Condensers:** In lieu of placing rooftop-mounted condensers on wood sleepers resting on the roof (see Figure 6), it is recommended that condensers be anchored to equipment stands. (Note: the attachment of the stand to the roof deck also needs to be designed to resist the design loads.) In addition to anchoring the base of the condenser to the stand, two metal straps with two side-by-side #14 screws or bolts at each strap end are recommended (see Figure 7).

***Figure 6. Sleeper-mounted condensers displaced by high winds.***

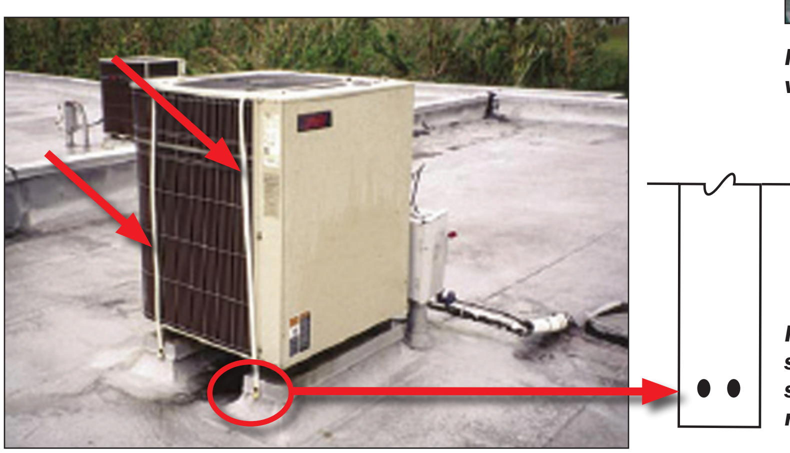

***Figure 7. This condenser had supplemental securement straps (see arrows). Two side-by-side screws with the proper edge and end distances are recommended at the end of the strap.***

**Vibration Isolators:** When equipment is mounted on vibration isolators, an isolator that has sufficient resistance to meet the design uplift loads should be specified and installed, or an alternative means to accommodate uplift resistance should be provided (see Figure 8).

**Access Panel Attachment:** Access panels frequently blow off. To minimize blow-off of access panels, job-site modification will typically be necessary (for example, the attachment of hasps and locking devices such as a carabiner). The modification details will need to be tailored for the equipment, which may necessitate detail design after the equipment has been delivered to the job site. Modification details should be approved by the equipment manufacturer.

***Figure 8. The equipment on this stand was resting on vibration isolators that provided lateral resistance but no uplift resistance (above). A damaged vibration isolator is shown in the inset (left).***

***Figure 9. Several of the equipment screen panels were blown away. Loose panels can break glazing and puncture roof membranes.***

**Equipment Screens:** Equipment screens around rooftop equipment are frequently blown away (see Figure 9). Equipment screens should be designed to resist the wind loads derived from ASCE 7.

**Note:** The extent that screens may reduce or increase wind loads on equipment is unknown. Therefore, the equipment behind screens should be designed to resist the loads previously noted.

**Other resources:** Three publications pertaining to seismic restraint of equipment provide general information on fasteners and edge distances:

- Installing Seismic Restraints for Mechanical Equipment (FEMA 412)
- Installing Seismic Restraints for Electrical Equipment (FEMA 413)
- Installing Seismic Restraints for Duct and Pipe (FEMA 414)