6 MECHANICAL DESIGN

Foundation and Mounting

Generator Set Mounting and Vibration Isolation

The installation design must provide a proper foundation to support the generator set, and to prevent damaging or annoying levels of vibration energy from migrating into the building structure. In addition, the installation should assure that the supporting infrastructure for the generator set does not allow vibration from the generator set to migrate into the stationary portion of the equipment.

All components that physically connect to the generator set must be flexible in order to absorb the vibration movement without damage. Components that require isolation include the engine exhaust system, fuel lines, AC power supply wiring, load wiring, control wiring (which should be stranded, rather than solid core), the generator set (from the mounting pad), and ventilation air ducts (for generator sets with skid–mounted radiators) (See **Figure 6–1**). Lack of attention to isolation of these physical and electrical interconnection points can result in vibration damage to the building or the generator set, and failure of the generator set in service.

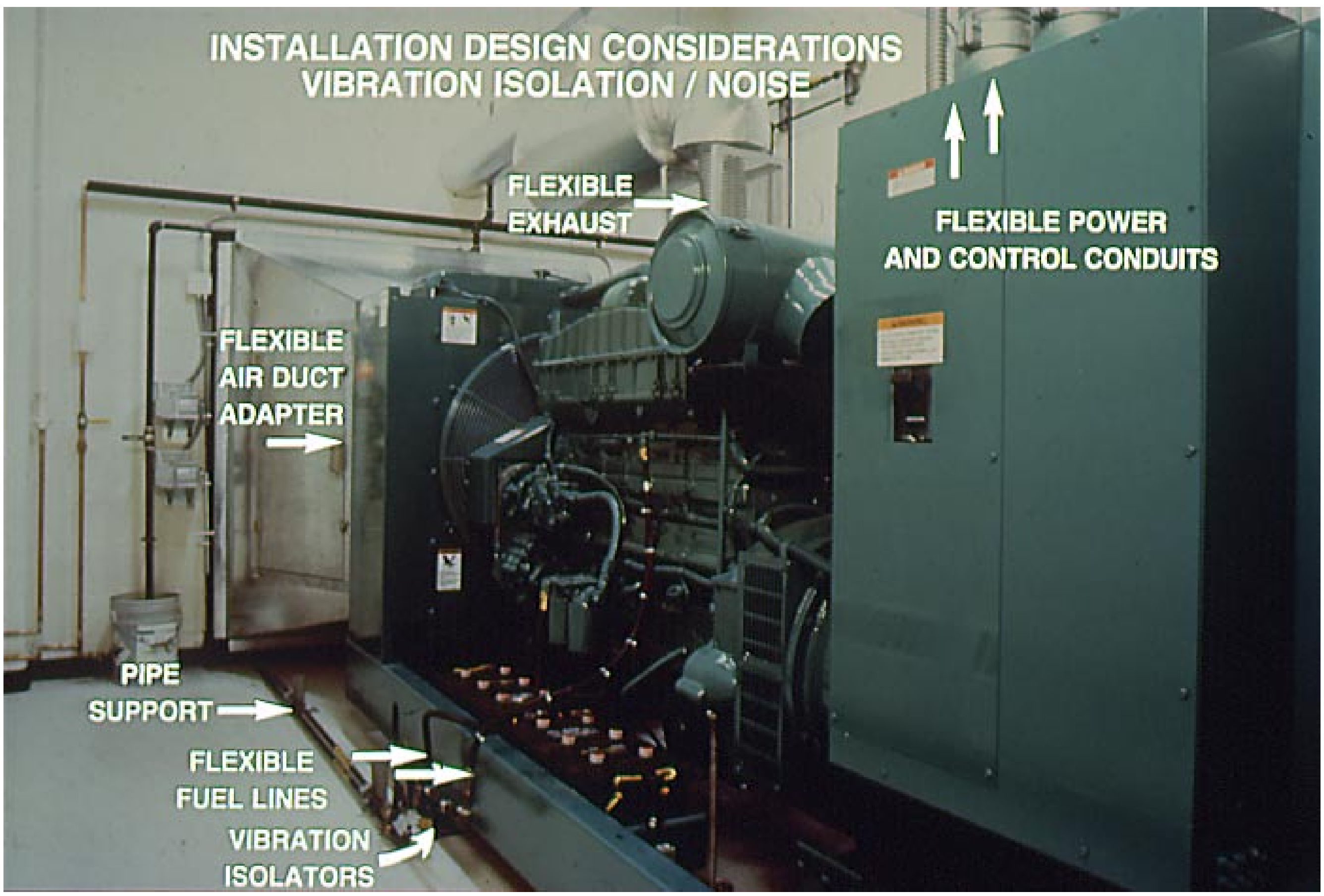

Figure 6–1. Anti–Vibration Provisions for a Typical Generator Set

The generator set engine, alternator, and other mounted equipment are typically mounted on a skid–base assembly. The skid–base assembly is a rigid structure that provides both structural integrity and a degree of vibration isolation. The foundation, floor, or roof must be able to support the weight of the assembled generator set and its accessories (such as a sub–base fuel tank), as well as resist dynamic loads and not transmit objectionable noise and vibration. Note that in applications where vibration isolation is critical the assembled weight of the package might include a massive mounting foundation (See Foundation Provisions in this section.)

Physical size, weight, and mounting configurations vary greatly between manufacturers and between various sizes of equipment. Consult the manufacturer's installation instructions for the specific model installed for detailed information on weights and mounting dimensions[1].

Foundation Provisions

Slab Floor: For many applications, a massive foundation is not necessary for the generator set. Gensets with integral vibration isolators can reduce transmitted vibrations by 60–80% and placing steel spring isolators between the genset and slab can isolate greater than 95% of vibrations (see vibration isolators later in this section). If vibration transmission to the building is not a critical concern, the major issue will be installing the generator set so that its weight is properly supported and so that the unit can be easily serviced. A concrete pad should be poured on top of a concrete floor to raise the generator set to a height that makes service convenient and to make housekeeping around the unit easier.

- The pad should be constructed of reinforced concrete with a 28–day compressive strength of at least 2500–psi (17,200 kPa).
- The pad should be at least 6 inches (150 mm) deep and extend at least 6 inches (150 mm) beyond the skid on all sides.

1 Detailed information on Cummins Power Generation products can be found on the Cummins Power Suite, or may be obtained from any authorized distributor.

See generator set manufacturer's drawings for physical locations of fuel lines, control and power interconnections and other interfaces that are planned to be cast into the concrete. These interfaces vary considerably from supplier to supplier.

Vibration isolators should be secured to the mounting pad with Type J or L bolts (rag or rawl bolts) set into the concrete pad. Positioning of "cast in" bolts is problematic, since even small errors in location can cause time consuming redrilling of the skid base. Some generator set designs allow use of concrete anchor bolts. These would require the mounting points to be carefully laid out based on actual location of the mounting points on the generator set and isolators.

The mounting pad for the generator set should be level and flat to allow for proper mounting and adjustment of the vibration isolation system. Verify that the mounting pad is level lengthwise, widthwise, and diagonally.

Piers (Plinth): Alternatively, the generator set can be mounted on concrete piers (plinth) oriented along the length of the skid of the generator set. This arrangement allows easy positioning of a drip pan underneath the generator set, and allows more room for servicing of the generator set. The piers should be physically attached to the floor.

Vibration Isolating Foundation

In applications where the amount of vibration transmission to the building is highly critical, mounting the generator set on a vibration isolating foundation may be required. In this case, additional considerations are necessary. **Figure 6–2** illustrates a typical vibration isolating foundation.

- The weight (W) of the foundation should be at least 2 times (and up to 5–10 times) the weight of the set itself to resist dynamic loading. (The weight of fuel in a sub–base fuel tank should not be considered to be contributing to the weight required of a vibration isolating foundation even though the isolators are between the tank and the generator set.)

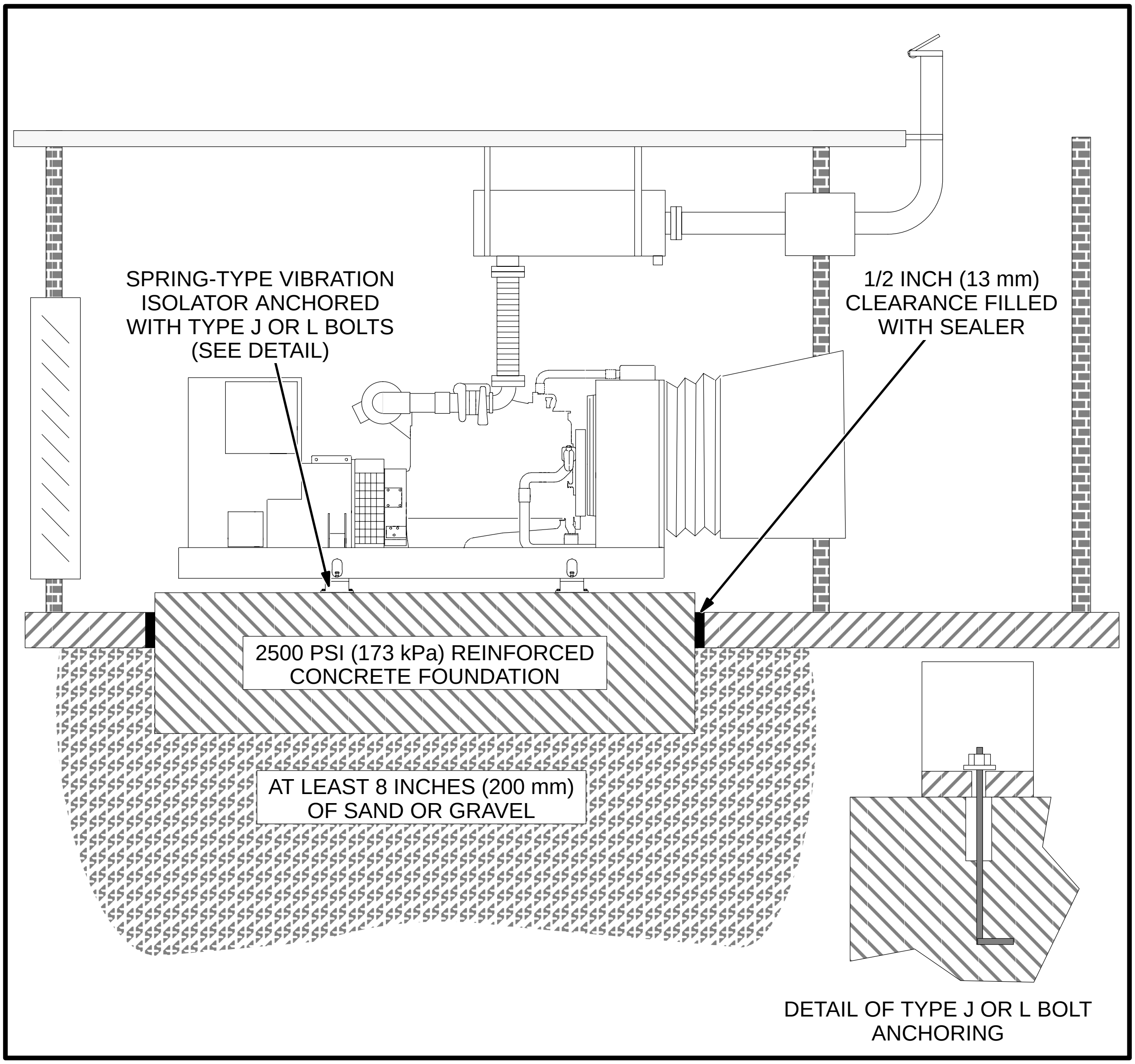

Figure 6–2 Typical Vibration Isolating Foundation

- The foundation should extend at least 6 inches (150 mm) beyond the skid on all sides. This determines the length (l) and width (w) of the foundation.
- The foundation should extend at least 6 inches (150 mm) above the floor to make service and maintenance of the generator set easier.
- The foundation must extend below the frost line to prevent heaving.
- The foundation should be reinforced concrete with a 28–day compressive strength of at least 2500 psi (17,200 kPa).
- Calculate the height (h) of the foundation necessary to obtain the required weight (W) by using the following formula:

$$h = \frac{W}{d \bullet l \bullet w}$$

Where:
h = Height of the foundation in feet (meters).
l = Length of the foundation in feet (meters).
w = Width of the foundation in feet (meters).
d = Density of Concrete – 145 lbs/f^3 (2322 kg/M^3)
W = Total wet weight of Genset in lbs (kg).

- The total weight of the generator set, coolant, fuel, and foundation usually results in a soil bearing load (SBL) of less than 2000 lbs/ft^2 (9800 kg/m^2)psi (96 kPa). Although this is within the load bearing capacity of most soils, always find out the allowable SBL by checking the local code and the soil analysis report for the building. Remember to include the weight of coolant, lubricant, and fuel (if applicable) when performing this calculation. Calculate the SBL by using the following formula:

$$\text{SBL (psi)} = \frac{W}{l \bullet w \bullet 144}$$

$$\text{SBL (kPa)} = \frac{W \bullet 20.88}{l \bullet w}$$

Sample Calculations (US units):

A 500kW genset weights approximately 10,000 pounds (4540 kg) wet (i.e., including coolant and lubricants). Skid dimension is 10 feet (3 meters) long and 3.4 feet (1 meter) wide.

l = 10 + (2 • 0.5) = 11 feet
w = 3.4 + (2 • 0.5) = 4.4 feet
Foundation weight = 2 • 10,000 = 20,000 lbs
Total weight = genset + foundation
=10,000 + 20,000 = 30,000 lbs

$$\textbf{SBL} = \frac{30{,}000}{11 \bullet 4.4} = \textbf{620 lbs/ft}^2$$

Vibration Isolators

The engine and alternator of a generator set must be isolated from the mounting structure where it is installed. Some generator sets, particularly smaller kW models, utilize neoprene/rubber vibration isolators that are inserted into the machine between the engine/alternator and the skid[2]. The skid of these generator sets usually can be bolted directly to the foundation, floor, or sub–structure. Other generator sets may be provided with a design that features the engine/alternator solidly attached to the skid assembly. Generator sets that do not include integral isolation should be installed using vibration isolation equipment such as pad, spring, or air isolators.

NOTE: Bolting a generator set that does not include integral isolators directly to the floor or foundation will result in excessive noise and vibration; and possible damage to the generator set, the floor, and other equipment. Vibrations can also be transmitted through the building structure and damage the structure itself.

Pad Isolators: Pad–type isolators are comprised of layers of flexible materials designed to dampen vibration levels in non–critical applications, such as those on grade or for generator sets mounted in their own outdoor enclosure, or where integral isolators are used with a generator set. Pad isolators vary in their effectiveness, but are approximately 75% efficient. Depending on construction, they may also vary in effectiveness with temperature, since at cold temperatures the rubber isolating medium is much less flexible than at higher temperatures.

Spring Isolators: **Figure 6–3** illustrates a steel spring vibration isolator of the type required for mounting generator sets that do not include integral vibration isolators. Depicted are the bottom rubber pad, isolator body, securing bolts, support spring, adjusting screw, and locking nut.

These steel spring isolators can damp up to 98 percent of the vibration energy produced by the generator set. Locate the isolators as shown on the generator set manufacturer's documentation. The isolators may not be located symmetrically around the perimeter of the generator set, because they are required to be located with consideration of the center of gravity of the machine. The number of isolators required varies with the ratings of the isolators and the weight of the generator set. See **Figure 6–4**.

When the machine is mounted on a sub–base fuel tank, the type of vibration isolators required to protect the sub–base fuel tank depends on the structure of the tank and the level of vibration force created by the machine. If synthetic rubber vibration isolators are installed between the engine/generator and the skid, additional vibration

2 Cummins Power Generation generator sets (200/175 kW and smaller) have rubber vibration isolators located between the skid and the engine–generator assembly and do not require use of external vibration isolators for most applications.

isolation is not usually required between the machine and the subbase tank. However, the natural frequency of the sub–base fuel tank at the points of attachment to the genset should be 200 Hz or greater. If the engine/alternator is solidly attached to the skid, additional vibration isolation between the skid and a sub–base tank is needed to protect the sub–base tank and adequately isolate the building from vibration. In all cases, follow the manufacturer's recommendations for the specific genset and sub–base tank combination.

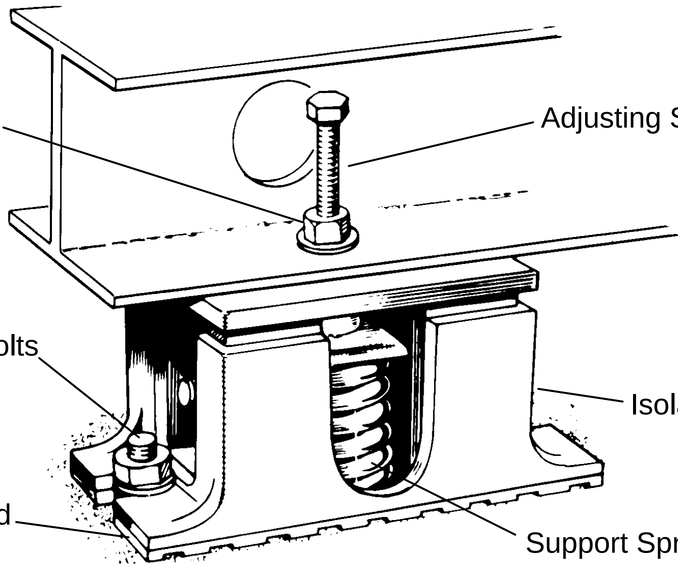

Figure 6–3. Typical Steel Spring Vibration Isolator

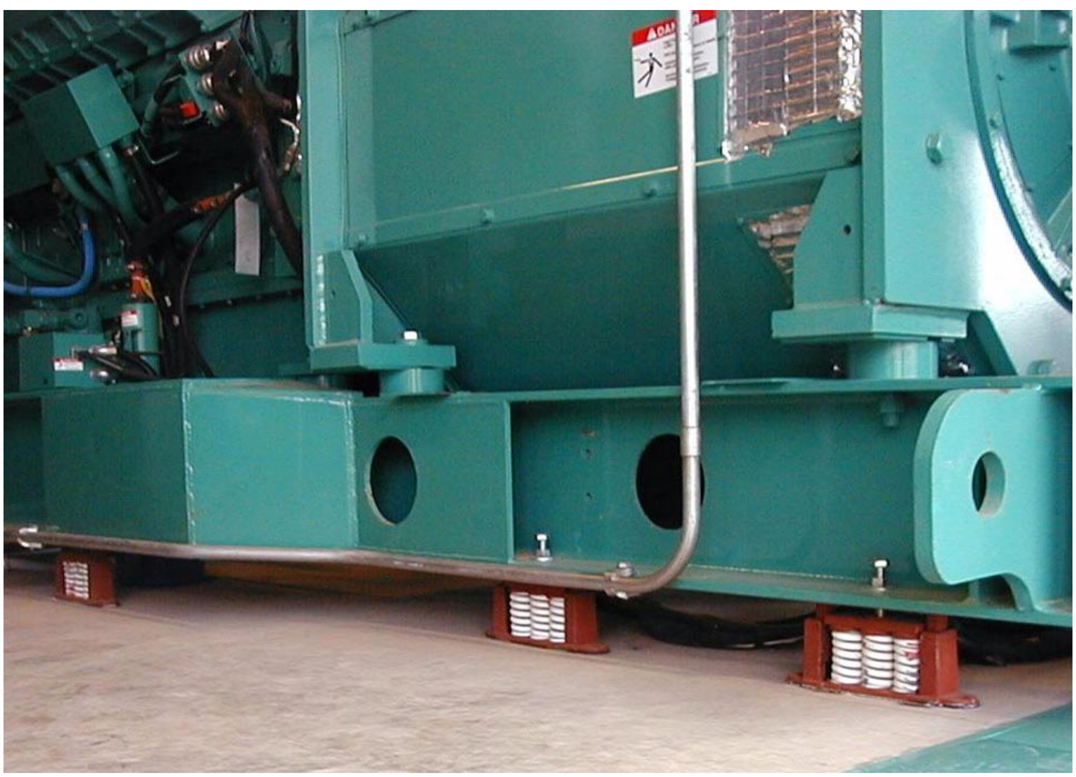

Figure 6–4. A Generator Set Mounted With Spring–Type Vibration Isolators

Spring–type vibration isolators must be properly selected and installed to provide effective isolation. The weight of the generator set should compress the isolator sufficiently to allow freedom of motion without allowing the isolator to “bottom out” during operation. This is accomplished by choosing the isolators and their number based on the isolator’s weight rating and the total weight of the generator set.

The isolator should be positively anchored to the mounting pad for the generator set using Rag (L or J bolts) or Rawl (concrete anchor) bolts.

Air Isolators: An air isolator (or air spring) is a column of gas confined in a container designed to utilize the pressure of the gas as the force medium of the spring. Air isolators can provide a natural frequency lower than can be achieved with elastomeric (rubber) and with special designs lower than helical steel springs. They provide leveling capability by adjusting the gas pressure within the spring.

Air isolators require more maintenance, and temperature limitations are more restrictive than for helical springs. Stiffness of air isolators varies with gas pressure and is not constant, as is the stiffness of other isolators. As a result, the natural frequency does not vary with load to the same degree as other methods of isolation. A failure of the air supply system or leak can cause the isolators to fail completely.

Dampening in air isolators is generally low with a critical dampening ratio in the order of 0.05 or less. This dampening is provided by flexure in the diaphragm or sidewall by friction, or by damping in the gas. Incorporating capillary flow resistance (adding an orifice to the flow) may increase damping between the cylinder of the air isolator and the connecting surge tanks.

Isolators Used in Seismic Locations: Additional factors must be considered for equipment installed in seismic areas. In addition to their typical role of protecting buildings or equipment from machine induced vibration, during a seismic event vibration isolators must also ensure that the equipment remains anchored and does not break free of the structure it is attached to.

In seismic areas, vibration isolators are often used between the genset skid–base and the structure it is attached to. Seismic isolator must be captive, meaning they restrain the generator set from excessive movement and must be strong enough to withstand the seismic forces encountered. Vibration isolators suitable for use in these applications are available in both synthetic rubber and steel spring types.

Vibration isolators, if installed between the engine/alternator and skid, must also adequately secure the engine/alternator to the skid. Normally these types of isolators are of the synthetic rubber type and must be of a “captive” design so as to adequately secure the equipment. The manufacturer or supplier of the equipment should be consulted to determine suitability to the specific application.

Whenever seismic events are a consideration, a qualified structural engineer should be consulted.

Earthquake Resistance

Cummins Power Generation generator sets, when properly mounted and restrained, are suitable for application in recognized seismic risk regions. Special design considerations are necessary for mounting and restraining equipment of the mass density typical of generator sets. Generator set weight, center of gravity, and mounting point locations are indicated on Cummins Power Generation generator set outline drawings.

Components such as distribution lines for electricity, coolant, and fuel must be designed to sustain minimal damage and to facilitate repairs should an earthquake occur. Transfer switches, distribution panels, circuit breakers and associated controls for critical applications[3] must be capable of performing their intended functions during and after the anticipated seismic shocks, so specific mounting and electrical connection provisions must be considered.

3 **US CODE NOTE:** NFPA110 requires these features for Level 1 and Level 2 systems.

Power and Control Wiring Strain Relief

Power wiring and especially control wiring should be installed with the wiring supported on the mechanical structure of the generator set or control panel, and not the physical connection lugs or terminations. Strain relief provisions, along with the use of stranded control wiring rather than single core wiring help to prevent failure of the wiring or connections due to vibration. See Electrical Connections in *Electrical Design.*

Exhaust System

Exhaust System General Guidelines

The function of the exhaust system is to convey engine exhaust safely outside the building and to disperse the exhaust fumes, soot, and noise away from people and buildings. The exhaust system must be designed to minimize backpressure on the engine. Excessive exhaust restriction will result in increased fuel consumption, abnormally high exhaust temperature and failures related to high exhaust temperature as well as excessive black smoke.

See **Figure 6–5** and **6–6**. Exhaust system designs should consider the following:

- Schedule 40 black iron pipe may be used for exhaust piping. Other materials that are acceptable include prefabricated stainless steel exhaust systems.

Figure 6–5: Typical Features of an Exhaust System for a Generator Installed Inside a Building.

- Flexible, seamless corrugated stainless steel exhaust tubing at least 24 inches (610 mm) long must be connected to the engine exhaust outlet(s) to allow for thermal expansion and generator set movement and vibration whenever the set is mounted on vibration isolators. Smaller sets with integral vibration isolation that are bolted directly to the floor must be connected by seamless corrugated stainless steel exhaust tubing at least 18 inches (457 mm) long. Flexible exhaust tubing must not be used to form bends or to compensate for incorrectly aligned exhaust piping.

- Generator sets may be provided with threaded exhaust, slip–type exhaust, or flange–type exhaust connections. Threaded and flanged connections are less likely to leak but more costly to install.

- Isolated non–combustible hangers or supports, NOT the engine exhaust outlet, must support mufflers and piping. Weight on the engine exhaust outlet can cause damage to the engine exhaust manifold or reduce the life of the turbocharger (when used), and can cause vibration from the generator set to be transmitted into the building structure. The use of mounts with isolators further limits vibration from being induced into the building structure.
- To reduce corrosion due to condensation, a muffler (silencer) should be installed as close as practical to the engine so that it heats up quickly. Locating the silencer close to the engine also improves the sound attenuation of the muffler. Pipe bend radii should be as long as practical.

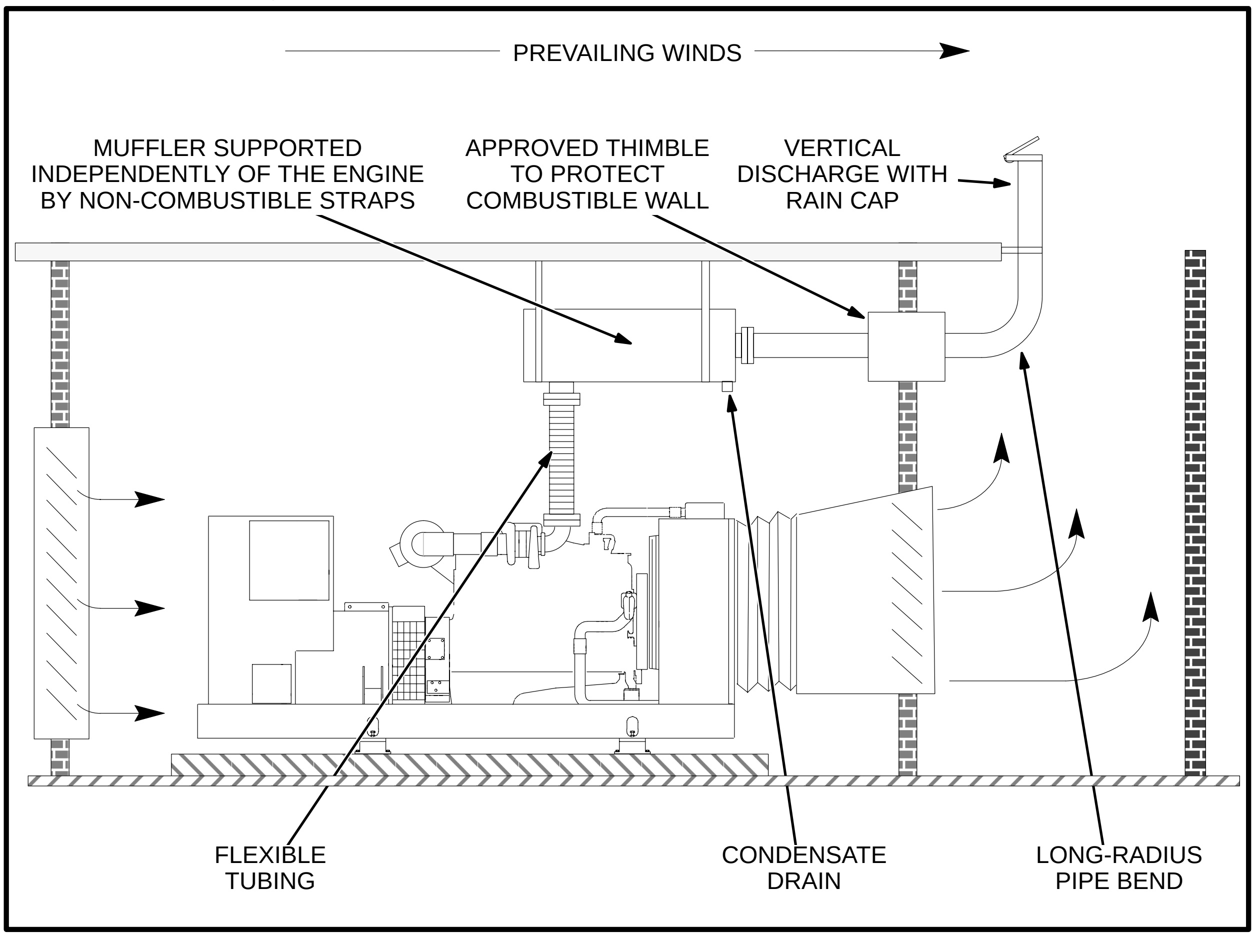

Figure 6–6. Typical Exhaust System

- Exhaust tubing and piping should be of the same nominal diameter as the engine exhaust outlet (or larger) throughout the exhaust system. Verify that the piping is of sufficient diameter to limit exhaust backpressure to a value within the rating of the specific engine used. (Different engines have different exhaust sizes and different backpressure limitations[4].) Piping of smaller diameter than the exhaust outlet must never be used. Piping that is larger than necessary is more subject to corrosion due to condensation than smaller pipe. Piping that is too large also reduces the exhaust gas velocity available for dispersing the exhaust gases up and into the outdoor wind stream.
- All engine exhaust system components should include barriers to prevent dangerous accidental contact. Exhaust piping and mufflers should be thermally insulated to prevent burns from accidental contact, prevent activation of fire detection devices and sprinklers, reduce corrosion due to condensation, and reduce the amount of heat radiated to the generator room. Expansion joints, engine exhaust manifolds, and turbocharger housings, unless water cooled, must never be insulated. Insulating exhaust manifolds and turbochargers can result in material temperatures that can destroy the manifold and turbocharger, particularly in applications where the engine will run a large number of hours. Routing of exhaust piping at least 8 feet (2.3 meters) above the floor will also help to prevent accidental contact with the exhaust system.
- Exhaust piping must be routed at least 9 inches (230 mm) from combustible construction. Use approved thimbles where exhaust piping must pass through combustible walls or ceilings (**Figure 6–7 and 6–8**).
- The exhaust system outlet direction should also be carefully considered. Exhaust should never be directed toward the roof of a building or toward combustible surfaces. Exhaust from a diesel engine is hot and will contain soot and other contaminants that can adhere to surrounding surfaces.

4 Exhaust system size and other exhaust data for specific generator sets is described in the Cummins Power Suite.

- Locate the exhaust outlet and direct it away from the ventilation air intakes.
- If noise is a factor direct the exhaust outlet away from critical locations.
- Exhaust pipe (steel) expands approximately 0.0076 inches per foot of pipe for every 100°F rise in exhaust gas above ambient temperature (1.14 mm per meter of pipe per 100° C rise). It is required that exhaust expansion joints be used to take up expansion in long, straight runs of pipe. Expansion joints should be provided at each point where the exhaust changes direction. The exhaust system should be supported so that expansion is directed away from the generator set. Exhaust temperatures are supplied by the engine or generator set manufacturer for the specific engine used[5].

Figure 6–7: Generator Set Exhaust System Features. Dual Side Inlet Silencer, Flex Connectors, Exhaust Thimbles, and Mounting Hangers are Shown.

5 Exhaust gas data for Cummins Power Generation products is available in the Power Suite CD package.

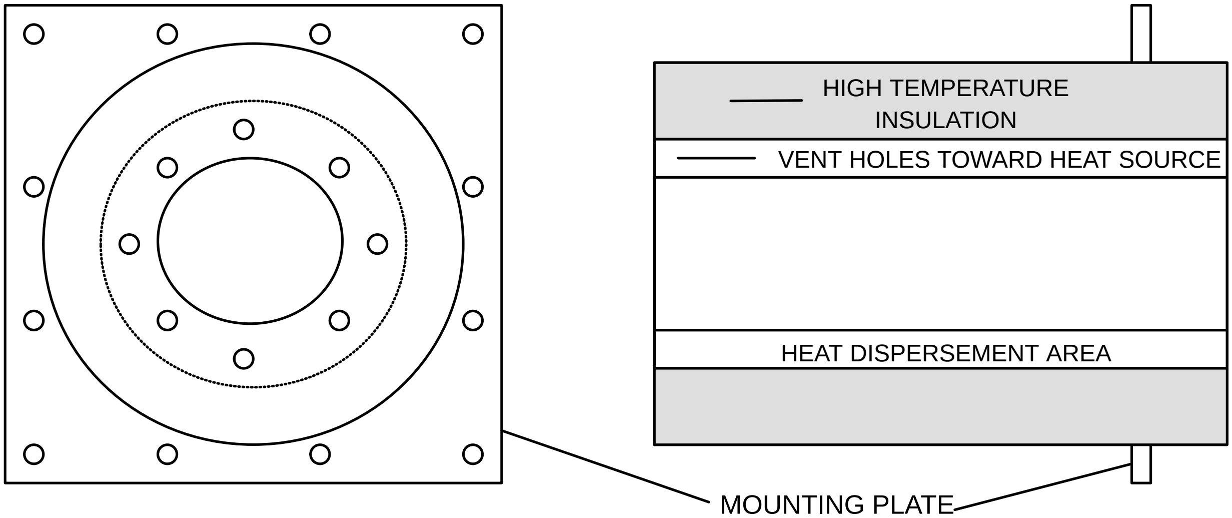

Figure 6–8: Typical Thimble Construction for Combustible Wall Installations.

- Horizontal runs of exhaust piping should slope downwards, away from the engine, to the out–of–doors or to a condensate trap.
- A condensate drain trap and plug should be provided where piping turns to rise vertically. Condensate traps may also be provided with a silencer. Maintenance procedures for the generator set should include regular draining of condensate from the exhaust system.
- Provisions to prevent rain from entering the exhaust system of an engine that is not operating should be provided. This might include a rain cap or exhaust trap (**Figure 6–9 and 6–10**) on vertical exhaust outlets. Horizontal exhaust outlets may be cut off at an angle and protected with birdscreen. Rain caps can freeze closed in cold environments, disabling the engine, so other protective devices may be best for those situations.
- A generator set should not be connected to an exhaust system serving other equipment, including other generator sets. Soot, corrosive condensate, and high exhaust gas temperatures can damage idle equipment served by a common exhaust system.
- Exhaust backpressure must not exceed the allowable backpressure specified by the engine manufacturer[6]. Excessive exhaust backpressure reduces engine power and engine life and may lead to high exhaust temperatures and smoke. Engine exhaust backpressure should be estimated before the layout of the exhaust system is finalized, and it should be measured at the exhaust outlet under full–load operation before the set is placed in service.
- See Exhaust Silencer Performance elsewhere in this section for information on exhaust silencers and various selection criteria for these devices.

WARNING: Engine exhaust contains soot and carbon monoxide, an invisible, odorless, toxic gas. The exhaust system must terminate outside the building at a location where engine exhaust will disperse away from buildings and building air intakes. It is highly recommended that the exhaust system be carried up as high as practical on the downwind side of buildings in order to discharge straight up to maximize dispersal. Exhaust should also discharge on the radiator air discharge side of the building to reduce the likelihood of exhaust gases and soot being drawn into the generator room with the ventilating air.

NOTE: Some codes specify that the exhaust outlet terminate at least 10 feet (3 meters) for the property line, 3 feet (1 meter) from an exterior wall or roof, 10 feet (3 meters) from openings into the building and at least 10 feet (3 meters) above the adjoining grade.

6 Exhaust backpressure information for specific Cummins Power Generation generator sets can be found in the Cummins Power Suite, or may be obtained from an authorized Cummins distributor.

Figure 6–9. A Simple Exhaust System Fitted With a Rain Cap to Prevent Rain From Entering the Exhaust.

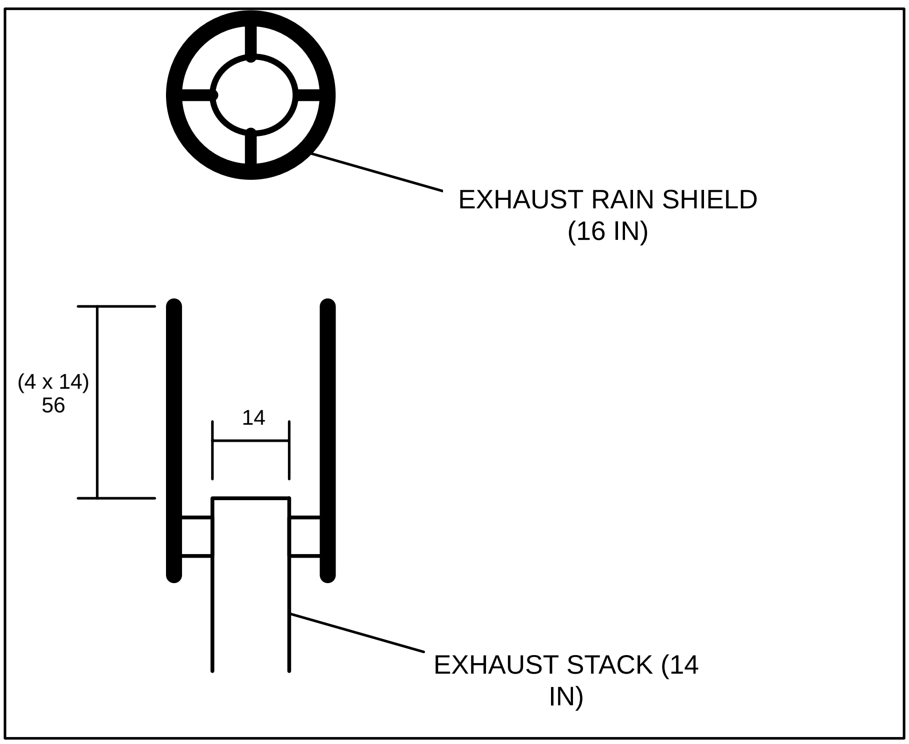

Figure 6–10. A Fabricated Rain Shield for Vertical Genset Exhaust Stack. Dimensions Shown are for a Typical 14–Inch Exhaust.

Exhaust System Calculations

Example Exhaust Backpressure Calculation (US Units): The layout of an exhaust system in **Figure 6–11** specifies a 5–inch (125–mm) diameter by 24–inch (610 mm) long flexible tube at the engine exhaust outlet, a critical grade muffler with a 6–inch (150–mm) diameter inlet, 20 feet (610 m) of 6–inch (150–mm) diameter pipe and one 6–inch (150 mm) diameter long–radius elbow. The generator set Specification Sheet indicates that the engine exhaust gas flow is 2,715 cfm (cubic feet per minute)(76.9 m^3/min) and that the maximum allowable exhaust back pressure is 41 inches (1040 mm) WC (water column).

This procedure involves determining the exhaust back pressure caused by each element (flexible tubes, mufflers, elbows, and pipes) and then comparing the sum of the back pressures with the maximum allowable back pressure.

1. Determine the exhaust backpressure caused by the muffler. **Figure 6–12** is a graph of typical muffler exhaust backpressures. For more accurate calculations obtain data from the muffler manufacturer. To use **Figure 6–12**:

   a Find the cross–sectional area of the muffler inlet using **Table 6–1** (0.1963 ft^2 in this example).

   b Find the exhaust gas flow rate from the engine manufacturer[7]. For this example 2715 cfm is given.

   c Calculate exhaust gas velocity in feet per minute (fpm) by dividing exhaust gas flow (cfm) by the area of the muffler inlet, as follows:

   $$\text{Gas Velocity} = \frac{2715\ \text{cfm}}{0.1963\ \text{ft}^2} = 13{,}831\ \text{fpm}$$

   d Using **Figure 6–12**, determine the back pressure caused by this flow in the specific muffler used.
   In this example, the dashed lines in **Figure 6–12** show that the critical grade muffler will cause a back pressure of approximately 21.5 inches W.C.

3) 20 feet of 6–inch Pipe 20 ft

7 Exhaust gas data for Cummins Power Generation products is in the Cummins Power Suite.

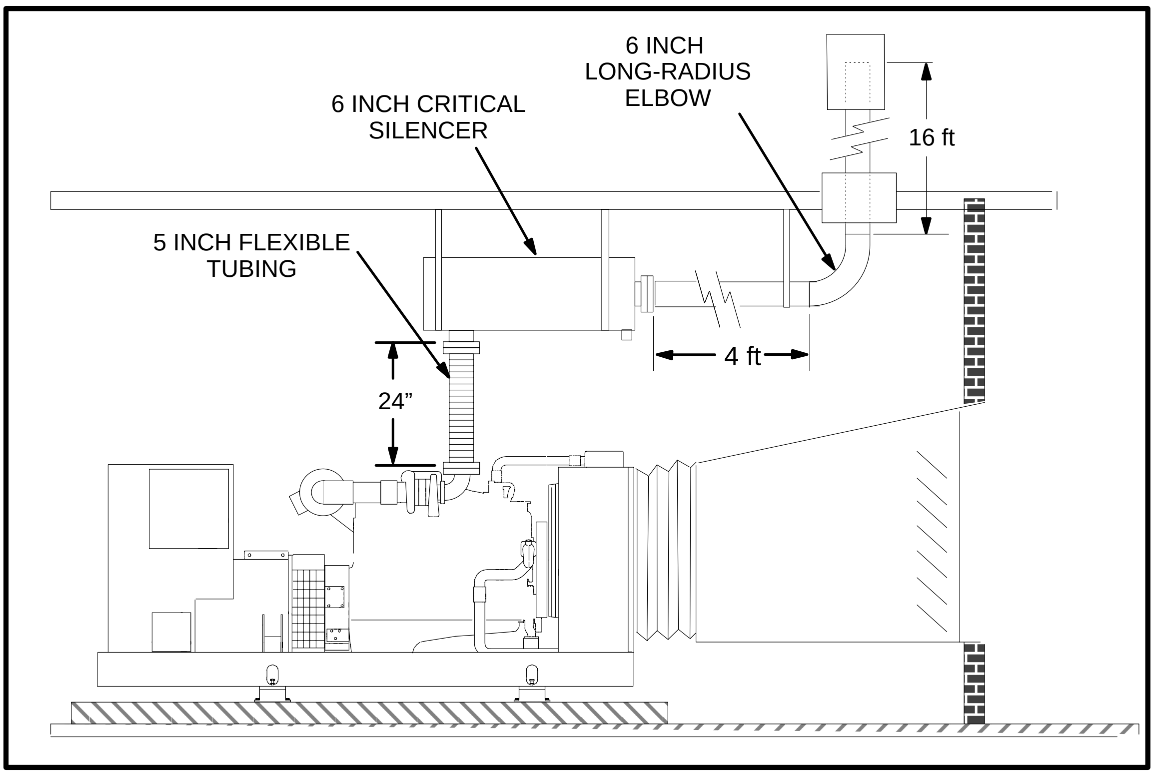

Figure 6–11. Sample Exhaust System for Calculation.

2. Find the equivalent lengths of all fittings and flexible tube sections by using **Table 6–2**.
   1) 24 inch flexible tube 4 ft
   2) 6–inch long radius elbow 11 ft
3. Find the back pressure at the given exhaust flow per unit length of pipe for each nominal pipe diameter used in the system. In this example, 5 inch and 6 inch nominal pipe is used. Following the dashed lines in **Figure 6–13**, 5 inch pipe causes a back pressure of approximately **0.34** inches WC per foot and 6 inch pipe approximately **0.138** inches WC per foot.

4. Add the total back pressures for all elements of the example, as follows:

1)	5 inch flexible tube (4•0.34)	1.4
2)	long–radius elbow (11•0.138)	1.5
3)	20 feet of 6–inch pipe (20•0.138)	2.8
4)	<u>muffler</u>	<u>21.5</u>
	Total Restriction (inches WC)	27.2

The calculation indicates that the piping layout is adequate in terms of exhaust back pressure since the sum of the back pressures is less than the maximum allowable back pressure of 41 Inches WC.

NOTE: On engines with dual exhaust, the exhaust flow as listed on genset specification sheets from Cummins Power Generation is total flow of both banks. The listed value must be divided by 2 for correct calculation for dual exhaust systems.

DIAMETER OF MUFFLER INLET (INCHES)	AREA OF MUFFLER INLET (FT^2)	DIAMETER OF MUFFLER INLET (INCHES)	AREA OF MUFFLER INLET (FT^2)
2	0.0218	8	0.3491
2.5	0.0341	10	0.5454
3	0.0491	12	0.7854
3.5	0.0668	14	1.069
4	0.0873	16	1.396
5	0.1363	18	1.767
6	0.1963		

Table 6–1. Cross Sectional Areas of Openings of Various Diameter

TYPE OF FITTING	NOMINAL INCH (MILLIMETER) PIPE SIZE											
	2 (50)	**2–1/2 (65)**	**3 (80)**	**3.5 (90)**	**4 (100)**	**5 (125)**	**6 (150)**	**8 (200)**	**10 (250)**	**12 (300)**	**14 (350)**	**16 (400)**	**18 (450)**
90° Standard Elbow	5.2 (1.6)	6.2 (1.9)	7.7 (2.3)	9.6 (2.9)	10 (3.0)	13 (4.0)	15 (4.6)	21 (6.4)	26 (7.9)	32 (9.8)	37 (11.3)	42 (12.8)	47 (14.3)
90° Medium Radius Elbow	4.6 (1.4)	5.4 (1.6)	6.8 (2.1)	8 (2.4)	9 (2.7)	11 (3.4)	13 (4.0)	18 (5.5)	22 (6.7)	26 (7.9)	32 (9.8)	35 (10.7)	40 (12.2)
90° Long Radius Elbow	3.5 (1.1)	4.2 (1.3)	5.2 (1.6)	6 (1.8)	6.8 (2.1)	8.5 (2.6)	10 (3.0)	14 (4.3)	17 (5.2)	20 (6.1)	24 (7.3)	26 (7.9)	31 (9.4)
45° Elbow	2.4 (0.7)	2.9 (0.9)	3.6 (1.1)	4.2 (1.3)	4.7 (1.4)	5.9 (1.8)	7.1 (2.2)	6 (1.8)	8 (2.4)	9 (2.7)	17 (5.2)	19 (5.8)	22 (6.7)
TEE, Side Inlet or Outlet	10 (3.0)	12 (3.7)	16 (4.9)	18 (5.5)	20 (6.1)	25 (7.6)	31 (9.4)	44 (13)	56 (17)	67 (20)	78 (23.8)	89 (27.1)	110 (33.5)
18 Inch Flexible Tube	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)
24 Inch Flexible Tube	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)

Table 6–2. Equivalent Lengths of Pipe Fittings in Feet (Meters)

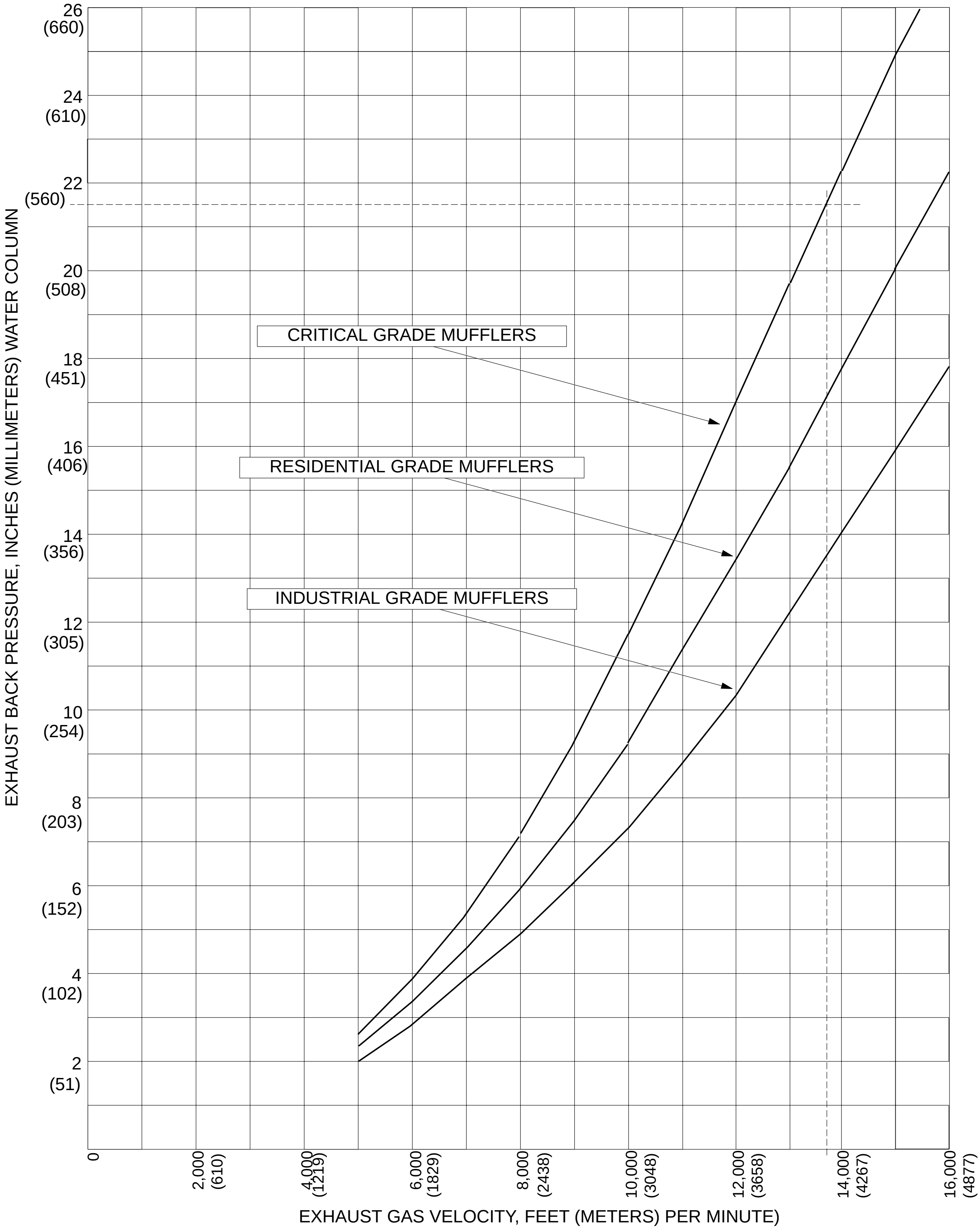

Figure 6–12. Typical Muffler Exhaust Back Pressure vs. Gas Velocity

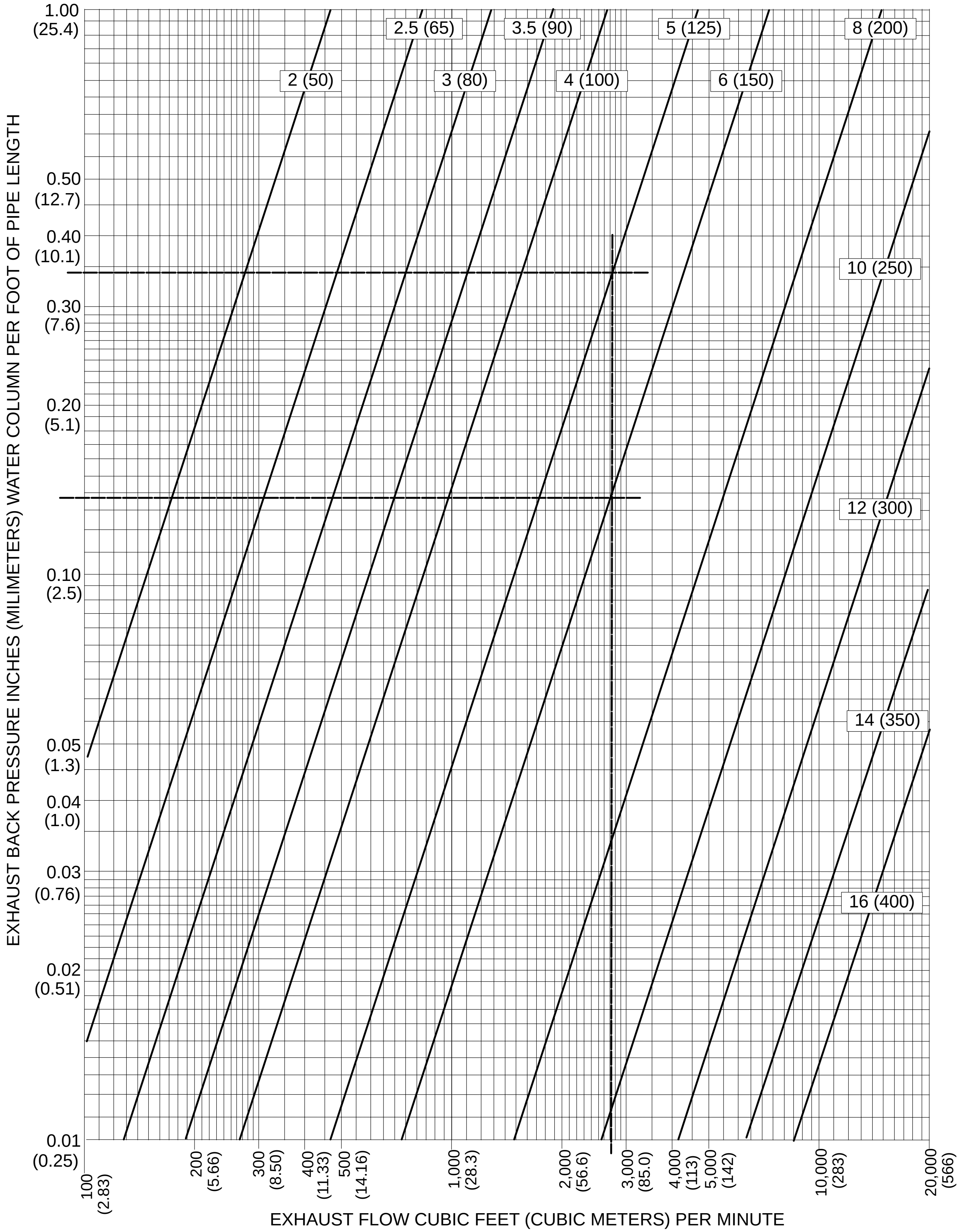

Figure 6–13. Exhaust Back Pressure in Nominal Inch (mm) Pipe Diameters