Course SS105

Air Distribution
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1. **The Total Comfort System**

The air distribution aspect of air conditioning and heating systems can often be misunderstood. We all know that cool or warm air is needed in each room in order to bring that space to a comfortable condition, but to achieve this correctly takes much more than tying a duct onto an air handler and letting it blow. Before getting into the air distribution system, there are some basic concepts and terminology that must be understood to achieve a system that will deliver comfortable conditions throughout the conditioned space.

1.1. **Total Air Volume – Cubic Feet per Minute (CFM)**

CFM refers to the total volume of air measured in cubic feet that is moved through the system in one minute. The total CFM that can be delivered through a duct is dependent on the pressure making the air move, combined with the size of the duct. Naturally the larger the duct is and the more pressure behind the air, the more air that can be moved. Normally you would expect to have a total air volume of approximately 400 CFM per ton of air conditioning moving through the air handler and duct system. Example: 3 tons x 400 CFM per ton = 1200 CFM total for a 3-ton unit.

Each area of a building has a specific heat gain and heat loss that determines how much air will be required to heat or cool that area. Once the required CFM is determined through a load calculation, it is then distributed proportionally to each area of the structure. It is very important to make sure that the air is delivered where it will not blow directly on the customer or create noise.

1.2. **Velocity - Feet per Minute (FPM)**

Velocity is measured in feet per minute (FPM) and indicates the speed of the air moving through a duct (similar to miles per hour). If you imagine an inspection hole in the side of a duct and a long piece of string suspended in the air stream traveling at the same speed of the air, the velocity (FPM) would be equivalent to how many feet of the string passed the inspection hole in one minute.

Noise is becoming a major factor in today's homes. The discriminating homeowner may be spending tens of thousands of dollars for a complete comfort system, and the last thing they want to do is keep adjusting the television volume when the blower cycles on or off. Excessive noise can be created by air moving through the system at a higher than designed speeds. The velocities referred to on the following pages are
recommended for residential homes and are lower than that of commercial buildings. Velocities of a comfort system can be measured with a velometer or calculated by knowing CFM and size of the duct.

With a given amount of CFM moving down a duct, as the size of the duct changes, the velocity changes to the same extent. If a duct were suddenly reduced to one half its original size, the velocity would double. On the other hand if the size of the duct were doubled, the velocity would be cut in half.

### 1.3. Static Pressure

Static pressure is a pressure that exerts force evenly in all directions (Fig 1). This is the pressure that causes air to leave the main trunk and go into the branch duct. Just like a tire that gets a hole in it, static pressure causes the air to exit the vessel. Unlike the tire, a duct system has air flowing through it as well as having static pressure in the duct. The static pressure within a duct also acts as resistance to airflow, so the higher the static pressure the lower the CFM the blower can move through the system.

Static pressure can sometimes makes the ductwork "pop" or swell up. To measure the static pressure in a duct, a hole can be tapped into the duct on any side and a tube from a pressure gauge inserted just slightly into the duct. The reading will be in inches of water column and could be either positive or negative depending on whether it is the supply or return duct.

### 1.4. Velocity Pressure

Velocity pressure is pressure that exerts force in only one direction (Fig 2). Inside the ductwork, velocity pressure is the pressure of the air moving down the duct measured in inches of water column. Although velocity and velocity pressure are closely related, it should be noted that they are two distinctly different measurements (velocity measures the speed of the air, whereas velocity pressure measures the pressure of the air in inches of water column). Measuring the velocity pressure in a duct is difficult, if not impossible because the static pressure in the duct affects the pressure reading. The easiest way to find velocity pressure is to calculate it based on the total pressure.
1.5. Total Pressure

Total pressure measures the total energy of the air in a duct (Fig 3) similar to the way Watts measures the total energy of electricity. It is the sum of static pressure and velocity pressure: \( SP + VP = TP \). Total pressure can easily be measured by pointing the tube from a pressure gauge directly into the air stream in the center of a duct. This reading is not only measuring the static pressure within the duct, but also measures pressure of the velocity, giving the combined reading of total pressure.

*Note: The best way to determine the velocity pressure is to subtract the static pressure from the total pressure.*
1.6. Converting Static Pressure into Velocity

Static pressure can be converted into velocity inside the ductwork. In Fig 4 we see a balloon that is filled with air. If the opening at the bottom of the balloon is pinched off, all you have in the balloon is static pressure. As you release the opening of the balloon (similar to tying a branch duct to a trunk line) you convert the static pressure to velocity.

As in the balloon, static pressure causes the air to leave the trunk and is converted back into velocity pressure in the branch duct.
2. Air Movement through the System

Air movement in a home comfort system begins at the blower, travels through the supply trunk to the branch ducts, then out of the supply registers and into the room. This air pressurizes the room, forcing the air back towards the return air grill. The air enters the return air grill and flows down the return branch ducts. It continues on through the return air trunk line until it gets back into the blower section to start the process again.

If any part of the air distribution process is oversized or undersized, closed off, or restricted, the entire system can be disrupted. Disrupted airflow can cause:

- Compressor flooding
• Motor wear
• Drafty rooms
• Noisy systems
• Humidity problems
• Positive or negative house pressure
• Mold / Mildew
• Dust
• Sweating ductwork
• Heat exchanger failure
• Electrical problems

2.1. The Blower

The blower is the heart of the air distribution system, delivering air at a high pressure into the supply ductwork and returning the same air back through the return ductwork at a low pressure. The difference between the two pressures is called external static pressure. The blower design dictates the amount of CFM it can deliver at a given static pressure. As the blower operates against a lower static pressure within the duct system, it can move more air, whereas, when the static pressure is higher due to the design of the air distribution system, the total CFM is reduced.

2.2. The Supply Trunk

The supply trunk is a large rectangular or round duct that delivers air from the air handler or furnace to the branch ducts. It is normally insulated when it is not in a conditioned space with either an internal liner or wrapped externally with an insulation and vapor barrier. A canvas connector or vibration isolator may be installed at the outlet of the furnace prior to the supply trunk to reduce motor noise and vibration from traveling down the ductwork. The recommended velocity for the supply trunk is 700-900 FPM.
2.3. **Volume Dampers**

Volume dampers are used to regulate the amount of air in the branch ducts. They should be installed with the blade in the direction of airflow and mounted as far as possible from the supply register in order to reduce noise problems (typically at the main trunk).

Dampers can only throttle down on the amount of air passing through a duct and are adjustable by loosening a wing nut, turning the damper blade to the desired setting, and then retightening the wing nut. Once a proper air balance is performed on a system, the dampers should not need further adjustment unless the home has a significantly different air requirement between summer and winter. This can happen in homes such as a two-story that is served by one HVAC system.

2.4. **Branch Ducts**

Branch ducts are usually round metal or flexible ducts and are sized to deliver the required amount of airflow to each space. They attach to the damper or start collar and become the conduit for air to travel to the supply boot and register. The recommended velocity for branch ducts is **600 FPM**.

2.5. **Supply Boot or Box**

Supply boots act as a transition from the round branch ducts to the rectangular or square registers. They are attached to the floor, wall, or ceiling, depending on your system and the registers mount to them.

2.6. **Supply Registers and Diffusers**

Supply registers are used when the outlet of the duct system is located in the floor or wall. Diffusers, however, are used when the outlets are found in the ceiling. Registers and diffusers serve the same purpose of delivering air into the room and usually have a damper in them so the customer can fine-tune their system. When you are making significant adjustment to the airflow, it should be done at the volume dampers rather than the registers or diffusers.

When making major air adjustments at the registers or diffusers, they can become very noisy as well as causing the throw of the air to be affected. The recommended velocity for registers or diffusers is **500-600 FPM**.
2.7. Return Air Grills

Return air grills are the beginning of the pathway for the air to flow back to the furnace or air handler from the conditioned space. The two primary types of return grills are Filtered and Non-filtered. A Filtered grill has a door that swings open and the filter is installed in the grill itself making it convenient for the customer to maintain. The Non-filtered return air grill has no means of filtering the air and serves only as the inlet for the air to flow. These grills are typically used when the duct system is designed with multiple returns. Return air grills are installed in various areas of the home, depending on the average climate, construction of the home, and the traditions of a particular market.

Although it is not mandatory, it is typical to see a high side-wall or ceiling return in a predominantly warm climate, whereas cool climates typically have low side-wall or floor returns. As mentioned before, the design and construction of the home has to be considered when determining the best location for the return.

Recommended velocity:

- Non-filtered Grill: 500 FPM
- Filtered Grill: 300 FPM

2.8. Return Air Branch Duct

When multiple return grills are used, the return air branch ducts convey air to the return trunk from the grills. The recommended velocity is 600 FPM.

2.9. Return Trunk

The return trunk is usually larger than the supply trunk because it has to move the same amount of air back to the blower but at a lower pressure and a slower velocity. This is done to help reduce the overall friction loss of the duct system as well as making the return quieter. It is also insulated in unconditioned spaces to help prevent thermal loss.

The recommended velocity for the return trunk is 600-700 FPM.
3. Review Questions

1) What is the recommended velocity for a main supply trunk?
   a) 200-300
   b) 400-600
   c) 700-900
   d) 1000-1200

2) CFM is the measurement of:
   a) Total pressure
   b) Velocity
   c) Static pressure
   d) Total air volume

3) Three tons of air conditioning will require how much CFM?
   a) 600
   b) 800
   c) 1200
   d) 1600
4) What pressure is exerted in only one direction?

   a) Velocity pressure
   b) Static pressure
   c) Total pressure
   d) Atmospheric pressure

5) Static Pressures exerts pressure in:

   a) All directions
   b) Same direction
   c) One direction
   d) Both directions

6) The total pressure in a duct is equal to:

   a) Velocity pressure plus Static pressure
   b) Static pressure minus Velocity pressure
   c) CFM plus Velocity
   d) The total air volume

7) What is the recommended FPM for return duct systems?

   a) 75-150
   b) 200-300
   c) 400-500
   d) 600-700
8) FPM is a measurement of:
   a) Total pressure
   b) Velocity
   c) Static pressure
   d) Total air volume

9) Volume dampers are primarily used:
   a) To control the noise in the supply air trunk.
   b) To control the noise in the return air trunk.
   c) To control the airflow in supply duct system.
   d) To control the airflow in the return duct system

10) Static pressure cannot be converted to velocity pressure.
    a) True
    b) False
4. Duct System Styles

4.1. Extended Plenum System

4.1.1. Extended Plenum Square Duct Trunk Systems

Extended plenum square duct trunk systems are used when a significant amount of air needs to be carried a distance before the branch take-offs are tapped in. This type of system is popular in homes where the duct system is in the basement. Extended plenum systems fall into two broad categories: the reducing plenum duct system and the non-reducing plenum duct system.

4.1.2. Reducing Plenum Duct System

The reducing plenum duct system (Fig 7) is the most versatile system and is best when trying to control airflow to specific areas, such as multi-story structures, large houses, or commercial buildings. Although there are no set parameters on when the reduction should occur, a general rule is after a significant amount of air has been removed by the branch ductwork (no more than 50 %), the plenum is then reduced or transitioned down. This maintains the static pressure and velocity and helps to ensure a properly balanced system. With the system properly sized and installed, the reducing plenum is the most effective way to be sure you will get the proper airflow you need for a particular area, especially when the take-off is at the end of the trunk.
4.1.3. Non-Reducing Extended Plenum Duct Systems

Non-reducing extended plenum duct systems (Fig 8) are easier to design and build because all of the ductwork is the same size. They do not transition down after branch take-offs, making the "air balance" more difficult because the static pressure and velocity are constantly changing. This system is much cheaper to install because the ductwork can be made in quantity without the need for transitions and field fabrication is minimal. This system is popular when all the take-offs are within a reasonable distance from the furnace or air handler.

When properly designed, the biggest advantage to this system is that the velocity and static pressure are maintained at a constant level throughout the supply trunk.
4.2. Perimeter Duct Systems

**Perimeter supply systems** can provide one of the best methods for both air conditioning and heating duct systems. It requires the installation of ductwork to terminate at the exterior walls, preferably under the windows where the heat gain and loss is the greatest. By introducing the warm air at this point, the chances of downdrafts of cold air from the windows, across the floor and into the occupied zone, is reduced. In the summer, the ductwork located at the windows helps to neutralize the heat where the greatest amount of it is typically found. By combating heat gain and loss at its source, the perimeter supply system can prove to be a very efficient means of air distribution. Any of the duct systems covered in this section can be installed as a perimeter system.

4.3. Radial Duct Systems

In **Radial duct systems** (Fig 9), the unit and return air grill are generally found in the center of the home in a common space, and the supply ducts branch out under the floor like the legs of a spider to the exterior
wall. These are generally used in small structures such as apartments or condominiums, where all the supply runs can be of nearly equal length.

*Fig 9*
5. Duct Placement

The outside walls of the home are typically the largest heat gain and loss in the home. Therefore, it is best to start conditioning there first and move inward. As you have seen in the perimeter system, air is introduced at the outside walls and returned via open doors and halls to the return duct. The process then starts over again.

In rooms where you are going to put a supply and a return grill, in most cases the supply would go on the exterior wall and the return would go across the room on an interior wall. In a room with no exterior walls, the supply should be located nearest to the heat source in the room and the return on the opposite side. If there is no return duct going into this room, the supply should go on the opposite side of the room from the door or return air path.

5.1. Warm Climates

High side wall or ceiling supply and return grills allow cool air to be forced down into the living space, cooling it down before it stratifies and rises back up into the high return grill.

5.2. Cool Climates

Low side wall or floor supply and return grills allow for warm air to be moved along the floor and forcing it up, warming the room before it stratifies. It then starts to fall back to the floor to be returned to the furnace for reheating.
6. **Throw**

Throw is the distance air needs to travel across a room before it reaches terminal velocity or begins to stratify.

Terminal velocity is reached when air speed becomes less than 50 FPM. At this speed air stratifies. Air that is cooler than room temperature begins to fall and air that is warmer than room temperature begins to rise.

It is important when throwing air horizontally across the room that the air be thrown by the grill approximately 1/2 the distance across the room before it begins to stratify. Proper throw will help to eliminate hot and cold spots in the room and can also help to reduce drafty rooms or the chill of high velocity air in the winter.

![Fig 10](image)

1. Good throw to the far side of the room.
2. Good stratification in the middle of the room.
3. Low noise level at supply register.

If the supply register is too large, velocity will be very low.

![Fig 11](image)

1. Poor throw to the far side of the room.
2. The air begins to stratify and fall too quickly.
3. Low noise level at supply register.
4. Hot spot on the far side of the room.
If the supply register is too small, velocity will be very high.

1. Throw is too strong.
2. Poor stratification in the middle of the room.
3. Supply register is very noisy.
4. Possible drafty room in heating season.
7. The Return Air System

The air conditioning system doesn't make air; it just circulates the air in your home over and over again. Like the refrigeration circuit, any restriction of flow can cause a detrimental effect on the output of the entire system. If you closed a service valve partially, the system may not perform properly. Closing supply grills, covering return grills, and/or closing doors can also have the same effect. First, let's talk about single vs. multiple return ducts in a home.

By having only one common return, the cost of a job is greatly reduced, but so is the control of airflow in the home. If the common return grill is in the hall in the center of the home, for instance, the system will be fine until the doors in the bedrooms or other rooms start getting closed off.

Each system is designed to move approximately 400 CFM of air per ton of air conditioning. If your 2-ton system is sized properly, your system is blowing 800 cubic feet of air out of the supply grills all throughout the house. If there are doors closed in a few of the rooms the air cannot make it back to the return.
8. Effects of a Poor Return Air Design

Inside a room with the closed door, air is being blown in and nothing is being removed except under the door and through the cracks in the windows. The wall receptacles are having air forced through them as well. This room has positive pressure, similar to blowing into a bottle. There is only so much air you can get in a room without removing what is already in there. Good conditioned air is being lost to the outside because the door is closed.

Outside the room that is closed off we see just the opposite happening on the return air side of the system. Remember that we said that your system would move 800 CFM. If losing air out the cracks in the windows and the wall receptacles, it has to bring air back into the home from somewhere to make up. So now the rest of the house has negative pressure, sucking air in through the cracks of the windows and doors. By having a return grill in these rooms, the doors can be closed without the return being isolated from the supply grills.

But what about the air going under the door? It usually isn't enough to make up what is being supplied. On a 36” door cut a full 1” above the carpet, you would move about 144 CFM under the door, about 4 CFM per square inch. Remember, an 8” metal duct supplies around 200 CFM into the room.

A dirty carpet line at a doorway may indicate a door that remains closed a lot of the time.
8.1. Duct Leaks

Air leaks in a system can cause dirty, unconditioned air to enter a residence. Leaks also contribute to a loss in efficiency as well as capacity. It is estimated that for every 1% loss in total airflow, there is a 1% loss in capacity.

Therefore, if a 2.5 ton system leaks only 100 CFM through its entire duct system, a 10% loss would reduce the capacity of the system to a 2.25 ton system.

<table>
<thead>
<tr>
<th>2.5 ton system</th>
<th>30,000 BTUH</th>
<th>1000 CFM</th>
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</thead>
<tbody>
<tr>
<td>- 3,000 BTUH</td>
<td>- 100 CFM</td>
<td>10% loss in air and capacity</td>
</tr>
<tr>
<td>27,000 BTUH</td>
<td>900 CFM</td>
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</table>

Ducts that leak in the supply side of the system do not put into the home the same amount of air that is being taken out by the return. This puts the house into a negative pressure. Conversely, if the leaks are in the return ductwork, the amount of air being taken out of the house is less than the amount of air being blown in, putting the house into a positive pressure.

8.2. Ductwork

Ductwork is the conduit for air to move throughout the home. It also moves dust and odors as well. It is very important to seal the ductwork with mastic at every joint, both longitudinal (along the duct) and transverse (across the duct). While ductwork doesn't cool or heat the air, it does play a major role in the efficiency and capacity of the system. As efficiencies increase, the tolerances we had with old duct systems will no longer apply. Proper design and installation practices are a must, or the new systems will not operate as desired. Insulation is a must when ductwork runs through unconditioned areas to reduce sweating, heat gain or loss, and maintain unit capacity.

Duct systems vary with installation practices and local codes. Noise levels, moisture, infiltration of dirt and air leaks can happen with any type of duct system, so how the duct system is sized and installed will prove it to be a good or poor duct system.

8.3. Sheet Metal

- Lined internal or wrapped external with insulation.
- Sheet metal trunks must be strapped every 5'.
- All joints, transverse and longitudinal, must be sealed.
• May have canvas connectors to reduce sound and vibration.

8.4. **Ductboard**

• Ridged insulation board.

• 1" and 1-1/2" thicknesses.

• Can be fabricated quickly on the jobsite.

• Very quiet.

• Flap joint must be stapled and sealed.

• Mastic all joints.

8.5. **Flexible**

• Externally lined with various R-values.

• Strapped every 4' horizontal and every 6' vertical with 1 1/2" strap.

• No more than 1/2" per foot sag when running horizontal.

• Usually sized larger than metal duct to move the same amount of air.

• Very quiet.
8.6. Flexible -VS- Metal Ductwork

Notice that in the same diameter duct, metal has a lower static pressure (resistance to airflow). This occurs because the inside of flex is not smooth like metal. Because of this, moving the same amount of air would require a larger flex duct. As a basic rule, flex ducts should be one duct size larger than metal ducts.
9. Review Questions

1) Air leaks in the return ductwork installed in the attic would place the home into:
   a) Barometric pressure
   b) Positive pressure
   c) Negative pressure
   d) Hydrostatic pressure

2) As a general rule on a reducing plenum duct system, when should the trunk be transitioned down to a smaller size?
   a) After 25% of the air has been removed from the system.
   b) After the second branch take-off duct.
   c) After the fourth branch take-off duct.
   d) After 50% of the air has been removed from the system.

3) The biggest advantage to using a reducing plenum duct system is that it:
   a) Maintains static and velocity pressure
   b) Keeps noise levels down
   c) Is made with flexible ducts so that it’s cheaper
   d) Is smaller.
4) As a general rule, flexible duct should:
   a) Never be used in attic spaces
   b) Be one size larger than metal duct
   c) Should only be run horizontally
   d) Only be used for a drier vent.

5) Ductwork for homes in cooler climates generally has:
   a) High supply and high return grills
   b) High supply and low return grills
   c) Low supply and low return grills
   d) Low supply and high return grills

6) It is estimated that for every 5% of airflow that is lost due to duct leakage, there is a
   a) 1% loss in efficiency
   b) 5% loss in efficiency
   c) 10% loss in efficiency
   d) 15% loss in efficiency

7) If a bedroom door is closed tight in a home that only has one central return, what effect could this
   have on the rest of the home?
   a) The home would have a positive pressure increasing the overall airflow.
   b) The airflow to the rest of the home would increase by 10%.
   c) The home would have a positive pressure, loosing air to the outdoors through leaks.
   d) The home would have a negative pressure, leaking air in from the outdoors.
8) Perimeter duct systems provide a desirable system performance because:
   a) It introduces air on an interior wall close to the return
   b) It introduces air on exterior walls close to the heat loss or gain
   c) It keeps the home in a positive pressure
   d) It keeps the home in a negative pressure

9) At 50 FPM air reaches terminal velocity and begins to
   a) Fall if it is warm
   b) Rise if it is cool
   c) Stratify
   d) Increase velocity

10) Supply side wall registers that are too small may have what effect on the system?
    a) Velocity will be reduced
    b) CFM will be increased
    c) No effect
    d) Increased noise levels
10. Duct Sizing Charts

The charts on the following pages will give the user a good idea of how large the ductwork should be for a certain CFM. The duct sizes listed are based on guidelines recommended by our industry for ideal friction loss per 100 equivalent feet of duct and recommended velocities. One hundred feet of duct may sound like a long duct in a residential home, but keep in mind that the fittings and elbows need to be accounted for. For instance, one square elbow can easily account for 30-50 feet worth of straight pipe depending on its design.

These charts are ideal to use as a quick reference if you find an airflow problem that you suspect may be caused by an insufficient duct system. The charts on filter sizing should be used anytime you are sizing a filter or recommending an upgrade for a customer. If two duct sizes are listed, the possible CFM is marginal, so if it is a very short duct, then the smaller duct can be used; if it is longer, the larger size should be used.

If you find a system that has ductwork sizing problems, it is always best to refer to a supervisor or comfort consultant that can check the design on the entire system before making a recommendation to the customer for changes to the system.
### 10.1. Supply Duct Sizing Guide

<table>
<thead>
<tr>
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<th>Round Metal</th>
<th>Round Flex</th>
<th>Rectangular Trunk</th>
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<td>12 x 10</td>
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</tr>
<tr>
<td>2000</td>
<td>20</td>
<td>N/A</td>
<td>20 x 15</td>
</tr>
</tbody>
</table>

**Notes:**

1) All ducts are designed @ .08 Static/100 ft. and 700-900 FPM Velocity.

2) If rectangular ductwork is lined with internal insulation, you need to add 2 inches to both rectangular dimensions to adjust for the loss of area in the duct. Example: a 12 x 6 duct would need to be built to a 14 x 8 to allow for the insulation, and get the net size of 12 x 6.
## 10.2. Return Duct Sizing Guide

<table>
<thead>
<tr>
<th>CFM</th>
<th>Round Metal</th>
<th>Round Flex</th>
<th>Rectangular Trunk</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>9</td>
<td>10</td>
<td>12 x 5.5</td>
</tr>
<tr>
<td>400</td>
<td>12</td>
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<td>12 x 9</td>
</tr>
<tr>
<td>600</td>
<td>14</td>
<td>16</td>
<td>12 x 12</td>
</tr>
<tr>
<td>800</td>
<td>14 – 16</td>
<td>16 – 18</td>
<td>12 x 15</td>
</tr>
<tr>
<td>1000</td>
<td>16</td>
<td>18</td>
<td>12 x 18</td>
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<td>1200</td>
<td>18</td>
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<td>12 x 20</td>
</tr>
<tr>
<td>1400</td>
<td>18 – 20</td>
<td>N/A</td>
<td>16 x 17</td>
</tr>
<tr>
<td>1600</td>
<td>20</td>
<td>N/A</td>
<td>16 x 19</td>
</tr>
<tr>
<td>1800</td>
<td>20</td>
<td>N/A</td>
<td>16 x 21</td>
</tr>
<tr>
<td>2000</td>
<td>21</td>
<td>N/A</td>
<td>18 x 20</td>
</tr>
</tbody>
</table>

Notes:

1) All ducts are designed @ .05 Static/100 ft. and 600-700 FPM Velocity.

2) If rectangular ductwork is lined with internal insulation, you need to add 2 inches to both rectangular dimensions to adjust for the loss of area in the duct. Example: a 12 x 20 duct would need to be built to a 14 x 22 to allow for the insulation, and get the net size of 12 x 20.
### 10.3. Return Air Grill and Filter Sizing

<table>
<thead>
<tr>
<th>CFM</th>
<th>Return Grill Fixed Blade (500 FPM)</th>
<th>Filtered Return Grill and Low Velocity Filter (300 FPM)</th>
<th>High Velocity Filter Duct Mounted Only (600 FPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>7 x 10</td>
<td>10 x 10</td>
<td>-</td>
</tr>
<tr>
<td>400</td>
<td>10 x 14</td>
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<td>8 x 12</td>
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<td>16 x 25</td>
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<td>20 x 17</td>
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<tr>
<td>2000</td>
<td>24 x 30</td>
<td>25 x 40</td>
<td>18 x 30</td>
</tr>
</tbody>
</table>

#### 10.3.1. Calculating Fixed Blade Return Air Grill Size

For sizes not listed above, the following formula can be used to calculate the proper size for a non-filtered, fixed blade return air grill (stamp face).

**NON-FILTERED RETURN:** \( \text{AIR GRILL HEIGHT x WIDTH x 3} = \text{CFM} \)

#### 10.3.2. Calculating Return Air Filtered Grill Size

For sizes not listed above, the following formula can be used to calculate the proper size for a return air filtered grill. This formula takes into consideration the filter and grill.

**FILTERED BACK RETURN AIR GRILL:** \( \text{HEIGHT x WIDTH x 2} = \text{CFM} \)

#### 10.3.3. Calculating Filter Size for Low Velocity Filters

Most filters on the market are designed for the air to move through them at around 300 FPM to perform correctly. At speeds above design, the filter will not collect the dust and partials that it is designed to catch, and the filter will have more restriction to air flow than is acceptable.
Whether the filter is located in the return grill, ductwork, or in the furnace, finding enough surface area for proper filtration can be a problem. When sizing a filter, you should always try to size it in the low velocity range.

Otherwise, when a filter is sized for high velocity, everything is fine until the customer or another service technician changes the high velocity filter (such as a “hog-hair”) to a standard throw-a-way filter. When this happens, the air is moving much too fast for a low velocity filter, and it becomes an air restriction and loses the performance on the filter. Even worse, when a high velocity filter is removed and upgraded to premium filter such as an electrostatic filter, the air restriction can become a significant problem and can be detrimental to the system. Many people blame the premium filter at this point when it chokes the system down. The problem is not because of the filter; it's because a high velocity filter was replaced with a premium low velocity filter THAT IS UNDERSIZED!

The following formulas can be used to easily determine the correct size filter to achieve proper surface area for low velocity filters.

\[
\text{HEIGHT} \times \text{WIDTH} = \text{CFM (same as filter grills), approx. 300 FPM} \\
\text{TONS} \times 1.25 \text{ sq ft} = \text{AREA OF FILTER NEEDED, approx. 320 FPM}
\]

Example:
\[
2.5 \times 144 (1 \text{ sq ft} = 144 \text{ sq in.}) = 360 \text{ sq in.} \\
\frac{360}{20} = 18 \text{ Filter Size of 20 x 18 @ 320 FPM}
\]
10.3.4. Increasing Filter Size for Low Velocity Filters

In a return duct with a straight filter rack, the velocity can easily be 600 FPM or more depending on the size of the duct and the amount of airflow. The only suitable filter for many straight-rack applications is a high velocity filter.

You have learned that if you increase the area, you can decrease the velocity. By increasing the size of the filter, the velocity can be reduced to accommodate a low velocity filter. Let’s look at a few ways you can achieve this in order to use a low velocity filter in an existing duct system.

(Use the previous charts and formulas to determine the necessary size that you will need for a specific application.)

10.3.5. Calculating Filter Size for High Velocity Filters

When low velocity filters cannot be used due to size, the following formula can be used to calculate the size for high velocity filters. Keep in mind that once a filter size is chosen, it usually stays that size for the life of the system. If the customer does not keep a high velocity filter in the system and replaces it with a low velocity filter, it becomes an air restriction, especially if it is a premium filter.

\[ \text{HEIGHT} \times \text{WIDTH} \times 4 = \text{CFM} \] (equates to approx 600 FPM)
11. CFM Calculations

Proper CFM is critical to system efficiency. Calculating the CFM can be done with a variety of methods such as a velometer, U-tube manometer, anemometer, or a flow hood.

One of the easiest ways for a technician to calculate the CFM is the temperature rise method. The temperature rise method requires you to run the furnace and measure the amount of heat picked up across the heat strips or heat exchanger. The heating fan speed must be swapped with the cooling fan speed for this calculation; otherwise, you will check CFM for the heater, not the A/C.

11.1. Electric Heat

When using an electric heater, the voltage and amperage of the entire heater, including the fan motor, must be measured. This can be done at the main power wires that feed the air handler.

    Volts x Amps x 3.413 = BTUH

The temperature rise should be measured as close to the air handler as possible without letting the thermometer be in line of sight of the heat strips (radiant heat).

Subtract the return temperature from the supply temperature. This is your temp rise (or is sometimes called TD or Delta T).

Insert the readings taken into the following formula.

    CFM = Volts x Amps x 3.413  
        TD x 1.08

11.2. Gas Heat

When using a gas furnace, make sure the gas pressure at the manifold has been properly set. Switch the heating and cooling fan speeds at the board or relay. Use the nameplate output BTUH rating of the furnace, along with the TD from the supply and return air as close to the furnace as possible, and insert this information into the following formula:

    Example: 80,000 output / 60 degree TD x 1.08 = 1235 CFM
or:

\[ \text{CFM} = \frac{\text{Output BTUH}}{\text{TD} \times 1.08} \]

**NOTE:** This method gives a quick check of the CFM in a gas heat system. It assumes that the combustion efficiency and output is in line with the original data plate rating. To get the most accurate CFM calculation, a combustion efficiency test must be performed and the output rating adjusted based on the results of that test.

By dividing the total CFM by the tonnage of the condenser, you should be able to determine the CFM per ton.

*Example: 1235 CFM ÷ 3 ton condenser = 411.6 CFM per ton*

Remember that most systems operate at approximately 400 CFM per ton.
12. Gas Furnace CFM Calculations

The following charts can be used to determine the approximate CFM of the system. Make sure the blower is running on the cooling speed tap. Using nominal nameplate input BTUH and unit efficiencies will give approximate CFM values. For a more accurate reading, calculate BTUH input by clocking the meter and checking burner efficiency with a combustion gas analyzer.

### 65% - 80% Efficient Furnace

<table>
<thead>
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<th>Temp Rise (F)</th>
<th>50,000</th>
<th>75,000</th>
<th>100,000</th>
<th>125,000</th>
<th>150,000</th>
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<td>2778</td>
<td>3704</td>
<td>4630</td>
<td>5556</td>
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<td>2222</td>
<td>2963</td>
<td>3704</td>
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<td>1852</td>
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<td>3086</td>
<td>3704</td>
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<td>35</td>
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<td>1587</td>
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<td>2646</td>
<td>3175</td>
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<td>1389</td>
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</table>
## 90% Efficient Furnace

<table>
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<th>Input BTUs</th>
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<td>65</td>
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</tr>
<tr>
<td>70</td>
<td>714</td>
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</table>
13. Properties of Air

Air moving through the system can be affected by the condition of the air itself. You have encountered air at some time that was "heavy." This air is harder to move through a system than "light" air. Let’s look at what heavy air is.

**Dry bulb** temperature measures the "intensity of heat." As you might suspect 90 degrees in Arizona probably feels better than 90 degrees in Louisiana. The reason for this is humidity. The wetter (more humid) the air is, the more heat it will hold.

**Wet bulb** temperature is used to determine the "amount of heat" in the air. This reading is measured by placing wet sock or cloth around a thermometer, then placing it into the stream of rapidly moving air. Wet bulb can give you a better understanding of the total heat in the air because it measures both the intensity of heat (dry bulb), and the amount of moisture in the air (humidity).

**Relative humidity** is the amount of moisture in the air compared to how much moisture the air can hold at a given temperature. All air contains humidity or moisture to some extent. The amount of moisture in the air can be determined by the percentage of "relative humidity." System design conditions are usually rated at around 50% relative humidity.

Measuring these conditions in the air will require an additional thermometer other than the one used to measure dry bulb alone. The psychrometer is a tool that can accomplish this and is a "must have" on every job to ensure proper charge of the refrigeration system.
## 14. Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFM</td>
<td>Cubic feet of air per minute. The total quantity of air moving through the duct system.</td>
</tr>
<tr>
<td>Delta T or T</td>
<td>The difference in two measured temperatures. Supply to return, return to supply, both sides of a coil or heat exchanger, etc.</td>
</tr>
<tr>
<td>Dry Bulb</td>
<td>The temperature measured using a plain thermometer, indicating an intensity of heat.</td>
</tr>
<tr>
<td>FPM</td>
<td>Feet per minute, or velocity, is the speed at which air travels across a specific distance in a given amount of time.</td>
</tr>
<tr>
<td>Nominal</td>
<td>The approximate size. Rounded up or down.</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>The amount of humidity contained in the air as compared with the amount the air can hold at the same temperature.</td>
</tr>
<tr>
<td>Static Pressure</td>
<td>Pressure in all directions; considered opposition to airflow or CFM.</td>
</tr>
<tr>
<td>Stratification</td>
<td>Stratified, stratify. The air as it reaches terminal velocity (50 FPM) and begins to fall or rise as dictated by the surrounding air.</td>
</tr>
<tr>
<td>Terminal Velocity</td>
<td>Speed of the air (50 FPM) where air begins to stratify.</td>
</tr>
<tr>
<td>Throw</td>
<td>Distance air must travel from a supply register or diffuser before reaching terminal velocity.</td>
</tr>
<tr>
<td>Velocity Pressure</td>
<td>Pressure of the air as it is being forced through the ductwork. Pressure in only one direction.</td>
</tr>
<tr>
<td>Wet Bulb</td>
<td>The temperature derived from a thermometer when it has a wet cloth around it and is placed into an air stream. It is used in evaluating the moisture in the air. It is our closest measurement to total heat.</td>
</tr>
</tbody>
</table>
15. Review Questions

1) Effective insulation of a duct system is essential to prevent sweating, and __________ of the system.
   a) Oxidation
   b) Static pressure
   c) Gain in capacity
   d) Loss in capacity

2) What is the formula \( \frac{\text{Output BTUH}}{\text{TD} \times 1.08} \) used to calculate on a heating system?
   a) Static pressure
   b) CFM
   c) FPM
   d) BTUH

3) What does Dry Bulb Temperature measure?
   a) The intensity of heat
   b) The total quantity of heat
   c) Humidity
   d) Relative humidity
4) The formula Height x Width x 2 = CFM for:

   a) High sidewall supply grills
   b) Metal supply ducts
   c) Return ducts
   d) Standard filters

5) What tool measures Wet-bulb, Dry bulb and Relative humidity?

   a) A thermometer
   b) A psychrometer
   c) A barometer
   d) A potentiometer

6) What does Relative humidity measure?

   a) The intensity of heat in the air.
   b) The amount of condensate the unit will remove in 1 hour.
   c) The amount of moisture in the air as compared to how much it can hold.
   d) The amount of droplets of moisture in the air.

7) The Wet-Bulb temperature is an indication of:

   a) The intensity of heat in the air.
   b) The combination of temperature and humidity.
   c) The amount of moisture in the air.
   d) The Delta T between the supply and return ducts.
8) What is the formula: Volts x Amps x 3.413 used to calculate on an electric heater?
   a) Velocity
   b) Static pressure
   c) CFM
   d) BTUH

9) What is the recommended FPM for most standard low velocity filters?
   a) 150
   b) 300
   c) 450
   d) 500

10) Delta T, T, Temp Rise and TD are all terms that mean about the same thing. How many temperature readings do you need to accomplish this?
    a) 1
    b) At least 2
    c) At least 3
    d) At least 4