



**PDHonline Course M302 (7 PDH)**

---

# **Seismic Design for Mechanical Equipment Installations**

*Instructor: Steven G. Liescheidt, P.E., CCS, CCPR*

**2020**

**PDH Online | PDH Center**

5272 Meadow Estates Drive  
Fairfax, VA 22030-6658  
Phone: 703-988-0088  
[www.PDHonline.com](http://www.PDHonline.com)

An Approved Continuing Education Provider

## INSTALLING SEISMIC RESTRAINTS FOR MECHANICAL EQUIPMENT



**Notice:** This guide was prepared by the Vibration Isolation and Seismic Control Manufacturers Association (VISCMA) under a cooperative agreement between the Federal Emergency Management Agency (FEMA) and the American Society of Civil Engineers (ASCE). Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of FEMA and ASCE. Additionally, neither FEMA, ASCE, VISCMA, nor any of their employees make any warranty, expressed or implied, nor assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, product, or process included in this publication. Users of information from this publication assume all liability arising from such use.

For additional copies of this guide, call the FEMA Distribution Center: 1-800-480-2520.

For further information concerning this guide or the activities of ASCE, contact the American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia, 20191, 703-295-6000.

For further information concerning the activities of the Vibration Isolation and Seismic Control Manufacturers Association, contact Mr. Robert Ecker, 610-971-4850.

All photos used with permission. Photos provided by:

A.O. Smith Water Products Company  
AdobeAir, Inc.  
Amber/Booth Company  
American Standard, Inc.  
ITT Industries/Bell & Gossett  
ITT Industries/Precision Stainless  
Bryan Steam, LLC  
Aqua-Chem, Inc.  
Culligan/USFilter Consumer & Commercial Division  
DRI-STEEM Humidifier Company  
Gardner Denver, Inc.  
Greenheck Fan Corporation  
KINETICS Noise Control  
M.W. Sausse & Co., Inc.  
Marley Cooling Technologies, Inc.  
Mason Industries, Inc.  
Seismic Source Company  
Taco, Inc.  
Taylor-Wharton, Harsco  
Tranter PHE, Inc.  
Vibration Eliminator Co., Inc.  
Vibration Mountings & Controls, Inc.

# INSTALLING SEISMIC RESTRAINTS FOR MECHANICAL EQUIPMENT

December 2002



**FEMA**



**ASCE**

*Developed by the Vibration Isolation and Seismic Control Manufacturers Association under a cooperative agreement between the Federal Emergency Management Agency and the American Society of Civil Engineers*

## ACKNOWLEDGEMENTS

This guide was prepared under Cooperative Agreement EMW-2001-CO-0379 between the Federal Emergency Management Agency and the American Society of Civil Engineers. The contributions of the following are gratefully acknowledged:

### Vibration Isolation and Seismic Control Manufacturers Association (VISCMA)

|                        |                                      |
|------------------------|--------------------------------------|
| Amber/Booth Company    | Thybar Corporation                   |
| Kinetics Noise Control | Vibration Mountings & Controls, Inc. |
| Mason Industries       | Vibration Eliminator Co., Inc.       |
| M. W. Sausse & Company |                                      |

### Concrete Anchors Manufacturers Association (CAMA)

### The American Society of Civil Engineers (ASCE)

#### *Project Team*

|                                       |                 |
|---------------------------------------|-----------------|
| Ugo Morelli, FEMA Project Officer     |                 |
| Thomas R. McLane, Project Manager     |                 |
| James Carlson, Principal Investigator |                 |
| J. Marx Ayres                         | James Henderson |
| James Borchers                        | Jerry Lilly     |
| Robert H. Ecker                       | Suzanne Ramsey  |
| Michael Hagerty                       |                 |

#### *Consulting Advisors - Representatives of*

|                          |                                      |
|--------------------------|--------------------------------------|
| Amber/Booth Company      | Thybar Corporation                   |
| IAPMO                    | Vibration Mountings & Controls, Inc. |
| Kinetics Noise Control   | Vibration Eliminator Co., Inc.       |
| Mason Industries, Inc.   | Wej-it Fastening Systems             |
| M. W. Sausse & Co., Inc. |                                      |

#### *Focus Group*

Peter Donohue, City of Culver City California  
Michael Werner, St. Louis County Commissioners  
Craig Barnett, Set Point Air Conditioning  
Bob Lucas, Santa Clarita Custom Air  
Wayne Chugg, Advanced Heating and Air Conditioning  
LeRoy Harbaugh, Coastland Air, Inc.  
Jeff Hayden, Master Cooling Corporation

#### *Editing and Layout*

Gary Clemmons, GC Ink

#### *Illustrations*

Scott Hiner, Creative Marketing Resources

### The Federal Emergency Management Agency (FEMA)

## TABLE OF CONTENTS

|  |            |
|--|------------|
| <b>INTRODUCTION</b>                                | <b>2</b>   |
| <b>EQUIPMENT</b>                                   | <b>4</b>   |
| Air Compressors                                    | 4          |
| Air Conditioning Units and Heat Pumps              | 6          |
| Air Handling Units                                 | 8          |
| Air Separators                                     | 11         |
| Boilers, Furnaces, Humidifiers, Water Heaters      | 12         |
| Chillers   | 14         |
| Coils and Heat Exchangers                          | 16         |
| Condensers and Condensing Units                    | 18         |
| Cooling Towers, Evaporative Coolers, Fluid Coolers | 20         |
| Fans   | 22         |
| Heaters  | 23         |
| Pumps  | 26         |
| Tanks and Gas Cylinders                            | 28         |
| VAV Boxes, Duct Silencers, Fan-coil Units          | 30         |
| <b>ATTACHMENT TYPES</b>                            | <b>32</b>  |
| Rigid Floor-mounted/Pad-mounted Attachment         | 32         |
| Roof-mounted Attachment                            | 48         |
| Suspended Attachment                               | 62         |
| Vibration-isolated/Floor-mounted Attachment        | 77         |
| Wall-mounted Attachment                            | 88         |
| <b>ANCHORS</b>                                     | <b>96</b>  |
| General  | 96         |
| Cast-in-place Anchors                              | 103        |
| Lag Bolts  | 104        |
| Masonry and Drywall Anchors                        | 106        |
| Steel Bolt Connections                             | 114        |
| Welding  | 119        |
| Anchor Sizes for Equipment Less than 400 Pounds    | 121        |
| <b>SPECIAL CASES</b>                               | <b>124</b> |
| Cables   | 124        |
| Control Panels                                     | 130        |
| Housekeeping Pads                                  | 135        |
| Residential Equipment                              | 139        |
| <b>ANCHOR SELECTION GUIDE</b>                      | <b>141</b> |
| <b>GLOSSARY</b>                                    | <b>149</b> |
| <b>INDEX</b>                                       | <b>157</b> |

## INTRODUCTION

This guide shows equipment installers how to attach mechanical equipment to a building to minimize earthquake damage. Many attachment examples are presented, to include anchoring and the use of special devices called *seismic restraint devices*.

Seismic restraint devices include vibration isolation systems, cable or strut suspension systems, roof attachment systems, and steel shapes.

Please note that this guide does not replace:

- Printed instructions shipped with the equipment.
- Instructions in contract drawings and specifications.
- Code-required, industry-accepted practices.
- Orders from your supervisor.
- Seismic Restraint Device Submittals.

Please note that this guide does not cover:

- Non-building structural framing required to elevate equipment above the floor.

**If you have questions about any information in this guide, check with your supervisor.**

This guide contains these sections:

- *Equipment*: Arranged according to different kinds of mechanical equipment such as Air Compressors, Cooling Towers, Pumps, etc.
- *Attachment Types*: Gives instructions on installing equipment in different arrangements known as *attachment types*.
- *Anchors*: Shows many many different types of anchors used to connect equipment to a building.
- *Special Cases*: Covers housekeeping pads, cable assemblies, supports for control panels, and residential equipment.

**Start with the Equipment section that best represents the equipment you are installing.**

- Use the Table of Contents to find the correct starting page.

- Using the table in the Equipment section, find the type of equipment you are installing in column 1. The method for installing this equipment is shown in column 2 and the attachment type is shown in column 3. An example is shown below:

| column 1                 | column 2                                 | column 3                                  |
|--------------------------|--|---|
| <i>Typical Equipment</i> | <i>How is equipment to be installed?</i> | <i>Attachment Type</i>                    |
| Any box or cabinet fan   | Connected to angles mounted to the floor | Rigid with angles<br><i>Go to page 36</i> |

- Turn to the page number for the attachment type in column 3.
- If you are not sure which attachment type is correct, ask your supervisor.

**Follow the instructions for the attachment type you have selected. These instructions will refer you to the correct anchor section so you can make the connection to the building structure.**

**All instructions in this guide are arranged in order using numbered steps.**

- Please follow every step in the sequence shown.

**Special precautions are marked:**



A flag means you should take special care before continuing. Read all the information next to a flag before attaching the equipment.



A warning sign means you can cause serious damage to the building, the device, or the equipment if you do not follow the instructions exactly.



A book means you should refer to the manufacturer's printed instructions before continuing.

Note that a Glossary and an Index are also available to facilitate use of this guide.

## EQUIPMENT

### Air Compressors



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

#### Step 1: Identify equipment



Figure 1: Housed air compressor (water-cooled).

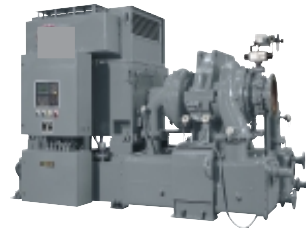


Figure 2: Air compressor skid-mounted (water-cooled).



Figure 3: Air compressor with vertical tank (air-cooled).



Figure 4: Reciprocating type air compressor with horizontal tank (air-cooled).



Figure 5: Skid-mounted equipment including large filter dryers.

#### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| <i>Typical Equipment</i>                     | <i>How is equipment to be installed?</i>   | <i>Attachment Type</i>                     |
|--|--|--|
| Any compressor except housed or skid-mounted | Mounted directly to the floor  | Rigid<br><i>Go to page 32</i>              |
|  | Floor-mounted on vibration isolators using restrained springs or open springs and snubbers | Vibration-isolated<br><i>Go to page 77</i> |
| Housed or skid-mounted compressors           | Connected to angles mounted to the floor   | Rigid with angles<br><i>Go to page 36</i>  |

Table 1: Air compressor installation types.

## Air Conditioning Units and Heat Pumps



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer’s instructions.

### Step 1: Identify equipment



Figure 6: Small rooftop air conditioning unit or heat pump (air-cooled).

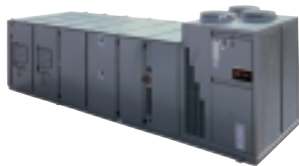


Figure 7: Large rooftop air conditioning unit (air-cooled).



Figure 8: Indoor air conditioning unit or heat pump (floor-mounted or suspended with remote condenser).



Figure 9: Self-contained water-cooled unit (floor-mounted or raised floor-mounted).



Figure 10: Through-the-wall air conditioning unit or heat pump.

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| Typical Equipment  | How is equipment to be installed?  | Attachment Type                                       |
|--|--|---|
| Any AC unit or heat pump   | Mounted directly to the floor  | Rigid<br>Go to page 32                                |
|  | Connected to angles mounted to the floor   | Rigid with angles<br>Go to page 36                    |
|  | Floor-mounted on vibration isolators using restrained springs or open springs and snubbers | Vibration-isolated<br>Go to page 77                   |
| Self-contained unit; use manufacturer's base designed for raised floor | Installed on a raised floor  | Raised floor<br>Go to page 43                         |
| Any rooftop unit   | Roof-mounted on a post and beam  | Post and beam<br>Go to page 48                        |
|  | Connected to a manufactured isolation curb on a post and beam                              | Isolated curb on a post and beam<br>Go to page 58     |
|  | Vibration isolated on a post and beam  | Isolation springs on a post and beam<br>Go to page 60 |
|  | Directly connected to a sheet metal curb with nailer                                       | Pre-manufactured curb<br>Go to page 51                |
|  | Directly connected to a wood roof curb   | Wood curb<br>Go to page 57                            |
| Indoor AC unit or heat pump  | Suspended from building structure above with rods and cables                               | Rods and cables<br>Go to page 62                      |
|  | Suspended from building structure above with angles  | Suspended with angles<br>Go to page 68                |
|  | Suspended from building structure above with isolators, rods, and cables                   | Isolator rods and cables<br>Go to page 70             |
| Through-the-wall unit  | Supported by the wall  | Wall-mounted with angles<br>Go to page 90             |

Table 2: AC unit and heat pump installation types.



### Air Handling Units



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

#### Step 1: Identify equipment



Figure 11: Small rooftop air handling unit.



Figure 12: Large rooftop air handling unit.



Figure 13: Horizontal indoor air handling unit (floor-mounted or suspended).



Figure 14: Vertical indoor air handling unit (floor-mounted).

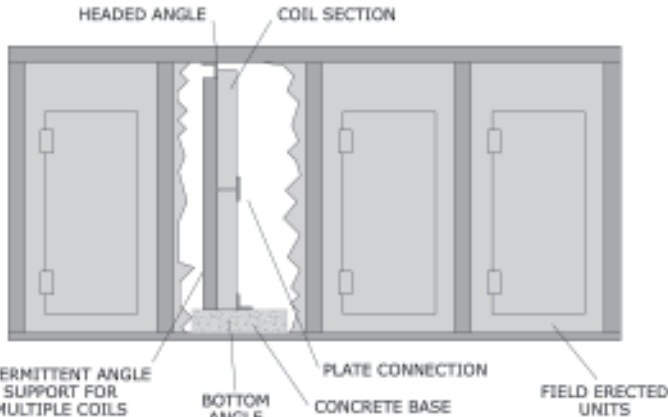


Figure 15: Built-up air handling units.

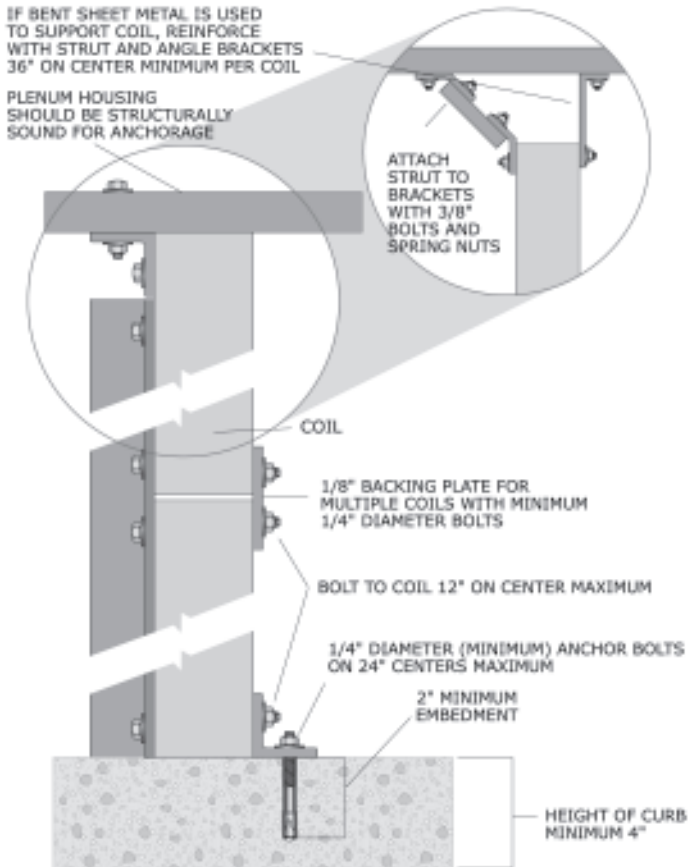


Figure 16: Coils in air handling units.

**Step 2: Select the type of attachment**

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| Typical Equipment   | How is equipment to be installed?  | Attachment Type                                       |
|---|--|---|
| Indoor air handling unit with a rigid base                  | Mounted directly to the floor  | Rigid<br>Go to page 32                                |
| Indoor air handling unit                                    | Connected to angles mounted to the floor   | Rigid with angles<br>Go to page 36                    |
|   | Suspended from structure above with rods and cables  | Rods and cables<br>Go to page 62                      |
|   | Suspended from structure above with angles   | Suspended with angles<br>Go to page 68                |
|   | Suspended from structure above with vibration isolation, rods, and cables                  | Isolator rods and cables<br>Go to page 70             |
| Weight-limited rooftop unit (see manufacturer's literature) | Directly connected to a sheet metal curb with nailer                                       | Pre-manufactured curb<br>Go to page 51                |
|   | Directly connected to a wood roof curb   | Wood curb<br>Go to page 57                            |
| Any rooftop unit  | Connected to a manufactured vibration isolation curb on a post and beam                    | Isolated curb on a post and beam<br>Go to page 58     |
|   | Roof-mounted on a post and beam  | Post and beam<br>Go to page 48                        |
| Large rooftop unit  | Vibration isolation on a post and beam   | Isolation springs on a post and beam<br>Go to page 60 |
| Any air handling unit                                       | Floor-mounted on vibration isolation using restrained springs or open springs and snubbers | Vibration-isolated<br>Go to page 77                   |

Table 3: Air handling unit installation types.

**Air Separators**



**Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.**

**Step 1: Identify equipment**



Figure 17: Air separator (floor-mounted).

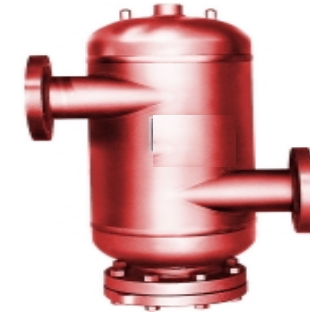


Figure 18: Air separator (suspended).

**Step 2: Select the type of attachment**

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| Typical Equipment | How is equipment to be installed?                                | Attachment Type                           |
|-------------------|--|---|
| Any unit          | Connected to angles mounted to the floor                         | Rigid with angles<br>Go to page 36        |
|                   | Suspended from the building structure above with rods and cables | Rods and cables<br>Go to page 62          |
|                   | Suspended from the building structure above with angles          | Suspended with angles<br>Go to page 68    |
|                   | Supported from the wall with angles                              | Wall-mounted with angles<br>Go to page 90 |

Table 4: Air separator installation types.

## Boilers, Furnaces, Humidifiers, and Water Heaters



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

### Step 1: Identify equipment



Figure 19: Small boiler.



Figure 20: Humidifier.

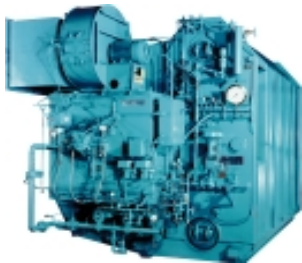


Figure 21: Water-tube (shown) or fire-tube boiler.



Figure 22: Flextube boiler.



Figure 23: Furnace.



Figure 24: Water heater.

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| <i>Typical Equipment</i>                 | <i>How is equipment to be installed?</i>                       | <i>Attachment Type</i>                                     |
|--|--|--|
| Any boiler or humidifier                 | Mounted directly to the floor                                  | Rigid<br><i>Go to page 32</i>                              |
| Any boiler, hot water heater, or furnace | Connected to angles mounted to the floor                       | Rigid with angles<br><i>Go to page 36</i>                  |
| Residential furnace                      | Furnace supported and restrained by rigid ductwork connections | Strap down similar to water heater<br><i>Go to page 90</i> |
| Residential water heater                 | Strapped to the wall   | Wall-mounted with straps<br><i>Go to page 90</i>           |
| Humidifier                               | Mounted directly to the wall                                   | Wall-mounted<br><i>Go to page 88</i>                       |

Table 5: Boiler, furnace, humidifier, and water heater installation types.

## Chillers



**Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer’s instructions.**

### Step 1: Identify equipment

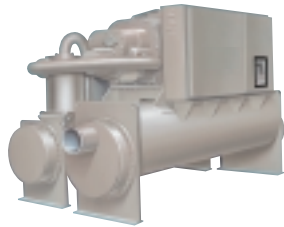


Figure 25: Centrifugal chiller (water-cooled).



Figure 26: Chiller with screw compressors (air-cooled).



Figure 27: Indoor chiller with scroll or screw compressors (water-cooled).



Figure 28: Small chiller with scroll and compressors (air-cooled).

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| <i>Typical Equipment</i> | <i>How is equipment to be installed?</i>  | <i>Attachment Type</i>                                 |
|--------------------------|---|--|
| Any chiller              | Mounted directly to the floor or concrete pad   | Rigid<br>Go to page 33                                 |
|                          | Floor-mounted vibration isolation using restrained springs or open springs and snubbers | Vibration-isolated<br>Go to page 77                    |
| Roof-mounted unit        | Roof-mounted on a post and beam   | Post and beam<br>Go to page 48                         |
|                          | Vibration isolation on a post and beam  | Vibration-isolated on a post and beam<br>Go to page 60 |

Table 6: Chiller installation types.

## Coils and Heat Exchangers



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

### Step 1: Identify equipment

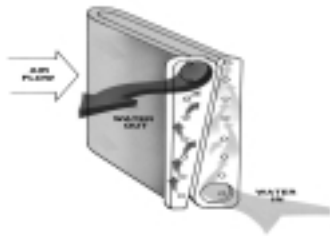


Figure 29: Duct-mounted coil.



Figure 30: A-coil.



Figure 31: Plate and frame heat exchanger.



Figure 32: Shell and tube heat exchanger.

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| Typical Equipment           | How is equipment to be installed?                       | Attachment Type                        |
|-----------------------------|---|--|
| Heat exchanger <sup>1</sup> | Mounted directly to the floor or concrete pad           | Rigid<br>Go to page 32                 |
| Duct-mounted coil           | Suspended from the building structure above with angles | Suspended with angles<br>Go to page 68 |
| A-coil                      | Sheet metal screws to furnace and sheet metal ducts     | N/A                                    |
| Coils in built-up plenums   | Plenum-mounted coils                                    | See Figure 16, page 9                  |

<sup>1</sup> This guide does not address structural frames required to elevate the heat exchanger above the floor.

Table 7: Coil and heat exchanger installation types.

## Condensers and Condensing Units



**Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.**

### Step 1: Identify equipment



Figure 33: Condenser/condensing unit (side condenser).



Figure 34: Condenser/condensing unit (totally enclosed).



Figure 35: Indoor condenser/condensing unit (see Air Handling Units for installation options).

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| <i>Typical Equipment</i>         | <i>How is equipment to be installed?</i>  | <i>Attachment Type</i>                                   |
|----------------------------------|---|--|
| Any condensing or condenser unit | Mounted directly to the floor or concrete pad   | Rigid<br><i>Go to page 32</i>                            |
|                                  | Floor-mounted vibration isolation using restrained springs or open springs and snubbers | Vibration-isolated<br><i>Go to page 77</i>               |
| Roof-mounted unit                | Roof-mounted on a post and beam   | Post and beam<br><i>Go to page 48</i>                    |
|                                  | Connected to a manufactured vibration isolation curb on a post and beam                 | Isolated curb on a post and beam<br><i>Go to page 58</i> |
| Small rooftop unit               | Directly connected to a wood roof curb  | Wood curb<br><i>Go to page 57</i>                        |

Table 8: Condenser and condensing unit installation types.

## Cooling Towers, Evaporative Coolers, and Fluid Coolers



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

### Step 1: Identify equipment



Figure 36: Fluid cooler cross flow with self-contained sump.



Figure 37: Cooling tower with self-contained sump.



Figure 38: Evaporative cooler.

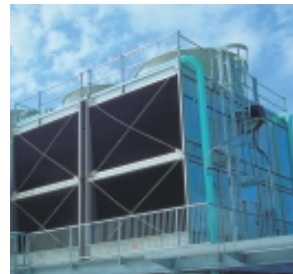


Figure 39: Large cooling tower.

### Step 2: Select the type of attachment to building

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| <i>Typical Equipment</i>  | <i>How is equipment to be installed?</i>  | <i>Attachment Type</i>                                 |
|---|---|--|
| Any unit with a rigid base or pedestal  | Mounted directly to floor or concrete sump  | Rigid<br>Go to page 32                                 |
| Any unit with a self-contained sump   | Roof-mounted on a post and beam   | Post and beam<br>Go to page 48                         |
| Fluid cooler, evaporative cooler, or cooling tower with a self-contained sump | Vibration isolated on a post and beam   | Vibration-isolated on a post and beam<br>Go to page 60 |
| Any unit with a structural base   | Floor-mounted vibration isolation using restrained springs or open springs and snubbers | Vibration-isolated<br>Go to page 77                    |
| Evaporative cooler  | Connected to angles mounted to the floor  | Rigid with angles<br>Go to page 36                     |
| Roof-mounted evaporative cooler   | Directly connected to a sheet metal curb with nailer                                    | Pre-manufactured curb<br>Go to page 51                 |

Table 9: Cooling tower, evaporative cooler, and fluid cooler installation types.

## Fans



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

### Step 1: Identify equipment

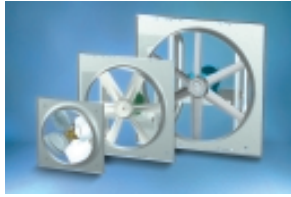


Figure 40: Wall propeller fan.



Figure 41: Rooftop fan.



Figure 42: Indoor box fan.



Figure 43: Indoor ceiling fan.



Figure 44: Axial fan.



Figure 45: Axial fan with remote motor.



Figure 46: Centrifugal fan.

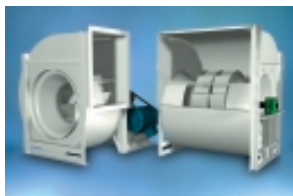


Figure 47: Industrial skid-mounted blower.

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| Typical Equipment                             | How is equipment to be installed?   | Attachment Type  |
|---|---|--|
| Centrifugal or industrial skid-mounted blower | Mounted directly to the floor   | Rigid<br>Go to page 32                                 |
| Any box or cabinet fan                        | Connected to angles mounted to the floor  | Rigid with angles<br>Go to page 36                     |
| Rooftop fan                                   | Directly connected to a sheet metal curb with nailer                                    | Pre-manufactured curb<br>Go to page 51                 |
|   | Directly connected to wood roof curb  | Wood curb<br>Go to page 57                             |
|   | Vibration isolation on a post and beam  | Vibration-isolated on a post and beam<br>Go to page 60 |
| Any propeller, box, cabinet, or axial fan     | Suspended from the building structure above with rods and cables                        | Rods and cables<br>Go to page 62                       |
|   | Suspended from the building structure above with angles                                 | Suspended with angles<br>Go to page 68                 |
|   | Suspended from the building structure above with isolators, rods and cables             | Isolator rods and cables<br>Go to page 70              |
| Centrifugal or skid-mounted blower unit       | Floor-mounted vibration isolation using restrained springs or open springs and snubbers | Vibration-isolated<br>Go to page 77                    |
| Propeller fan                                 | Mounted directly to the wall  | Wall-mounted<br>Go to page 88                          |
|   | Vibration isolation from the building structure   | Vibration-isolated off the wall<br>Go to page 93       |

Table 10: Fan installation types.



## Heaters



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

### Step 1: Identify equipment



Figure 48: Electric unit heater.



Figure 49: Water or steam unit heater.



Figure 50: Gas unit heater.



Figure 51: Gas-fired unit heater (see Air Handling Units for installation options).

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| <i>Typical Equipment</i>     | <i>How is equipment to be installed?</i>                                     | <i>Attachment Type</i>                           |
|------------------------------|--|--|
| Any unit heater              | Suspended from the building structure above with rods and cables             | Rods and cables<br><i>Go to page 62</i>          |
|                              | Suspended from the building structure above with angles                      | Suspended with angles<br><i>Go to page 68</i>    |
|                              | Suspended from the building structure above with isolators, rods, and cables | Isolator rods and cables<br><i>Go to page 70</i> |
|                              | Supported off the wall with a bracket  | Wall-mounted with angles<br><i>Go to page 90</i> |
| Relatively thin unit heaters | Suspended from the building structure with two rods and cables               | Double rods and cables<br><i>Go to page 75</i>   |

Table 11: Heater installation types.

## Pumps



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

### Step 1: Identify equipment

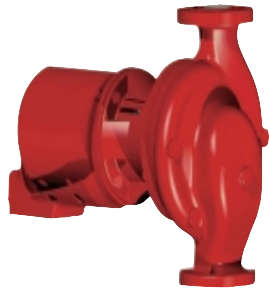


Figure 52: In-line pump.

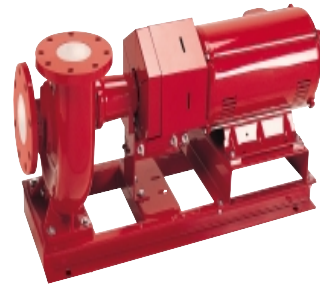


Figure 53: Horizontal end-suction or split-case pump.

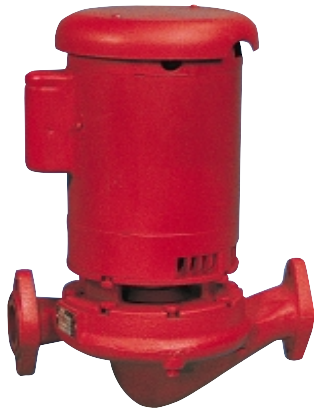


Figure 54: Close-coupled pump.



Figure 55: Vertical pump.

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| Typical Equipment  | How is equipment to be installed?   | Attachment Type                           |
|--|---|---|
| Base-mounted pump including end-suction pump and vertical pump | Mounted directly to the floor   | Rigid<br>Go to page 32                    |
| Base-mounted pump including end-suction pump                   | Connected to angles mounted to the floor  | Rigid with angles<br>Go to page 36        |
|  | Floor-mounted vibration isolation using restrained springs or open springs and snubbers | Vibration-isolated<br>Go to page 77       |
| In-line or close-coupled pump                                  | Supported off the floor with a steel angle  | Rigid with angles<br>Go to page 36        |
|  | Suspended from the building structure above with rods and cables                        | Rods and cables<br>Go to page 62          |
|  | Suspended from the building structure above with angles                                 | Suspended with angles<br>Go to page 68    |
|  | Suspended from the building structure above with isolators, rods and cables             | Isolator rods and cables<br>Go to page 70 |
|  | Mounted directly to the wall  | Wall-mounted<br>Go to page 88             |
|  | Supported off the wall with an angle bracket  | Wall-mounted with angles<br>Go to page 90 |

Table 12: Pump installation types.

## Tanks and Gas Cylinders



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

### Step 1: Identify equipment



Figure 56: Small expansion tanks or water tanks (with rolled steel plate base).



Figure 57: Expansion tanks, water storage tanks, on legs.



Figure 58: Water softeners.



Figure 59: Vertical tanks.



Figure 60: Horizontal tanks including concrete-lined tanks.



Figure 61: Gas cylinders.

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| Typical Equipment <sup>1</sup>   | How is equipment to be installed?        | Attachment Type                                     |
|--|--|---|
| Tanks with attachment stands, legs or brackets                         | Mounted directly to the floor            | Rigid<br>Go to page 32                              |
| Tanks with rolled steel plate bases                                    | Connected to angles mounted to the floor | Rigid with angles<br>Go to page 36                  |
| Tanks less than 4 feet in diameter with a flat bottom or gas cylinders | Tanks built into a plate and frame       | Strut and frame<br>Go to page 46                    |
| Tanks less than 2 feet in diameter                                     | Attached to the wall with straps         | Wall-mounted with angles or straps<br>Go to page 90 |
| Tanks or gas cylinders   | Chained to the wall                      | Wall-mounted with chains<br>Go to page 95           |

<sup>1</sup> This guide does not address structural frames required to elevate tanks.

Table 13: Tank and gas cylinder installation types.

## VAV Boxes (Terminal Units), Duct Silencers, and Fan-coil Units



Be sure to refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.

### Step 1: Identify equipment

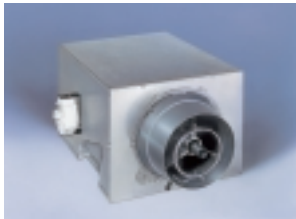


Figure 62: VAV damper.



Figure 63: VAV box with fan (series or parallel).



Figure 64: Dual duct box.



Figure 65: Vertical fan-coil unit.



Figure 66: Horizontal fan-coil unit.



Figure 67: Duct silencer.

### Step 2: Select the type of attachment

Using the following table, select how the equipment is to be installed, select the attachment type that best matches the installation you have selected, then turn to the page under the attachment type.

| Typical Equipment  | How is equipment to be installed?  | Attachment Type                            |
|--|--|--|
| Fan-coil unit  | Mounted directly to the floor  | Rigid<br>Go to page 32                     |
|  | Connected to angles mounted to the floor                                     | Rigid with angles<br>Go to page 36         |
| Any VAV box, duct silencer, or fan-coil unit                               | Suspended from the building structure above with rods and cables             | Rods and cables<br>Go to page 62           |
|  | Suspended from the building structure above with angles                      | Suspended with angles<br>Go to page 68     |
|  | Suspended from the building structure above with isolators, rods, and cables | Isolator rods and cables<br>Go to page 70  |
| Any VAV box, duct silencer, or fan-coil unit weighing less than 150 pounds | Suspended from the building structure above with two attachment angles       | Suspended with two angles<br>Go to page 75 |

Table 14: VAV box (terminal unit), duct silencer, and fan-coil unit installation types.

## ATTACHMENT TYPES

This section gives instructions on attaching equipment in many different arrangements. The attachment types are:

- Rigid Floor-mounted/Pad-mounted (this page).
- Roof-mounted (page 48).
- Suspended (page 62).
- Vibration-isolated/Floor-mounted (page 77).
- Wall-mounted (page 88).

### Rigid Floor-mounted/Pad-mounted Attachment

The six ways to rigidly attach equipment to a floor are:

- Directly to the floor/pad (this page).
- Using additional structural steel shapes that transfer load to the building floor (page 36).
- Using bumpers to restrict horizontal movement (page 41).
- Beneath a raised floor (page 43).
- At a single point—light equipment only (page 45).
- Using a strut and plate frame—tanks and gas cylinders only (page 46).

#### Directly to the floor/pad

Equipment may be bolted or welded to the building floor or pad. To bolt to concrete, use post-installed anchors, embedded headed studs or embedded J-bolts.

Attachment of equipment with sheet steel housings is shown in Figure 69 (page 33).

Attachment of equipment with a steel structural framing or base is shown in Figure 70 (page 34).

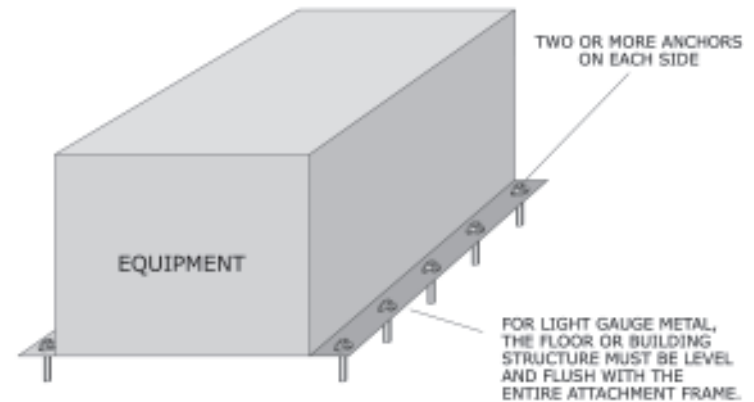


Figure 68: Direct attachment of equipment with sheet steel housing to a building.



**Do not add shims under equipment with sheet steel housings as shown in Figure 68 above. If the concrete floor/pad is irregular, reinforce housing with angles as shown in Figure 72 (page 37).**

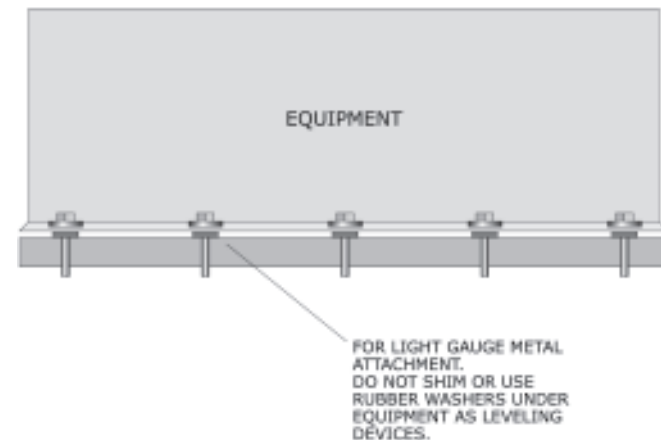


Figure 69: Side view of equipment with sheet steel housing.

## Attachment: Rigid Floor-mounted/Pad-mounted

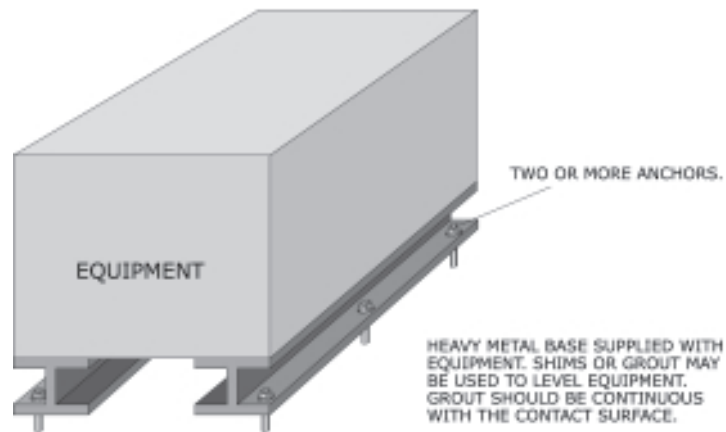


Figure 70: Direct attachment of equipment with structural steel frame or base to a building.

### Step 1: Determine where to bolt the equipment

Accurately draw the bolt pattern on the floor, concrete pad, or steel beams using one of the following methods:

- Set the equipment in place and mark the holes.
- Make a template.
- Use measurements and shop drawings to lay out the bolt hole pattern.

You may drill additional holes into the equipment assembly or building steel beams as shown on construction drawings or the manufacturer's instructions.



**USE CAUTION WHEN DRILLING INTO EQUIPMENT.** Internal components can be damaged or the manufacturer's warranty may be voided. **DO NOT DRILL OVERSIZED HOLES.**



**New holes cannot be oversized or oval in shape.** Repair oversized holes as shown in Figure 71 (page 35), if necessary.

## Attachment: Rigid Floor-mounted/Pad-mounted

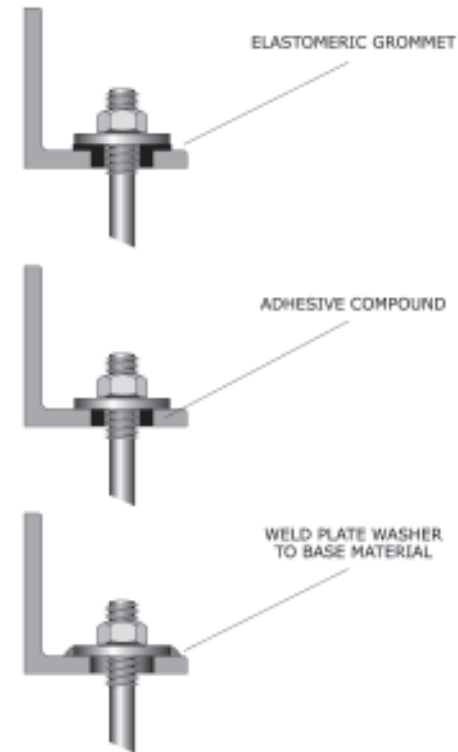


Figure 71: Three options to repair oversized holes.

### Step 2: Install anchors

If the equipment is to be anchored to concrete, drill and install post-installed anchors or pour concrete with cast-in-place studs or J-bolts (see Anchors, page 96).



**If the equipment is to be bolted to steel, drill holes in the steel as shown on construction drawings or the manufacturer's instructions.**

### Step 3: Move equipment into place



**BE CAREFUL NOT TO DAMAGE THE ANCHORS WHEN SETTING THE EQUIPMENT.**

### Step 4: Attach nuts or weld equipment

Attach nuts to the anchor/bolt and torque.

Weld equipment to steel beams or embedded plates (page 119).

Piping, ductwork, and raceways may be connected.

**END OF ATTACHMENT.**

### Using additional structural steel shapes

Attach additional structural shapes to the equipment with bolts and then attach steel shapes to the building with concrete anchors, steel bolts, or welding. When bolting to concrete, use post-installed anchors, embedded headed studs, or embedded J-bolts.

Five different configurations for using angles to attach equipment to the building structure are shown in the following figures.

- Full-size angles on each side of equipment: Figure 72 (page 37).
- Four or more angles on each side of equipment bolted to the concrete floor/pad: Figure 73 (page 38).
- Four or more angles welded to equipment and bolted to the floor/pad: Figure 74 (page 38).
- Four or more angles on each side of equipment welded to embedded plates: Figure 75 (page 39).
- Three or more angles used to bolt down equipment with a round base: Figure 76 (page 39).

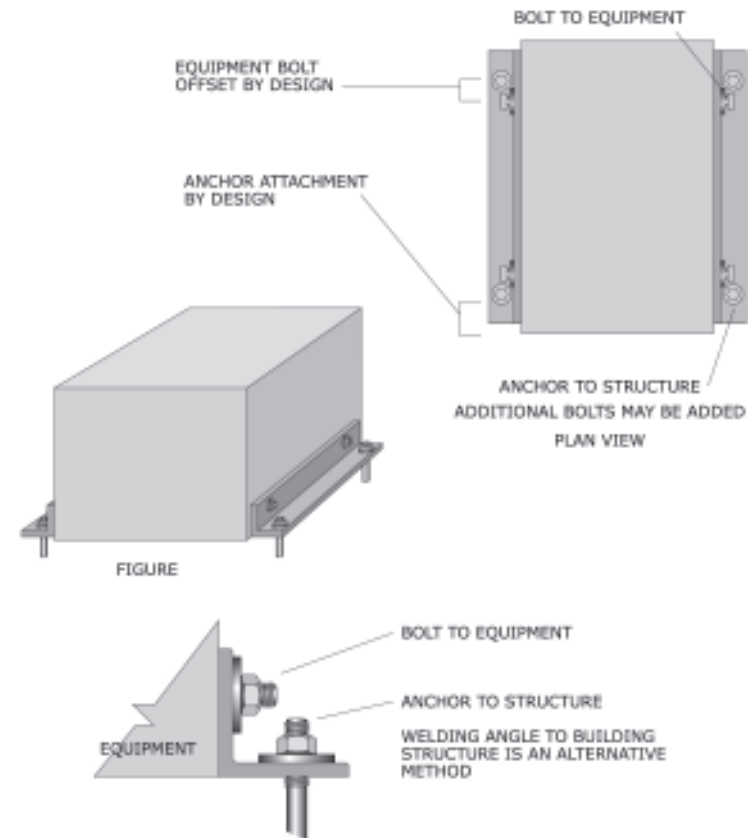


Figure 72: Two angles used to attach the equipment to the building.

Attachment: Rigid Floor-mounted/Pad-mounted

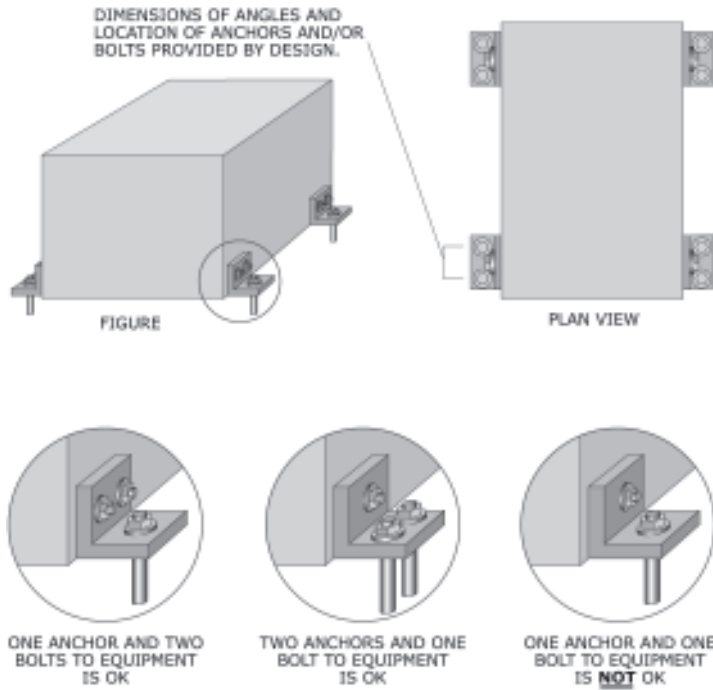


Figure 73: Four or more angles used to attach the equipment to the building.

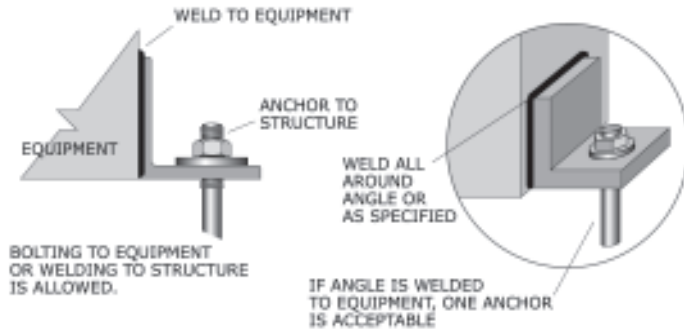


Figure 74: Four or more angles welded to equipment and bolted to the floor/pad.

Attachment: Rigid Floor-mounted/Pad-mounted

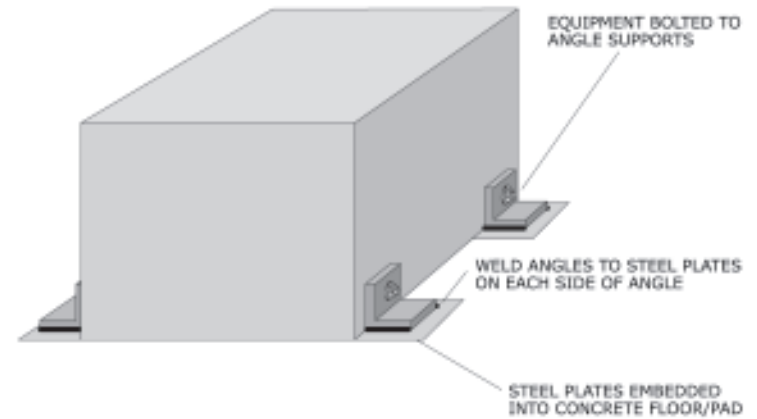


Figure 75: Four or more angles on each side of equipment welded to embedded plates. Figure 150 (page 119) gives examples of embedded steel plates.

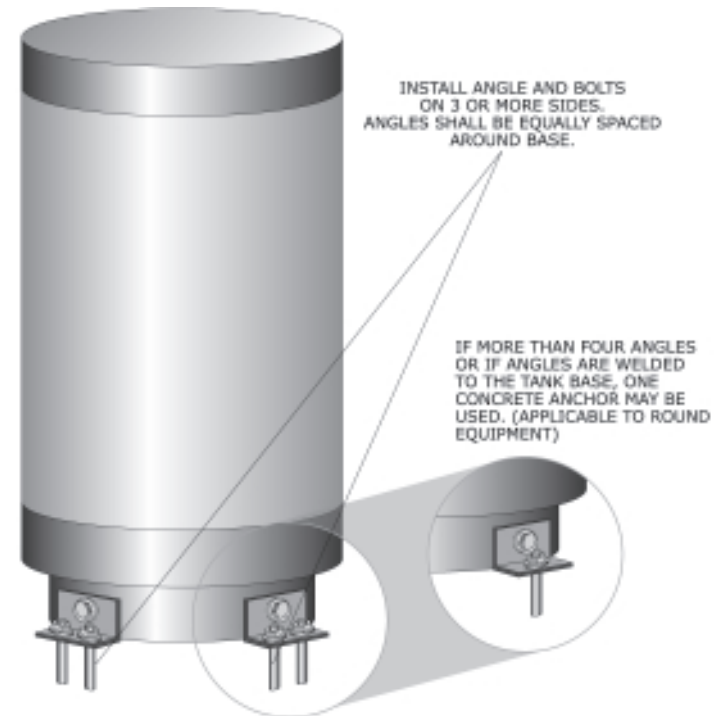


Figure 76: Three or more angles used to bolt down equipment with a round base.



**Step 1: Determine where to bolt the equipment**

Accurately draw the bolt pattern on the floor, concrete pad, or steel beams using one of the following methods:

- Set the equipment in place and mark the holes.
- Make a template.
- Use measurements and shop drawings to lay out the bolt hole pattern.



**You may drill additional holes into the equipment assembly or building steel beams as shown on construction drawings or the manufacturer's instructions.**



**USE CAUTION WHEN DRILLING INTO THE EQUIPMENT. Internal components can be damaged or the manufacturer's warranty may be voided. DO NOT DRILL OVERSIZED HOLES.**



**New holes cannot be oversized or oval in shape. Repair oversized holes as shown in Figure 71 (page 35), if necessary.**

**Step 2: Install anchors**

If the equipment is to be anchored to concrete, drill and install post-installed anchors or pour concrete with embedded studs or J-bolts (see Anchors, page 96).



**If the equipment is to be bolted to steel, drill holes in the steel as shown on construction drawings or the manufacturer's instructions.**

**Step 3: Move the equipment into place**

**BE CAREFUL NOT TO DAMAGE THE ANCHORS WHEN SETTING THE EQUIPMENT.**

You may bolt or weld angles to the equipment before moving the equipment into place.

**Step 4: Attach nuts or weld equipment**

Attach nuts to the anchor/bolt and torque (see Anchors, page 96 or Welding, page 119).

Piping, ductwork, and raceways may be connected.

**END OF ATTACHMENT.**

**Using bumpers to restrict horizontal movement**

Use this attachment type when equipment is mounted to a concrete inertia base or steel frame, but:

- The base is not attached to the building, or
- The equipment has a rigid base with a flat surface near the bottom.

Bumpers are used to restrain the base from moving horizontally when there is no chance that the equipment will tip over. Bumpers are only bolted to the building structure. Use post-installed anchors to bolt to concrete, as shown in Figures 77 and 78 (below).

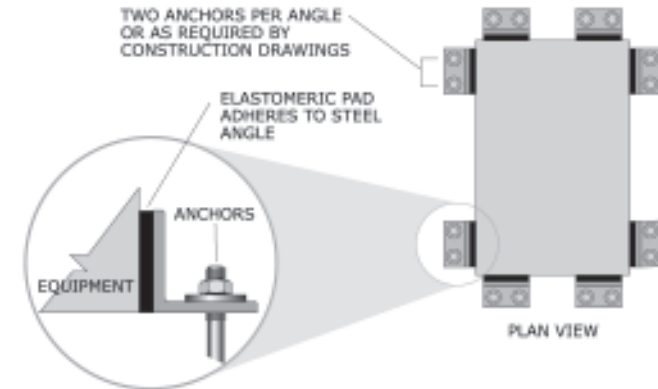


Figure 77: Equipment installed with bumpers.



**If anchors are near a joint in the concrete, see detail in Figure 78.**

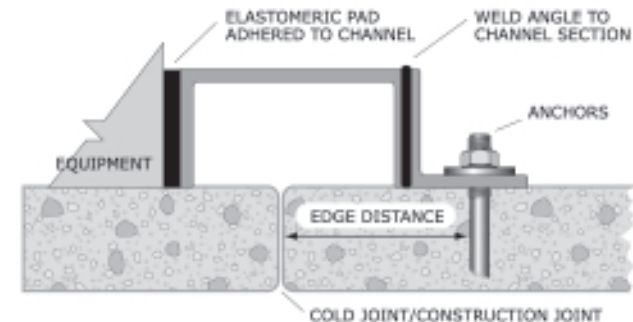


Figure 78: Alternate installation detail of bumpers installed near a concrete joint.

### Step 1: Determine where to bolt the equipment

Accurately draw the bolt pattern on the floor, concrete pad, or steel beams using one of the following methods:

- Set the bumpers in place and mark the holes.
- Use measurements and construction drawings to lay out the bolt hole pattern.

### Step 2: Install anchors

See Anchors (page 96). If the anchors are near a concrete joint, refer to the detail in Figure 78 (page 41).

### Step 3: Install bumpers

### Step 4: Attach nuts to the anchor/bolt and torque

See Anchors, page 96. Figure 78 shows equipment restrained with bumpers next to a cold joint. Notice in Figure 79 below that the application is near a concrete joint.

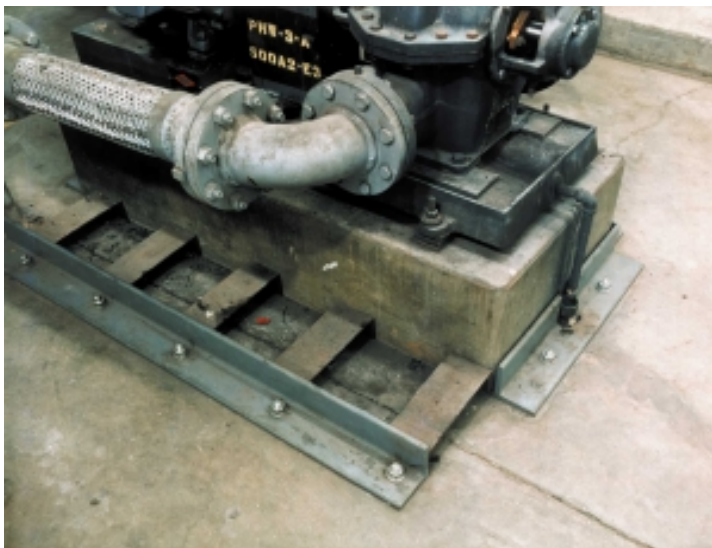


Figure 79: Equipment restrained with bumpers.

### Beneath a raised floor

Air conditioning units for computer spaces typically move air through a raised floor. A stand rated for the weight of the air conditioning unit and laterally braced to withstand seismic loads must be provided. Equipment is rigidly attached to the stand and the stand is rigidly bolted to the floor beneath the raised floor. Portions of the raised floor are removed to allow installation of the stand and equipment as shown in Figure 80 (below).

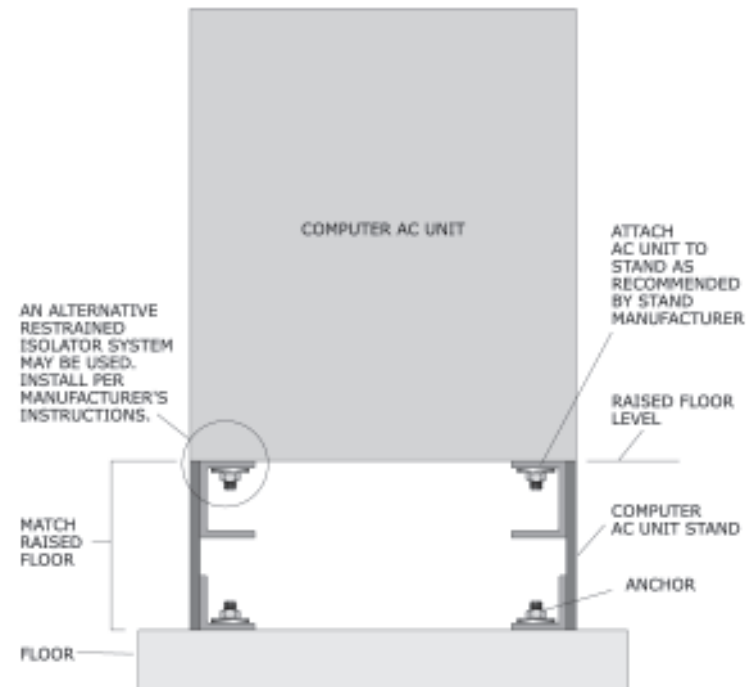


Figure 80: Air conditioning unit for a raised floor.

### Step 1: Determine where to bolt the equipment

Accurately draw the bolt pattern on the floor using one of the following methods:

- Set the frame in place and mark the holes.
- Make a template.
- Use measurements and construction drawings to lay out the bolt hole pattern.

**Step 2: Install anchors**

See Anchors, page 96. Set the frame in place and apply nuts to the anchor/bolt and torque.

**Step 3: Move the equipment into place**

Bolt equipment to the frame (see Steel Bolt Connections, page 114). You may drill additional holes into the equipment assembly or building steel beams as shown on construction drawings or the manufacturer's instructions.

 **New holes cannot be oversized or oval in shape. Repair oversized holes as shown in Figure 71 (page 35), if necessary.**

Piping, ductwork, and raceways may be connected.

**END OF ATTACHMENT.**

**At a single point—light equipment only**

Air separators or inline pumps weighing less than 400 pounds may be supported on both the inlet and outlet using a floor support as shown in Figure 81 (below). A single support may be used if the equipment weighs less than 150 pounds. A rigid connection with rods and cables supported from the building structure above is optional.

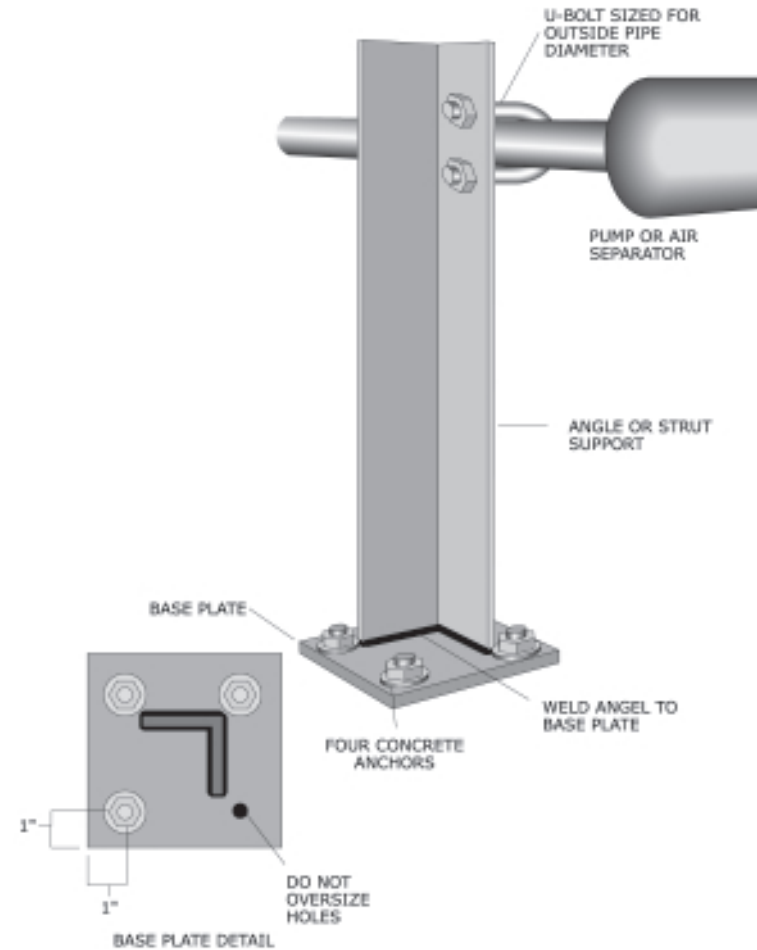


Figure 81: Angle floor support.

**Step 1: Determine where to bolt the equipment**

Accurately draw the bolt pattern of the base plate on the floor using one of the following methods:

- Set the base plate in place and mark the holes.
- Make a template.
- Use measurements and construction drawings to lay out the bolt hole pattern.

**Step 2: Install anchors**

Install post-installed anchors as described in Anchors (page 96). Set the base plate with the angle support in place. Apply nuts to the anchor/bolt and torque.

**Step 3: Attach piping**

Attach piping to the angle with a U-bolt (see Steel Bolt Connections, page 114.)

**END OF ATTACHMENT.**

**Using a strut and plate frame—tanks and gas cylinders only**



Figure 82: Small gas cylinder storage.

**Step 1: Determine where to bolt the equipment**

Accurately draw bolting pattern of the strut frame on the floor using one of the following methods:

- Set the base plate in place and mark the holes.
- Make a template.
- Use measurements and construction drawings to lay out the bolt hole pattern.

**Step 2: Install anchors**

Install post-installed anchors as described in Anchors (page 96). Set the bottom frame in place. Apply nuts to the anchor/bolt and torque.

**Step 3: Complete frame and plate assembly**

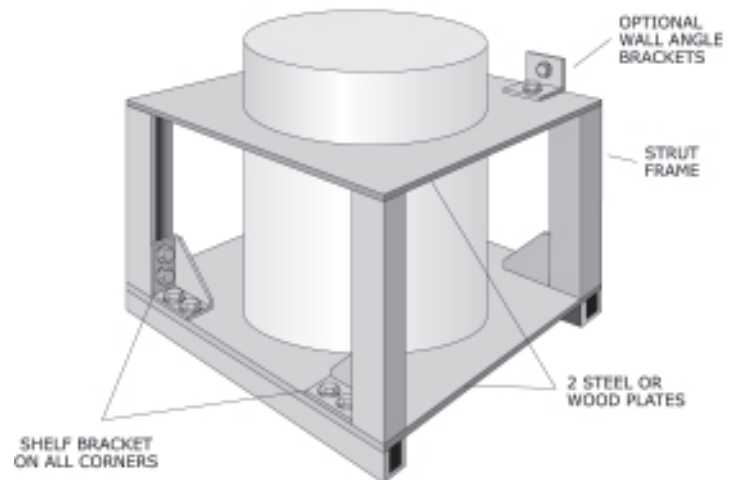


Figure 83: Tank and gas cylinder support.

**Step 4: Install additional anchors**

Additional anchors may be installed in the wall for extra support. See Anchors (page 96) or Masonry and Drywall Anchors (page 106).

Tanks and gas cylinders may be attached.

**END OF ATTACHMENT.**

## Roof-mounted Attachment

The five ways to rigidly attach equipment to a roof are:

- Using leveling stanchions—also called post and beam (this page).
- To seismic built-up or seismic pre-manufactured curb (page 51).
- To a wood frame (page 57).
- Using a pre-manufactured seismic vibration isolation curb or leveling stanchions with equipment support frame (page 58).
- Using restrained springs on leveling stanchions (page 60).

### Using leveling stanchions—post and beam

#### Step 1: Attach posts or stanchions

Bolt or weld stanchions to the building structure. To attach stanchions to different building structure types, see the detail in Figure 84 (page 49).

Support stanchions can be made from many different structural shapes.



**Coordinate attachment points with the general contractor. Additional intermediate building structure beams may be required to accommodate the equipment.**



**The building structure must be capable of supporting the point load of the stanchions.**

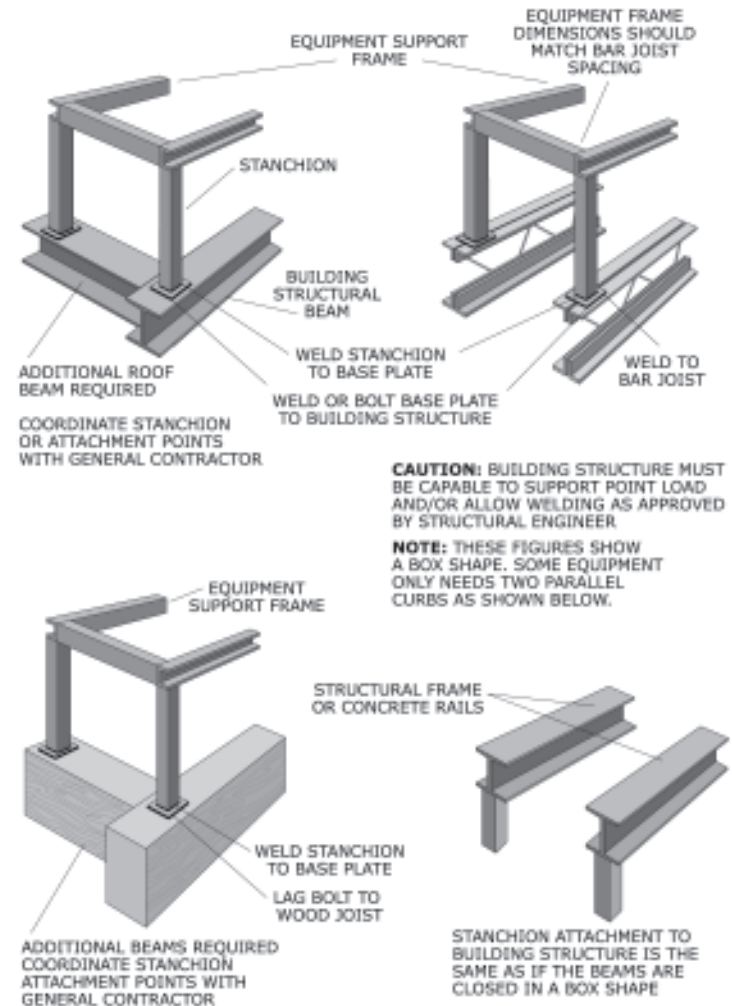


Figure 84: Attaching a stanchion to a building.

#### Step 2: Apply flashing to stanchions

Use standard details to flash around pipe stanchions or steel tubing. For flashing around a stanchion, which may not be uniform like an angle, channel, or I-beam steel shape, see Figure 85 (page 50).

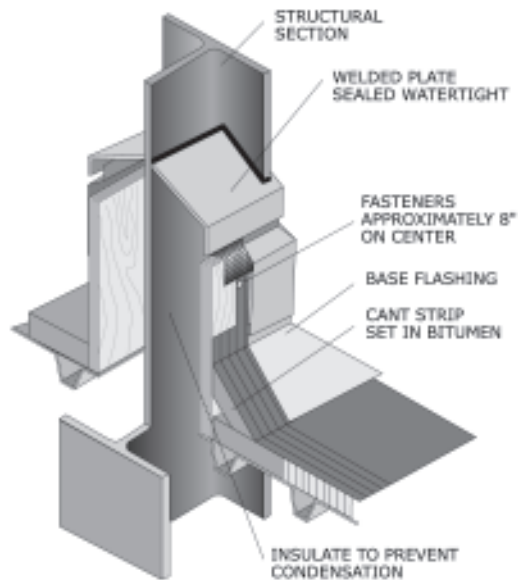


Figure 85: Flashing around a stanchion.

### Step 3: Weld/bolt equipment support frame to stanchion

The equipment support frame may be box-shaped or have two parallel beams. The equipment support frame may be made from steel shapes such as angles, tubes, channels, or I-beams.

### Step 4: Attach equipment

To rigidly attach the equipment to the equipment support frame, see Figure 86 (page 51).

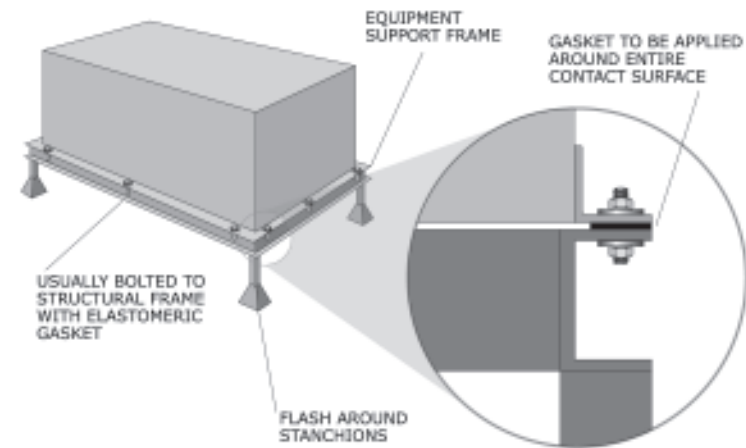


Figure 86: Rigid attachment of equipment to a support frame.

### END OF ATTACHMENT.

### To seismic built-up or seismic pre-manufactured curb

#### Step 1: Attach curb to roof or building structure

To attach the curb to the building structure, see Anchors (page 96).

To attach seismic-rated built-up curb to a roof structure, see Figure 87 (page 52) for one method of building a curb.

To attach seismic-rated pre-manufactured curb:

- Directly to the roof, see Figure 88 (page 53).
- To the building structure, see Figure 89 (page 54).

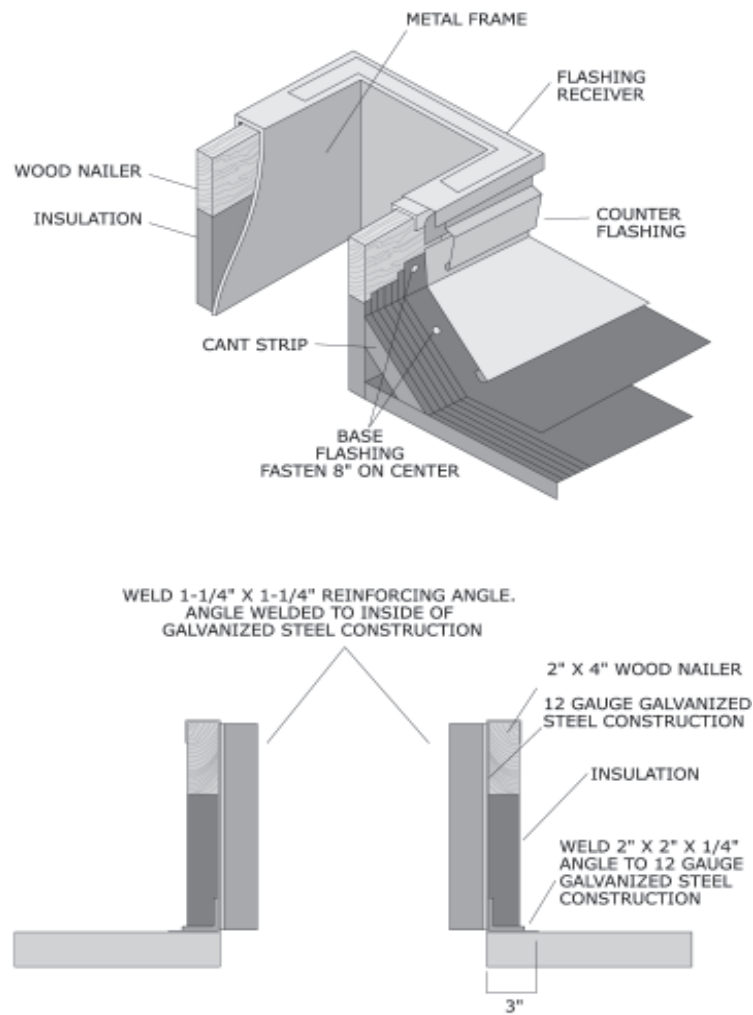


Figure 87: Seismic built-up curb details.

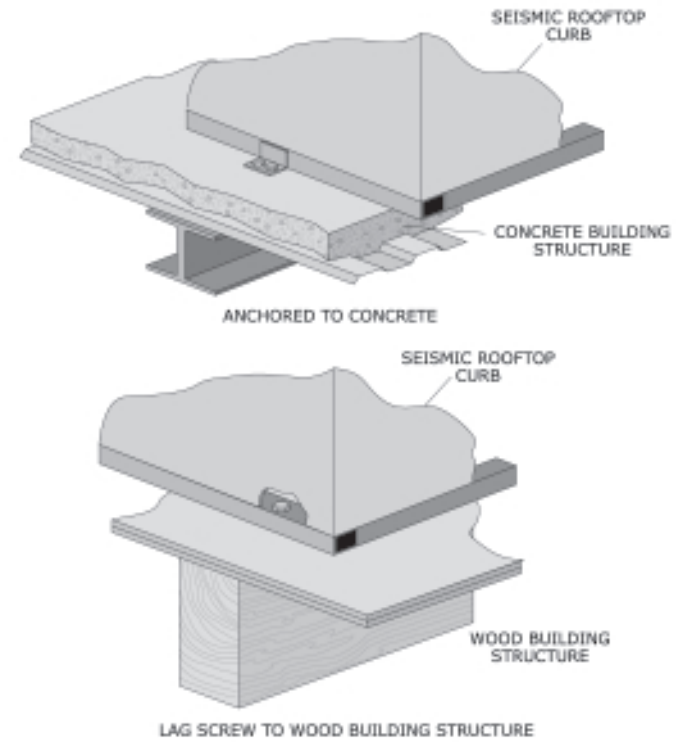
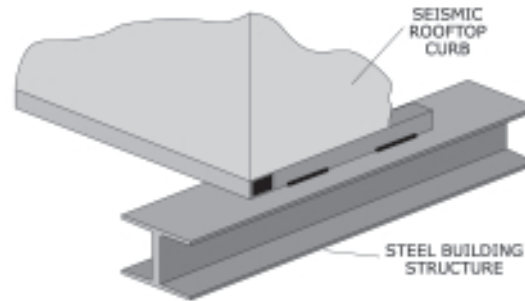


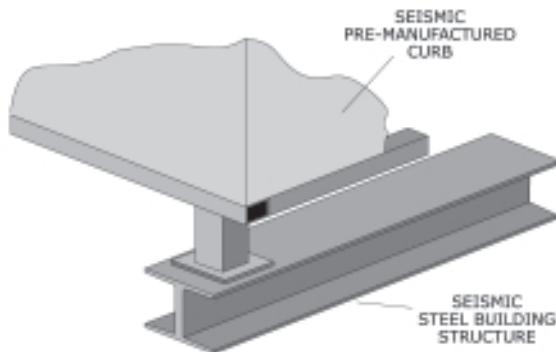
Figure 88: Pre-manufactured curb attached to a roof.



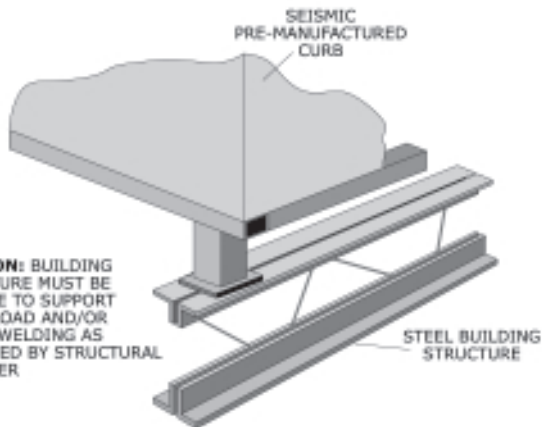
**Follow the manufacturer's instructions for installing all seismic pre-manufactured curbs.**



WELDED DIRECTLY TO BUILDING STRUCTURE



WELDED TO LEVELING STANCHIONS



WELDED TO BAR JOIST

**CAUTION:** BUILDING STRUCTURE MUST BE CAPABLE TO SUPPORT POINT LOAD AND/OR ALLOW WELDING AS APPROVED BY STRUCTURAL ENGINEER

Figure 89: Pre-manufactured curb attached to the building structure.

### Step 2: Weld reinforcing angles

For built-up curb, weld reinforcing angles to the metal frame as shown in Figure 87 (page 52).

### Step 3: Install flashing

Figure 87 shows the flashing for built-up curbs. This may be used for pre-manufactured curbs.

### Step 4: Attach equipment

Attach the equipment to seismic built-up curb using lag wood screws/lag bolts as shown in Figure 90 (page 56). Space the lag wood screws or lag bolts according to the manufacturer's instructions.



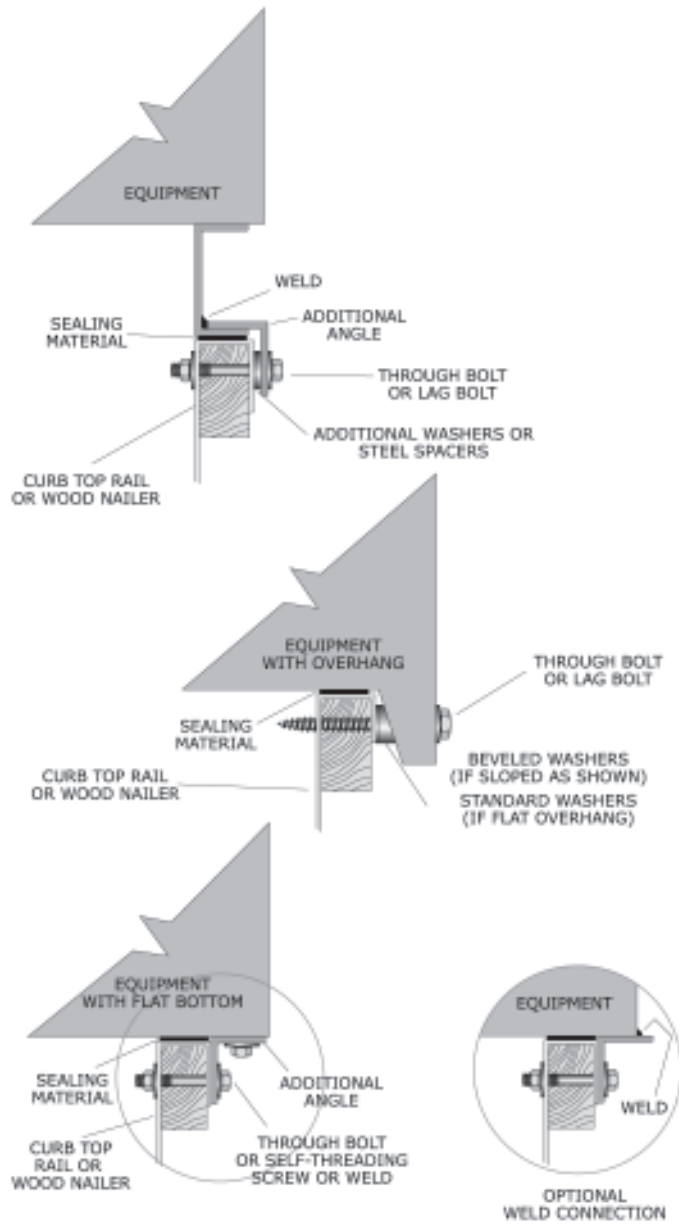


Figure 90: Attachment of equipment to a built-up curb or pre-manufactured curb.

**END OF ATTACHMENT.**

**To a wood frame**

**Step 1: Attach wood frame to building structure**

Figure 91 (below) shows a typical wood frame attachment.

**Step 2: Install flashing**

Figure 91 (below) shows typical flashing.



**Use contract documents for flashing details.**

**Step 3: Attach equipment to the wood frame**

Attach equipment directly to the wood frame as shown below. Wood frames can restrain equipment with internal frames or with support legs as shown.

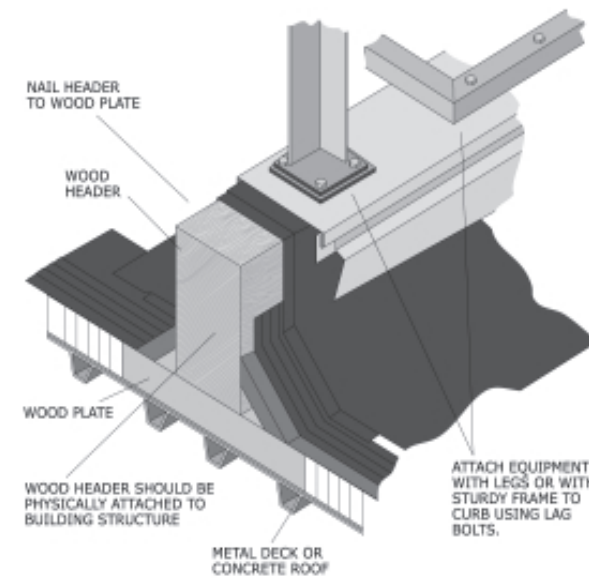


Figure 91: Attachment of equipment to a wood frame.

**END OF ATTACHMENT.**

**Using a seismic pre-manufactured vibration isolation curb**

Figure 92 (below and next page) shows the vibration isolation curb attached to a rigid base. The base may be a rigid curb as shown in Figure 92 or a post and beam frame (see Figure 84, page 49).

**Step 1: Attach curb or post and beam with equipment support frame to building structure**

If a rigid curb is the base of the vibration isolation curb, go to page 51 and follow instructions for rigidly attaching equipment to a built-up or pre-manufactured curb.

If a post and beam is the base of the vibration isolation curb, go to page 48 and follow instructions for rigidly attaching equipment with leveling stanchions.

**Step 2: Install flashing**

Install flashing for a rigid curb as shown in Figure 87 (page 52) or flash the stanchions as shown in Figure 85 (page 50).

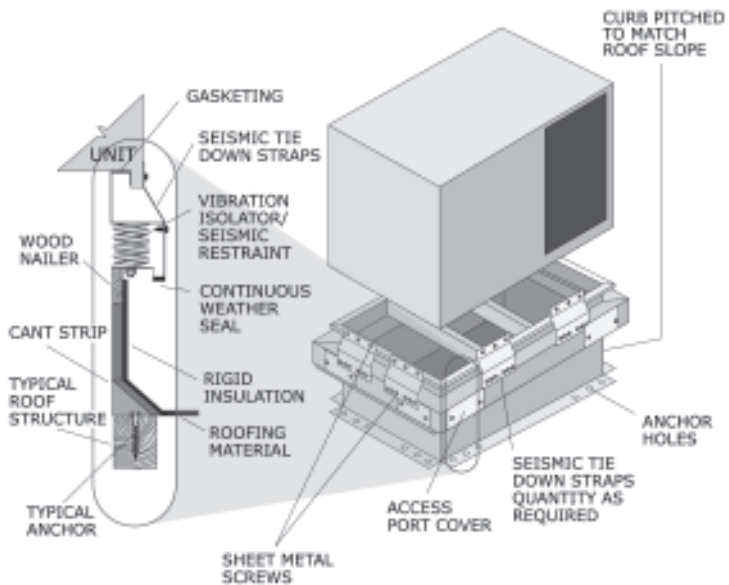


Figure 92: Various types of manufactured isolator systems (continued on next page).

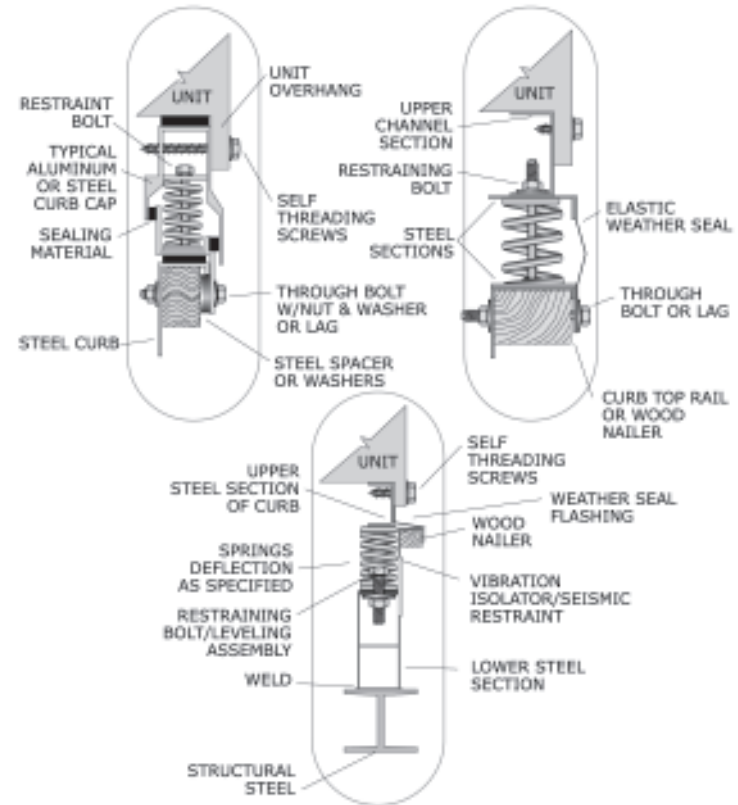


Figure 92: Various types of manufactured isolator systems.

**Step 3: Attach vibration isolation curb to base**

Figure 92 (page 58 and above on this page) shows through-bolts or lag screws used to attach curb to base.



**Use contract documents for flashing details.**

**Step 4: Attach equipment to the vibration isolation curb and level**

Figure 92 (page 58 and above on this page) shows various seismic attachment methods used to attach equipment to a vibration isolation curb and level.

**END OF ATTACHMENT.**

### Using restrained springs on leveling stanchions

Figure 93 (below) shows a typical installation of restrained spring vibration isolated equipment on stanchions and an equipment support frame.

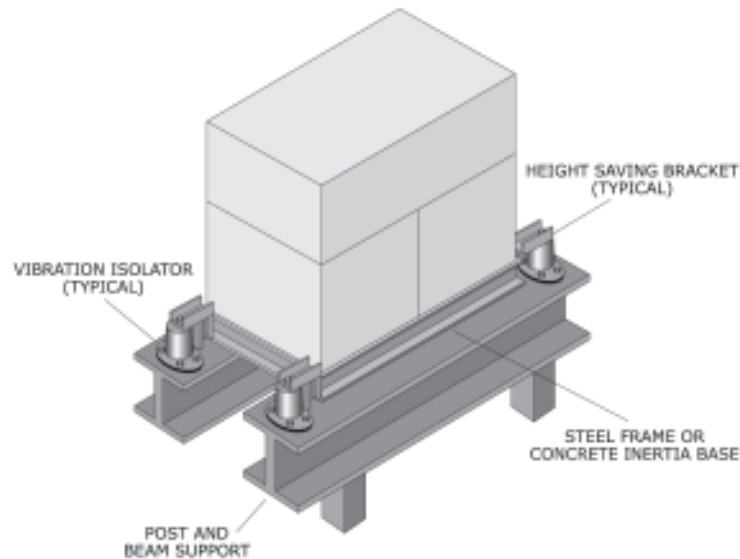




Figure 93: Equipment attached using restrained springs on a post and beam.

 **More than four restrained springs may be required. See the manufacturer's instructions.**

 **Verify that the spring is properly aligned according to the manufacturer's recommended clearances. If the spring shaft rubs against the snubber element, a short-circuit may occur, causing noise problems.**

#### Step 1: Attach posts or stanchions

Bolt or weld stanchions to the building structure. Refer to the detail in Figure 84 (page 49) for attaching stanchions to different building structure types. Support stanchions can be made from many different structural shapes.

 **Coordinate attachment points with the general contractor. Additional intermediate building structure beams may be required to accommodate the equipment.**

 **THE BUILDING STRUCTURE MUST BE CAPABLE OF SUPPORTING THE POINT LOAD OF THE STANCHIONS.**

#### Step 2: Apply flashing to stanchions

Use standard details to flash around pipe stanchions or steel tubing. For flashing around a stanchion, which may not be uniform like an angle, channel, or I-beam steel shape, refer to Figure 85 (page 50).

#### Step 3: Weld/bolt equipment support frame to stanchions

The equipment support frame may be box-shaped or have two parallel beams. The equipment support frame may be made from steel shapes such as angles, tubes, channels, or I-beams.

#### Step 4: Attach restrained springs

Attach restrained springs to the curb using steel bolts.

 **The support frame must be wider than the base plate of the restrained spring.**

#### Step 5: Install equipment on springs

Install equipment on springs with attachment nuts and level.

 **Bases are required for mounting equipment with restrained springs. Do not use restrained springs on a built-up curb.**

**END OF ATTACHMENT.**

## Suspended Attachment

The four ways to suspend equipment are by:

- Rigid connection to the building structure using four threaded vertical rods with horizontal cable supports (this page).
- Rigid connection to the building structure using angle/strut supports (page 68).
- Isolated connection to the building structure using four threaded vertical rods and horizontal cable supports (page 70).
- Double angle attachment—bolted or welded to the building (page 73).
- Double rod attachment—bolted to the building (page 75).

### Rigid connection to the building structure using four threaded vertical rods with horizontal cable supports

Equipment should have pre-installed brackets that can support the attachment to the building.

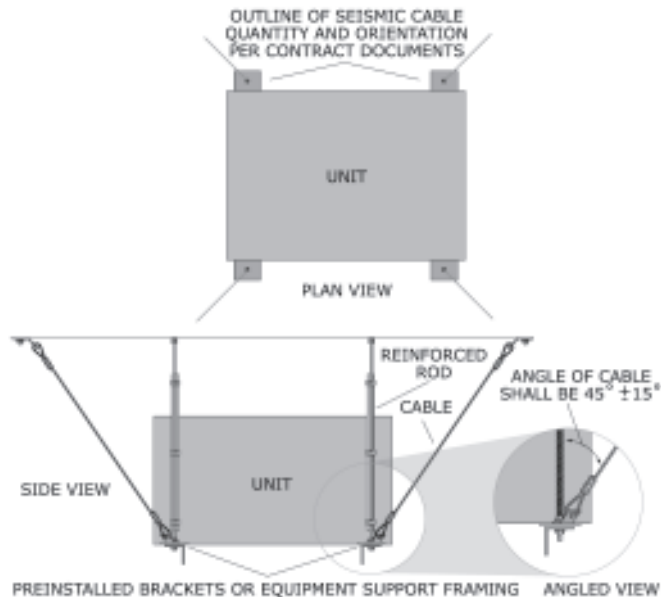


Figure 94: Rigid connection to the building structure.



**Cables provide horizontal support for seismic loads and should not be installed to hang equipment.**

### Step 1: Attach the equipment to the building structure using threaded rods and anchors

Lay out all attachment points before anchoring. For building structure attachment details, see Figures 95 to 100 (below and pages 64-65). For instructions on bolting directly to the building structure, see Steel Bolt Connections (page 114).

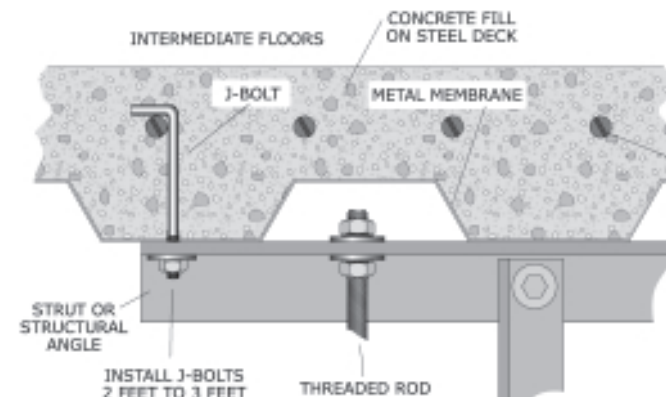


Figure 95: Cast-in-place anchor; concrete fill on steel deck.

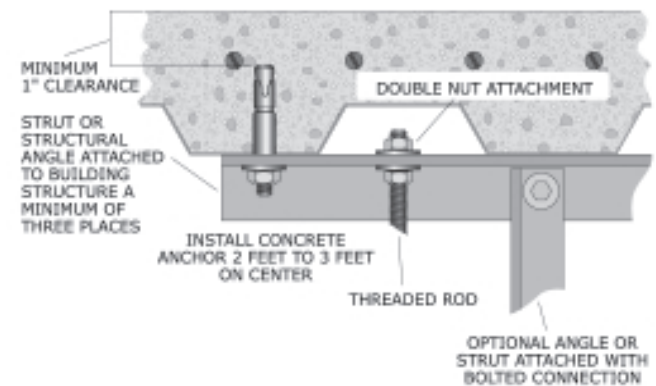


Figure 96: Post-installed anchor; concrete fill on steel deck.

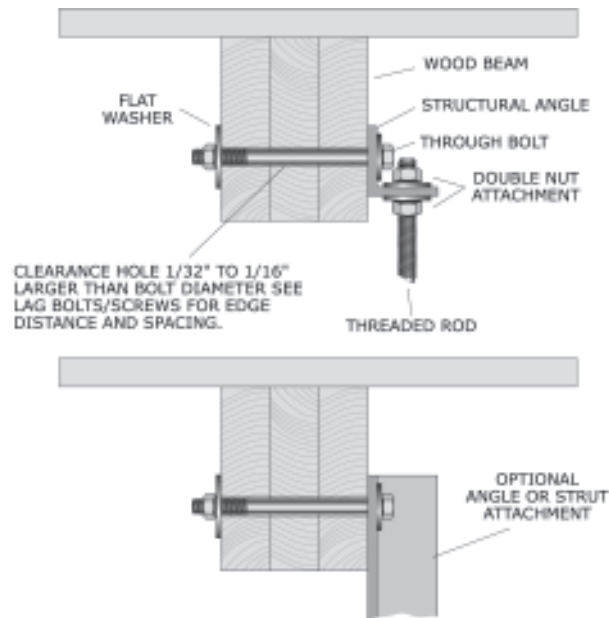


Figure 97: Wood beam construction.

**For edge distances and spacing, see Lag Bolts (page 104).**

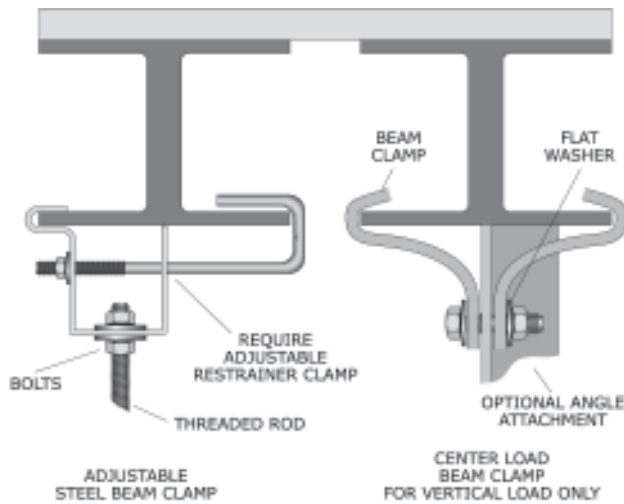


Figure 98: Steel beam construction.

**Use center load beam clamps for vertical loads. Do not use for cables, rods, or structural members positioned at an angle.**

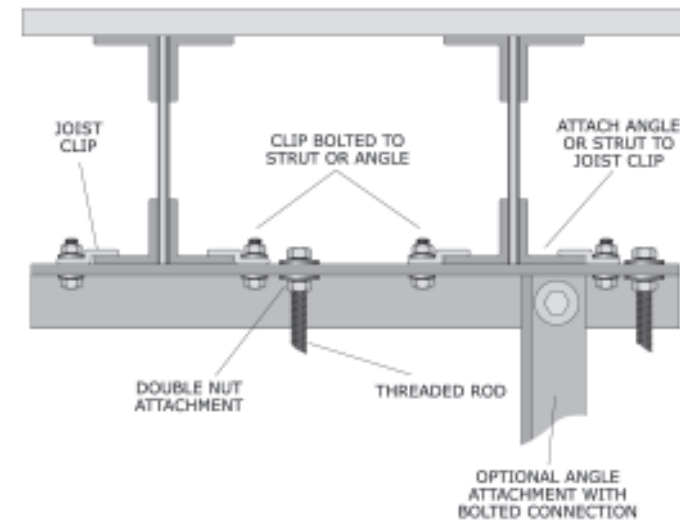


Figure 99: Bar joist construction.

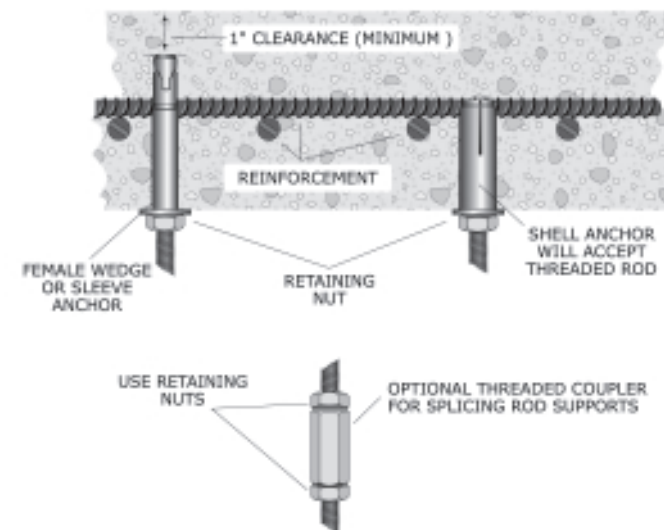


Figure 100: Concrete slab construction.

### Step 2: Add rod stiffeners

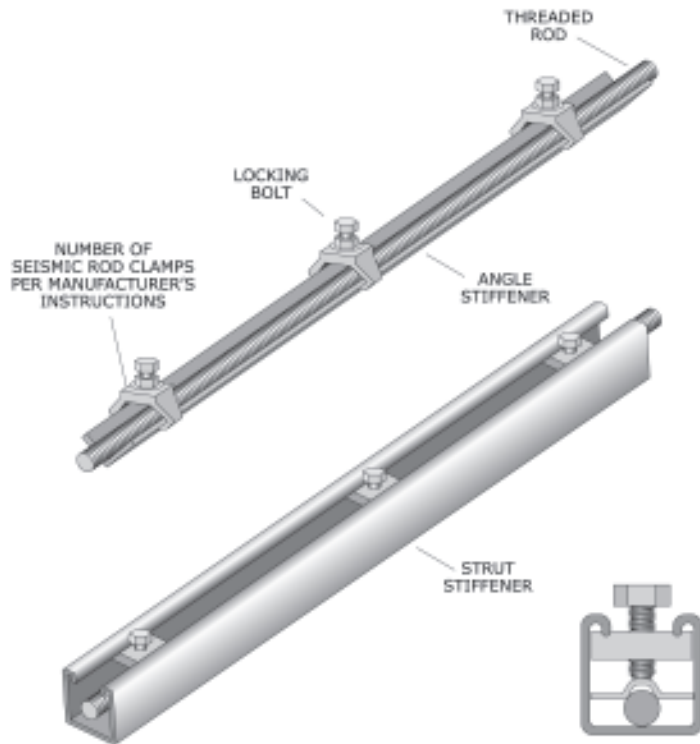


Figure 101: Rod stiffeners.

### Step 3: Attach anchors to the building structure for cable attachment

Figure 102 (page 67) shows typical anchorage to different building construction. See Anchors, page 96.

### Step 4: Attach cable to the building structure

For cable assembly instructions, see Cables (page 124).

For details on attaching cable to the building structure, see Figure 102 (page 67).

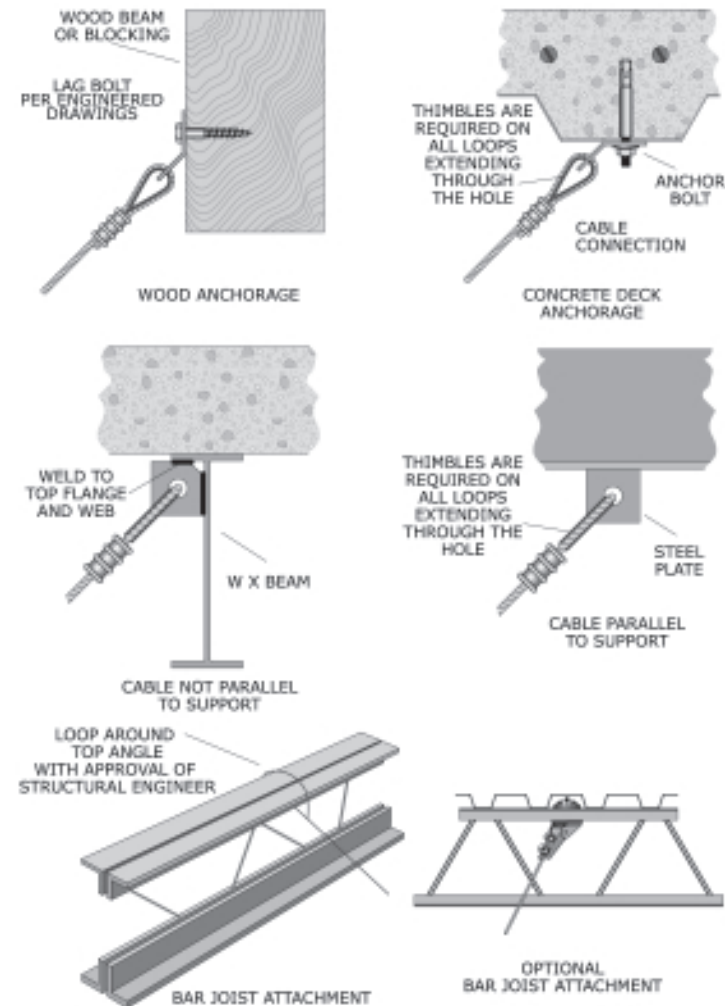


Figure 102: Attachment of cable to the building structure.

### Step 5: Attach cables to equipment

For details on attaching cable to the equipment, see Figure 103 (page 68).

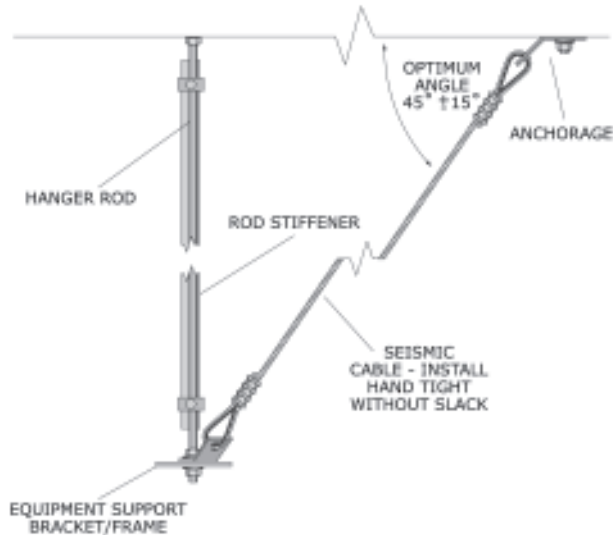


Figure 103: Attachment of cable to the equipment.

**END OF ATTACHMENT.**

**Rigid connection to the building structure using angle/strut supports**

Equipment may have pre-installed brackets for angle support attachments as shown in Figure 104.

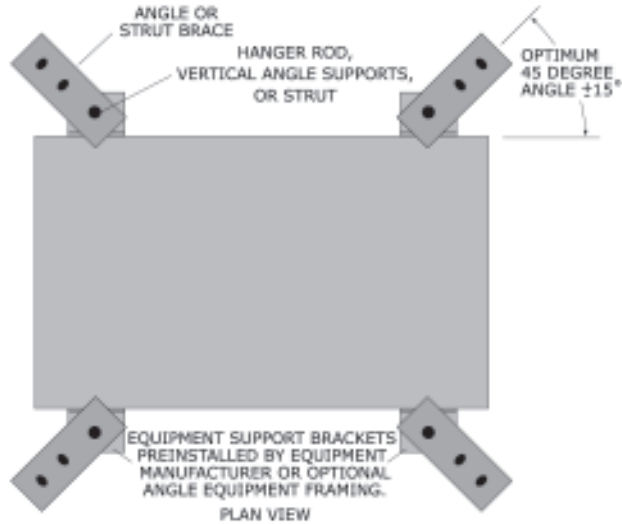


Figure 104: Rigid attachment of angles to the building structure.

**Step 1: Attach the equipment to the building structure using threaded rods and anchors**

Lay out all attachment points before anchoring. For building structure attachment details, see Figures 95 to 100 (pages 63-65). See Anchors (page 96). Rod stiffeners are not required.

**Step 2: Attach anchors to the building structure for angle or strut supports**

For building structure attachment details, see Figures 95 to 100 (pages 63-65). See Anchors (page 96).

**Step 3: Attach angles or strut supports to the building structure**

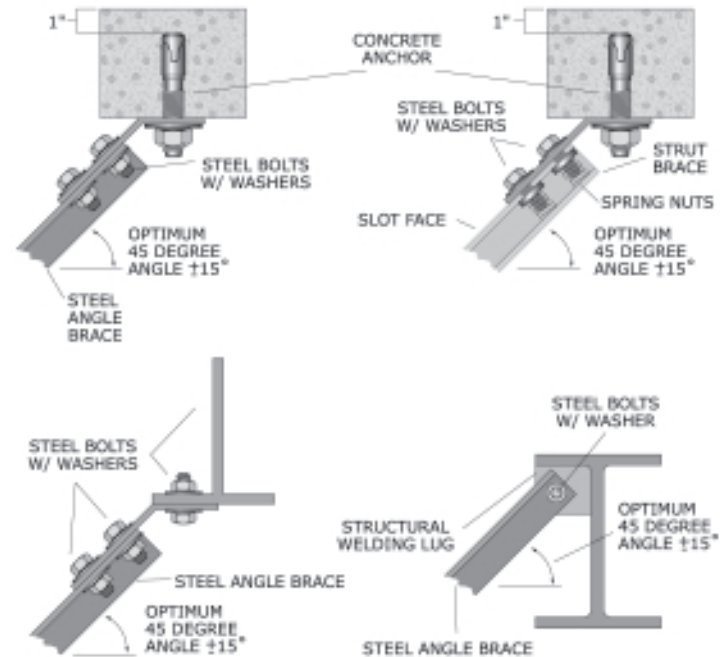


Figure 105: Attachment of angle or strut to the building structure.

**Step 4: Attach angle or strut to equipment**

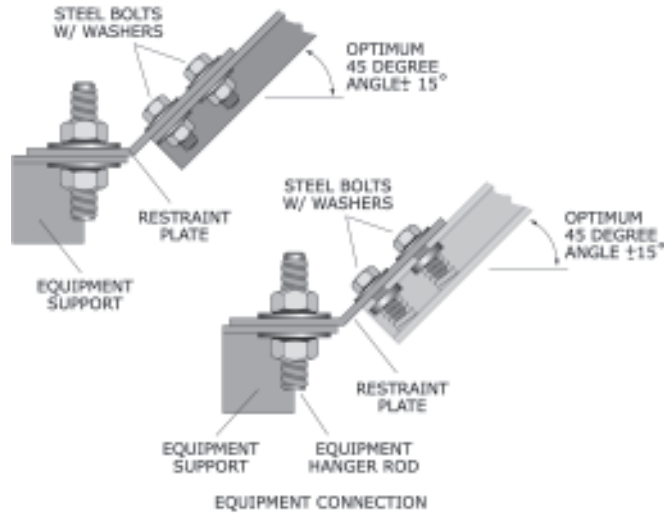


Figure 106: Attachment of angle or strut to the equipment.

**END OF ATTACHMENT.**

**Isolated connection to the building structure using four threaded vertical rods and horizontal cable restraints**

Equipment may have pre-installed brackets for angle support attachments. See Figure 107 (below) and Figure 108 (page 71).

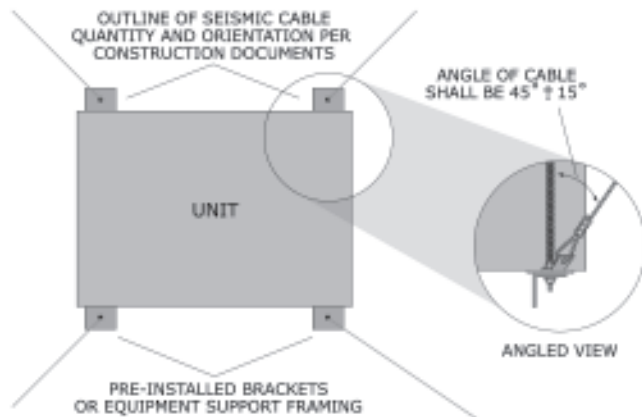


Figure 107: Plan view of vibration isolation suspended attachment to the building structure.

Side view shows vibration isolators, rods (without rod stiffeners), and cables.

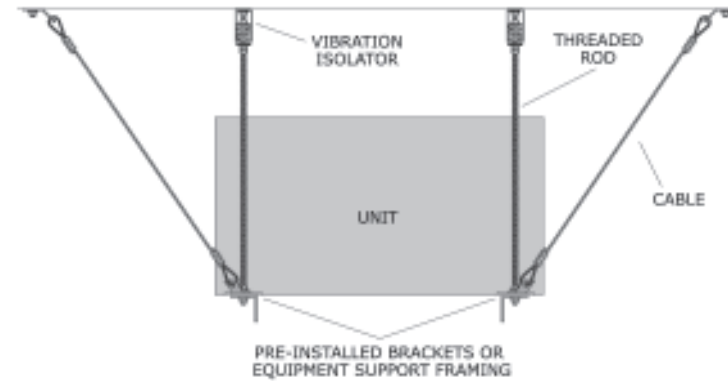


Figure 108: Side view of vibration isolation suspended attachment to the building structure.

**Step 1: Attach equipment to the building structure using threaded rods, isolators and anchors**

For the isolator detail, see Figure 109 (below). For building structure attachment details, see Figures 95 to 100 (pages 63-65).

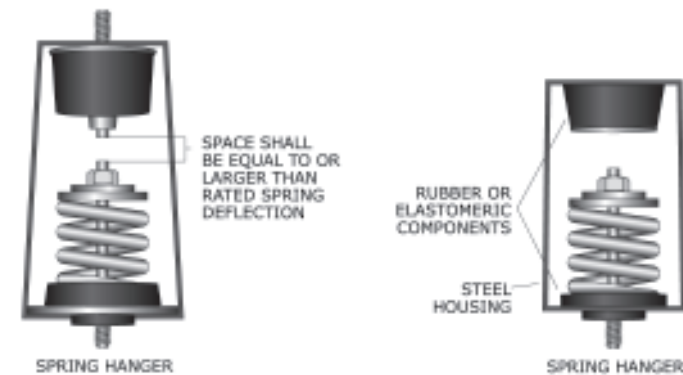


Figure 109: Isolator detail.



**Step 2: Attach anchors and cable to the building structure**

For details on anchorage and cable connection to the building structure, see Figure 102 (page 67).

**Step 3: Attach cables to equipment**

For cable assembly, see Cables (page 124). For cable attachment to equipment, see Figure 110 (below).

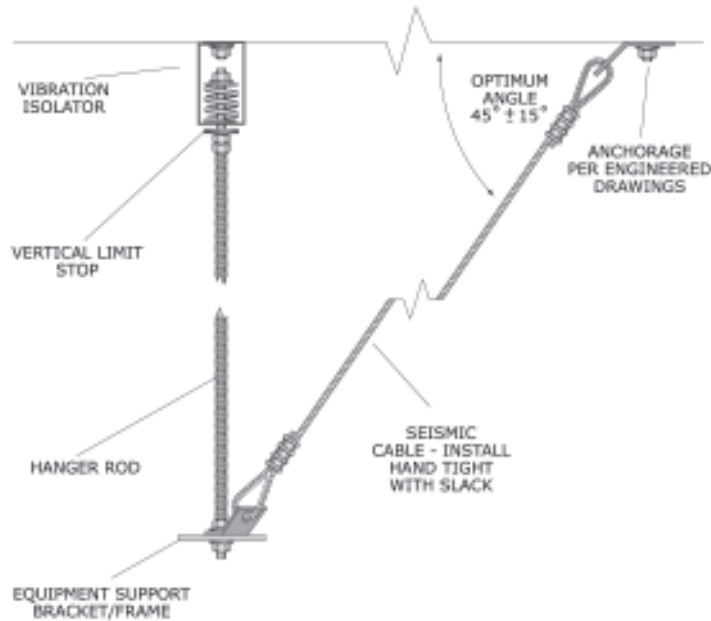


Figure 110: Attachment of cable/rod assembly to the equipment.

**END OF ATTACHMENT.**

**Double angle attachment—bolted or welded to the building**

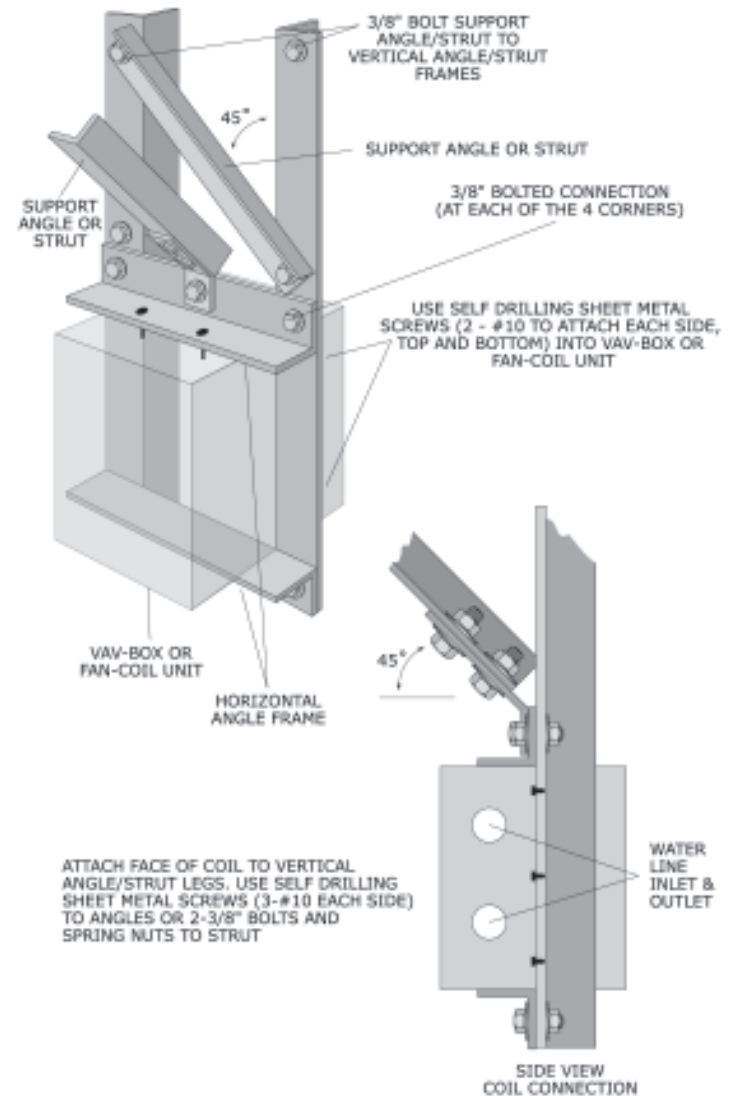


Figure 111: Attachment of double angles for equipment support.

Use this type of installation for duct-mounted coils, VAV boxes, or fan-coil units weighing less than 150 pounds.

**Step 1: Attach anchors and vertical angles or strut to the building structure**

For building structure attachment details, see Figures 95 to 100 (pages 63-65).

**Step 2: Attach horizontal framing**

For attachment details, see Figure 111 (page 73).

**Step 3: Attach anchors to the building structure for angle or strut restraints**

For building structure attachment details, see Figure 105 (page 69). See Anchors (page 96).

**Step 4: Attach support angles or struts**

One support is attached to the two vertical angles or struts. One support is attached to the building structure and to the top horizontal frame. For details on angle or strut attachment, see Figure 111 (page 73).

**Step 5: Attach equipment**

Attach equipment to the support assembly as shown in Figure 111 (page 73).

**END OF ATTACHMENT.**

**Double rod attachment—bolted to the building**

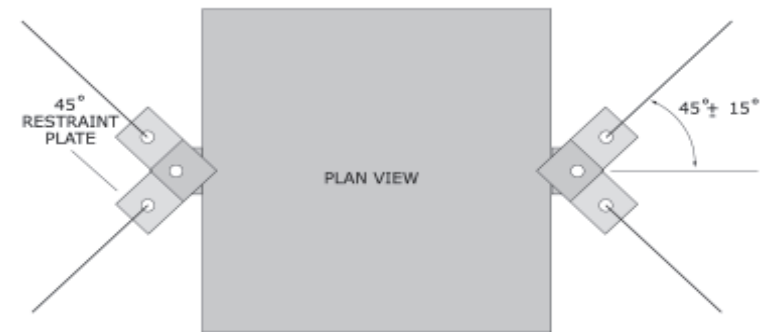
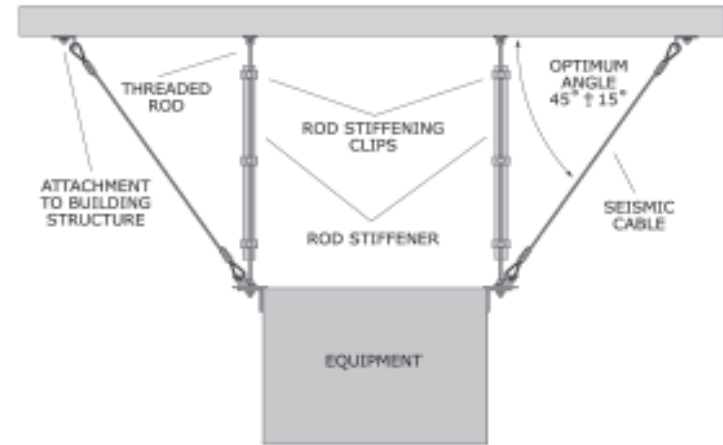



Figure 112: Equipment attachment for double rod support.

Use this type of installation for unit heaters.

### Step 1: Attach anchors and vertical rods to the building structure

Lay out all attachment points before anchoring. For building structure attachment details, see Figures 95 to 100 (pages 63-65). Attach equipment to the vertical rods.

 **The attachment should be located just above the center of gravity to minimize swinging. It should be a rigid attachment with brackets to the equipment using double nuts, especially if connected at the top as shown in Figure 112 (page 75).**

### Step 2: Attach rod stiffeners

For attachment details, refer to Figure 101 (page 66).

### Step 3: Attach anchors to the building structure for cable attachment

Figure 102 (page 67) shows typical anchorage to different building construction. See Anchors (page 96).

### Step 4: Attach cable to the building structure

For cable assembly see Cables (page 124).

For details on attaching cable to the building structure, see Figure 102 (page 67).

### Step 5: Attach cables to equipment

The detail in Figure 112 (page 75) shows the attachment to the equipment.

## Vibration-isolated/Floor-mounted Attachment

Vibration isolation uses springs in many different shapes to isolate equipment vibrations from the building structure. Their shapes are open (see Figure 113 below left), housed (see Figure 113 below right), and restrained (see Figure 114, page 78).

 **NEVER USE HOUSED SPRINGS FOR SEISMIC RESTRAINT APPLICATIONS. Housed springs cannot resist uplift.**

Snubbers (see Figure 115, page 78) are restraint devices to limit the movement of equipment that is isolated. Bumpers (see Figure 116, page 79) also limit the movement of equipment and are similar to snubbers.

 **NEVER USE SNUBBERS THAT ARE NOT SPECIFIED. Some snubbers only restrict movement in one direction.**

 **NEVER USE OPEN SPRINGS WITHOUT SNUBBERS OR BUMPERS. Equipment mounted on open springs without snubbers or bumpers will fail.**



Figure 113: Open spring and housed spring.

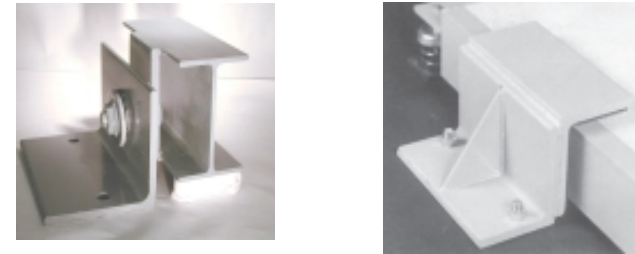


Figure 116: Two examples of bumpers.

Bases are steel structures made from angles, channels, or I-beams.

**Flags** Bases are required for mounting isolated equipment. The equipment manufacturer or the isolator manufacturer may provide the bases.

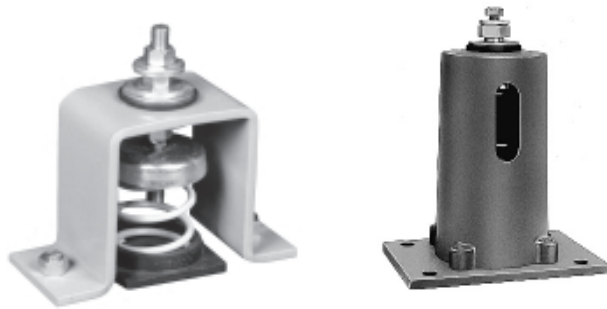


Figure 114: Four types of restrained springs.

The two ways of attaching vibration-isolated/floor-mounted equipment are on:

- Restrained springs (this page).
- Open springs combined with snubbers (page 83).

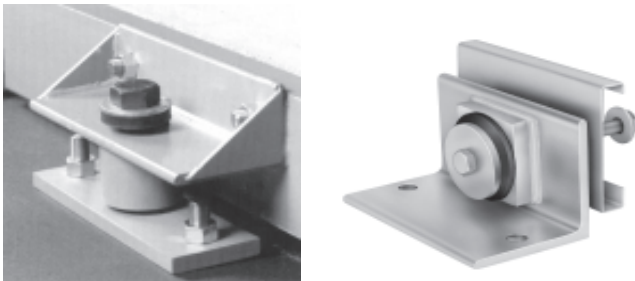


Figure 115: Two examples of snubbers.

**Flags** Verify that the spring is properly aligned according to the manufacturer's clearances. If the spring shaft rubs against the snubber element, a short-circuit may occur, causing noise problems.

### Restrained springs

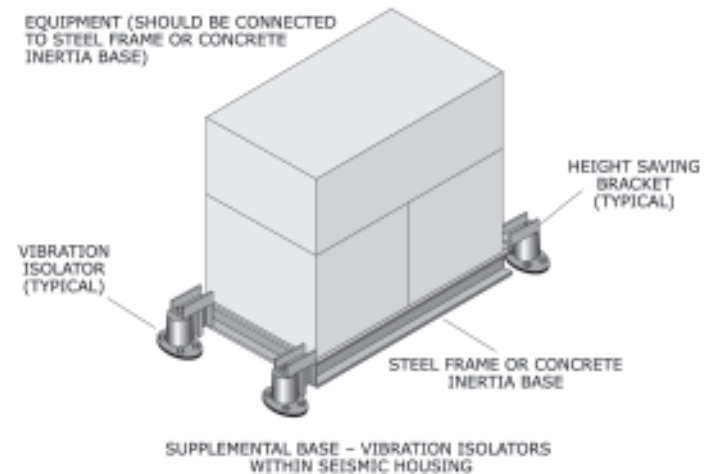


Figure 117: Typical installation of restrained spring installation.



**More than four restrained springs may be required. See the manufacturer's instructions.**

### Step 1: Determine where to bolt the equipment

Accurately draw the bolt pattern on the floor or pad using one of the following methods:

- Set the equipment in place and mark the holes.
- Make a template.
- Use measurements and shop drawings to lay out the bolt hole pattern.

### Step 2: Install anchors

Drill and install post-installed anchors or pour concrete with embedded studs or J-bolts (see Anchors, page 96).

### Step 3: Set restrained spring isolators and bolt to anchors

Install restrained springs to the building structure as shown in Figure 118 (page 81). Attach nuts to the anchor. Use bolts for shell-type anchors or internally threaded wedge or chemical anchors. Torque as recommended by the anchor manufacturer.



**BE CAREFUL NOT TO DAMAGE THE ANCHORS WHEN SETTING THE EQUIPMENT OR ISOLATOR.**

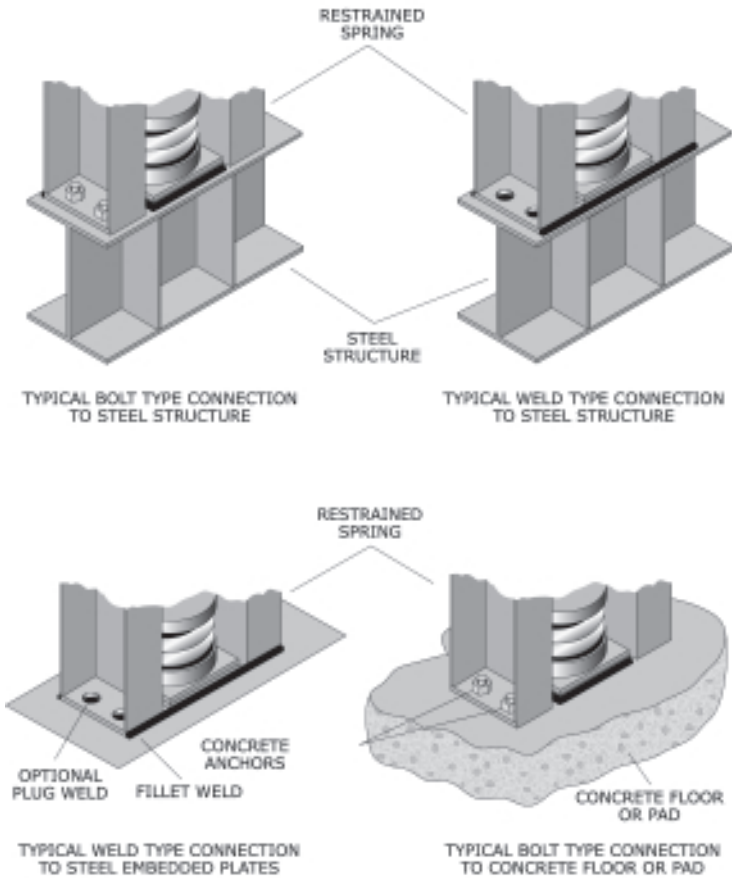


Figure 118: Attachment of restrained springs to the building structure.

### Step 4: Move the equipment into place over the isolators

Use leveling nuts to level the equipment. Use attachment nuts to attach the base of the equipment to the isolator.

Figure 119 (page 82) shows typical ways to connect the equipment to the restraints.

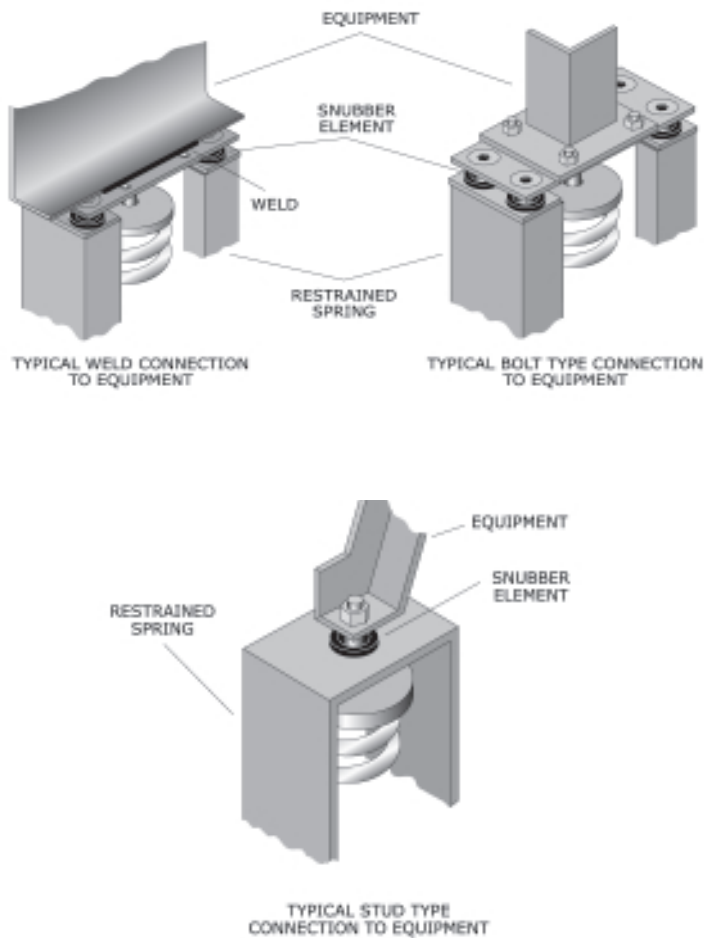


Figure 119: Attachment of equipment to restrained springs.

**END OF ATTACHMENT.**

**Open springs combined with snubbers**

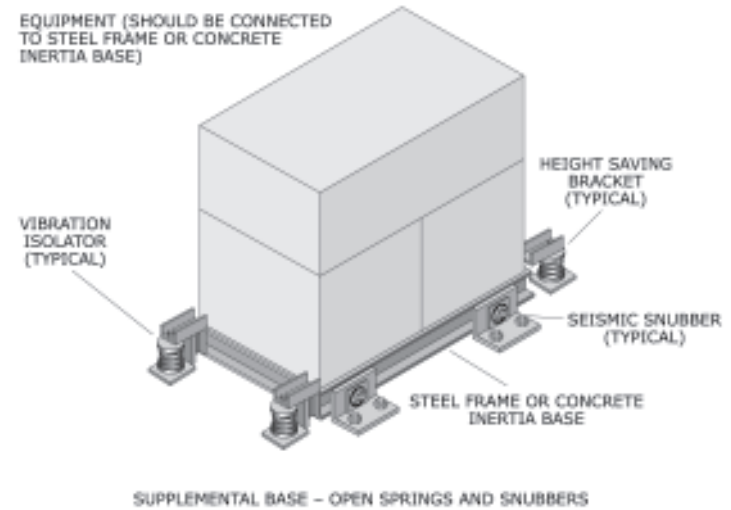


Figure 120: Typical installation of open springs and snubbers.

 **Additional snubbers may be required. See the manufacturer's instructions.**



Figure 121: Typical installation of an open spring arrangement with snubbers.

**Step 1: Determine where to bolt the equipment**

Accurately draw the bolt pattern for the open spring mounting plate on the floor or pad using one of the following methods:

- Set the equipment in place and mark the holes.
- Make a template.
- Use measurements and shop drawings to lay out the bolt hole pattern.

**Step 2: Install post-installed anchors for open springs only (snubbers are covered in later steps)**

Drill and install post-installed anchors for spring isolators (see Anchors, page 96).

**Step 3: Attach open spring isolators to concrete floor or pad with anchors installed in Step 2**

**Set isolator, apply nuts and torque. Use bolts for shell-type anchors or internally threaded wedge or chemical anchors. Install according to the anchor manufacturer's instructions.**



**BE CAREFUL NOT TO DAMAGE THE ANCHORS WHEN SETTING THE ISOLATOR.**

**Step 4: Set equipment on open springs**

Set equipment on isolators but do not level or torque attachment nuts.



**Equipment must have a structural frame capable for point load at the open spring isolators.**

Some installations require the base to be concrete-filled. See Figure 122 (page 85) for a typical concrete-filled installation.



**Coordinate the location of equipment attachment points and snubber attachment points before filling with concrete.**

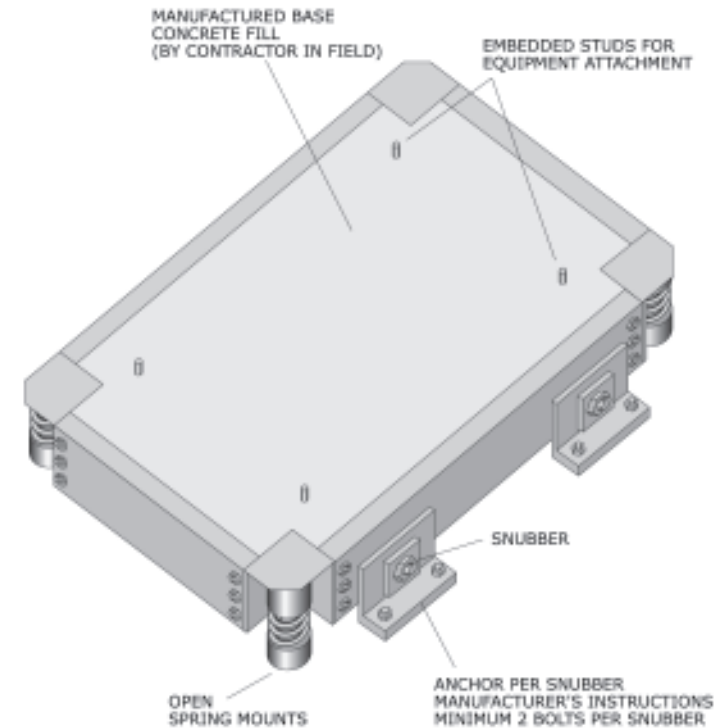


Figure 122: Concrete-filled inertia base.

**Step 5: Determine where to attach snubber**

A snubber has two assemblies: the snubber equipment assembly and the snubber base assembly.

Level the equipment. Final leveling will be required in later steps. Accurately draw the bolt pattern for the snubber mounting plate on the floor or pad and on the equipment.



**All snubber clearance requirements for aligning the snubber must be met. Shims may be provided.**

**Step 6: Attach snubber equipment assembly to equipment**

Attach the snubber equipment assembly to the equipment by bolting it to embedded bolts in a concrete-filled base (see Figure 122, page 85), or by bolting or welding it to a steel base.

**Step 7: Determine where to bolt snubber base**

Accurately draw the bolt pattern for the snubber mounting plate on the floor or pad.

**Step 8: Drill and install post-installed anchors**

See Anchors (page 96).

**Step 9: Raise the equipment**

Raising the equipment allows the snubber base assembly to be placed over the anchors installed in Step 6.

**Step 10: Lower the equipment**



**Level equipment and connect the two snubber assemblies as specified in the manufacturer’s instructions. Verify that spacing requirements are met. Complete the final attachment to open springs.**



**DO NOT INSTALL THE ISOLATOR OR SNUBBERS IN ANY CONFIGURATION OTHER THAN THAT SHOWN IN THE MANUFACTURER’S INSTRUCTIONS.**

The equipment is now installed to resist earthquakes. Flexible piping connections, flexible ductwork connections, and flexible conduit connections must be used when connecting systems to isolated equipment.

Figure 123 (page 87) is an example of the requirements for flexible system connections.

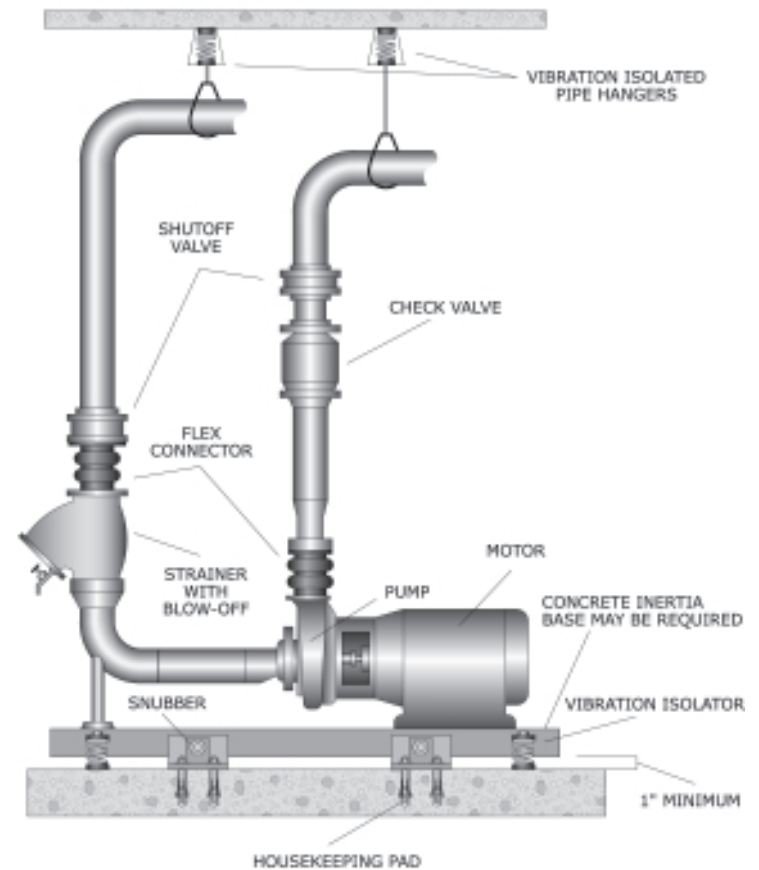


Figure 123: Typical pump installation.

**END OF ATTACHMENT.**



## Wall-mounted Attachment

The four types of wall mounting are:

- Directly to the wall (this page).
- To additional structural steel shapes attached to the wall (page 90).
- Vibration-isolated off the wall (page 93).
- Directly to the wall—gas cylinders only (page 95).

### Directly to the wall

Equipment should have pre-installed brackets that can support attachment to the building as shown in Figure 124 (below).

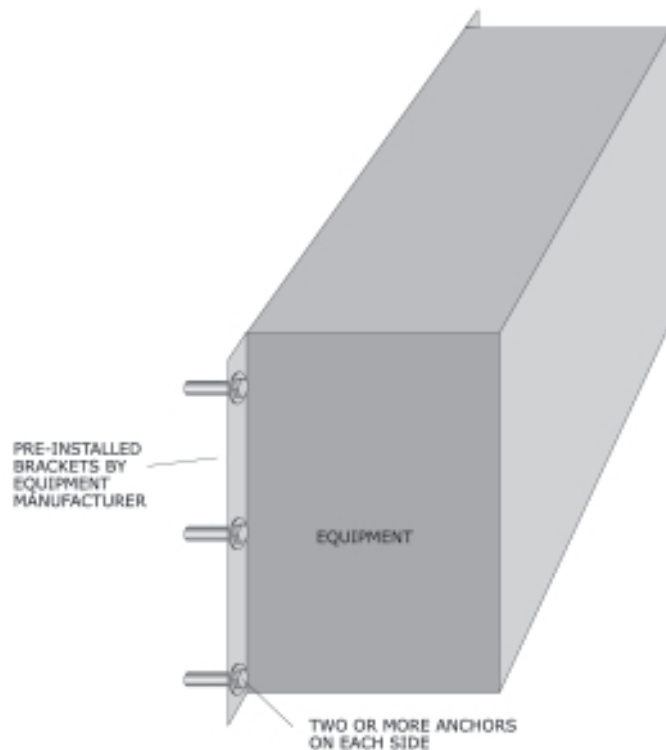


Figure 124: Direct attachment to a wall.

### Step 1: Determine where to bolt the equipment

Accurately draw the bolt pattern on the wall using one of the following methods:

- Set the equipment in place and mark the holes.
- Make a template.
- Use measurements and construction drawings to lay out the bolt hole pattern.

Drywall or masonry walls may require additional holes in equipment attachment brackets as shown on construction drawings or in the equipment manufacturer's instructions.



**ONLY USE MOUNTING BRACKETS PROVIDED. DO NOT DRILL INTO THE EQUIPMENT HOUSING.**



**New holes cannot be oversized or oval in shape. Repair oversized holes as shown in Figure 71 (page 35).**

### Step 2: Install post-installed anchors

If anchoring to concrete, install post-installed anchors (see Anchors, page 96, or Masonry and Drywall Anchors, page 106).

### Step 3: Move the equipment into place



**BE CAREFUL NOT TO DAMAGE THE ANCHORS WHEN SETTING THE EQUIPMENT.**

### Step 4: Attach nuts



**Attach nuts to the anchor or bolt and torque according to the manufacturer's instructions.**

Piping, ductwork, and raceways may be connected.

**END OF ATTACHMENT.**

### To additional structural steel shapes attached to the wall

Equipment attaches to the wall with additional structural steel shapes and bolts. Shapes may be welded. These steel shapes are attached to the building using concrete anchors, masonry anchors, or drywall anchors.

Figures 125 to 127 (pages 90-92) show how straps, angles and struts can be used for attachment to a wall. Angles and struts must accommodate wall construction attachment points and obstructions. Figure 159 (page 133) shows a strut attachment for equipment.

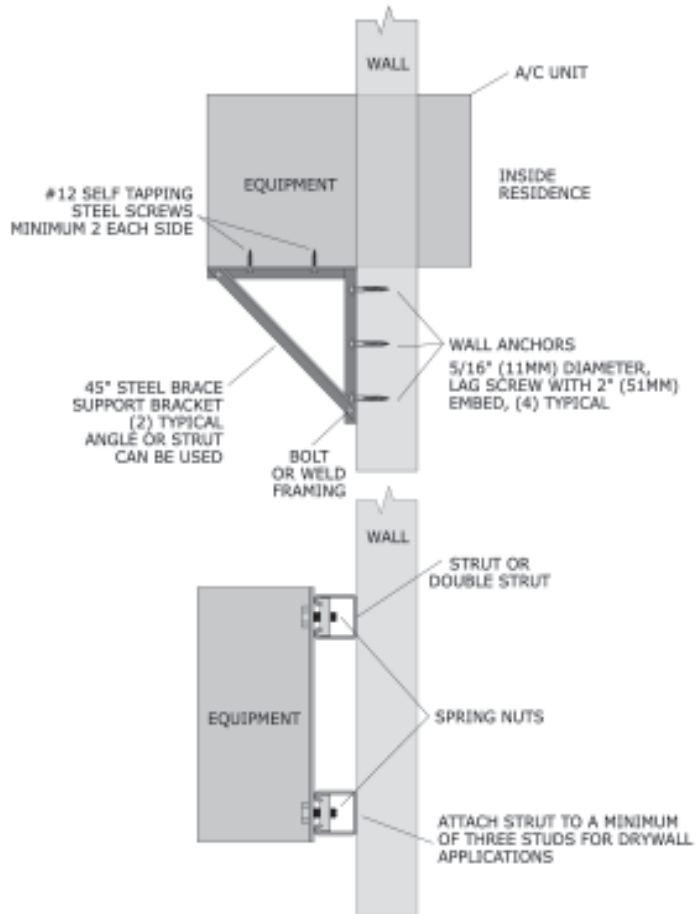


Figure 125: Angle or strut support.

A versatile attachment is an angle welded to a base plate, as shown in Figure 126 (below). This can be used for in-line piping specialties or for equipment. Two supports on each side of the equipment may be required. Rigid connection with rods and cables supported from the building structure above is optional.

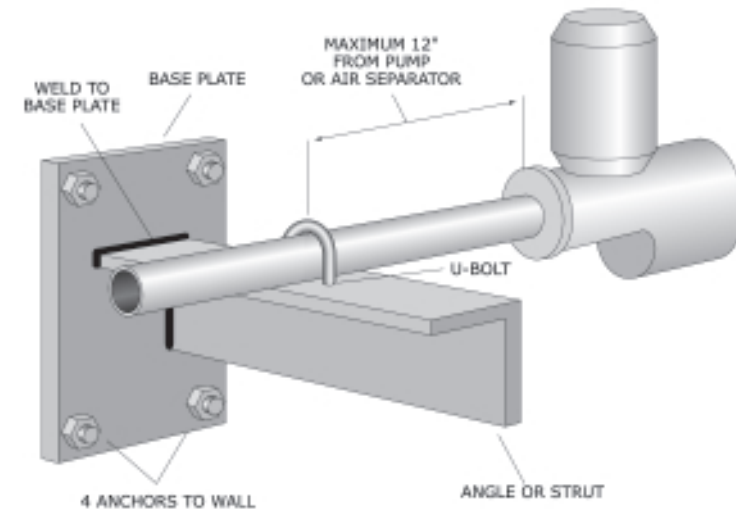


Figure 126: Angles welded to a base plate.

Water heaters or water tanks may be attached to the wall with a simple strap arrangement, as shown in Figure 127 (page 92).

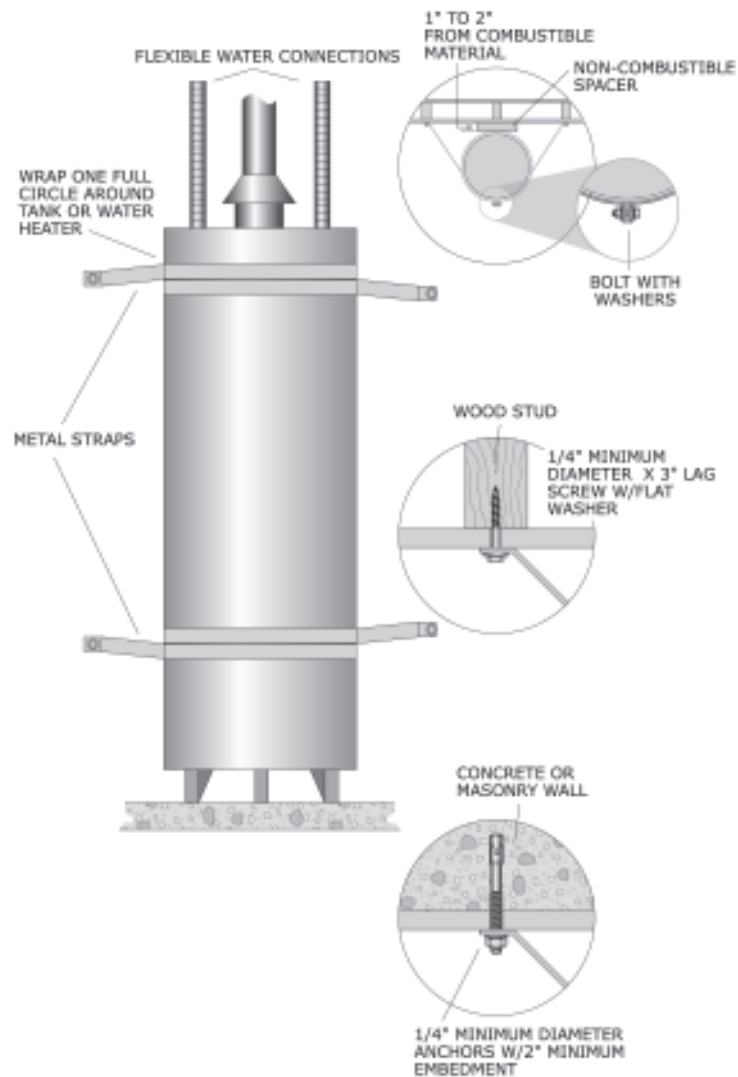


Figure 127: Water heater or water tank attachment.

### Step 1: Determine the anchor locations

Find studs in drywall. Use measurements and construction drawings to lay out the bolt hole pattern and mark the anchor locations.

### Step 2: Install anchors

If anchoring to concrete, install post-installed anchors (see Anchors, page 96, or Masonry and Drywall Anchors, page 106).

### Step 3: Move equipment into place and bolt to frame



**You may drill additional holes into the equipment assembly or building steel beams as shown on construction drawings or the manufacturer's instructions.**



**New holes cannot be oversized or oval in shape. Repair oversized holes as shown in Figure 71 (page 35).**

Piping, ductwork, and raceways may be connected.

**END OF ATTACHMENT.**

### Vibration-isolated off the wall

Equipment attaches to the wall with additional structural steel shapes, threaded rods and vibration isolators. Shapes may be welded. These steel shapes are attached to the building using concrete anchors, masonry anchors, or drywall anchors.

Figure 128 (page 94) shows how rods, angles and struts can be used to isolate equipment attached to a wall. Angles and struts accommodate wall construction attachment points.

Vibration-isolated equipment prevents the transmission of noise and vibration into the building structure. See Figure 109 (page 71) for isolator detail.

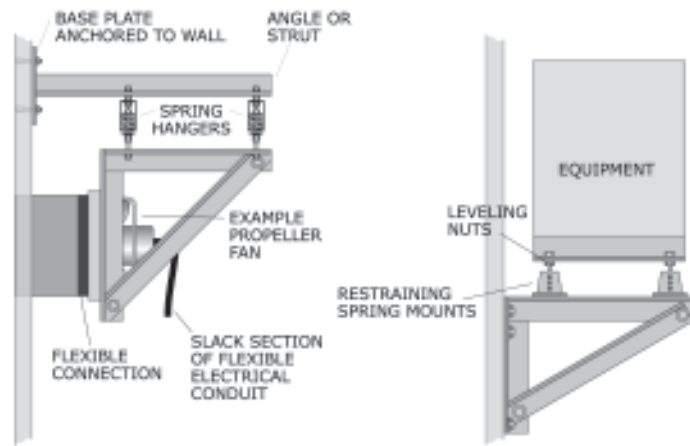


Figure 128: Wall-mounted, vibration-isolated equipment.

### Step 1: Assemble wall frame with isolators

Accurately draw the bolt pattern on the wall using one of the following methods:

- Set the frame in place and mark the holes.
- Make a template.
- Use measurements and construction drawings to lay out the bolt hole pattern.

### Step 2: Install anchors

If anchoring to concrete, install post-installed anchors (see Anchors, page 96, or Masonry and Drywall Anchors, page 106).

### Step 3: Attach isolators, rod, and hang equipment

Attach the isolators to the framing. Attach the equipment to the isolators using threaded rod.

Piping, ductwork, and raceways may be connected.

**END OF ATTACHMENT.**

### Directly to the wall—gas cylinders only

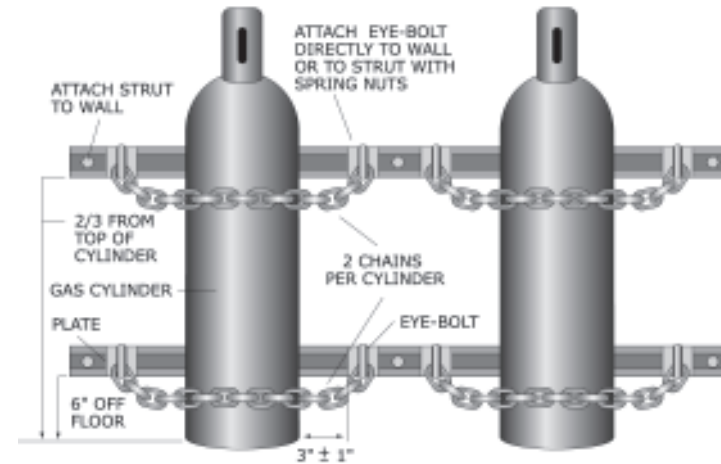


Figure 129: Gas cylinder supports.

### Step 1: Assemble brackets

Accurately draw the bolt pattern on the wall using one of the following methods:

- Set the brackets in place and mark the holes.
- Use measurements and construction drawings to lay out the eye-bolt hole pattern.

### Step 2: Anchor brackets or eye bolts to wall

If anchoring to concrete, install post-installed anchors (see Anchors, page 96, or Masonry and Drywall Anchors, page 106).

### Step 3: Install chains to store gas cylinders in the upright position

Install two chains to restrain each cylinder. Install one chain across the cylinder near the top and one near the bottom.



**Chains should fit snugly so there is little or no room for the cylinder to move.**

**END OF ATTACHMENT.**

# ANCHORS

## General Anchors



**IMPORTANT: Installation methods depend on the type of anchor and the particular application. Always follow the anchor manufacturer's installation instructions.**



Figure 130: Types of anchors.

### Step 1: Determine the type of anchor

Using Figure 130 (page 96), identify the anchor recommended for your application. Anchors 1-5 are post-installed anchors and instructions for installing them begin on this page. Anchors 6-10 are specialty anchors and instructions are shown on pages 103-120.

The various methods for installing anchors into concrete, brick, and concrete block anchors are shown below.

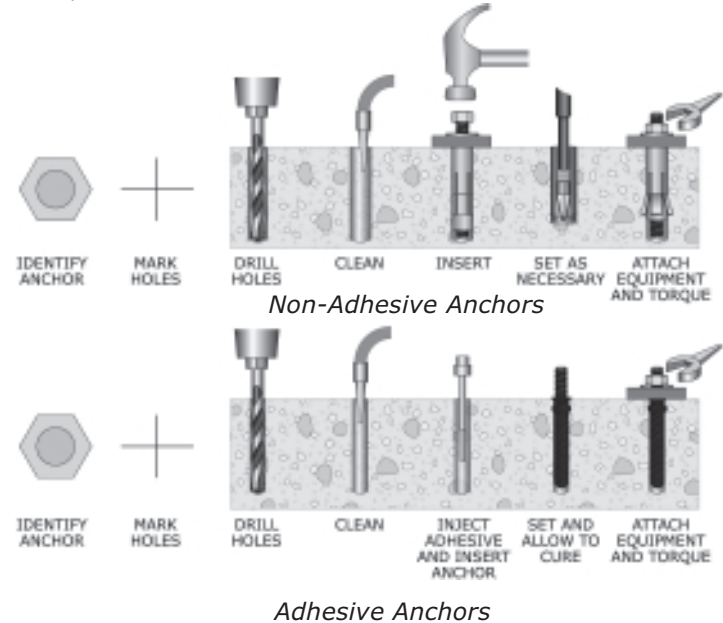


Figure 131: Summary of installation steps.



**Contract documents may require special inspection to torque anchors or for proof load using hydraulic rams.**

### Step 2: Determine where to drill the hole

To determine anchor locations for the equipment you are installing, follow the instructions for the Attachment Type you are using (pages 32-95). Coordinate the equipment connections and hole locations with the location of any steel reinforcement or tendons.

Determine the depth and location of any steel reinforcement or tendons *before* drilling. This may require relocating equipment slightly to avoid the reinforcement.

**! FOR POST-TENSIONED BUILDINGS, LOCATE THE TENDONS BEFORE DRILLING. EXTREME DAMAGE MAY OCCUR IF A TENDON IS NICKED OR CUT.**

When using electronic locating devices to find reinforcement and tendons, make sure you know the limitations of the device. Calibrate and test with a known standard or location to confirm accuracy. Check the area of concern in two directions. Inform the contractor performing the work of the precision of the test unit and record the results. For example: *agreed upon mark +/- 1/4" location vertical, horizontal, and depth +/- 1/2".*

Coordinate the location of anchors with the edge of the concrete, construction joints, and other anchors.

**Do not install the anchor too close to the edge of the concrete base. Typically the anchor's distance from the edge is 1½ times the embedment depth.**

**Do not install an anchor too close to another anchor. Typically the minimum spacing between anchors is two times the anchor's embedment depth.**

### Step 3: Drill the hole

**Drill the right-sized hole for the anchors. Use the appropriate ANSI-rated drill bit for the application.**

**Do not drill holes into concrete at an angle.**

For wedge, undercut and sleeve anchors, drill the hole deeper than the required embedment depth.

**The required hole depth may be different from the embedment depth. See Figure 132 (page 99).**

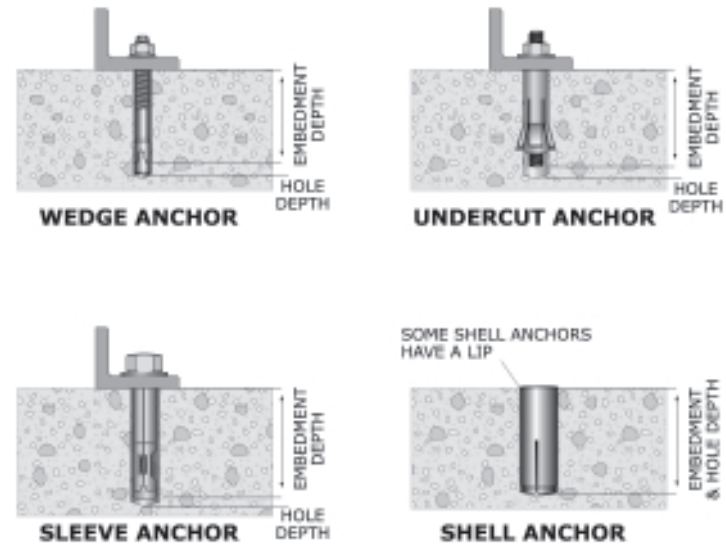


Figure 132: Embedment depth and hole depth of four anchor types.

The depth of the concrete base must be at least one inch greater than the hole you are drilling.

**Some undercut anchors require an even deeper concrete base.**

**If you strike steel reinforcement when drilling, you must have the damage inspected. As directed, fill the hole with approved grout and select a new location according to minimum spacing requirements. Drill a new hole (see below).**

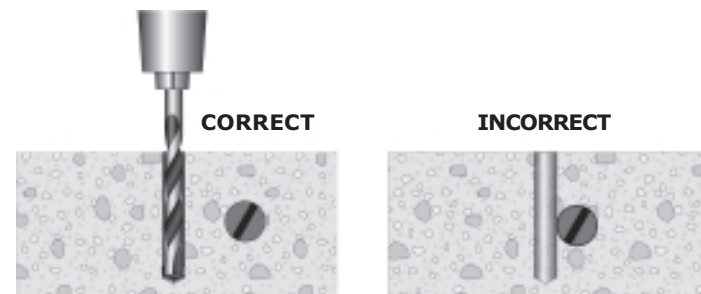


Figure 133: Drilling into concrete with rebar.

**Step 4: Clean out the hole**

Drilled holes must be cleaned before you can insert the anchor. Use clean, dry compressed air to blow out dust and debris. The type of anchor or application also may require you to use water or a brush.



**See the anchor manufacturer’s instructions for cleaning the hole.**



**Cleaning is important: a “dirty” hole can significantly reduce an anchor’s performance.**

**Step 5: Insert the anchor**

If you are installing any anchor *other than* an adhesive anchor, drive the anchor into the hole with a hammer.



**IMPORTANT: DO NOT DAMAGE THE THREADS DURING INSTALLATION. DO NOT FORCE THE ANCHOR. If you use a larger hammer than recommended by the manufacturer, you may damage the anchor.**

If you are installing an adhesive anchor, insert the capsule or inject non-capsule adhesive into the hole. Slowly rotate the anchor into place as shown below.

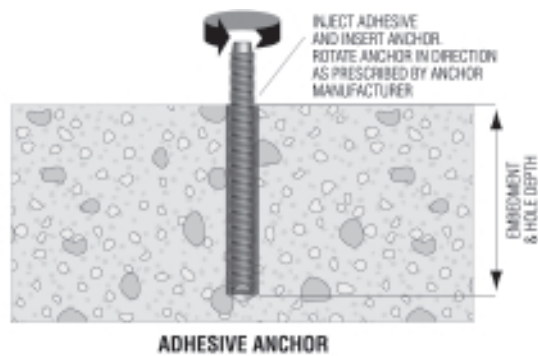


Figure 134: Adhesive anchor installation.

If you have installed a wedge or sleeve anchor, go to Step 7.

**Step 6: Setting shell, adhesive and undercut anchors ONLY**



**Shell Anchor:** Drive the prescribed setting tool into the anchor until the setting tool shoulder meets the edge of the anchor, as shown below.

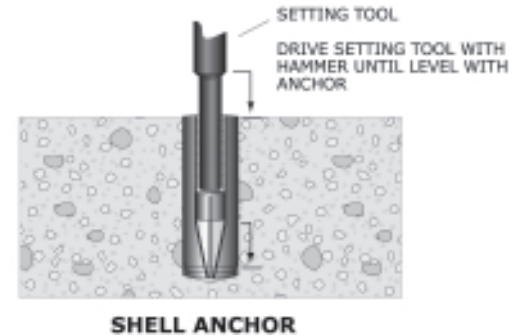


Figure 135: Set shell anchors.



**Adhesive Anchor:** Allow enough time for the adhesive to fully cure. The curing process may take a long time. See the manufacturer’s instructions.



**Undercut Anchor:** Use special tools provided by the anchor manufacturer to set the anchor, as shown below.

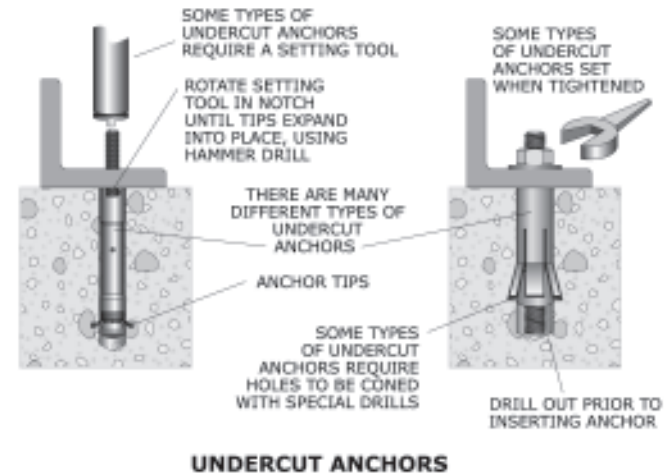


Figure 136: Set undercut anchors.

### Step 7: Set the equipment and tighten the anchors

Set the equipment in place. Check for gaps. Gaps under the equipment must not be greater than 1/8" as shown below. If the gap is greater than 1/8", dry pack the gap with grout and repeat this step.

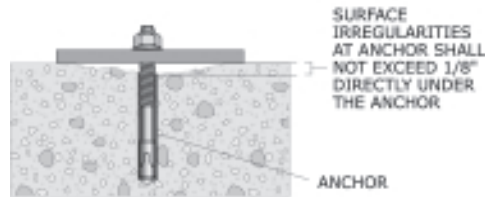


Figure 137: Acceptable gap for grouted plate.

**! Do not bolt equipment directly to concrete anchors where equipment sheet metal is less than 16 gauge if the anchor is larger than 3/8" in diameter.**

For anchor bolts larger than 3/8", the equipment housing should be reinforced using a structural angle bracket as shown in Figure 138 (below).

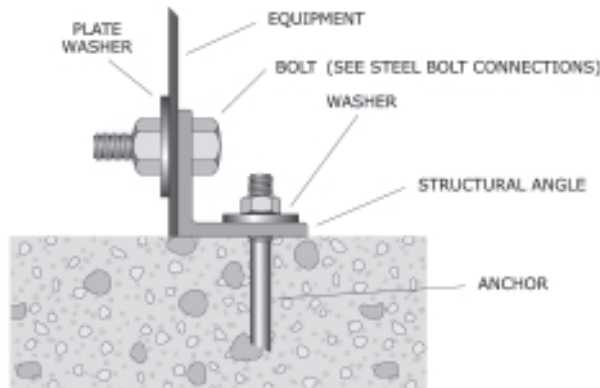


Figure 138: Installing a reinforcing angle bracket to equipment.

**! Tighten the anchor bolt to the correct torque setting in the manufacturer's instructions or construction drawings. Use a calibrated torque wrench.**

### Cast-in-place Anchors

Cast-in-place anchors are embedded in the concrete when the floors or walls are poured. Bolts are firmly held in place while the concrete is poured to maintain proper alignment and position. The size and location of the anchors can be determined from construction drawings.

### Step 1: Move the equipment into place and attach the bolts

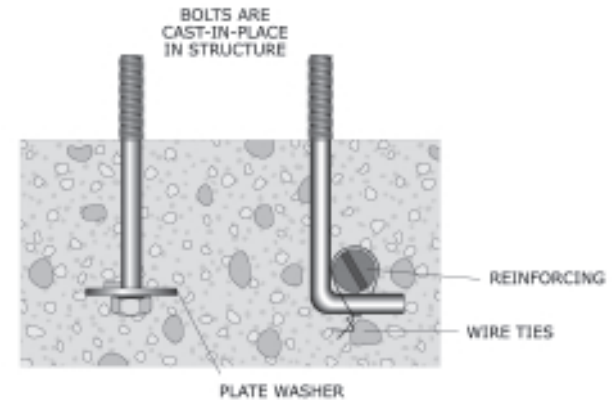


Figure 139: Bolting equipment to cast-in-place anchors.

### Step 2: Place and secure equipment

Once the equipment is in place, apply washers and nuts and then tighten.

**! Tighten the anchor bolt to the correct torque setting in the manufacturer's instructions or on the construction drawings.**

Use a calibrated torque wrench or turn-of-nut method (see Table 15, page 115).



## Lag Bolts

Lag bolts are used to attach equipment or steel shapes to wood structures. The size and location of the anchors can be determined from construction drawings (see Figure 140, below).

- The edge distance is  $1\frac{1}{2}$  times the bolt diameter.
- The spacing between bolts is 4 times the bolt diameter.
- The end distance is 7 times the bolt diameter.

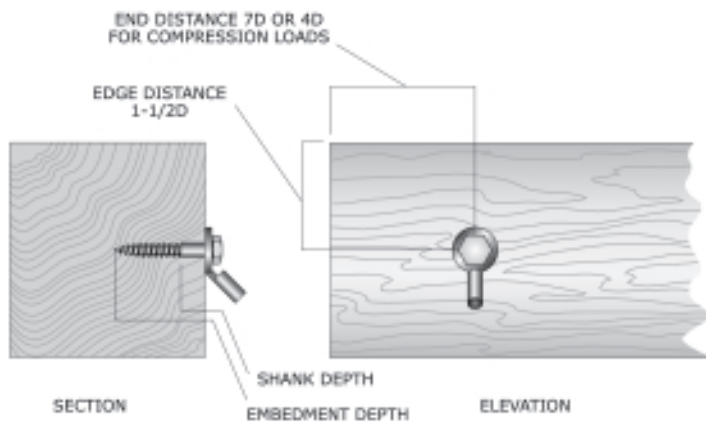


Figure 140: Spacing requirements for wood lag bolts.

### Step 1: Mark the location of the lag bolts

Lead holes and clearance holes are not required for lag bolts that are  $\frac{3}{8}$ " or smaller. If the lag bolt is smaller than  $\frac{3}{8}$ ", go to Step 4.

### Step 2: Drill a clearance hole

Drill a hole with a drill bit the same size as the shank of the bolt. The depth of the hole is the same as the length of the unthreaded shank that will extend into the wood (see Figure 140, above).

### Step 3: Drill a lead hole

Drill a hole with a drill bit that is 60% to 70% of the diameter of the shank of the bolt. The depth of the hole is the same as the embedment depth of the bolt (see Figure 140, page 104).

### Step 4: Move the equipment or steel shape into place

### Step 5: Drive the lag bolt in with a wrench

You may use soap or other lubricant on the lag bolt.



**DO NOT USE A HAMMER TO DRIVE IN LAG BOLTS.**

### Step 6: Tighten the bolt

Hand-adjust the lag bolt where there is firm contact between the lag bolt and connected metal components. Tools may be used to bring the lag bolt and metal components into contact until the components are snug tight.

## Masonry and Drywall Anchors

### Step 1: Determine the type of anchor

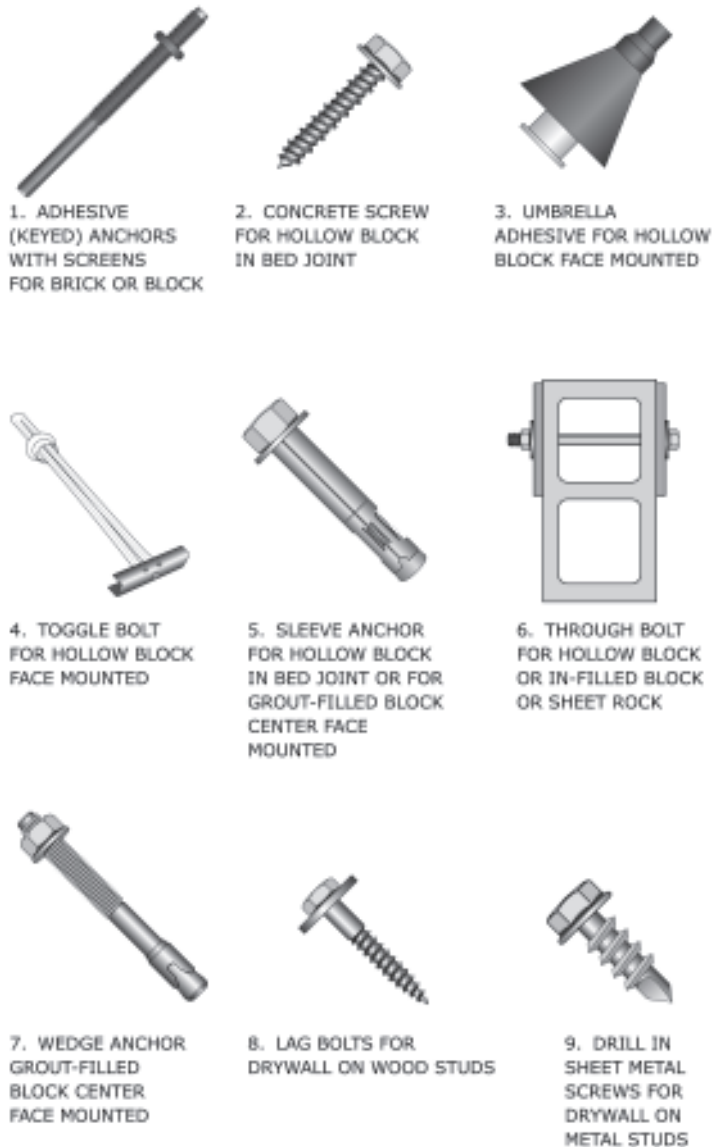


Figure 141: Types of masonry and drywall anchors.

### Step 2: Determine where to drill the hole

Anchors shown in Figure 141 (page 106) must be installed in specific areas of hollow block and in-filled block. See Figure 142 (below) for approved anchor hole locations when using any of the concrete block anchors shown in Figure 141.

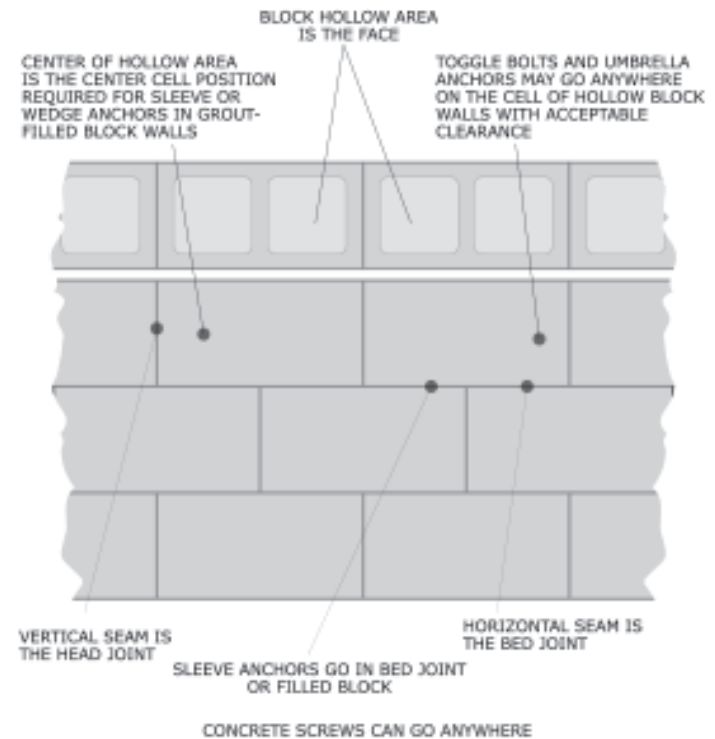


Figure 142: Block wall locations.

The location of the anchors should be coordinated with the block webs, or centered in the cell face, and properly spaced from other anchors.



**DO NOT POSITION THE HOLES IN THE HEAD JOINT. Carefully note the location of anchors in the face location, centered face location, and bed joint as they apply to different anchors.**



**Find webs in block walls, reinforcement in grout-filled walls, or studs in drywall. Location of through-bolts: Avoid webs in concrete block and studs in drywall walls.**



**Location of lag bolts and sheet metal screws in drywall: Install in a wood or metal stud as appropriate.**



**Determine the depth and location of any steel reinforcement in grout-filled block walls or brick before drilling. This may require relocating equipment slightly to miss reinforcement.**

When using electronic locating devices to find reinforcements and tendons, make sure you know the limitations of the device. Calibrate and test with a known standard or location to confirm accuracy. Check the area of concern in two directions. Inform the contractor performing the work of the precision of the test unit and record the results. For example: *agreed upon mark +/- 1/4" location vertical, horizontal, and depth +/- 1/2".*

### Step 3: Drill the hole



**Drill the right-sized hole for the anchors. Use the appropriate ANSI-rated drill bit for the application.**

Use masonry drill bits for brick and block.



**DO NOT CUT STEEL REINFORCEMENT WHEN DRILLING HOLES.**



**If you strike steel reinforcement when drilling, you must have the damage inspected. As directed, fill the hole with approved grout and select a new location according to minimum spacing requirements. Drill a new hole (see Figure 133, page 99).**



**Holes for concrete screws are smaller than screw size. See the manufacturer's instructions for specific requirements.**

### Step 4: Clean out the hole

Drilled holes must be cleaned before you can insert the anchor. Use clean, dry compressed air to blow out dust and debris. The type of anchor or application also may require you to use water or a brush.



**See the anchor manufacturer's instructions for cleaning the hole.**



**Cleaning is important: a "dirty" hole can significantly reduce an anchor's performance.**

### Step 5: Insert the anchor

The following anchors use different insertion methods.

- Adhesive screen anchor in a brick wall or hollow block wall (this page).
- Adhesive anchor in a hollow block wall (page 110).
- Concrete screw (page 111).
- Toggle bolt (page 111).
- Concrete anchor (sleeve anchor or wedge anchor) (page 112).
- Drywall anchor (lag bolts and sheet metal screws) (page 112).

### Adhesive screen anchor in a brick wall or hollow block wall



**See the anchor manufacturer's instructions before connecting the anchor to a brick or hollow block wall.**

A screen insert is shown in Figure 143 (page 110). Insert the screen in the wall. Inject the adhesive. Slowly insert the anchor with a twisting motion.



**Screens may be filled with adhesive before inserting the screen into the hole.**

For details on installing adhesive anchors in a brick wall, see Figure 144 (page 110). Similar installation applies to hollow block walls. Adjust the anchor by hand while the adhesive sets.



**DO NOT TOUCH THE ANCHOR WHILE THE ADHESIVE IS CURING.**



METAL SCREEN TUBES

Figure 143: Brick/block wall insert.

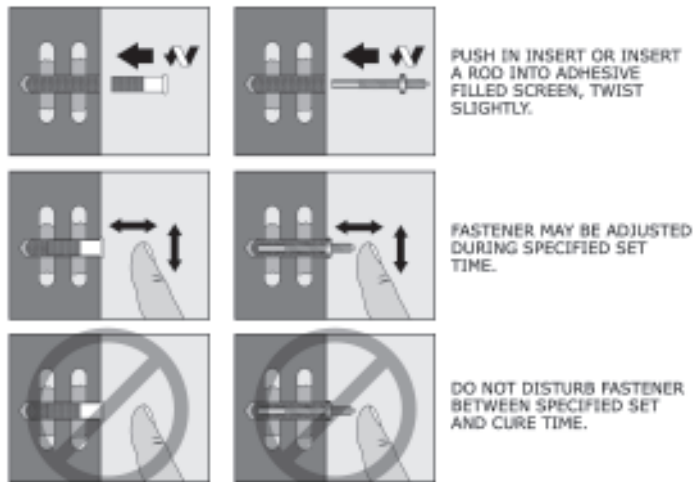


Figure 144: Brick wall adhesive anchor.

**Adhesive anchor in a hollow block wall**



**See the anchor manufacturer's instructions before connecting the anchor to a hollow block wall.**

Push an umbrella anchor into the hole until the umbrella unfolds in the block cavity. Inject adhesive into the umbrella. Slowly insert stud or fastener with a twisting motion.



**DO NOT LEAK ADHESIVE ON THE THREADED PORTION OR CLEAN WITH SOLVENT. The threaded area must be free of debris to attach to a threaded rod or steel bolt.**

UMBRELLA INSERTS - SPECIFICALLY DESIGNED FOR FASTENING TO THE FACE OF CONCRETE BLOCK, CLAY TILE OR TERRA COTTA. ACCEPTS RODS BETWEEN 1/4" AND 1/2"

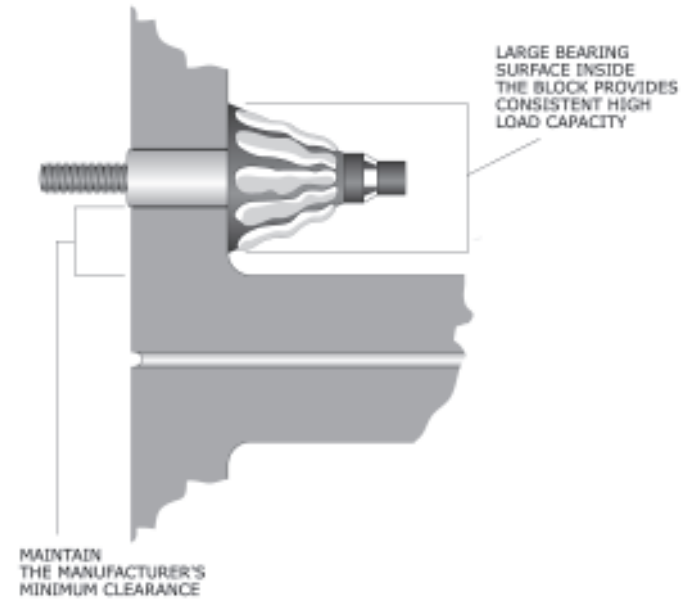


Figure 145: Umbrella anchor in a hollow block wall.

**Concrete screw**

Drill bits may be specifically sized for each manufacturer, and typically are smaller in diameter than the nominal or fractional diameter of a screw. Install a concrete screw with a rotary drill and bolt the head attachment.

**Toggle bolt**

Hold the toggle flat alongside the plastic straps and slide the channel through the hole. Slide the holding ring toward the wall until the channel is flush with the wall. Cut off the straps at the holding ring. Insert the bolt with a rotary drill over the bracket or equipment mounting.

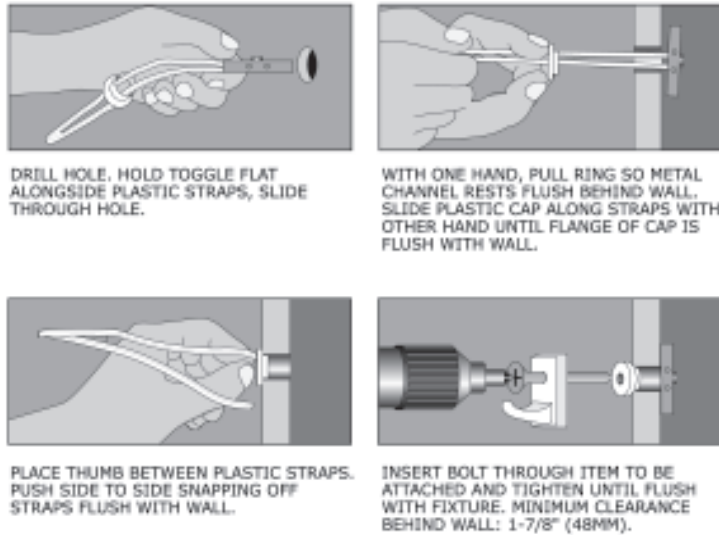


Figure 146: Toggle bolt installation.

**! DO NOT OVER-TIGHTEN.**

**Concrete anchor (sleeve anchor or wedge anchor)**

Use a hammer to drive the anchor in the hole.

**! DO NOT FORCE THE ANCHOR. If you use a hammer larger than recommended, you may damage the anchor.**

To determine the embedment depth of post-installed anchors, see Figure 132 (page 99).

**Drywall anchor (lag bolts and sheet metal screws)**

Use a rotary drill to insert the anchor.

**! DO NOT OVER-TIGHTEN.**

**Step 6: Set the anchor (adhesive only)**

Allow enough time for the adhesive to harden and adhere to the concrete. *This may take several hours.*

**Step 7: Set the equipment and tighten the anchors**

**! Tighten the anchor bolt to the proper torque setting as shown in the anchor manufacturer's instructions or construction drawings.**

In-filled block walls will have gaps in the grout fill or the grout will slightly crack, requiring anchors to be installed in the center of the cell.

**! If the grout cracks severely, or if you miss a grouted block, the anchor will not tighten and will pull out. If it pulls out, move the anchor to a new centered cell location.**

## Steel Bolt Connections

The three ways to attach bolted connections are:

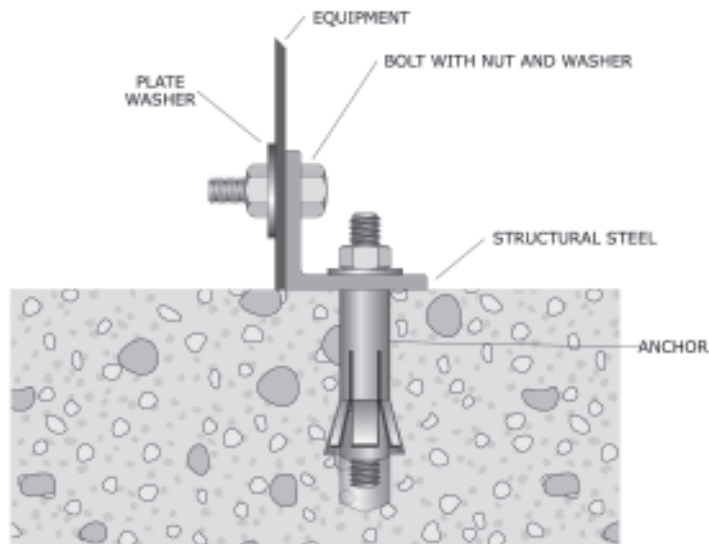
- Connecting the base of the equipment to an angle bolted to a concrete floor (this page).
- Bolting two structural steel shapes together (page 116).
- Bolting a threaded rod to steel shapes or strut (page 116).

### Connecting the base of the equipment to an angle bolted to a concrete floor

#### Step 1: Preparation



**Determine the bolt size or sheet metal screw and material requirements from construction drawings or printed instructions supplied by the manufacturer.**



USE PLATE WASHER TO REINFORCE LIGHT SHEET METAL HOUSINGS

Figure 147: Bolting equipment to an angle.

#### Step 2: Locate holes

Use pre-drilled holes wherever possible. Holes may not have been pre-drilled at the attachment locations shown in the instructions. In these cases, carefully drill new holes in the correct locations.



**Use caution when drilling into equipment. Internal components can be damaged. DO NOT DRILL OVERSIZED HOLES. See Figure 71 (page 35) for repair of oversized holes.**

#### Step 3: Install bolts, washers, and nuts

Once the equipment is in place, apply washers and nuts and then tighten.



**Tighten the anchor bolt to the correct torque setting shown in the manufacturer's instructions or the construction drawings.**

For turn-of-nut tightening, hand-adjust the bolt snug tight where there is firm contact between the bolt and connected metal components. Tools may be used to bring the bolt and metal components into contact. Following contact, tighten the nut as shown below.

| <i>Length of Bolt</i>                           | <i>Additional Tightening</i> |
|---|------------------------------|
| Up to and including 4 diameters                 | 1/3 turn                     |
| Over 4 diameters and not more than 8 diameters  | 1/2 turn                     |
| Over 8 diameters and not more than 12 diameters | 5/6 turn                     |

Table 15: Hand-adjusted tightening.

**Bolting two structural steel shapes together**

**Step 1: Preparation**

 **Determine the bolt size and material requirements from construction drawings or the manufacturer’s instructions.**

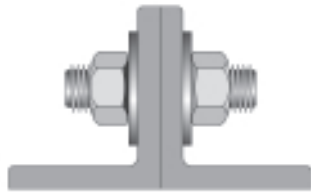



Figure 148: Bolting structural shapes.

**Step 2: Locate holes**

Carefully drill new holes in the structural steel shapes.

**Step 3: Install bolts, washers, and nuts**

Apply washers and nuts, then tighten.

 **Tighten the anchor bolt to the correct torque setting shown in the manufacturer’s instructions or the construction drawings. Use a calibrated torque wrench or turn-of-nut method (see Table 15, page 115).**

**Bolting a threaded rod to steel shapes or strut**

A threaded rod is used with suspended equipment. This section includes attachment to the equipment and attachment at the top (see Suspended Attachment, page 62).

**Step 1: Preparation**

 **Determine the threaded rod size from construction drawings or printed instructions supplied by the manufacturer.**

The three different ways to attach the threaded rod are shown in Figure 149 (below).

**Step 2: Attach the top connection of the threaded rod**

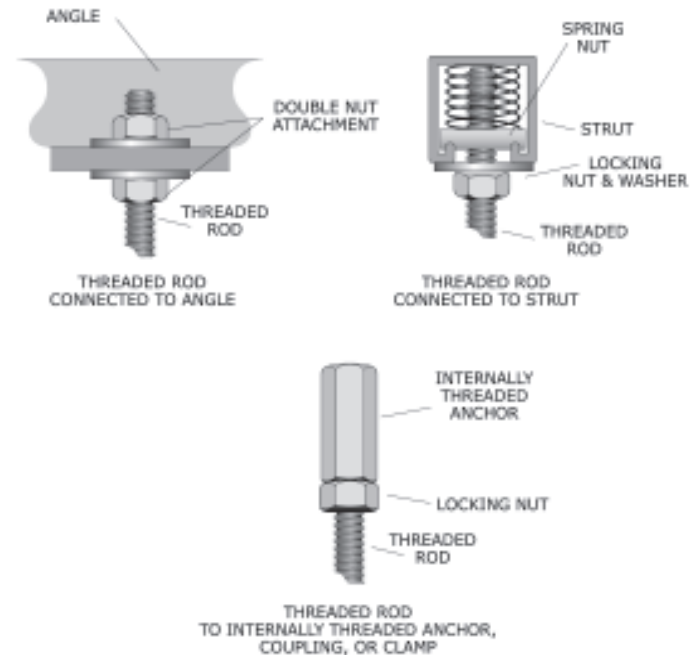



Figure 149: Attaching the top of threaded rod.

Apply washers and nuts, then tighten.

 **Tighten the anchor bolt to the correct torque setting shown in the manufacturer’s instructions or the construction drawings. Use a calibrated torque wrench or turn-of-nut method (see Table 15, page 115).**

### Step 3: Attach threaded rods to equipment brackets

Equipment without attachment brackets requires additional steel shapes for connections to the building structure and/or roof.

Once the equipment is in place, apply washers and nuts, then tighten.



**Tighten the anchor bolt to the correct torque setting shown in the manufacturer's instructions or the construction drawings. Use a calibrated torque wrench or turn-of-nut method (see Table 15, page 115).**

## Welding



**Before welding, refer to construction drawings and specifications, seismic restraint submittals, and manufacturer's instructions.**

**Attaching equipment to embedded plates:** Plates are embedded in the concrete during the floor or wall pour. Plates are firmly held in place while the concrete is poured to maintain proper alignment and position. The size and location of the plate can be determined from construction drawings. See Figure 150 (below) for weld locations.

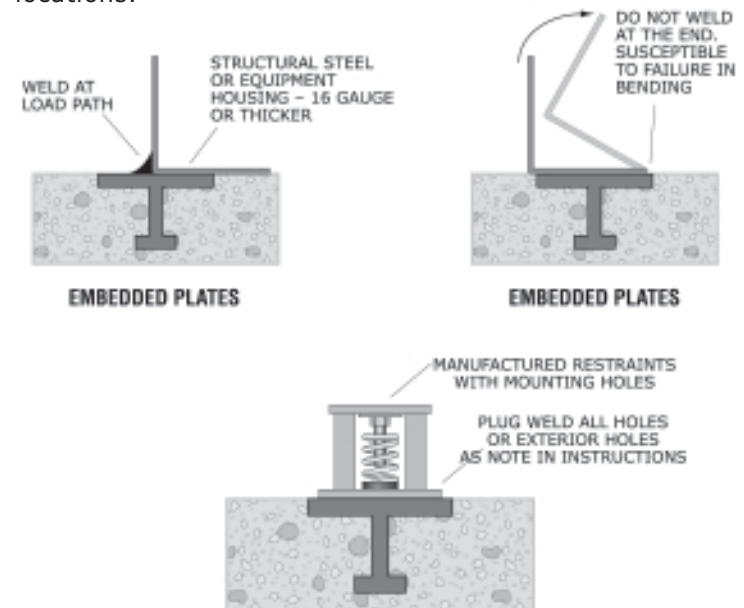


Figure 150: Welding to embedded plates.

**Attaching structural shapes and plates:** Shapes and plates are welded to provide equipment attachment. All weld base material must be thick enough for the weld size specified.

**Step 1: Determine the weld material, shape, and dimensions for each piece**



## Anchors: Welding

### Step 2: Fit the material to ensure proper weld joint preparation

### Step 3: Clean the surfaces

Surfaces must be dry and free of galvanized coating, hot-dipped or rust inhibitor, paint, scale, rust, oil, grease, water, and other foreign material for a minimum of one inch from the estimated toe of the weld.

### Step 4: Weld the materials

The weld must be as prescribed in the welding procedure specifications (WPS).

WPS for shop and field pre-qualified weld joints and weld joints qualified by test must be prepared for review and approval before fabrication. All welding procedure items such as base metals, welding processes, filler metals and joint details that meet the requirements of AWS D1.1 Section 5.1 will be considered prequalified. Any change or substitution beyond the range or tolerance or requirements for pre-qualification will be qualified by test pre-AWS D1.1 Section 5 part B.



**DO NOT WELD OVER PAINT. You may paint after welding has cooled to room temperature.**

### Step 5: Inspect the weld

Make sure the surface is free of slag, dirt, grease, oil, scale, or other contaminants.

Welds cannot have cracks. Adjacent layers of weld metal and base metal must be thoroughly fused together.

All craters must be filled to the full cross-section except outside the effective weld length.

Underrun must not exceed 1/16". Undercut must not exceed 1/16" for any 2" per 12" weld or 1/32" for the entire weld.

Surfaces must be free of coarse ripples, grooves, abrupt ridges, and valleys. The faces of fillet welds must be flat or slightly convex.

## Anchor Sizes for Equipment Weighing Less than 400 Pounds

### Rigid floor-mounted equipment

Bolt equipment to a concrete floor or weld to a steel beam according to Table 16 (below). Install one anchor at each corner. Torque anchors according to the manufacturer's instructions.

| Anchor      | Embedment (in.)        | Minimum Edge Distance (in.) |
|-------------|------------------------|-----------------------------|
| 1/4" wedge  | 2"                     | 3" to edge of concrete      |
| 3/8" sleeve | 1-1/4"                 | 2" to edge of concrete      |
| 1/8" weld   | 1" long at each corner | N/A                         |

Table 16: Rigid floor-mounted anchor sizes.



**These anchor/weld selections apply to equipment in which the height of the center of gravity (center of equipment mass) is less than twice the base length AND twice the base width.**

### Roof-mounted equipment

Anchor equipment to concrete deck, a wood beam, or directly to a steel structural shape according to Table 17 (page 122). Install one anchor at each corner. Torque anchors according to the manufacturer's instructions.

| <i>Anchor</i>                           | <i>Embedment (in.)</i> | <i>Minimum Edge Distance (in.)</i>   |
|---|------------------------|--------------------------------------|
| 1/4" wedge                              | 2"                     | 3"                                   |
| 3/8" sleeve                             | 1-1/4"                 | 2"                                   |
| 3/8" lag bolt to a 2x4 wood beam (min.) | 1-1/2"                 | 5/8" to edge of wood and 3" from end |
| 1/4" steel bolt                         | N/A                    | 1/2"                                 |
| 1/8" weld                               | 2" long at each corner | N/A                                  |

Table 17: Roof-mounted anchor sizes for rigid connections.



**These anchor/weld selections apply to equipment in which the height of the center of gravity (center of equipment mass) is less than twice the base length AND twice the base width.**

### Suspended equipment

Rigidly attach equipment to building structure above with angles or rods and cables according to Table 18 (below and next page). Torque anchors according to the manufacturer's instructions.

| <i>Vertical threaded rod</i> | <i>Quantity</i>    | <i>Anchors per Rod</i> |
|------------------------------|--------------------|------------------------|
| 1/2" rod with rod stiffener  | One on each corner | 1                      |

Table 18: Suspended equipment anchor sizes for rigid connections (table continued on next page).

| <i>Rod anchor</i>                       | <i>Embedment (in.)</i> | <i>Minimum Edge Distance</i>         |
|---|------------------------|--------------------------------------|
| 1/2" wedge                              | 2-1/4"                 | 3-1/2"                               |
| 1/2" sleeve                             | 2-1/4"                 | 3-1/2"                               |
| 3/8" lag bolt to a 2x4 wood beam (min.) | 2"                     | 5/8" to edge of wood and 3" from end |
| 1/2" steel bolt                         | N/A                    | 1"                                   |

| <i>Cable</i>                      | <i>Quantity</i>                  | <i>Anchors per cable</i> |
|-----------------------------------|----------------------------------|--------------------------|
| 1/8" pre-stretched aircraft cable | 4 at 45 degrees from each corner | 1                        |

| <i>Cable anchor</i>                     | <i>Embedment (in.)</i> | <i>Minimum Edge Distance (in.)</i>   |
|---|------------------------|--------------------------------------|
| 1/2" wedge                              | 2-1/4"                 | 3-1/2"                               |
| 1/2" sleeve                             | 2-1/4"                 | 3-1/2"                               |
| 3/8" lag bolt to a 2x4 wood beam (min.) | 2"                     | 5/8" to edge of wood and 3" from end |
| 1/2" steel bolt                         | N/A                    | 1"                                   |

Table 18 (continued): Suspended equipment anchor sizes for rigid connections.

## SPECIAL CASES

### Cables

The three ways to assemble a cable connection are by using:

- Bolts with center holes (page 125).
- Ferrule clamps (page 126).
- Wire rope grips (page 128).

Other end fittings may be acceptable.

Cables should be installed at a 45-degree slope. Where interferences are present, the slope may be a minimum of 30 degrees or a maximum of 60 degrees.

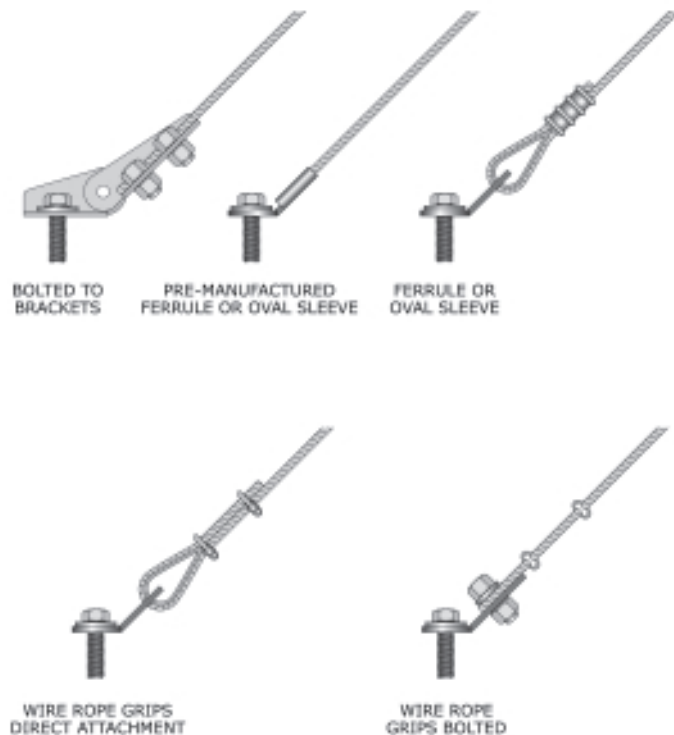


Figure 151: Cable attachments.

### Bolts with center holes

The manufacturer provides this type of cable assembly, along with the cables, mounting bolts with holes, and brackets that attach directly to the building structure or equipment frame. Assemble the cable as shown below.

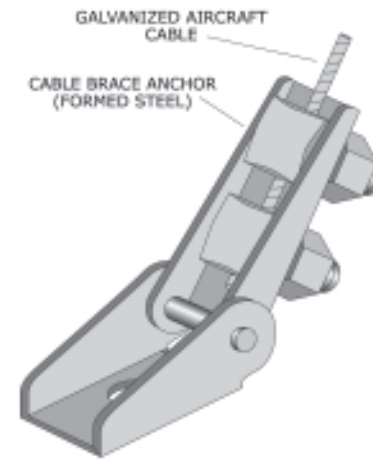


Figure 152: Cable attached with bolts to a bracket.

**Step 1: Drill anchor holes in the building structure as required**

**Step 2: Attach brackets to both the building and the equipment frame**

**Step 3: Cut the cable to desired length and slide it through the holes in the bolts**

**Step 4: Tighten the cable**

For rigid connections, pull the cable hand tight. Pull the cable hand-tight and let out 1/8" for vibration-isolated components. Avoid using too much tension or too much slack.

**Step 5: Torque bolts**



Refer to the manufacturer's instructions.

**Ferrule clamps**

Ferrule clamps may be connected to various types of attachments. Figure 153 (below) and Figure 154 (page 127) show attachments and identify the parts ferrules or sleeve and thimbles used in the assembly.



**Ferrules must be made of steel, zinc-plated copper, or steel alloys (including stainless steel). Do not use aluminum ferrules.**

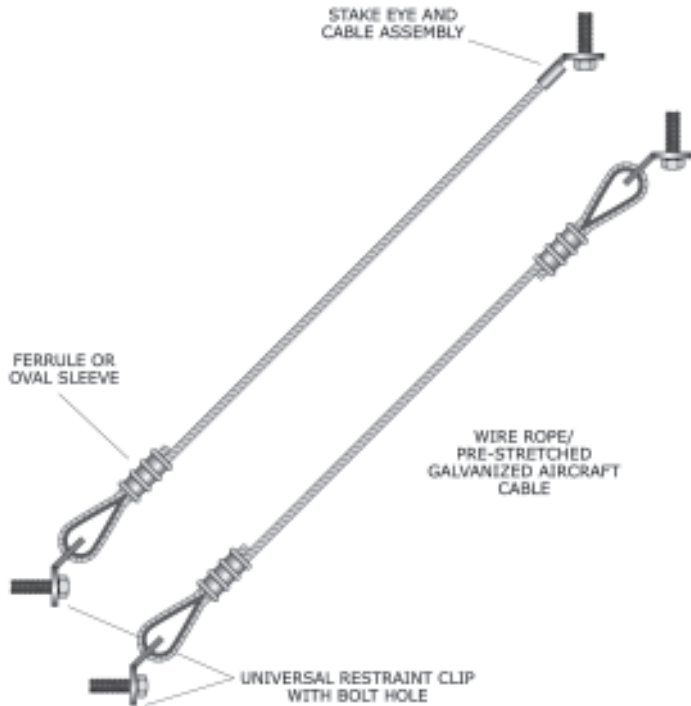


Figure 153: Ferrule assemblies.

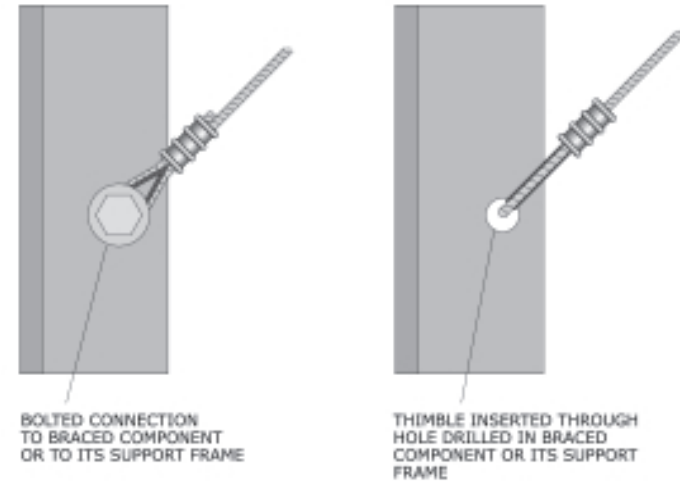


Figure 154: Ferrule attachments.

**Step 1: Install brackets with mounting holes, eye-bolts, or drill mounting holes**

Install brackets with mounting holes to the structure. Attach cables to the top of cord angles. See Suspended Attachment (page 62).

**Step 2: Cut the cable to the desired length and slide the oval ferrule (sleeve) onto the cable**

**Step 3: Wrap the cable around the thimble and pass it through the mounting bolt or holes and back through the ferrule**

**Step 4: Tighten the cable**

For rigid connections, pull the cable tight. For isolated components, leave a small amount of slack. Avoid using too much tension or too much slack.

**Step 5: Crimp the ferrule or oval sleeve two or three times as specified in the cable or ferrule manufacturer's instructions**

Use crimp tools and gauges specified by the manufacturer. Crimp and verify the depth of the crimp using a gauge.

### Wire rope grips

Installing cables attached with wire rope grips is similar to attaching ferrule clamps, as shown below.

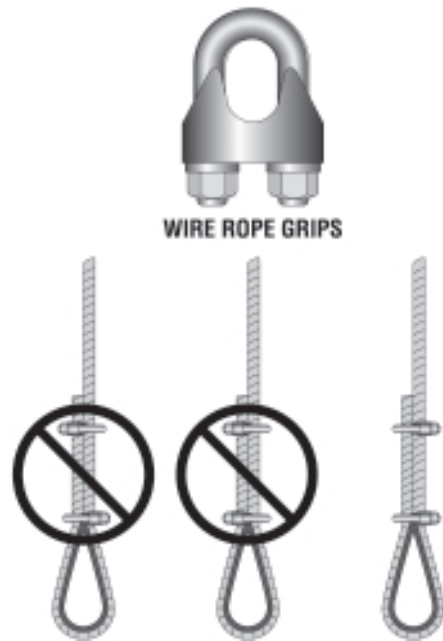


Figure 155: Wire rope grip assemblies.

**Step 1: Install brackets with mounting holes, eye-bolts, or drill mounting holes**

**Step 2: Cut cable to the desired length and slide three wire rope grips and thimbles onto the cable**

**Step 3: Pass the cable through the mounting bolt or holes provided and then back through each of the wire rope grips**



**Use thimbles for all cable installations with wire rope grips.**

### Step 4: Tighten the cable

For rigid connections, pull the cable tight. For isolated components, leave a small amount of slack. Avoid using too much tension or too much slack.

### Step 5: Torque all bolts evenly

Use the turn-of-nut tightening method described in Steel Bolt Connections (page 114).



**DO NOT OVER-TIGHTEN.**

## Control Panels

Control panels may be built into units, mounted in a separate electrical panel attached to equipment assemblies, or mounted as a separate electrical panel attached to the building structure.



**Be sure to refer to construction drawings and specifications, seismic restraint submittals, and the manufacturer's instructions.**



**If an electrical panel is mounted separately from the unit and the unit is vibration-isolated, use flexible electrical connections to allow for differential movement.**

### Step 1: Select control panel support configuration

If the control panel is:

- Built into the equipment, no other action is needed.
- An electrical panel attached to the assembly, check that the attachment is rigid and tight. No other action is needed.
- A remote panel attached directly to the building structure or attached using support angles or strut, continue with the following instructions.

The four ways of supporting control panels are by attaching them to:

- Walls with wall anchors as shown in Figure 159 (page 133).
- Vertical angles or strut extending down to the floor with angles slanted back to the floor as shown in Figure 156 (page 131). This is the typical method. Details are shown in Figure 158 (page 132).
- A double-strut support spanning the floor and ceiling as shown on the right in Figure 157 (page 131). Struts are attached to the building structure with small angle clips.
- An aluminum plate extending from the floor to the ceiling. The aluminum plate is attached to the floor and ceiling with angles, as shown on the left in Figure 157 (page 131).



Figure 156: Typical control panel support using angles. Additional angle supports may be required (see below).



Figure 157: Two different ways to support control panels: using a metal plate attached to floor and ceiling with steel angles (left); using struts extending to floor and ceiling (right).

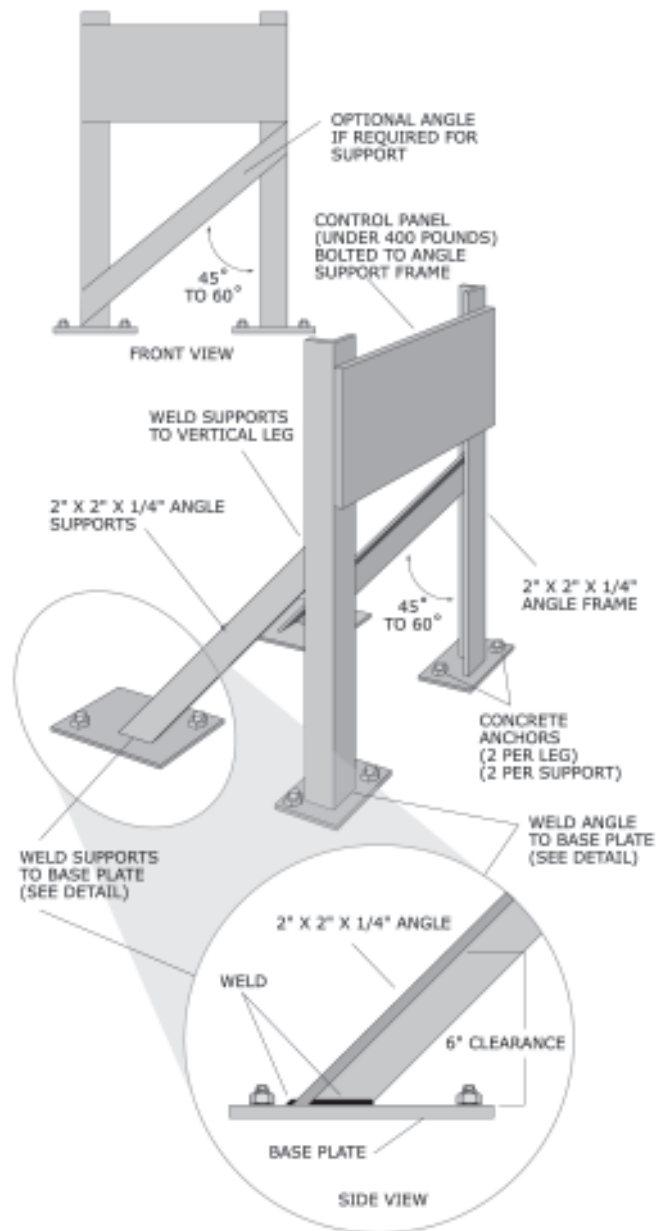


Figure 158: Angle assembly support from floor.

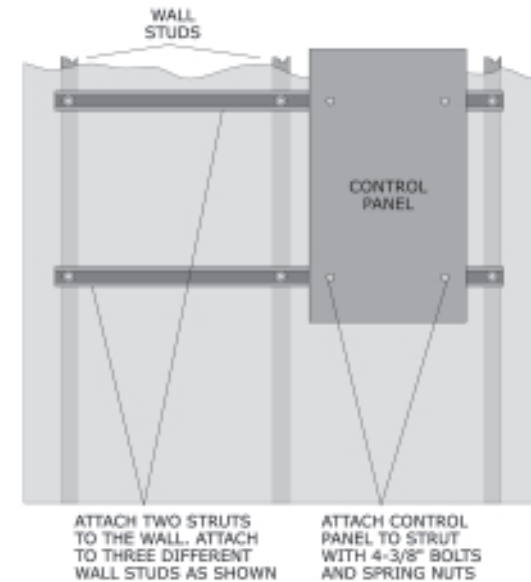


Figure 159: Direct attachment of a strut assembly support to wall.

### Step 2: Assemble the mounting frame

Use bolts or weld the support framing together as shown in Figures 156 to 159 (pages 131-133). See Steel Bolt and Sheet Metal Screw Connections (page 114), or Welding (page 119) for more information.

### Step 3: Attach the mounting frame to floor or wall with anchors

Locate and mark hole locations in the building structure. Install the anchors. See Anchors (page 96) for more information.

Attach the mounting frame to the building structure.

- To attach strut angles for strut floor-mounted supports, see Figure 157 (page 131).
- To attach bases for angle floor-mounted supports, see Figure 158 (page 132).
- To attach strut to wall studs, see Figure 159 (above).

**Step 4: Attach control panel to frame with a minimum of 4 steel bolts**

See Steel Bolt Connections (page 114).

## Housekeeping Pads



**Be sure to refer to contract drawings, specifications and the manufacturer's instructions.**

The construction of housekeeping pads is shown below.

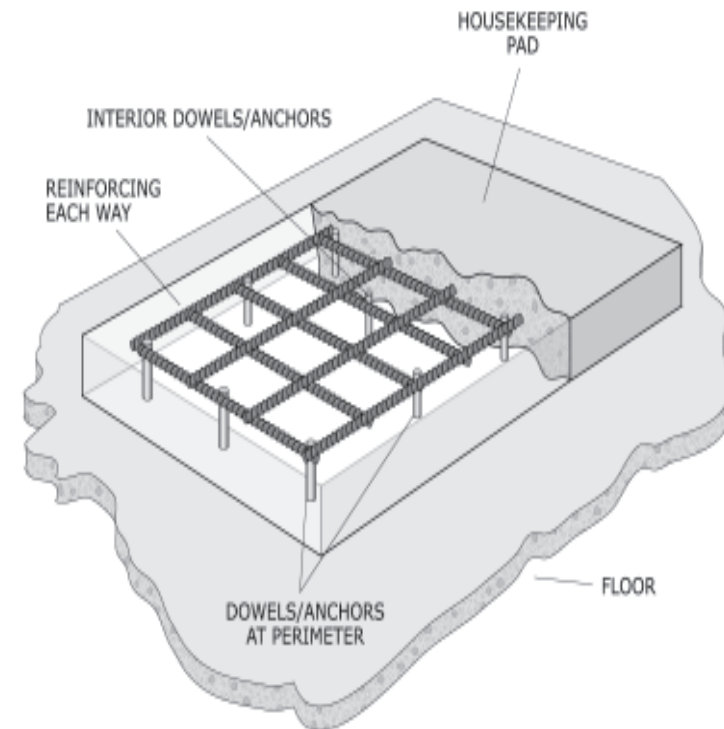


Figure 160: Housekeeping pad.

The housekeeping pad must be a minimum of one inch thicker than the anchor hole depth, or as required for the concrete anchors shown in Figure 161 (page 136).



**Housekeeping pads must be designed for the equipment weight and seismic load.**



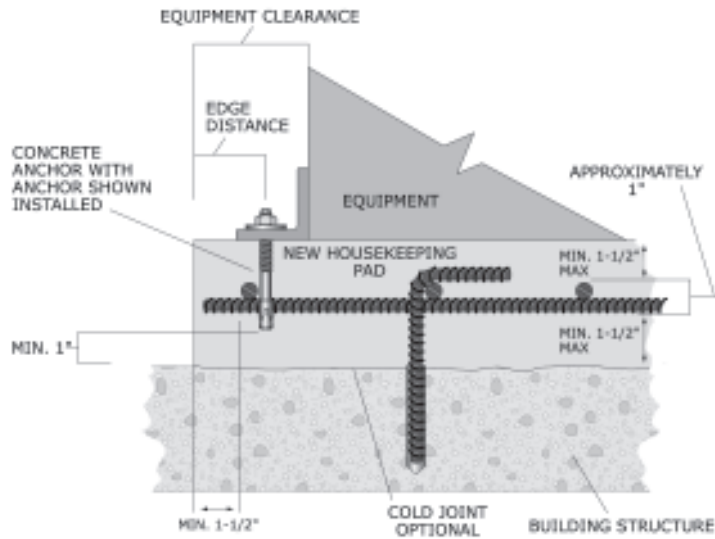


Figure 161: Housekeeping pad in section view.



**If edge distance is not met, get an evaluation.**

Dimensions for the pad footprint must be large enough for the equipment, attachment steel (as required), and the edge distance of concrete anchors (see Anchors, page 96), as shown in Figure 162 (below).

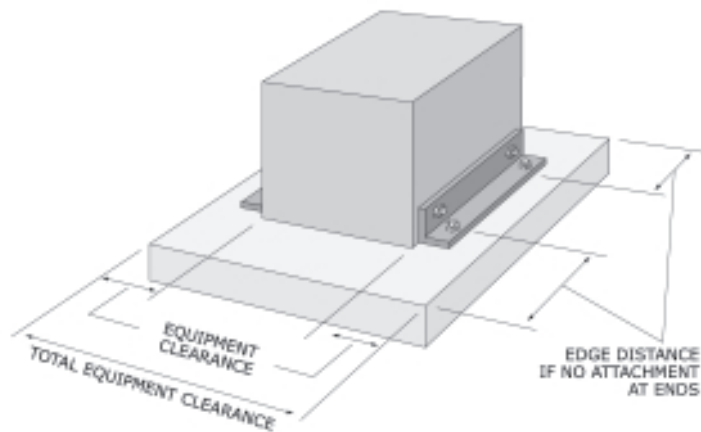


Figure 162: Housekeeping pad dimensions.

**Step 1: Install dowels into the floor**

Attachment details for dowels are shown in Figure 163 (below).

- Use measurements and shop drawings to lay out the size of the dowels and the dowel pattern.
- Coordinate the location of embedded "Z" bar shown in Figure 163 with the concrete subcontractor.

Obtain the size of doweling and reinforcement from contract drawings, specifications, or the manufacturer's printed instructions. Exterior dowels must be 1/2" to 1" in diameter. Interior dowels must be 1/2" to 3/4" in diameter.

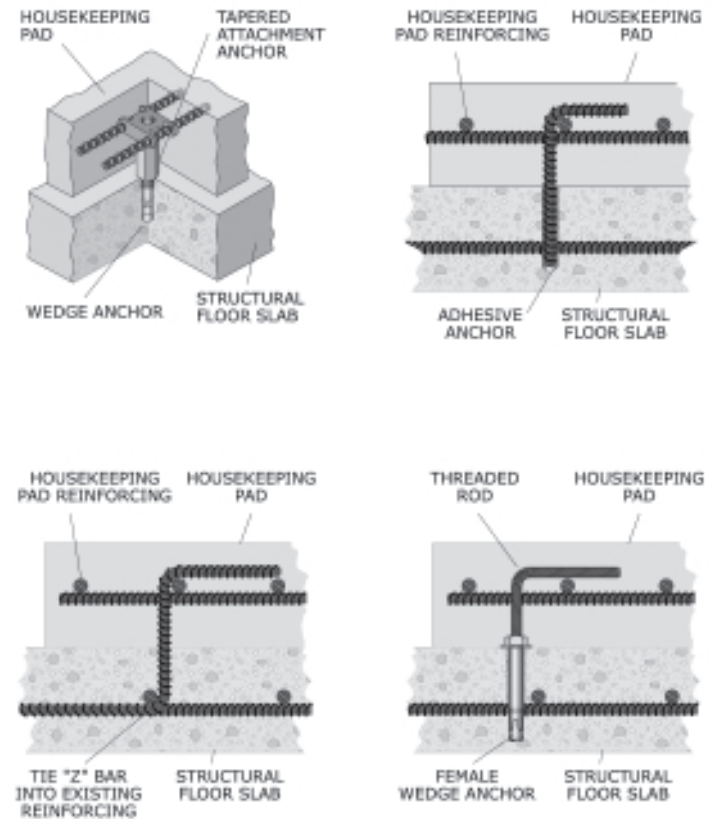


Figure 163: Doweling to the building floor.

### Step 2: Assemble reinforcement

Assemble the reinforcement as shown in Figure 160 (page 135). Connect the dowels using wire.

### Step 3: Pour concrete and allow to cure

### Step 4: Drill holes and attach the equipment to concrete after the concrete has cured

## Residential Equipment

Mechanical equipment in residential applications should be rigidly attached to the building structure or concrete pad. The types of equipment used for residential HVAC include:

- Water heater
- Furnace
- Condensing unit with an indoor A-coil attached to a furnace
- Through-the-wall air conditioner.

### Water Heater

A water heater may be bolted to the residential structure with straps (see Figure 127, page 92). For gas water heaters below 100,000 BTUH, use flexible pipe to attach the water heater to the gas piping.

### Furnace

A furnace may be bolted to the residential structure with straps and/or restrained at the bottom with bumpers. Straps may be attached to the residential structure in a manner similar to that of water heaters.

To use bumpers, see Figure 77 (page 41). To use straps, see Figure 127 (page 92). Bumpers may be constructed using wood studs for furnaces inside a raised closet.

For gas furnaces below 100,000 BTUH, use flexible pipe to attach the furnace to the gas piping.

### Condensing unit

A condensing unit may be bolted to a concrete pad outside and next to the residential structure or mounted on the roof of the structure.

- For a condensing unit mounted on the roof, use a sheet metal curb with a wood nailer to attach the unit on the roof. See Figure 87 (page 52) for instructions on installing the curb. The curb must be firmly attached to the roof structure with lag bolts. Attach the condensing unit to the curb with lag bolts.

## Special Cases: Residential Equipment

- For a condensing unit bolted to a concrete pad outside, attach the equipment using angles. See Figure 72 (page 37), Figure 73 (page 38), or Figure 76 (page 39).

### A-coil

An A-coil may be attached on top of a furnace with sheet metal screws.

### Through-the-wall air conditioner

An air conditioner should be attached to the residential structure. Some air conditioners have brackets used to directly attach the unit to the structure using lag bolts. A bracket support may be provided as shown in Figure 125 (page 90).

## ANCHOR SELECTION GUIDE

| Powder-Actuated  |  |
|--|--|
| Description  | Warning  |
| <p><b>Threaded Studs</b></p> <p>Used in cases where the fastened equipment is to be removed later, or where shimming is required.</p> <p>Threaded studs for concrete have a 0.140" to 0.180" shank diameter, with typical penetration of 3/4" (minimum) to 1-1/2" into concrete.</p> <p>Threaded studs for steel plate applications have a 0.140" to 0.180" shank diameter when the steel plate thickness is 3/16" or greater.</p> | <p><b>Safety is the primary concern when using powder-actuated tools (PAT). PAT tools pose the greatest risk to the operator and others in the area of use. Observe the following safety precautions:</b></p> <p>Typically not used for equipment weighing more than 40 pounds.</p> <p>Never allow a tool to be used until the operator is properly trained for the specific tool and application.</p> <p>Never use a tool unless all safety features are functioning properly.</p> <p>Always have the operator and others around wear the proper safety devices.</p> <p>Never use more powerful loads than required for the particular application.</p> <p>Always be aware of the potential of the fastener passing through the substrate or being deflected from its intended target.</p> <p>Make sure that all areas are clear behind and around the target area.</p> <p>Have an action plan in place to properly handle and dispose of misfired loads.</p> <p>Always make sure the tools are low velocity and not standard velocity. (Standard velocity tools are not typically allowed on most jobsites because of the danger.)</p> |
| <p><b>Drive Pins</b></p> <p>Used to directly fasten equipment for permanent installation.</p> <p>Drive pins used for concrete have a 0.140" to 0.180" shank diameter, with typical penetration of 3/4" minimum to 1-1/2" into concrete.</p> <p>Drive pins for Steel plate applications have a 0.140" to 0.180" shank diameter when the steel plate thickness is 3/16" or greater.</p>  |  |

| Adhesive   |  |
|--|--|
| Description  | Warning  |
| <p><b>Capsule Spin-In</b><br/>Adhesive mixes in hole when anchor is drilled by a rotary hammer drill only. Various strengths and types of rods or fasteners can be used. Multiple types of coatings on rods are available. Most commonly used in concrete; some might be suitable for use in other substrates. Most capsules cure quickly compared to epoxy.</p> | <p>Do not over-spin during installation. The rod must have a roof cut end with a single or double 45-degree angle/bevel for mixing. The hole must be clean and dry to achieve the maximum strength. Rod must be clean and must not be disturbed during curing. Many capsules produce strong odors during the curing process.</p> |
| <p><b>Capsule Hammer-in</b><br/>Adhesive mixes in hole when a rod is driven by a hammer. Various strengths and types of rods or fasteners can be used. Multiple types of coatings on rods are available. Most commonly used in concrete; some might be suitable for use in other substrates. Most capsules cure quickly compared to epoxy.</p>                   | <p>The hole must be clean and dry to achieve the maximum strength. Rod must be clean and must not be disturbed during curing. Many capsules produce strong odors during the curing process.</p>  |

| Adhesive (cont.)  |  |
|---|--|
| Description   | Warning  |
| <p><b>Epoxy</b><br/>Used by mixing two or more components with a mixing nozzle at the point of application. Can be used with multiple forms of fasteners or as an adhesive. Many brands can be used in wet, damp, or dry conditions. Many formulas are allowed for use for USDA food processing areas. Some may be able to be used overhead. Permitted many times in freeze-thaw and severe weather conditions. Allows minimal edge distance and anchor spacing. Typical shelf life greater than that of other adhesives used for anchoring. Not as susceptible to damage from high storage temperatures.</p> | <p>Typically requires long curing times compared to that of other adhesives. Can be virtually odor free or can emit a strong odor, depending on the formula. Can be difficult to apply if the epoxy is thick. Generally not suggested for use at temperatures below 32 degrees F. Most epoxies require holes to be cleaned to obtain maximum values.</p> |
| <p><b>Acrylic Adhesive</b><br/>Dispenses and cures quickly. Some adhesives can be used overhead. Some adhesives can be installed in damp or water-filled holes. Typically can be used with many fastening devices such as threaded rod, dowels, and anchors.</p>  | <p>Many types of acrylics produce a strong odor during the curing process. Others have a minimal odor.</p>   |
| <p><b>Adhesive Undercut Anchors</b><br/>Used in heavy-duty applications where substrate is of poor quality.</p>   | <p>Generally purchased from the manufacturer as a complete anchoring system. Any substitution of materials must be authorized before installation.</p>   |

| Externally Threaded   |  |
|---|--|
| Description   | Warning  |
| <p><b>Heavy Duty Undercut</b></p> <p>Used in heavy-duty applications. Typically two types: self-undercutting and adhesive.</p> <p>Self-undercutting types use a special undercutting drill bit are similar to heavy-duty sleeve anchors except they fill a cavity greater than the initial hole diameter.</p> | <p>May require special tools and specific drill bits. Typically cannot be used at variable embedment depths. Can be complicated to install. May be difficult to verify proper installation.</p>  |
| <p><b>Wedge Anchor</b></p> <p>The most common concrete anchor for heavy- to light-duty applications. Many configurations are available for most applications. Made from a variety of materials.</p>   | <p>Typically designed for static loads and not used with reciprocating engines or in situations where vibrations are present.</p>  |
| <p><b>Heavy Duty Sleeve Anchor</b></p> <p>Expansion anchor for heavy-duty requirements.</p>   | <p>A large hole is required for this anchor. Some anchors have metric diameters. Some have multiple parts that can be unassembled. If re-assembled improperly, the anchor may not perform properly. If the nut is removed after the stud is inserted in the hole, the stud could be partially separated from the expansion cone, causing a reduction in anchor strength, or be detached from the expansion cone, requiring anchor replacement. These conditions are not visible.</p> |

| Externally Threaded (cont.)  |  |
|--|--|
| Description  | Warning  |
| <p><b>Center Pin Anchor</b></p> <p>Medium-duty expansion anchor. The anchor is correctly installed when the pin is completely inserted. Installation procedures are simple; no torque is required to set the anchor.</p> | <p>Typically designed for static loads and not used with reciprocating engines, motors or in situations where vibrations are present.</p>  |
| <p><b>Sleeve Anchor</b></p> <p>Universal anchor for light- to medium-duty applications. Multiple head designs fit many applications and can be installed in masonry.</p>   | <p>A large hole is required for this anchor. Some anchors have metric diameters. Some have multiple parts that can be unassembled. If re-assembled improperly, the anchor may not perform properly. If the nut is removed after the stud is inserted in the hole, the stud could be partially separated from the expansion cone, causing a reduction in anchor strength, or be detached from the expansion cone, requiring anchor replacement. These conditions are not visible.</p> |

| Internally Threaded  |   |
|--|---|
| Description  | Warning   |
| <p><b>Internally Threaded Undercut Anchor</b></p> <p>Used in heavy-duty applications. Typically come in two types: self-undercutting and those using a specialized undercutting drill bit. Anchors have internal threads. Shallow embedment and small edge distances and spacing are possible.</p> | <p>May require special tools and specific drill bits. Typically cannot be used at variable embedment depths. Can be complicated to install. May be difficult to verify proper installation.</p> |
| <p><b>Shell Anchor</b></p> <p>Flush-mount or sub-surface internally threaded anchor for medium- to light-duty applications. Comes in fractional and metric sizes and is available in a variety of materials.</p>   | <p>A special setting tool is required and must be supplied by the anchor manufacturer. The setting tool is designed for each anchor size and style.</p>   |
| <p><b>Others</b></p> <p>Similar to the wedge concrete anchor and used in heavy- to light-duty applications. Many configurations are available to fit most applications. Made from a variety of materials.</p>  | <p>Typically designed for static loads and not used with reciprocating engines or in situations where vibrations are present.</p>   |

| Light Duty Fastenings   |  |
|---|--|
| Description   | Warning  |
| <p><b>Drive Pin (nail) Anchors (metal and plastic)</b></p> <p>Light-duty anchor with fast and easy installation in many substrates.</p>   | <p>Use only for static loads. Typically not used in overhead applications.</p> <div style="background-color: red; color: white; text-align: center; padding: 5px; font-weight: bold;">                     DO NOT USE FOR SEISMIC RESTRAINT                 </div> |
| <p><b>Concrete Screws Medium- to Light-Duty</b></p> <p>A variety of lengths and diameters are available. Often used for temporary anchorage.</p>  | <p>Typically not used in situations where extensive vibrations are present. Requires the use of a special drill bit (some metric) supplied by the anchor manufacturer.</p>   |
| <p><b>Special Style Head Wedge (ring) anchor</b></p> <p>Wedge anchor with integrated connection (head) designed for tie wires or suspended ceilings.</p>  | <p>Typically designed for static loads and not used with reciprocating engines or in situations where vibrations are present.</p>  |
| <p><b>Single and Double Expansion Shields</b></p> <p>Multi-purpose anchor used in concrete, Concrete Masonry Unit (CMU), brick, or stone. This anchor distributes fairly even pressure making its use popular in CMU, brick, and natural stone. Typically use in conjunction with machine bolts, which can be removed and replaced.</p> | <p>Anchor material is malleable and the threads can be stripped.</p> <div style="background-color: red; color: white; text-align: center; padding: 5px; font-weight: bold;">                     DO NOT USE FOR SEISMIC RESTRAINT                 </div>           |

| Light Duty Fastenings (cont.)   |   |
|---|---|
| Description   | Warning   |
| <p><b>Lead Expansion Anchors</b><br/>                     Similar to expansion shields, but typically considered light-duty. Many can be used with a variety of screws or bolts. Quick and simple to install. Can be used in concrete, CMU, brick, or stone.</p>  | <p>Anchor material is malleable and the threads can be stripped. Anchor should not be used in any applications.</p> <div style="text-align: center; background-color: red; color: white; padding: 5px; font-weight: bold; font-size: 1.2em;">                         DO NOT USE<br/>                         FOR SEISMIC<br/>                         RESTRAINT                     </div> |
| <p><b>Toggle or “Molly”-type Anchors</b><br/>                     Light- to medium-duty anchor with easy installation in many substrates. No drilling is required for some anchor types or in some substrates. Some anchors are supplied with bolts or screws. Anchors are made from variety of materials and colors including plastic, zinc alloys, and steel.</p> | <p>May require a large hole. Anchor may or may not be reusable if the bolt is removed. Severe damage to the substrate can result if these anchors are removed after installation.</p>   |

## GLOSSARY

- A Adhesive anchor** – An anchor designed to bond directly to concrete within a pre-drilled hole using epoxy or other adhesive.
- Anchor** – A device for connecting equipment and attachments to the building structure.
- Attachments** – Support systems used to connect equipment, pipe, conduit, or ductwork to the building.
- Attachment type** – Use of attachments to floors, walls, roofs, ceilings, and vibration isolators.
- B Bar joist** – Ceiling joists supporting intermediate floors or roof made from steel angles and steel bars.
- Base plate** – A steel plate used for support and anchorage of an angle support or vibration isolator.
- Bed joint** – A horizontal seam in a brick or concrete block wall. Also see **Head joint**.
- Bolt diameter** – Thickness or width of the outside of the threaded portion of the bolt.
- BTUH** – The heating and cooling capacities of equipment in British Thermal Units per Hour.
- Building structure** – Steel, concrete, masonry and wood members or surfaces that transfer the weight of the building and equipment to the ground.
- Bumpers** – Angles or other steel shapes with elastomeric padding rigidly mounted to the building structure in a pattern around the equipment base to limit horizontal movement.
- Busbars** – A conducting bar (usually made of copper) that carries currents to various electric circuits.
- C Cabinet** – An enclosure designed for surface mounting or flush mounting that houses controls and electrical components.

**Cable brace** – A steel cable designed for use as a seismic sway brace for suspended equipment, piping, ductwork, or raceways. Also see **Pre-stretched cable**.

**Cant strip** – A material used to fill voids in roof flashing.

**Cantilevered** – A support member connected at one end and unsupported at the other end.

**Cast-in-place** – A steel shape embedded into concrete.

**Cast-in-place anchor** – A headed steel bolt or J-bolt set within a concrete form before concrete is poured.

**Cold joint** – An edge between two concrete surfaces.

**Construction documents** – Drawings, specifications, and manufacturer's instructions that define the scope of a project and provide detailed information to seismically restrain the equipment, piping, ductwork, or raceways.

**Counter flashing** – A light-gauge sheet metal folded support or equipment frame to shed water or snow onto the roof.

**Curb** – Raised or enclosed framework that supports equipment.

**Cure** – To gain internal strength over time to withstand external forces.

**Cure time** – The total time it takes for the material to be at an absolute full load capacity.

**D** **Differential movement** – The movement between two objects or surfaces.

**E** **Edge distance** – The distance between a concrete anchor and the edge of a concrete surface or concrete cold joint.

**Elastomeric** – A material with flexibility in all directions that will return to its original shape if removed from its environment.

**Embedded** – Fixed firmly in the surrounding material.

**Embedment** – How far a post-installed anchor is inserted into a hole in concrete or wood after the anchor is set in place and torqued.

**Embedment depth** – See **Embedment**.

**Enclosure** – A case or housing to protect electrical components.

**Equipment** – Any mechanical or electrical component.

**Expansion anchor** – A post-installed anchor that uses some form of wedge or shell held against the edge of a drilled hole with friction.

**F** **Ferrule** – A small metal tube that can be crimped around steel cables.

**Fillet weld** – A weld between two pieces of steel where the welded surfaces are at right angles.

**Flashing** – Metal, asphalt, or elastomeric material with one or more layers surrounding a roof penetration specifically designed to weatherproof the building.

**Flexible connector** – A connector designed to allow slight movement between a piece of equipment, component, or system and another system in the amount of relative movement in the event of an earthquake.

**Flexible mounted equipment** – A piece of equipment supported on or from a vibration isolator.

**G** **Gel time** – A specified amount of time for an adhesive to form a jelly-like substance with strength to hold its own weight or the weight of a light steel anchor.

**Grommet** – A rubber or elastomeric bushing-shaped ring that may be used in restrained springs, snubbers, or with bolts to provide a cushioned or flexible connection.

**Groove joint** – A mechanical connection between two pipe sections using a tongue-and-groove configuration and elastomeric gasket.



**H Hand tight** – The force applied by hand to bring two or more materials together without a space and without the use of tools.

**Head joint** – A vertical joint between two concrete blocks in a block wall or two bricks in a brick wall. Also see **Bed joint**.

**Headed stud** – A large bolt with a threaded shaft and a hexagonal shaped bolt head typically used for embedment into concrete surfaces or in-filled concrete walls.

**Height-saving bracket** – A bracket used to accommodate the height of spring isolators without raising the equipment base more than a few inches.

**Housed spring** – A spring isolator with steel guides usually separated by an elastomeric sheet located on two opposite sides of the spring.

**Housekeeping pad** – A concrete pad under equipment that raises the elevation of the equipment above the building structure or structural slab. Also called plinths.

**I Inertia base** – A heavily weighted base, usually made of concrete, that weighs more than the equipment it supports.

**In-filled block** – A concrete block wall whose cells are reinforced with rebar and filled with a sand-grout mixture.

**Inlet** – The location or connection to equipment where a substance such as water or air enters the equipment.

**Isolation curb** – See **Manufactured isolation curb**.

**Isolators** – See **Vibration isolators**.

**L Leveling stanchions** – See **Stanchions**.

**Load path** – Seismic support of equipment and internal components that can be traced through connections and support steel to the building structure.

**Load transfer angles** – Angles bolted to equipment and to the building structure, transferring the weight and earthquake load through the angles to the building structure.

**Longitudinal brace** – A brace that restrains pipes, ducts, or raceways parallel to the longitudinal direction of the pipe, duct run, or raceway.

**M Manufactured isolation curb** – A factory-built curb designed to attach equipment to a roof and containing vibration isolators, which allow for slight movement of the equipment.

**N No-hub pipe** – Pipe designed for connections that do not interlock or permanently join.

**Nominal diameter** – The diameter across the outermost edges of a bolt or threaded rod.

**O Open spring** – A spring isolator with a bolt attachment at the top of the spring for connecting to equipment without any horizontal support.

**Outlet** – The location or connection to equipment where a substance such as water or air exits the equipment.

**P Plenum** – An enclosed space usually made from galvanized sheet steel allowing airflow from one duct system to another; the entrance to and/or exit from a fan or air handling unit.

**Plug weld** – The weld of a plate or base plate to another metal surface where a plate is perforated with one or more holes, which are then filled with the weld filler material.

**Point load** – Weight and seismic forces that are focused to a single point connection to the building structure.

**Post and beam** – An elevated structure usually made from beams resting on posts or stanchions connected to the building structure.

**Post-installed anchor** – Anchors installed after the building structure is completed.

**Post-tension building** – A concrete building structure surface with internal steel cables that are stretched and restrained to permanently compress the concrete surface.

**Pre-manufactured curb** – A sheet metal curb manufactured at a factory and sent to the job site.

**Pre-stretched cable** – Cable that is stretched after it is manufactured.

**R Raceway** – A channel (conduit or open raceway) designed to hold wires and cables or busbars.

**Rated spring deflection** – The dimension a spring will compress when the weight of equipment is applied.

**Rehabilitation** – A new installation within an existing facility.

**Restrained spring** – A vibration isolator containing a spring enclosed in a welded or bolted steel housing that limits the movement of the spring equipment attachment in all directions.

**Rigid-mounted equipment** – Equipment solidly braced or bolted directly to the building structure without vibration isolation.

**S Screen** – A tube of steel wire mesh used as an adhesive anchor for anchoring to block or brick walls.

**Seismic cable** – A steel or stainless steel braided rope.

**Seismic restraint device** – An attachment device designed to restrict movement of equipment during an earthquake.

**Seismic restraint device submittals** – Documents created by contractors or vendors describing the means and methods for installing seismic restraint devices and submitted for design approval.

**Seismic rod clamp** – A clamping device for attaching rod stiffeners to a vertical threaded rod.

**Self-drilling** – A special type of concrete shell anchor with cutting teeth for drilling into concrete.

**Self-tapping** – Either a sheet metal screw with blades on the end (similar to a drill bit), allowing the screw to drill a hole and embed itself into a steel shape, or a concrete screw with a point and specially designed threads allowing the screw to grip the concrete and embed itself into the concrete.

**Set time** – The specific time required for material to harden when a light load may be applied.

**Shallow concrete anchor** – Any anchor with an embedment depth measuring less than 1/8th of its diameter.

**Sheet metal curb** – A square or rectangular box made from galvanized steel sheets used to connect equipment to a roof.

**Sheet steel housings** – Sheet steel that fully or partially encloses a piece of equipment.

**Shim** – A thin wedge of material used to fill a space.

**Snubber** – A seismic restraint device used on isolated systems with an air gap and elastomeric bushing or oil-filled hydraulic cylinder (shock absorber) restricting the rapid motion of a pipe.

**Snug tight** – The force applied by hand to bring two or more materials together without a space and without the use of tools.

**Solid brace** – A steel angle or strut channel designed for use as a seismic sway brace for suspended equipment, piping, ductwork, or raceways.

**Spring-isolated** – See **Vibration-isolated**.

**Stanchions** – Columns or short structural steel shapes placed vertically that connect to equipment bases or horizontal structural steel frames to provide equipment support.

**Structural steel shapes** – A manufactured steel component in a variety of shapes.

## Glossary

**Strut** – A manufactured steel shape in various U-shaped patterns and sizes.

**Strut frame** – Steel framing made from strut members that act as a support to transfer the equipment weight to the building structure. See **Strut**.

**Sway brace** – Solid braces or cable braces that provide seismic restraint.

**T Tendons** – Steel cables used in post-tension buildings. Also see **Post-tension building**.

**Thimble** – A metal spacer used on a cable to protect it from being bent and damaged.

**Transverse brace** – A brace that restrains pipes, ducts, or raceways perpendicular to the longitudinal direction.

**Toe of the weld** – The edge of a fillet weld.

**Torque** – A turning force around a bolt applied by twisting a bolt head or nut so the components will not separate.

**Turn-of-the-nut method** – A process to properly torque a bolt without a special tool like a calibrated torque wrench.

**V VAV boxes** – A terminal unit or plenum with an internal damper and control actuator that can vary airflow quantities.

**Vibration-isolated** – Allows flexible motion between equipment, piping, ductwork, or raceways and the building structure.

**Vibration isolators** – Components containing springs used to separate equipment from the building structure.

**W Web** – A thin metal strip in a structural steel shape.

**Weld base material** – The material composition of an item being welded.

## INDEX

A-coil 16-17, 139, 140  
air compressor 4-5  
air conditioning unit 6-7, 139, 140  
air handling unit 8-10  
air separator 11  
anchor 96-102, 149  
    adhesive 96-97, 100, 101, 106, 109-111, 142-143, 149  
    cast-in-place 35, 63, 96, 103, 104, 150  
    concrete 112  
    concrete screw 106, 111  
    drywall 112  
    embedded plates 36, 96, 119  
    externally threaded 144-145  
    general 96  
    inserting 100-101, 109  
    internally threaded 146  
    lag bolts 96, 104, 106, 108, 112  
    light-duty fastenings 147  
    masonry and drywall 96, 106-113  
    non-adhesive 97  
    post-installed 63, 96  
    powder-actuated 141  
    sheet metal screw 106, 108, 112, 114  
    shell 96, 99, 101  
    sizes for equipment less than 400 pounds 121-123  
    sleeve 96, 99, 106  
    steel bolt 96, 114-115  
    through-bolt 106  
    toggle bolt 106, 111-112  
    umbrella 106, 110-111  
    undercut 96, 99, 101  
    wedge 96, 99, 106  
    welding 119-120  
anchor selection guide 141-148  
angle 36-40, 45, 68-70, 73-74, 90-92, 93, 130-132  
attachment types 32-95, 149  
    rigid floor-mounted/pad-mounted 32-47  
    roof-mounted 48-62  
    suspended 62-76  
    vibration-isolated/floor-mounted 77-87  
    wall-mounted 88-95

bar joist 65, 149  
 base 79  
   inertia 41, 85, 152  
   plate 91, 149  
   round 36, 39  
 block walls 107, 109, 110, 111, 113  
 boiler 12-13  
 bracket 62, 68, 70, 76, 88, 95, 102, 118, 125  
 bumpers 41-42, 77, 79, 149

cable 62-68, 70-72, 76, 124-129  
   attach using:  
     bolts with center holes 125-126  
     ferrule clamps 126-127  
     wire rope grips 128-129  
 chain 95  
 chiller 14-15  
 coil 9, 16-17  
 concrete  
   joint 41-42  
   pouring 138  
   slab 65  
 condenser, condensing unit 18-19, 139  
 control panels 130-134  
 cooling tower 20-21  
 curb 58-59, 150  
   built-up 51-56  
   isolation 58-59  
   pre-manufactured 51-56  
 curing 110, 113, 138, 150

dowel 137  
 duct-mounted coil 16-17, 73  
 duct silencer 30-31  
 ductwork 36, 40, 89, 93

embedment depth 98-99, 105, 112  
 end-suction pump  
 equipment 4-31  
   less than 150 pounds 45, 73  
   less than 400 pounds 45, 121-123  
   setting/moving in place 35, 40, 44, 81, 84, 86, 89, 93, 103, 105, 113, 151  
   typical 5, 7, 10, 11, 13, 15, 17  
 evaporative cooler 20-21

fan 22-23  
 fan-coil unit 30-31  
 ferrule clamps 126-127, 151  
 flashing 49-50, 55, 57, 58, 61, 151  
 floor-mounted 32-47, 77-87  
 fluid cooler 20-21  
 frame 46-47, 50-51, 57, 58-59, 60-61, 94, 133-134  
 furnace 12-13, 139

gap 102  
 gas cylinder 28-29, 47, 95  
 grout 102, 108, 113

head joint 107  
 heater 24-25, 75  
 heat exchanger 16-17  
 heat pump 6-7  
 hole 97-100, 107-109, 115  
   cleaning 100, 109  
   clearance 104  
   drilling 98-99, 107-108, 115, 125, 138  
   lead 105  
   oversized, repair of 35  
 housekeeping pad 135-138, 152  
 humidifier 12-13

masonry and drywall anchors (see anchors)

pad-mounted (see rigid floor-mounted/pad-mounted attachment)  
 piping 36, 40, 89, 93  
 plate 130-132  
 post and beam 48-51, 58-59, 153  
 pump 26-27, 87

raceways 36, 40, 89, 93, 154  
 raised floor 43-44  
 rebar 99  
 residential equipment 139-140  
 rigid floor-mounted/pad-mounted attachment 32-47  
   at a single point 45-46  
   beneath a raised floor 43-44  
   directly to the floor/pad 32-36  
   using a strut and plate frame 46-47  
   using additional structural steel shapes 36-40  
   using bumpers to restrict horizontal movement 41-42

rods 62-68, 70-72, 75, 76, 93, 116-117, 118

roof-mounted attachment 48-61

- to a wood frame 57
- using leveling stanchions—post and beam 48-51
- using restrained springs on leveling stanchions 60-61
- using seismic built-up/pre-manufactured curb 51-55
- using seismic pre-manufactured vibration isolation 58-59

screen insert 109

seismic restraint device 2, 154

sheet steel 32, 33, 155

snubber 77-78, 83, 85-86

special cases 124-140

- cables 124-129
- control panels 130-134
- housekeeping pads 135-138
- residential equipment 139-140

spring 77-78

- housed 77
- isolator 84, 86
- open 77, 83-87
- restrained 60-61, 78, 79-82, 154

stanchion 48-51, 58-61, 155

stand 43

steel beam 64

steel bolt connection 114-120

- bolted to a concrete floor 114-115
- bolting two structural shapes together 116
- bolting a threaded rod to steel shapes or strut 116-118

steel shape 36-40, 90-93, 104, 118, 119, 155

strap 91-93

structural framing 32, 34

strut 70, 74, 90, 93, 130-133, 156

stud 92

suspended attachment raised 62-76

- rigid using 4 threaded rods with horizontal cable supports 62-68
- rigid using angle supports 68-70
- isolated using threaded rods and horizontal cable supports 70-72
- double angle attachment—bolted or welded to the building 73-74
- double rod attachment—bolted to the building 75-76

tank 28-29, 47

tendons 98, 156

terminal unit 30-31

thimble 129, 156

through-the-wall air conditioner 140

torque 102, 103, 115, 116, 117, 118, 126, 127, 156

turn-of-nut method 115

VAV box 30-31, 73, 156

vibration-isolated/floor-mounted attachment 77-87

- on open springs combined with snubbers 83-87
- on restrained springs 79-82

vibration isolators 93-94, 156

wall-mounted attachment 88-95, 133

- directly to the wall 88-89
- directly to the wall—gas cylinders only 95
- to additional structural shapes attached to the wall 90-93
- vibration-isolated off the wall 93-94

water heater 12-13, 92, 139

webs 107-108, 156

weld 36, 40, 50, 55, 61, 119-120

wire rope grips 128-129

wood beam 64

wood frame 57

“Z” bar 137