Application & Engineering Guide

REVOLUTION TFX AIR HANDLING UNITS
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FIG. 1 – BASIC REVOLUTION TFX WITH MIXING BOX, RIGID FILTER, COOLING COIL, AND SUPPLY FAN
Fan Laws (Recommended Accepted Practice)

The fan laws are used to calculate performance characteristics; fan speed (RPM), fan air capacity (CFM), static pressure (SP) and brake horsepower (BHP) of a particular fan at conditions other than those at which the data was taken.

By using the fan laws in conjunction with a fan curve, the fan performance can be calculated accurately at various operating conditions. Every fan has its own unique fan curve. FIG. 2 shows a fan curve at various RPMs.

The system resistance curve relates the total pressure loss in an air handling system to the flow rate of air through the system. The system curve is unique to each system because it expresses the pressure losses associated with the system. (AHU cabinet, coils, filters, supply and return ductwork, grilles and diffusers). The SP and CFM values are used to create the system curve for the particular system. FIG. 3 represents a fan curve with 2 system curves identified.

System curves will always have a square function slope (parabola) because the SP varies as a square of the CFM. The point where the system curve intersects the RPM curve is the operating point of the fan (point A). If the system resistance changes (i.e., dirty filters or change in ductwork), the operating point will move along the RPM curve to a different operating point and therefore, new system curve (point B). With a fixed system, the effects of change in RPM, air density of BHP can be calculated and plotted on the system curve by using the following fan laws:

- The CFM varies directly with the RPM:
  \[ CFM_2 = CFM_1 \times \left( \frac{RPM_2}{RPM_1} \right) \]

- The SP varies as a square of the RPM:
  \[ SP_2 = SP_1 \times \left( \frac{RPM_2}{RPM_1} \right)^2 \]

- The BHP varies as a cube of the RPM:
  \[ BHP_2 = BHP_1 \times \left( \frac{RPM_2}{RPM_1} \right)^3 \]

- The SP and BHP are directly proportional to the air density:
  \[ SP_2 = SP_1 \times \left( \frac{Density_2}{Density_1} \right) \times \left( \frac{RPM_2}{RPM_1} \right)^2 \]
  \[ BHP_2 = BHP_1 \times \left( \frac{Density_2}{Density_1} \right) \times \left( \frac{RPM_2}{RPM_1} \right)^3 \]

The fan laws can only be used to project performance along a specific system curve. Referencing FIG. 3, Point A can be used to project the performance of Point C and similarly, Point B can be used to project the performance of Point D. Point A cannot be used to predict any other point on the RPM curve, it can only project performance on the system curve created by Point A.
FAN APPLICATION REVIEW

Variable Air Volume

A common mistake when selecting a fan with variable air volume is to assume a fan with VAV will follow a constant design system curve (passing through the point 0 CFM and 0 TSP) to maintain control. VAV systems do not have a constant system line, but rather a range of operating points necessary to satisfy the building requirements. In VAV systems, the operating point will continue to move based on the air modulation and as the CFM and SP change, the fan is modulated to match the new requirements, developing its own system curve. This modulation is accomplished by using inlet vanes, variable speed drives or discharge dampers. Before finalizing the fan selection, plot the new VAV system curve to confirm the modulation range required does not enter into the instability range of operation.

Example

Calculate the minimum CFM and at least 2 arbitrary points which fall within the stable operating range of the curve (using equations below) and plot these points along with the design points to create the new VAV system. (See FIG. 4.)

Design CFM = 40,000 CFM = CFMd
Design TSP = 4.5 in WG = SPd
Static Pressure Control Point = 1.25 in WG = SPd

1st: Calculate the Minimum CFM:

\[ \text{Min CFM} = \text{CFM}_6 \times \sqrt{\frac{\text{SP}_d}{\text{CFM}_6}} + \frac{\text{SP}_s - \text{SP}_e}{\sqrt{3 \times \left( \frac{\text{CFM}_6}{\text{CFM}_6} \right)^2 + 1.25 - 4.5}} = 40,000 \times \sqrt{\frac{1.25}{40,000}} + \frac{40,000 - 15,000}{\sqrt{3 \times (40,000/15,000)^2 + 1.25 - 4.5}} = 10,517 \]

where: \( \text{CFM}_6, \text{SP}_1 = \) arbitrary point located on surge line
\( \text{Min CFM} = 10,517 \)

2nd: Calculate the Arbitrary Points:

\[ \text{SP}_2 = \left( \frac{\text{CFM}_6}{\text{CFM}_6} \right)^2 \times (\text{SP}_d - \text{SP}_s) + \text{SP}_s \]

\[ \text{SP}_2 = \left( \frac{30,000}{40,000} \right)^2 \times (4.5 - 1.25) + 1.25 \]

\[ \text{SP}_2 = 3.1 \]

\[ \text{SP}_2 = \left( \frac{20,000}{40,000} \right)^2 \times (4.5 - 1.25) + 1.25 \]

\[ \text{SP}_2 = 2.1 \]

Select the most efficient fan that can deliver both the design and minimum CFM requirements. If the initial selection does not provide sufficient “turn down”, select the next smallest fan and re-plot the VAV system for the smaller fan and re-evaluate. Typically, the largest fan that can supply the required modulation is the most efficient. Each application should be considered individually and evaluated to be sure the fan will not be forced into the unstable region at modulated condition.

For variable speed drive (VSD) applications, the fan drive assembly is selected to operate approximately in the middle of the VSD’s range. When selecting a fan to be used with a VSD, if the RPM is close to or approaching the Class I limit, select the Class II fan. Selection of a Class I fan may result in premature bearing failure.
**Revolution TFX Component Temperature Margins**

- Standard motors (Class B Insulation) - 104°F.
- Motors with Class F Insulation - 140°F.
- Power Wiring - 140°F.
- Controls & Control Wiring - 140°F.
- Pre-filters - 150°F.
- High Efficiency Filters - 200°F.
- Fan Bearings - 120°F (FC), 180°F (AF)
- Gasketing - 200°F
- Foam - Flash Point: 415°F (213°C)

---

**FIG. 4 – FAN CURVE AT VARIOUS RPMs**

<table>
<thead>
<tr>
<th>Fan Motor Heat (MBH)</th>
<th>Horsepower</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HEAT</strong></td>
<td>5</td>
</tr>
<tr>
<td>Fan Motor</td>
<td>2.8</td>
</tr>
<tr>
<td>Fan</td>
<td>12.7</td>
</tr>
<tr>
<td>Fan &amp; Fan Motor</td>
<td>15.5</td>
</tr>
</tbody>
</table>
Flexibility and Performance illustrate the variety of coils which are available to meet every application. These carefully engineered coils are designed for an optimum balance between air pressure drop and heat transfer coefficient, to allow the maximum amount of cooling or heating capacity without the added expense of high air-pressure drops. The coil designs are subjected to constant extensive evaluation studies comparing different fin corrugations with various tube arrangements. The Titus rep in your area will welcome the opportunity to assist you with your coil applications.

Cooling Coils – Water and Direct Expansion

Revolution optimizes coil performance with customized coil options. Revolution coils are offered in a wide variety of types, sizes, arrangements and materials. Coil software optimizes capacity and pressure drop requirements.

AHU Chilled water cooling coil
- Available in CC, VC, MZ segments

AHU Hot water heating coil
- Available in CC, VC, HC, MZ segments

AHU (DX) Direct Expansion cooling coil
- Available in CC, VC, MZ segments

Notes & Options

Hand of Unit determines connection side of coil. See page 9.

Header material:
- Copper
- Red Brass
Connector material:
- Red brass
- Steel
Connection Type:
- MPT
- Grooved
Fin type:
- 5/8" tube: Sine or Flat
- 1/2" tube: Sine corrugated only
Fin Material & Thickness:
- Aluminum - 0.006", 0.008", 0.010"
- Copper - 0.006"

Fin Spacing:
- A vast range of fins per inch available

Fin Coatings: (Coatings reduce max face velocities)
- Electro-finish
- Phenolic
- Heresite

Coil Casing:
- Galvanized
- Stainless Steel

Choice of heat transfer medium:
- Water, Glycol (Ethylene glycol coils are ARI certified)
- DX – (a variety of refrigerants to choose from)
Heating Coils – Integral face and bypass

Integral face and bypass coils have alternating channels of heat transfer surface and bypass zones. The air flow is directed over the heat transfer surface or through the by-pass zone by modulating dampers that are integral with the coil construction.

Integral face and bypass coil (IFB/VIFB)
- Coils are available in the ‘IC’ segment
- Tubes either Vertical or Horizontal
- Coils for maximum freeze protection
- Hot water or Steam coils
- Multiple rows deep

Notes & Options

<table>
<thead>
<tr>
<th>Coil Style:</th>
<th>Rows:</th>
<th>Fin Material:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• IFB</td>
<td>• SCH 40 pipe</td>
<td>• Aluminum</td>
</tr>
<tr>
<td>• VIFB</td>
<td>• None</td>
<td>Fin Spacing:</td>
</tr>
<tr>
<td>Coil Type:</td>
<td>• Electric</td>
<td>• A range of fins per inch available</td>
</tr>
<tr>
<td>• Water (Glycol)</td>
<td></td>
<td>Coil Casing:</td>
</tr>
<tr>
<td>• Steam</td>
<td></td>
<td>• Galvanized</td>
</tr>
</tbody>
</table>

Heating Coils – Steam Distributing

The construction of a Steam Distributing Coil is entirely different than that of a Standard Steam.

Everyplace that you see an outside tube or header, there is an inside tube and header that you can’t see. Steam is distributed through these inside tubes and headers and slowly released to the outside tubes as the steam turns to condensate. The condensate then flows back down the outside tubes in the same direction that the entering steam comes from. The idea is that all the steam in the inside tubes keeps the condensate in the outside tubes from freezing when air passes across the coil at less than 32° F. However, under exactly the correct conditions, even steam distributing coils can freeze.

Steam Distributing - 1” diameter tube
- Available in CC, VC, HC, MZ segments
- A vast range of fins per inch available
- Multiple tube wall thickness options
Typical Application of Air Handling Coils

Heating Coils

Heating coils can use steam or hot water to add heat to the air stream. In a cooling-only VAV system, the heating coil is generally placed in the 'preheat' position between the filters and cooling coil. The preheat coil can be omitted in this system if the minimum outside air requirement is low and would not result in a mixed air temperature below 50°F to 55°F.

Heating coil capacity is controlled by means of a modulating control valve in the water or steam piping. The control valve position is usually controlled by means of a thermostat in the supply air duct in sequence with the cooling coil control valve.

Cooling Coils

Cooling coils remove both sensible and latent heat from the mixed air and can use chilled water, chilled brine, or refrigerant as the cooling source. In the case of chilled water, the supply water temperature generally ranges from 42°F to 50°F, depending on the latent load to be removed. Brine or a solution of ethylene or propylene glycol in water is traditionally used at temperatures of 32°F to 40°F for applications in which piping is exposed to freezing temperatures. Control of the cooling coil capacity at the air-handling unit is achieved by means of a two-way 'throttling' or three-way 'mixing' control valve. In VAV systems, a supply duct thermostat is typically used to modulate the control valve so as to maintain a constant temperature of air leaving the unit, usually 55°F to 60°F.

When refrigerant is used as the cooling source, it enters the coil in liquid form from a condensing unit and provides cooling by a process called 'direct expansion'. The liquid refrigerant evaporates as the warmer air moves across the coil, removing heat from the air during the process. The evaporated refrigerant is then compressed in the condensing unit, which also houses the condensing coil where the heat is rejected to the outside. Control of the coil capacity is typically by means of a series of solenoid valves in the refrigerant liquid lines, which are energized to shut-off the flow of refrigerant to part of the coil. There are several problems with the application of VAV to a direct expansion (DX) coil which require the designer to take special precautions when considering this system. First, the balance point temperature for the DX coil will change as the air flow rate changes. Assuming constant coil capacity, reducing the CFM will reduce the suction temperature and pressure, making close control of air temperature difficult. In addition, compressor unloading at reduced load will cause step changes in capacity and suction temperature, which can cause hunting in the flow control loop. In short, the use of variable air flows with a DX coil requires careful consideration of the effect air flow changes make to the system. Balance point temperatures must be carefully considered.

Design Considerations

In order to insure predicted coil performance, air distribution must be uniform. There are two design checks for this:

1. '45 degree rule' – This rule states that the performance of the coil will not be affected as long as the diffusion angle from the most restrictive block-off to the finned portion of the coil is 45 degrees or less. This rule holds true unless there are unusual flow fields, caused by such components as upstream fans or mixing boxes where not applied properly.

2. 'Uniform pressure rule' – This rule states that the performance of the coil will not be affected as long as the maximum difference in upstream, downstream, and combined static pressure due to local velocity pressure at any one point on the coil is 10 percent of the pressure drop through the coil. The basis for this rule is that the flow rate through the coils at any one point is a function of the local upstream and downstream pressures, and if pressure differences are small, distribution will be uniform.
REVOLUTION TFX SEGMENT IDENTIFICATION

FAN SEGMENTS
• FS – Supply
  • Forward Curved
  • Airfoil
  • Industrial Airfoil
  • SWSI Plenum
    (Belt and Direct Drive)
• FR – Return
  • Forward Curved
  • Airfoil
  • Industrial Airfoil
  • SWSI Plenum
    (Belt and Direct Drive)
• FE – Exhaust
  • Forward Curved
  • Airfoil
  • Industrial Airfoil

COIL SEGMENTS
• CC – Cooling Coil
• HC – Heating Coil
• VC – Vertical Coil
• MZ - Multizone

HEAT SEGMENTS
• IC – Integral Face & Bypass Coil
• IG – Indirect Gas Fired Furnace
• EH – Electric Heater

ENERGY RECOVERY
• ER – Energy Recovery

FILTER SEGMENTS
• FF – Flat Filter (2” or 4”)
• AF – Angle Filter (2” & 4”)
• RF – High Efficiency Filter
• Rig Filter (12”)”
• Bag Filter (21”)”
• Mini-Pleat Filter (4”)

INLET SEGMENTS
• MB – Mixing Box
• FM – Filter/Mixing Box
• EF – Filter/Economizer
• EE – Economizer
• IP – Inlet Plenum
• VE – Vertical Economizer
• VF – Vertical Filter/Economizer

ACCESSORY SEGMENTS
• VP – Vertical Plenum
• DP – Discharge Plenum
• TN – Turning Plenum
• DI – Diffuser
• XA – Access segment
• AB- Air Blender
• EB – External Bypass
• IB – Internal Bypass
• FD – Face Damper
• AT – Attenuator
• HM - Humidifier
• UV - UVC Lamps

Unit & Coil Hand Identification
Fan Applications

Fan segments are available as supply, return and or exhaust applications. Unit configurations have a segment option of utilizing a single fan or a dual fan arrangement. Isolation consists of 1” or 2” springs with a seismic snubber option. Thrust restraints and OSHA belt guards are available as required.

Double-width/Double-inlet (DWDI)
- Forward Curve or Airfoil centrifugal
- Belt Driven

Single-width/Single-inlet (SWSI)
- Airfoil plenum
- Belt Drive or Direct Drive

Bearing options for fans with lubricating bearings:
(refer to Notes & Options)
- Extended Lube Line
- External Lube Line

In most fan systems a segment with a single fan is adequate for the required system design and rating. Methods of control can vary and may include dampers or variable speed drives. Also included in a single fan design may be the allowance for future expansions.

In some situations, there may be a need for a system design using dual fans in a cabinet. The following are some reasons to consider a dual fan arrangement:

Dual Fan Considerations

1. One fan may be too large and not fit into the desired space, or it may weigh too much if supported on upper levels.
2. The required operating range of the system may necessitate multiple fans instead of one large fan controlled over a wide operating range.
3. Dual fans for capacity control may be more economical if cost of operation is critical, especially at very low flow rates for long time intervals.
4. Critical systems are often equipped with redundant or back-up fans in case of a fire or accident or some other emergency that requires a sudden increase in flow. Redundant fans are also used to eliminate downtime during fan maintenance.
5. Some systems for process applications may require pressures that are greater than a single fan can produce or when noise may be a special concern.

Dual Fan Applications

Revolution dual fan application methods include 50/50 where both fans operate together to share the load equally or 100/100 where only one fan at a time is in operation.

- In a 50/50 application, the failure of one fan will result in a condition where the other fan will continue to operate. The single fan will provide partial load capabilities
- In a 100/100 application, the failure of one fan will result in the operation of the other (standby) fan to provide full capacity
Door and Discharge Locations

Fan and fan motor may be oriented in the fan segment. Consideration must be given to which orientation is used where. Upstream/downstream usage follow.

Where Doors are used:
Rear/rear-inverted discharge – Upstream
Top/bottom discharge – Downstream

Front/front inverted discharge – Downstream
Top-inverted/bottom-inverted discharge – Upstream

AIRFLOW
Double-width/Double-inlet (DWDI) Options – Belt Drive

Fan and fan motor may be oriented in the fan segments as shown. Consideration must be given to which orientation is used where. Upstream/downstream images shown below.

Motor Beside

Motor Behind

Notes & Options (DWDI)

1. If a discharge plenum is immediately downstream of a fan section and the discharge plenum has a top discharge, the fan section will be rear inverted discharge.
2. If the discharge plenum has a rear, side or bottom discharge, the fan will be rear discharge.
3. When a diffuser is ordered immediately downstream of a fan section, the fan will be rear or rear inverted discharge.
4. Door width is sized to remove max HP motor with connection box removed.

NOTE: Doors follow motor location. See door locations illustration on page 11.

Fan type available
- Forward Curve centrifugal
- Airfoil centrifugal

Class I (S) construction
- Permanently sealed bearings
- Fan sizes: 7x7 thru 18x18 (Forward Curve)

Class 1 Construction
- Lubricating bearings
- Fan sizes: 20x15 thru 40x40

Class II construction
- Lubricating bearings
- Fan sizes: 7x7 thru 40x40

Thrust restraints are optional for rear and front discharge airfoil fans only.
- Not available for FC fans.
- Required for AF with TSP over 6"
**Single-width/Single-inlet (SWSI) Options**

Fan and fan motor may be oriented in the fan segments as shown. Consideration must be given to which orientation is used where. Upstream/downstream images shown below.

1. The plenum fan segments can accommodate multiple duct outlets, thus reducing the amount of field duct work and transitions.
2. When any filter segment (EF, FM, FF, AF, RF, or HF) or coil segment (CC or HC) is located upstream of a FS-SWSI, FR-SWSI or FE-SWSI, sufficient transition length will be required between the FS segment and the filter segment.
3. Fan discharge locations - rear, front, bottom, top, left and right.
4. Single Width, Single-Inlet (SWSI) air foil plenum fans are available as Class I, II & III. (with lubricating bearings)
5. Thrust restraints are required with TSP over 3".

---

**Notes & Options (SWSI)**

Belt Drive

Direct Drive
Double-width/Double-inlet (DWDI) Options – Belt Drive

Fan type available:

- Forward Curve centrifugal
- Airfoil centrifugal

Class I (S) construction
- Fan sizes: 7x7 thru 18x18 (Forward Curve)

Class I construction
- Fan sizes: 20x15 thru 22x22

Class II construction
- Fan sizes: 7x7 thru 22x22

DWDI motor location – Behind only

Notes & Options

Access doors are provided on both sides of the segment.
- Allow sufficient access-to and clearance-around the segment for motor removal from either side.

Separation Panel Option
- Optional safeguard when servicing requires that the system be in a running status. A separation panel is positioned between the fans.

Flow Isolation Options
- Optional isolation method to prevent air from an energized fan going back through a fan that is not energized.

- DWDI option is mounted on fan discharge.
- Note: Not available with fan exhaust (FE)
- Option is required with 100%/100% method.

Options include (depending on type of fan):  
1. Manual sliding panel  
2. Back-draft damper with counter balance  
3. Mechanical Control damper

---

**FS**

**FR**

**FE**

**NOTES:**
1. DAMPER OPTIONS ARE ONLY AVAILABLE FOR FRONT/FRONT INVERTED/REAR/REAR INVERTED DISCHARGE.
2. DAMPERS OPTIONS ARE NOT AVAILABLE FOR TOP/TOP INVERTED/BOTTOM/BOTTOM INVERTED DISCHARGE.
Single-width/Single-inlet (SWSI) Options – Belt-Drive or Direct Drive

Fan type available:

- Standard Airfoil (AF) 10” – 30”
- *Industrial Airfoil (AF) 12” – 30”
- Class I, II, *III

SWSI motor location:

- 10” to 16” fans - behind motor only
- 18” to 30” fans - top motor only
- Fans with top motor location will require thrust restraint

Notes & Options

Access doors are provided on both sides of the segment.
- Allow sufficient access-to and clearance-around the segment for motor removal from either side.

Separation Panel Option
- Optional safeguard when servicing requires that the system be in a running status. A separation panel is positioned between the fans.

Flow Isolation Options
- Optional isolation method to prevent air from an energized fan going back through a fan that is not energized.

• SWSI option is mounted on fan inlet.
• Note: Not available with fan exhaust (FE)
• Option is required with 100 %/100 % method.
Options include (depending on type of fan):
1. Manual sliding panel
2. Back-draft damper with counter balance
3. Mechanical Control damper
SWSI Plenum vs. DW DI Housed Fan Application

SWSI Plenum airfoil fans offer superior performance for many applications. Typical concerns with fan performance are efficiency, noise, and air velocity profile through components. Plenum fans offer advantages for all three concerns. Additionally, these fans provide flexibility with outlet configurations, reduced mechanical space footprint, and the benefit of direct-drive.

Efficiency:

DWDI housed fans use a scroll to increase their efficiency. However, optimizing this fan requires a process referred to as “static regain”. Housed fans are tested with an outlet duct of 2.5 to 3.5 times the wheel diameter in length. This outlet duct allows the “static regain” process, where velocity pressure is converted to static pressure. Housed fans applied without this outlet duct will require a system effect factor (SEF) which decreases the fan efficiency. Housed fans in blow-through positions will also require an air diffuser which decreases the efficiency further. The combination of these two system effects brings even the best housed DW DI airfoil fan efficiency to, or below that, of the SWSI plenum fan, thereby eliminating the benefit of the fan scroll.

Noise:

Plenum fans have the benefit of effectively utilizing the entire unit as the fan housing, which offers superior attenuation. The same factors that decrease the housed fan’s efficiency discussed above also increase the noise level of the housed fan. Also, since the SWSI plenum fan has no scroll, typically there is room within the air handling unit for a larger wheel (33” SWSI plenum vs. 27” DW DI housed, for example), which generally produces better sound characteristics. For design pressures at or below 6.00 in. W.C., it is very common to see supply air sound power levels lower when using a SWSI plenum airfoil fan instead of the DW DI housed airfoil fan. Additionally, perforated liners may be used in plenum fan sections for greater attenuation.

Velocity Profile:

Due to the relatively small outlet/blast area of housed DW DI fans, an air diffuser must be applied to the discharge of the fan to obtain an acceptable velocity profile through the next component. Air diffusers add static pressure which decreases fan efficiency and increases fan noise levels. SWSI plenum fans positively pressurize the entire cabinet, they do not require a diffuser with its associated performance losses.

Outlet Flexibility:

SWSI Plenum fans serve to pressure the entire fan plenum, allowing for multiple duct take-off from the AHU. Additionally, these openings can be tailored to match virtually any duct configuration, be it rectangular or round/flat-oval with bellmouth fittings for improved acoustic and optimized pressure drop performance.

Mechanical Space Optimization:

A housed DW DI fan requires a straight run of duct per AMCA guidelines at the outlet of the fan before elbows can be applied. This constraint imposes restrictions on duct layout and mechanical space design which generally increase overall footprint requirements. The ducted take-offs from pressurized plenums, as in the case of a SWSI plenum fan, does not have a requirement for a straight run and affords greater flexibility to the architect and engineer in ductwork design.

Direct-Drive Benefit:

Specially housed DW DI fans can be used in direct-drive arrangements, where the fan wheel is directly mounted onto the motor shaft, most-typically, housed fans are driven by a belt and sheave system. Belt-drive systems typically allow for 3-5% of efficiency loss and impose maintenance requirements not present in direct-drive systems. Additionally, belts wear and give off debris in the form of belt dust. Anymore, discerning engineer’s apply direct-driven SWSI plenum fans with VFD’s for efficient variable air volume duty and trouble-free maintenance.
**Fan Motor Control Methods**

Motor control options can be explained as any one of the 3 items described below.

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Features</th>
</tr>
</thead>
</table>
| **Disconnect**                | This is a device for the source of power (line voltage as provided through the building electrical utility) from the controlled device (motor). | • Low Cost  
• Constant Volume  
• No BAS control needed |
| **Across-the-line Starter**   | Motor Controller will provide a start / stop operation of a motor. An integral disconnect (shall incorporate a “lockout/tag-out” system) shall provide disconnecting of “line side” power from the electrical utility system. | • Higher Cost  
• Constant Volume  
• Start/Stop controlled remotely  
• Thermal Overload Protection  
• Under/over Voltage Relay  
• Disconnect Option - Fused only |
|                              | The motor controller will also contain the proper short circuit and thermal overload protection for the motor that it is controlling. | Indoor Enclosure - NEMA 3R  
Indoor Voltages - 200, 208, 230, 380, 460, 575 |
| **Variable Frequency Drive (VFD)** | The Air-Modulator type controller varies speed of the motor by pulse width modulation of the alternating current waveform. | • Highest Cost  
• Variable Volume  
• Start/Stop controlled remotely  
• Integrated basic unitary controller (can also integrate with BAS)  
• Comprehensive Protection  
• Disconnect Options - Fused, Non-fused, or None |
|                              | An integral disconnect (incorporates a “lockout/tag-out” system) provides disconnecting of “line side” power from the electrical utility system. | Indoor Enclosure - NEMA 1  
Voltages - 200, 208, 230, 460 |
|                              | This motor controller will also contain the proper short circuit and thermal overload protection for the motor that it is controlling. |                                                                                               |
COIL SEGMENT – CC, HC AND VC

Cooling Coil – (CC)

When cooling 100% OA there are precautions required. Summer design conditions are such that when air is cooled down to normal coil leaving temperatures, there is a considerable amount of condensate generated. Many applications suggest cooling coils should be selected for an air velocity under 500 FPM. If the unit is selected as a 100% OA application, the drainage area for larger face area coils will be increased to properly compensate for the probable condensate.

Notes & Options

Coils
- A combination of Water and DX coils in the same segment requires all coils to be of the same tube diameter.
- Multiple Water coils configured in the same segment must be of the same tube diameter.
- Steam coils may be configured with 5/8” tube coils. A spacer must be used between a steam coil and any water coil or DX coil.

Headers
- Usual header location is drive side.
- All headers in the same segment must exit the unit on the same side

Heating Coil – (HC)

When heating only is required the heating coil segment is an excellent minimally sized housing which shall accommodate a single heating coil. Coils are offered with left or right hand connections. Coils will be individually mounted and easily removable.

Coil segment panels (side panels and top panel) shall be easily removable to allow for removal and replacement of coils, without affecting the structural integrity of the unit.

Notes & Options

Coils
- Only hot water and steam coils are available in the HC segment.
- Only one coil (hot water or steam) is permitted per segment.

Headers
- Usual header location is on the drive side.

Doors
- Usual door location is drive side.

Liner – Galvanized or Stainless Steel
Vertical Coil – (VC)

This segment shall provide for a 90-degree change in airflow direction from horizontal to vertical, after passing air through the coil space.

Coils are configured for horizontal air flow to minimize segment length. Drains pans are extended to assure complete condensate drainage and coil access. Coil segment panels (side panels) shall be easily removable to allow for removal and replacement of coils, without affecting the structural integrity of the unit.

Notes & Options

Coils
• All coils located in the same coil segment must have the same coil hand.
• Multiple Water coils configured in the same segment must be of the same tube diameter.
• A combination of Water and DX coils in the same segment requires all coils to be of the same tube diameter.
• The steam coil is available for use in the VC segment. Steam coils may be configured with 5/8" tube coils. A spacer must be used between a steam coil and any water coil or DX coil.

Headers
• Usual header location is on the drive side.
• All headers in the same segment must exit the unit on the same side.

Doors
• Usual door location is on the drive side.
• Doors are always last in the air stream of the segment

Drain pans
• IAQ drain pan liner - Galvanized or Stainless Steel
• Usual drain location is on header side
STAGGERED COIL OPTIONS – CC, HC AND VC

Staggered Coil configurations are available as an option for the Revolution TFX units. Angled Wall or Back-to-Back configurations are available in both heating and cooling coil segments.

Angle Wall

Staggered coil design increases coil face area and allows increased CFM without having to increase cabinet size.

Notes & Options

Coils
• A staggered coil can not be combined with a non-staggered coil in the same segment.
• Each coil bank will be located over a drain pan.
• Not available as a reduced face coil option.

Controls
• Optional control valve and valve jack (manifolded together external of unit).

Drain pans
• Pan connection hand follows coil hand except for outside units where the drain connection is opposite the coil hand.
• If coil connections are on both sides, the drain pan connection follows the “primary” side of the unit.

Headers
• Coil connections can be on the same side or opposite sides.
• Optional factory extended piping connections for each coil to the exterior of the unit.
• Optional insulation for extended piping.
• Extended piping does not apply to DX coils.

Back-to-Back

Staggered coil design is specifically for a reduced coil pull distance and for opposite side connections. Two shorter coils will be used in place of one longer coil.

Notes & Options

Coils
• A staggered coil can not be combined with a non-staggered coil in the same segment.
• Not available as a reduced face coil option.

Drain pans
• The drain pan connection follows the “primary” side of the unit.

Headers
• Coil connections can be on the same side or opposite sides.
Multi-zone Segment – (MZ)

MZ heating and air conditioning units offer design and application advantages over various smaller single zone units. The Revolution unit is designed to carry on that tradition by including a MZ segment into the design of the unit.

MZ and Dual Deck air-handling units can be configured for heating and cooling, or cooling and ventilation, or ventilation and heating applications.

Rear or Top discharge MZ configurations:
• The bottom tier is the cold deck and contains a diffuser and a cooling coil space.
• The top tier is the hot deck and contains a heating coil mounted horizontally at the upstream side of the hot deck.

Air enters the diffuser then splits into two streams.
• One stream turns up through the hot deck coil and exits the rear or top through the hot deck damper.
• The other stream continues horizontally through the cooling coil and exits the rear or top through the cold deck damper.

The MZ unit is optionally available less the zone dampers for use on dual duct or other blow-thru systems. If a hot deck opening is not required, it may be blanked-off in the field.

Notes & Options

The MZ segment is for indoor applications only and will be the last segment in air-stream.
Air pressure drop balance plates shall be used to equalize pressure drop across the hot and cold deck coils when required.
Door is optional for cold deck.

Discharge options:
• Top with damper or without damper
• Rear with damper or without damper
Integral Face & Bypass – (IC)

The Integral Face & Bypass coil controls air temperature while full steam pressure or water flow is maintained in the coil at all times. The temperature of the discharge air is controlled by proportioning the entering air through the multiple heating and by pass channels.

Applications ideally suited for:
1. Make-up Air
2. Combustion Air Make-up
3. Penthouse units
4. Air conditioning preheat and heating/ventilating units.

Features & Benefits:
• Maximum freeze protection
• Constant volume
• Minimum temperature override
• Minimum stratification
• Accurate temperature control

Notes & Options

1. Coil connections must be located opposite the access door.
2. All piping to be supplied by field, coil connections are internal from factory.

Headers:
Usual header location is on the drive side. Header location must be opposite the access door.

Coils:
Only hot water and steam applications are available for this segment

Doors:
Access doors and viewing ports must be located in adjacent segments.
A door is required in the immediate downstream segment from the IC segment.

Auxiliary Drain pans:
An auxiliary drain pan is optional.

Usual drain location:
• IFB on header side
• VIFB on left side of the unit
Indirect Gas-Fired Furnace – (IG)

The IG segment must be positive pressure. (Fan segment is not allowed downstream of the IG Segment.) Furnaces in VAV applications are designed to be used only with 100% supply fan airflow.

- Use of furnace in reduced airflow operation may result in serious damage to equipment and may be hazardous.
- Indirect Gas-Fired Furnace Maximum Temperature rise = 90°F
- Indirect Gas-Fired Furnace Maximum A.P.D. = 2.00" W.C.
- The Maximum Temperature at the IG segment discharge = 190°F

Furnace includes a series stainless steel primary heat exchanger. A secondary stainless steel heat exchanger is also included.

- An access door is required upstream of any IG segment.
- Gas pipe train options are available

The IG segment pipe chase is a single pipe chase that covers only the IG segment.

- The pipe chase is not intended for trapping or piping, but for the connections only.
- Pipe chase enclosure is optional
Turndown Examples and Guidelines – (IG)

Description

Indirect Fired Gas Heater section consists of the stainless steel primary and secondary heat exchanger with the power burner design. The basic design allows the power burner to inject the correct ratio of air and gas into the primary heat exchanger where the main combustion occurs. The heated products of combustion then pass through the multiple secondary tubes heating each tube for maximum heat transfer. The products of combustion then pass to the inducer draft fan and through the flue. The air is heated by passing around the primary and secondary tubes for optimal heat transfer. The heater is designed for 80% efficiency.

- The furnace comes wired with all necessary safety controls and valves installed.
- The controls vary based on the BTU level and Insurance Requirements selected.
- These units are designed to handle Natural Gas as a standard.
- The gas pressure available at the unit needs to be considered when ordering the equipment.

Equations:

- BTU Output Required = CFM x 1.08 x Temperature Rise Required
- BTU Input = BTU Output x .80

The Solution furnaces are available with burner firing arrangements:

- 3-1 MODULATION: The burner will modulate for 100% - 33% of full fire
- 10-1 MODULATION: The burner will modulate from 100% - 10% of full fire
- 25-1 MODULATION: The burner will modulate from 100% - 4% of full fire

Choosing Considerations

When choosing the proper turn down three issues should be considered.

1. Greater modulation provides improved temperature control. If the furnace is modulated to its minimum fire position, and controls determine there is too much furnace capacity, then the furnace is staged on and off, on carefully chosen time delays, to satisfy the light load heating requirements. The 3-1 option is generally sufficient particularly if design temperature rise does not exceed 30-40 degrees.

2. The greater the range of modulation the greater the cost.

3. Experience requires that a furnace should not turn down to a temperature rise less than 5-8 degrees.

Greater modulation decreases the flue stack temperature at low fire, increases the amount of condensation, and can decrease the life of the heat exchanger even though all Revolution furnaces utilizes a stainless steel primary and stainless steel secondary heat exchanger tubes along with condensate drains.

The condensate line must be adequately sized, trapped, along with drainage of the condensate per local code.
**Electric Heat – (EH)**

The EH segment can be installed in either a draw through or blow through arrangement.

**Remote Mounted terminal panels**
- An electric heat control panel may be selected as a remote panel.
- In this case the panel will be shipped separate to the customer for field installation.

An optional wide access door may be ordered on the opposite side of the electric heater control panel.

An SCR Controller is available on all heaters with a height dimension greater than 26.5”.

\[
\text{Delta T} = \frac{kW \times 3160}{\text{CFM}}
\]

**Notes & Options**

- Electric heaters are of “open coil” construction, with 80% nickel, 20% chromium coil elements machine crimped to stainless steel terminals and amply supported on ceramic bushing isolators. Open coil heaters are furnished with a disk-type, automatic reset thermal cutout for primary over-temperature protection. Heaters are also being furnished with disk-type, load-carrying manual reset thermal cutouts, factory wired in series with heater stages for secondary protection.
- Heaters are rated for the voltage, phase and number of heating stages indicated in the schedule. All three-phase heaters will have equal, balanced, three-phase stages.
- Finned tubular construction - optional
- All internal wiring shall be stranded copper with 105° C minimum insulation and shall be terminated in crimped connectors or box lugs.
- Power and control terminal blocks shall be provided and clearly marked for all field wiring and shall be sized for installation of 75° C copper wire rated in accordance with NEC Table 310-16, not more than three conductors in a conduit.
- Heaters shall be furnished with built-in fuses per NEC. Heaters with loads greater than 48 amps will be furnished with built-in fusing. Heaters shall be sub-circuited into a maximum of 48 amps per circuit. Low resistance single element fuses will be mounted in phenolic fuse blocks fitted with extra tension springs to assure cool connections. Fuses shall be sized at least 125% of the load.
HEATING SEGMENTS

Typical Applications

An electric heating system will use either an open wire element or an element encased in a sheathed ceramic material. For most applications either construction can be used, however, in applications with potentially high humidity (i.e., 100% OA application), the encased element will have a longer life expectancy and is recommended.

Selection of the proper unit, heating load and temperature control system is dependent on the application of the unit.

1. Make-up Air Unit is used for heating 100% OA air to the indoor design temperature with a typical discharge temperature of 55-70°F.
2. Space Heating Unit is used for heating 100% RA from the conditioned space to make up for building heat loss.
3. Combination Make-up Air & Space Heating is used to heat OA & RA combined through a mixing box.

Optional Control Methods

1. Proportional step control – multi-staging control of circuits
2. SCR Controller – a time proportioning type controller that modulates the heater and supplies the exact amount of power to match the heat demand. Precision controlled from zero to 100% in direct response to the modulating thermostat signal system. 100% step-less and noise-less operation. *Note – SCR’s are limited to a maximum KW. Multiple SCR’s may be applied to larger heaters. Multiple SCR’s do not imply full face control. See “Special Application Considerations”.
3. Vernier Proportional Control – used on larger KW heaters where very close heat control is required. The system employs a combination of SCR and non-SCR steps. This is accomplished by satisfying most of the heat requirement through the non-SCR steps and then the last portion of the heat requirement is “fine-tuned” by the modulating SCR controller. The SCR step is nominally equal to the KW of a non-SCR step to provide an even transition between steps.

*Special Application Considerations: (contact factory for special applications)

It is always important to ensure the proper control method so that the heater effectively treats the required amount of outdoor air regardless of temperature, without risking over heating and or tripping the low limit thermostat.

1. In applications where air flow varies and temperature ranges are extreme, the face area of the heater should be designed for full face simultaneous control, thus avoiding problems of air and temperature stratification. This is extremely relevant on heaters with large face areas. The full face control method, for a partial of fully active electric heat coil, eliminates the concern of air bypass through inactive circuits. Thus, almost any load split can be safely achieved.
2. With lower airflows under VFD control, one must assure there is even air flow across the face area of the heater. This may require special consideration of the air-inlet position and size, (i.e. inlet to be centered on the front of the unit).
   a. Instability in temperature can easily occur if the variation in the air flow characteristic is excessive. Large temperature variations can occur as specific stages and circuits are modulated on and off. In extreme cases, this instability can cascade and cause extreme over-heating on the complete heater face or in spots of the heater face due to low-air-flow augmented by unit inlet opening locations and distance.
Recommended Safety Control Options:

A fan relay and an airflow switch provide added protection for applications listed above.
- Fan relay provides the advantage of being a positive electrical interlock between the fan and the heater.
- Airflow switch is normally used to prevent a heater from operating unless air is flowing.

Minimum Air Flows

Electric heaters differ from steam or hot water coils in that the heat output is constant as long as the heater is energized. Therefore, sufficient air flow must be provided to prevent overheating and nuisance tripping of the thermal cutouts.

The minimum required velocity is determined from the graph on the basis of entering air temperature and watts per square foot of cross segmental heating coil area.

EXAMPLE:

Determine whether the minimum air velocity requirement is met for a 108 kW heater installed for an air handling unit operating at 18,000 cfm at a maximum inlet temperature of 65°F.

1. Heating Coil Area = 33 sq. ft.
2. kW / sq ft. = 108 kW / 33 sq. ft. = 3.3 kW / sq ft.
3. Use top curve (below 80°F inlet air). Find 3.3 kW per square foot on the vertical axis.
   Read the minimum face velocity required, which in this case is 250 feet per minute (fpm).
4. AHU FV = 18,000 cfm = 545 fpm 33 sq. ft.

*Since 545 FPM exceeds the minimum velocity requirement of 250 FPM, this installation is satisfactory for heater operation.*

Equations: Use these formulas as rough guidelines for estimating purposes only:

EQUATION 1: \( MBH = kW \times 3.412 \)

EQUATION 2: \( \Delta T = \frac{kW \times 3160}{Scfm} \)

EQUATION 3: Actual kW = Rated kW \times \frac{V_{actual}}{V_{rated}}

EQUATION 4: Load Amps = \( \frac{kW \times 1000}{V \times 1.732} \)}
Energy Recovery

An HVAC system that utilizes energy recovery is more energy efficient, improves humidity control, and reduces peak demand charges.

Revolution Energy Recovery wheels:

– Improve building HVAC system performance by efficiently preconditioning the outdoor air supply.

The ER segment transfers heat & humidity from adjacent exhaust air & outside air streams.

– Improves HVAC system efficiency up to 40%
– Improves de-humidification capacity up to 75%

Thermal performance is certified by the manufacturer in accordance with ASHRAE Standard 84, Method of Testing Air-to-Air Heat Exchangers and ARI Standard 1060, Rating Air-to-Air Energy Recovery Ventilation Equipment

Notes & Options

ER has only one type of configuration – supply air fan draw-thru and exhaust air fan draw-thru.

1. Indoor - Vertical wheel segment with stacked construction
   a. All doors are usually on drive side with two on top tier (both sides of wheel) and two on bottom tier (both sides of wheel).
2. Horizontal wheel segment with single tier construction
   a. Outside Air inlet is located on both sides of segment
   b. Access door is usually on drive side for horizontal wheel segments.

Wheel control
   • Damper control
   • VFD

– Auxiliary drain pan – none
– Purge function – Optional
Application and Options Table

<table>
<thead>
<tr>
<th>FILTER SEGMENT</th>
<th>APPLICATION AND OPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF - ANGLE FILTER</td>
<td>Application: (AF) - Pre-filter side-load negative pressure configuration - Single stage filtration Options: - Auxiliary Drain pan options - 2” &amp; 4” Low Efficient media - 4” High Efficient media</td>
</tr>
<tr>
<td>FF - FLAT FILTER</td>
<td>Application: (FF) - Pre-filter side-load negative pressure configuration - Single stage filtration Options: - Auxiliary Drain pan - 2” &amp; 4” media - Low Efficient media</td>
</tr>
<tr>
<td>RF - RIGID FILTER</td>
<td>Application: (RF) - Pre filter negative pressure configurations: Side-load, front load and rear load - Final filter positive pressure configurations: Front-load (upstream access required) Rear-load (downstream access required) Side-load Options: - 2-stage filtration. - Auxiliary Drain pan - 4” &amp; 12” High Efficient Media (65%-95%)</td>
</tr>
<tr>
<td>RF - BAG FILTER</td>
<td>Application: (Bag) - Pre filter negative pressure configurations: Side-load, front load and rear load - Final filter positive pressure configurations: Front-load (upstream access required) Rear-load (downstream access required) Side-load Options: - 2-stage filtration. - Auxiliary Drain pan - High Efficient Media (65%-95%)</td>
</tr>
</tbody>
</table>

Caution – Never place a blow-thru final filter segment directly downstream of a cooling coil with a saturated leaving air temperature. Once the relative humidity has reached 100%, adiabatic cooling applies to the expanding air and associated temperature drop. Moisture deposits may form on final filters.
Mechanical Air Filters

Mechanical air filters remove dust by capturing it on the filter medium, the filter element. A mechanical air filter is any type of dry media filter. All of the throwaway air filters used in HVAC systems and Air Handlers are mechanical air filters. Any man made or natural fiber filter is a mechanical air filter.

Comparing Various Air Filters To MERV Ratings

Dry-media filters exhibit an increase in efficiency as they collect dirt and dust. A dry media filter is at the lowest efficiency rating when it is 'clean'. The increase in efficiency corresponds to a decrease in open area as the media collects fibers and particles. In dust critical environments the user typically can't wait for the increased efficiency. As a result of this type issue, ASHRAE 52.2 defined the minimum efficiency reporting value (MERV) to describe filter performance.

The MERV is based on the worst case performance of a filter through all six stages of dust loading and all particles 0.3-10 microns. Because the rating represents the worst-case performance, end users can use it to assure performance in applications where a maximum particle count must be maintained over the filter’s entire life.

ASHRAE 52.1 arrestance and dust-spot tests used either weights or times to generate a ratio, or efficiency. This efficiency was an easy way to describe a filter’s performance. Thus, a 50 percent filter would stop a nominal 50 percent of the particles in the air stream as averaged over the test period. Unfortunately, this average over time told a user nothing about performance for a specific particle size at a specific stage in a filter’s life.

ASHRAE Standard 52.2 rates filter arrestance differently. Standard 52.2 testing protocol includes the reliable and consistent testing of filter performance on particles of nominal 0.3-10 microns in diameter. This testing provides an accurate and clear description of arrestance at each stage, rather than the average produced by Standard 52.1.
MERV Analysis

The required MERV rating for filters will follow directly from the maximum allowable particle concentrations in the three bands of 0.3-1.0 microns, 1.0-3.0 microns and 3.0-10.0 microns.

1. A rating of MERV 10 corresponds to 50-65 percent efficiency for particles 1-3 microns and above 85 percent efficiency for particles 3-10 microns.
2. A rating of MERV 13 corresponds to less than 75 percent arrestance efficiency for particles 0.3-1 microns, above 90 percent efficiency for particles 1-3 microns, and above 90 percent efficiency for particles 3-10 microns.
3. A rating of MERV 15 corresponds to 85-95 percent arrestance efficiency for particles 0.3-1.0 microns, above 90 percent efficiency for particles 1-3 microns, and above 90 percent efficiency for particles 3-10 microns.

Note: The entire list of MERV ratings based on particle arrestance efficiency is found in Table 12-1 of Standard 52-2.

As an example, if you are concerned with pulling out a high percentage of molds, mold varies in size from about 4 microns to 40 microns.

- The greatest numbers of mold spores are less than 10 microns in diameter.
- The chart indicates a MERV 8 filter will pull out at least an average of 70% of the particles down to 3 microns.
- Pleated filters are available in a MERV 11. The MERV 11 would give you an average of at least 85% mold removal.
Mixing Box/Mixing Segment (MB/FM)

Revolution has designed a mixing box (MB) which combines fresh air and re-circulated air by means of interconnected dampers.

Revolution’s space saving combination filter mixing segment (FM) offers an angle filter as an integral part of the mixing segment to economically provide filtering and mixing capability.

Notes & Options

- The MB/FM Segment typically must be the first segment in direction of airflow.
- Access doors are optional.
- Auxiliary drain pans optional except when bottom opening is selected.
- Combination filter mixing segment (FM) provides a full-height access door for filter service.
- Variable size openings and dampers are optional.
- Safety grate option for bottom openings.

Economizer

Revolution offers numerous economizer configurations for various ventilation applications. The economizer is designed with factory packaged controls in-mind. Correctly set-up economizers will constantly track building pressurization as well as both indoor and outdoor air temperatures using transducers, mixed air sensors and enthalpy control that monitors air temperature and humidity.

Notes & Options

- The EE or EF segment may be first in the air-stream or may be used in conjunction with other segments in an economizer application.
**Vertical Economizer**

Solution offers a Vertical Economizer arrangement which consists of tiered segments; top and bottom. Both top and bottom segments are designed to be of minimum length required. The VE arrangement is designed to be first in the air-stream unless it is immediately preceded by XA, FR (DWDI), FR (SWSI), FE (DWDI), FE (SWSI).

The VE segment must be configured in a top tier arrangement per the following rules:
1. Only one VE per unit
2. Must be tiered over the MB or FM segment
3. MB or FM segment must have a top damper

**General Considerations:**

1. VE segment shall be available for all Revolution unit sizes provided engineering rules for stacking allow the top section of VE segment to be tiered.
2. VE segment shall be designed for the configurations described in the sketches below
3. Both top and bottom sections of the VE segment shall be designed to be of minimum length required. The design shall allow the two sections of VE segment to be of different lengths.
4. Sound data shall be provided for all configurations of VE segment.
5. Filter option shall be available in the bottom section of the VE segment similar to FM segment.
6. Doors are available as an option

**Notes & Options**

- VE segment will have the same construction materials as the MB or FM segment.
- No optional auxiliary drain pain.
- Optional Access Doors & View-ports.
- Auxiliary drain pans optional except when bottom opening is selected
- Variable size openings and dampers are optional.
- Safety grate option for bottom openings
This Mixing Box Optimization chart provides techniques and suggestions to meet the desired needs for your specific mixing box design process. It is a decision-making process in which the effectiveness of a mixing box must be considered. Ideally, mixing boxes should provide adequate mixing.

<table>
<thead>
<tr>
<th>Mixing Box Assessment</th>
<th>Mixing Effectiveness</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Mixing Box with/without Angle Filter</td>
<td>GOOD APPLICATION Most effective 1. In constant volume system • Parallel blade control damper • Blade orientation and rotation promotes mixing</td>
<td>• Lowest first cost • Space saving</td>
<td>• Risk of low mixing effectiveness • with filter • with VAV • Risk of nuisance low limit tripping • Risk of stratification</td>
</tr>
<tr>
<td>Standard Mixing Box without filters and *Sequenced Controlled Dampers (sequence listed below)</td>
<td>BETTER APPLICATION Most effective 1. In VAV system 2. With Min Max damper 3. With opposed blade control damper * Sequenced damper control is most suitable for low air flow – low velocity applications</td>
<td>• Lower first cost • Mixes outside and return air more proportionately • Improves system performance at low flow rates • Sequence will add stability to the control loop</td>
<td>• Risk of nuisance low limit tripping • Risk of possible stratification</td>
</tr>
<tr>
<td>Standard Mixing Box without filters and Static Air Mixer (blender)</td>
<td>BEST APPLICATION Most effective 1. Outside air designs at freezing and sub-freezing temperatures 2. Constant or VAV systems *Sequenced opposed control dampers are recommended for VAV systems</td>
<td>• Greatly improves mixing of sub-freezing air streams • Greatly reduces, if not eliminates, stratification in short distances • Works effectively and consistently</td>
<td>• Higher first cost among damper designs • Increases unit length • Some additional static pressure loss</td>
</tr>
</tbody>
</table>

*Suggested sequence of operation as follows:

1) Start the fan with the return air damper fully open and the outdoor air damper fully closed.
   a) An independent signal shall be sent to the Outdoor air damper
      i) Minimum open position
   b) An independent signal shall be sent to the Return air damper
      i) Full open position
2) The outdoor air damper shall modulate further open to admit additional outdoor air as required to satisfy the (mixed air), (discharge air) temperature sensor or IAQ requirements.
3) Once the outdoor air damper is fully open, if additional outdoor air is required, the return air damper shall modulate toward its closed position.
Typical Economizer Application

ASHRAE Standards Demanding Economizer Considerations:

ASHRAE 90 - The ‘standard’ details requirements for a high performance & energy-efficient design of buildings (which includes equipment as part of the building system).

What is high performance?
• Lower energy usage
• Lower life cycle cost
• Durable
• Healthy
• Productive

How buildings use energy?
• Different building types use it differently
• Occupancy & equipment schedule
• Internal vs. external load dominated buildings
• Building occupants

ASHRAE 62 - The ‘standard’ details Indoor Air Quality issues with the purpose to establish acceptable ventilation procedures & standard-of-care.

What are ventilation procedures?
• Mechanical ventilation systems shall include controls, manual or automatic, that enable the fan system to operate whenever the spaces served are occupied
• The system shall be designed to maintain the minimum outdoor airflow as required under any load condition

What is a standard-of-care?
• Guidelines to designers addressing contaminant source control, minimum maintenance activity & frequency, filtration and managing relative humidity

Building Pressurization

Building Pressurization – is defined as the relative air pressure in a building, as compared to the exterior or ambient air pressure. A design amount of outside air must be introduced to insure design building ventilation.

This difference in pressure has a large impact on how the building operates and it can have undesirable if not peculiar impacts on building operations. Over-pressurized buildings will have doorways which are transformed into wind tunnels. Under-pressurization will create a building that has become negatively pressurized and infiltration makes indoor climate control difficult.

The difference between the amount of OA and EA must remain constant at all operating conditions to maintain proper building ventilation and pressurization.

Over Pressurization caused by -
• Too much OA
• Not enough EA

Results in -
• Excessive energy consumption
• Perimeter doors opening

Under Pressurization caused by -
• Too little OA
• Too much EA

Results in -
• Ventilation problems with occupants
• Excessive building odors
• Poor temperature control (infiltration)
• Excessive energy costs
• Difficulty in opening doors

Knowing how to correct and avoid pressurization problems can prevent minor, inconvenient and comfort related issues from growing into insurmountable problems and liability issues.
Methods of Pressurization Control

*Full Return Air Fan Economizer* -
Handles pressure losses through
• Return air system
• Exhaust dampers

*Supply Fan* handles pressure losses through
• Outside air dampers
• Mixed air dampers

**Dedicated Exhaust Fan Economizer** -
Fan runs only when economizer opens the OA dampers
Handles pressure losses through
• Return air system when in exhaust mode
• Exhaust air path

Building pressurization provides insight in identifying, diagnosing, correcting and most importantly, avoiding some unusual building operational problems.

---

**Economizer Arrangements**

**EE** - Economizer with vertical mixing damper. **EF** - Filter/Economizer. **VE** - Vertical Economizer.

**Note:** VE (Vertical/Filter Economizer) is available with filtration.
Face Damper – (FD)

The FD segment contains a full face damper
- Face dampers are sized to cover whole components downstream within tunnel.
The FD is available
- The FD can be located first in air stream or last in air stream.

Access doors and viewing ports must be located in adjacent segments.
- Access is required immediately upstream of the FD segment to access damper actuator and linkage.

Damper material option:
- Galvanized
- Aluminum

Inlet Plenum – (IP)

The Inlet Plenum is as its name implies; a segment used to provide a proper means of air entry into the air handler.

Openings may be applied to top, bottom, front, left side and right side.

The variable size opening option allows the opening to be properly aligned and sized for airflow convergence and or divergence

Notes & Options

If a plenum fan is used as a return fan and return air is ducted, an IP segment must be provided upstream of the plenum fan.
- Dampers are not available as an option

- Access Door - Optional
- Auxiliary Drain Pans – Optional
ACCESSORY SEGMENTS

Diffuser Segment – (DI)

The diffuser segment is constructed of heavy gauge galvanized steel with a built-in perforated plate, which prevents high velocities through the center of the downstream component. This segment is mainly used for blow-thru type applications immediately after a DWDI fan or locations where even air distribution across the unit cross section is a necessity.

Notes & Options

The Diffuser Segment must be placed immediately downstream of a DWDI fan segment when filters, attenuators, humidifiers, electric heater and/or coils immediately follow the fan.

• Auxiliary Drain Pan - Optional
• Access Door – Optional

Access Segment – (XA)

The Access Segment is a functional segment provided to allow access to or inspection of any component in adjacent segments. The access segment assists in determining the best segment arrangement for a specific function and or layout.

It is designed for flexibility with full sized access doors and variable segment length.

Notes & Options

Access Segments may be used at any point in the unit configuration; positive pressure (blow thru) or negative pressure (draw thru) configurations.

Access segments may be provided for maintenance, cleaning, service and or spacing for correct air flow requirements.

• Auxiliary Drain Pan - Optional (minimum segment length applies)
• Access Door – Optional (both sides of the unit -minimum segment length applies)
Vertical Plenum – (VP)

The Vertical Plenum (VP) is a segment designed for vertical configurations (top tier) with unique discharge arrangements.

Multiple and variable size supply air openings are available through the VP segment.

The VP segment may be applied as an acoustical chamber, with perforated panel option, that dampens low frequency sound. In addition, the air stream expansion reduces turbulence and creates an acoustical end reflection.

Notes & Options

Discharge locations available are top, front, rear, left side and right side.

Discharge opening options are rectangular, round and oval. Doors are optional (Inward opening for positive pressure)

Discharge Plenum – (DP)

The Discharge Plenum (DP) is a segment designed for horizontal configurations with unique discharge arrangements.

Multiple and variable size supply air openings are available through the DP segment.

The DP segment may be applied as an acoustical chamber, with perforated panel option, that dampens low frequency sound. In addition, the air stream expansion reduces turbulence and creates an acoustical end reflection.

Notes & Options

Discharge locations available are top, bottom, rear, left side and right side.

Discharge opening options are rectangular, round and oval.

- Auxiliary Drain Pan – Optional
- Access Door – Optional (both sides of the unit – Inward opening for positive pressure)
Sound Attenuator – (AT)

Sound Attenuators are rated for two flow conditions, FORWARD and REVERSE.

- Forward flow occurs when air and sound-waves travel in the same direction, as in a supply air duct or fan discharge.
- Reverse flow occurs when sound-waves and air travel in opposing directions, as in a typical return-air system.

Because attenuation values are generally higher in the first five octave bands in the reverse flow mode, compared to the forward flow mode, more economical silencer selections can often be made on the return-air systems. These phenomena are illustrated below.

Notes & Options

Silencer Length Options:
- 3ft, 5ft, 7ft
Face Velocity
- Low
- Ultra Low
Media Types:
- Standard
- Film-lined (Hospital media)
- None (No media)

Frequency Range
- Normal
- Low
Casing Materials:
- Galvanized
- Stainless Steel

Access doors and viewing ports must be located in adjacent segments. When AT segment is located immediate downstream of DWDD fan segment a Diffuser segment is needed to ensure even airflow distribution.
**Noise & Vibration**

Any mechanical device is capable of generating noise and vibration for a variety of reasons. The air handler unit noise emanates simultaneously from three distinct sources: aerodynamic, mechanical, and electrical.

Noise generally applies to any problem in which the ears are the main sensor. Noise is made up of many different sound frequencies at various loudness levels. Noise when compared to vibration is similar in that they both have amplitude and frequency. Usually noise is a much lower amplitude and energy content which is measured in db referenced to Watts. Typically noise has a much wider frequency range and a higher upper limit than vibration (63Hz – 8KHz)

Vibration generally applies to any problem in which the hands or touching are the main sensor. Amplitude is large when there is a problem. It has much greater energy content with a smaller frequency range (3Hz – 500Hz)

**Noise Considerations and Characteristics**

Mechanical and electrical noise sources usually begin as vibration and are later transferred into airborne noise.

**Vibration Considerations and Characteristics**

Rotating devices, such as air handling units, all create vibration which can be transmitted to other parts of the structure. The magnitude of this vibration is subject to a number of things, the most significant of which is the amount of unbalance of the rotating components. The frequency at which this occurs is the operating RPM of the components. There are many different sources of vibration. One of the most difficult tasks is the systematic identification of the vibration characteristic; amplitude, frequency, location or direction.

<table>
<thead>
<tr>
<th>Aerodynamic</th>
<th>Mechanical</th>
<th>Electrical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generated noise is caused by turbulence, high velocities, and instabilities due to pulsation and surge. Technically speaking it relates to pressure pulsations and is characterized by a continuous broadband frequency spectrum with an objectionable superimposed pure tone.</td>
<td>Generated noise has a different sound quality and characteristic. It can have a metallic sound caused by metal-to-metal contact or working noise radiating from belts and bearings. This noise may be constant or intermittent.</td>
<td>Generated noise is a function of motors, relays, motor controls, or unbalanced line voltages into the motor</td>
</tr>
</tbody>
</table>

To avoid unsatisfactory noise levels, many factors should be considered at the design stage. Noise is generally considered low quality, unwanted sound. Characteristic words such as tone, pitch, steady, unsteady and intermittent help to define whether the source of the noise is aerodynamic, mechanical or electrical.
### ACCESSORY SEGMENTS

**Air Blender/Mixers – (AB)**

The static mixer provides a high level of mixing in a minimal distance and at a low pressure drop. Mixers placed just after the mixing segment improves mixing outside and return air streams. Mixers work effectively and consistently. There are no moving parts.

<table>
<thead>
<tr>
<th>Applications (When used):</th>
<th>Features &amp; Benefits:</th>
</tr>
</thead>
<tbody>
<tr>
<td>– Eliminates air stratification</td>
<td>– Provides most mixing in shortest possible distance</td>
</tr>
<tr>
<td>– Reduces low limit-stat nuisance trips</td>
<td>– Requires negligible energy (typical application is between 0.10 - 0.20” w.g.)</td>
</tr>
<tr>
<td>– Improves accuracy of temperature control systems</td>
<td>– Provides expected mixing for every cabinet size</td>
</tr>
<tr>
<td>– Mixes outside ventilation air into supply air stream to satisfy IAQ/IEQ requirements</td>
<td>– Provides reliable pressure drop rating which includes the effect of mixer to plenum area ratio.</td>
</tr>
<tr>
<td>– Allows for greater use of economizer operation</td>
<td></td>
</tr>
<tr>
<td>– Provides uniform velocity profile for even filter loading and enhanced coil performance</td>
<td></td>
</tr>
</tbody>
</table>

#### Notes & Options

AB segment should be applied immediately after the mixing box/economizer segment. AB segment is designed to mix air from openings on any combinations of: top, bottom, end and sides. Minimum velocity through a mixer is 400 FPM.

Air mixer arrangements may include one mixer, two horizontal mixers, three horizontal mixers, two vertical mixers or three vertical mixers. The arrangement depends upon upstream segment configuration.

- Door – optional
- Drain pan – optional
- Mixer material option: Aluminum or Stainless Steel
Face & Bypass Damper Segments – (IB), (EB)

Internal Face & Bypass – (IB)
The IB Segment must be located immediately upstream of a reduced face coil.
• Designed to divert airflow around a coil.

When a full face coil is required downstream of the reduced face coil, access segment(s) must be included between the coils.

IB segment is used to control
• Humidity
• Low temperature flows across water coils

Notes & Options

Access doors and viewing ports must be located in adjacent segments.
• An 18” access door is required immediately upstream of the IB segment to access damper actuator and linkage.

Damper material option:
• Galvanized
• Aluminum

External Face & Bypass – (EB)

Each EB segment must be configured with a “bypass air inlet” downstream in the configuration for reintroducing the bypassed air to the unit. The EB segment cannot exist without such a “bypass air inlet” partner.
• The EB segment is available for indoor application only

The external face and bypass damper is located upstream of a full-face coil. External Bypass damper is a balanced opposed blade face damper with interconnecting linkage.
• Bypass duct is to be field supplied

Notes & Options

Damper material option:
• Galvanized
• Aluminum
Door is optional
• It is designed to divert airflow through an external bypass duct.
• External Bypass segment assumes ‘top’ outlet.

Drain pan is optional
ACCESSORY SEGMENTS

Turning Segments – (TN)

The purpose of the Turning Segment is to assist air turning in a vertical direction.

A Turning Segment (TN) can only be located at the end of a unit configuration.

Segment lengths are engineered for a variety of tiered space saving configurations.

Notes & Options

TN segments are available for configuring in both top and bottom tiers. Drain pan is optional for bottom tier segments.

Access Door – Optional (both sides of the unit - Inward opening for positive pressure)

Humidifier Segment – (HM)

Adding humidification for full winter comfort and productivity is just as important as air conditioning in the summer months. Temperature control must be combined with humidity control to maintain proper comfort parameters. ASHRAE 62 indicates that relative humidity is part of acceptable ventilation procedures & standard-of-care.

Revolution provides a standard steam injection distribution type humidifier with a short absorption manifold for use where short steam absorption distances are critical.
• Steam is distributed evenly through the full length of the manifold.
• The header size, number and spacing of distribution tubes shall be determined so that all steam is absorbed by the air before reaching the next component in the air stream depth.

Notes & Options

• Electric, gas and steam-to-steam generator types
• Optional auxiliary drain pan
• Optional access doors
• Optional controls
• The recommended location of the HM segment is downstream of the HC segment but upstream of the CC segment.
• The humidifier segment may be configured upstream of RF, FF, and AF filter segments.
• Valve package shall be supplied and shipped loose. Field installation and wiring is required.
• The Humidifier Vendor humidifier selection software shall size the valve package.

• Valves cannot be selected as an off-the-shelf item; each valve has a specific plate/orifice specifically cut per order specifications.
• Control valve actuation shall be electronic and shall be compatible with either a 0-10V DC signal or a 4-20 mA control signal.
• Factory mounted controls are not available in the Humidifier segment. Any FMED device in a downstream segment should be located at least the absorption distance away from the humidifier manifold.
• Usual humidifier headers are located the same side as coil headers.
• Optional stainless steel supports and liner
UV Segment – (UV)

UV-C lighting options control the growth and transfer of surface and airborne microbial agents. By incorporating UV light options into your air handling unit it is now possible to control microbiological infestations, using ultraviolet light technology to disinfect the unit, thereby maintaining the cleanliness of the unit and the re-circulated air of the space being conditioned. By eliminating a multitude of microorganisms, IAQ is improved and occupants are healthier.

Surface Decontamination Option – is done by incorporating UV-C lights in the coil segment downstream of all cooling coils and above all drain pans. In this application reflectivity of the UV light is of dominant importance. Exposure time is unlimited. Any increase in reflectivity enhances the UV effectiveness and efficiency. The kill rate increases dramatically with this application method.

Airborne Inactivation Option – is accomplished by installing the stand-alone “Airborne Inactivation” segment upstream and/or downstream of all cooling coil segments to control airborne microbial agents. UV-C lights for this type of application are of higher intensity and are designed for “On-the-fly” kill of airborne contaminants. Lamps are configured for 360° UV irradiance for maximum air-stream cleansing.

Combining Both Options – If both Surface Decontamination and Airborne Inactivation options are used together, they can virtually clean your unit and the air you breathe. Working together with various filtration systems and complying with the requirements of ASHRAE Standard 62.1 will assure the best possible IAQ when a designer combines all of these technologies.

Notes & Options

Optional Radiometer
- Radiometer detects and measures intensity of radiant thermal energy
Optional Access Door
- Access is optional for servicing the UV lights.

- Mechanical interlock switch to assure that the UVC assembly will be de-energized when accessed.
- Optional View-port
Optional stainless steel supports and rails
CONTROLS

Power Wiring Options

All motor wiring will be sized and installed based upon National Electrical Code requirements. The wire-ways will be categorized as follows:

- High Voltage – (120V and higher) is usually on drive side of the product
- Low Voltage – (24V) is usually on opposite drive side.
- All motor wiring will be installed neatly in perpendicular and/or parallel planes with the unit walls and floors.

Single Point Power (SPP) is defined as:

1. ALL electrical loads in a specific unit configuration wired to a common point of connection through the proper motor control protection devices. This requires the customer to bring only one source of power to the unit.

2. Where motor controls (VFD, starter or wired disconnect) are NOT selected, no motor wiring shall be provided. Should 120V or 24V elements be selected where motor controls are not included, they shall require field wiring.

3. Where multiple motor control devices are selected, optionally, single point power connections shall be provided. The field power supply point shall be the supply fan segment.

4. Where an external wired disconnect option is selected for either supply or return/exhaust fans (or both), single point wiring shall NOT be available.

There are three different sizes of transformers available; 150VA, 500VA, and 2000VA.

- The transformer being the device, used to transform power from a primary voltage of 460 volts, 230 volts, or 575 volts, to a secondary voltage level. An example of a secondary voltage would be 120 volts.

A disconnect panel will be required anytime there are (2) or (3) 3-phase loads that require a common factory terminated wiring connection. A maximum of (3) 3-phase loads are allowed for single point power option.

3-phase loads are as follows:
I. Supply Fan Motor Controller
II. Return / Exhaust Fan Motor Controller.
III. Gas Heater.
IV. Electric Heater.
V. Energy Wheel Motor Controller.
INDUSTRY FORMULAS

### Electrical

- **Watts ÷ Amps** = Volts
- **Volts x Amps** = Watts
- **Watts ÷ Volt** = Amps
- Volts (V) = a measure of electrical potential
- Watt (W) = a measure of power an electrical device consumes

\[
PUMP\ KW = \frac{FLOW\ (gpm) \times PD\ (ft)}{5311 \times E\ pump \times E\ motor}
\]

\[
FAN\ KW = \frac{7457 \times BHP}{E\ motor}
\]

1.73 = \sqrt{3} FOR THREE PHASE SERVICE

- Amp (A) = a measurement of rate of flow of electrons along a wire
- Kilowatt (kw) = a thousand watts
- BTU = KW x 3415
- 1KW = 1.34 HP
- 1 HP = 2545 BTUH

\[
PUMP\ HP = \frac{FLOW\ (gpm) \times HEAD\ (ft)}{5311 \times E\ pump \times E\ motor}
\]

\[
FAN\ HP = \frac{CFM \times SP}{6350 \times E\ fan}
\]

\[
FAN\ STATIC\ EFF = \frac{CFM \times SP}{6350 \times BHP}
\]

\[
FAN\ MECH\ EFF = \frac{CFM \times TP}{6350 \times BHP}
\]

### Basic Fan Laws

- CFM varies directly as the RPM
  - \( CFM_1 = RPM_1 \)
  - \( CFM_2 = RPM_2 \)

- Static pressure varies as the square of the RPM
  - \( SP_1 = (RPM_1)^2 \)
  - \( SP_2 = (RPM_2)^2 \)

- HP varies as the cube of the RPM
  - \( BHP_1 = (RPM_1)^3 \)
  - \( BHP_2 = (RPM_2)^3 \)

### Drive Calculations

Motor RPM x Motor Pulley PD = Blower RPM x Blower Pulley PD

**Example:**

- \( 1.750 \times 7.2 = 11.8 \) PD Blower Pulley
- \( 1.750 \times 7.2 = 11.8 \) Blower RPM
- 10% too much CFM:
  - \( 1.750 \times 7.2 = 11.8 \) PD Blower Pulley
  - 1,190 x (0.90)

### Air

- **TOTAL COOLING LOAD (MBH) = 4.5 x CFM STANDARD AIR x (ENTHALPY ENT. AIR - ENTHALPY LVG. AIR) / 1000**
- 4.5 = 0.075 (WT. OF STD. AIR, # / FT3) x 60 (MIN./HR.)

- **SENSIBLE COOLING LOAD (MBH) = CFM x 1.08 x (EDB-LDB) / 1000**
- 1.08 = 0.075 (WT. OF STD. AIR, # / FT3) x 60 (MIN./HR.) x .24 (Specific Heat of dry air)

- **SENSIBLE HEAT RATIO = \( SH = \frac{MBH}{MBH/\text{Sq. Ft. x FA} \times 1000} \)**

- **TOTAL COOLING LOAD (BTW/HR) = GPM x 500 x (EWT-LWT)**
  - 500 = 8.33 (WT. OF H2O @ 60 deg F, # / GAL) x 60 (MIN./HR.) x 1.0 (Specific heat of water)

### Metric Conversions

- CFM x 1.6992 = m3/hr
- Ft/min x 0.00508 = m/s
- BTU x 0.00029 = kWh
- CFM x 0.4719 = L/s
- Inch x 25.4 = mm
- Gpm x 0.063 = L/s
- HP x 0.7457 = kW
- Lb x 0.4535 = kg

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