THE ELECTRIC DUCT HEATER EXPERIENCE

TUTCO®
HEATING SOLUTIONS GROUP

DUCT HEATERS

TUTCO Duct Heaters

TUTCO is the world's largest supplier of electric resistive heating elements and holds 80% of the US patents in open coil heating technology. Tutco products can be found in countless industrial, commercial and residential electric heating applications.

TUTCO Duct Heaters offer a unique design that provides a free flow of air and the lowest pressure drop through the heating elements. Our E-Series Flip-Able Duct Heater has been specifically designed, developed and tested with symmetry in mind. One heater may be installed in four different positions eliminating the need for different right and left handed designs.

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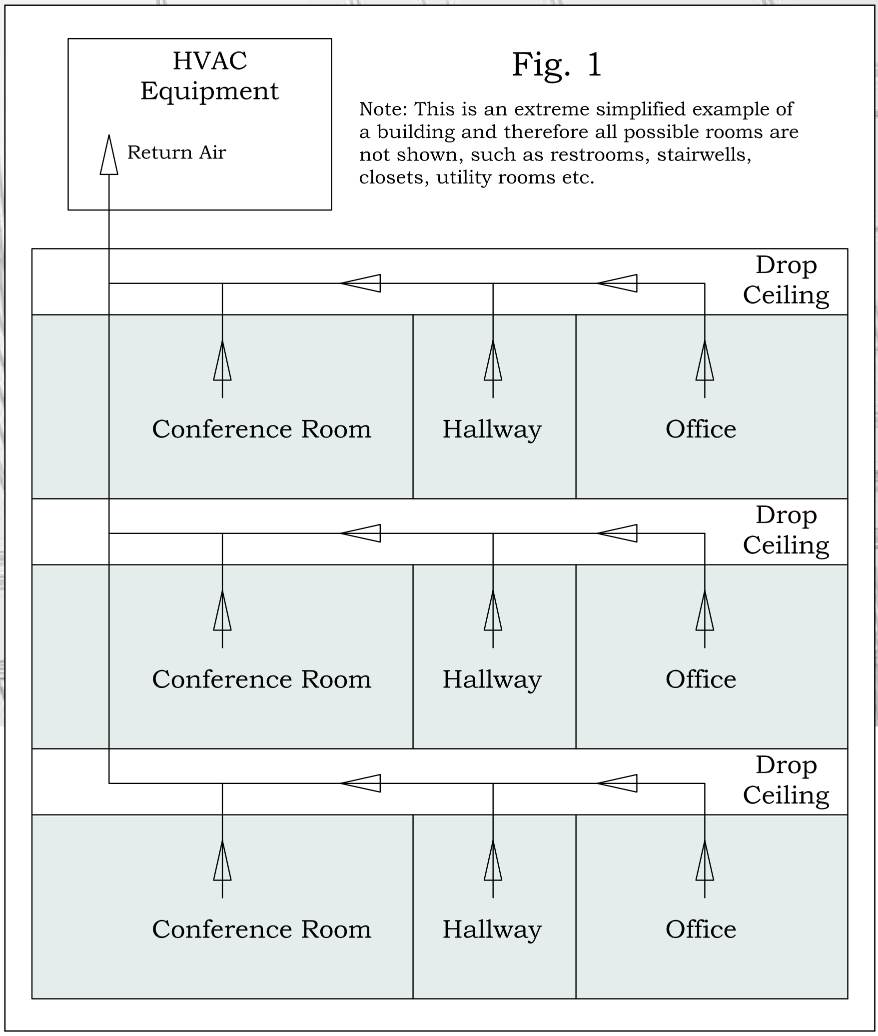
Call 931.432.4141 or email customerservice@tutco.com

Tutco Duct Heaters, 500 Gould Drive, Cookeville, TN 38506

Electric Heaters are used for many purposes and applied to various applications. One specific application for these electric heat products could be described as basic space heating. Consider specifically Electric Duct heaters being used alone or in combination with various HVAC equipment in order to provide comfortable, conditioned air to occupied or unoccupied spaces within commercial or residential building areas.

Commercial Office Buildings

Commercial buildings could be considered large or small depending upon the number of floors involved and the actual size of these floors. Consider a large building with many floors occupied by office employees or residents. The building HVAC system may begin on the rooftop with a large piece of equipment which can draw available air from all the building spaces and condition the air to a higher or lower temperature. The building HVAC system could however begin with a slightly smaller piece of equipment (one located on each floor) which may be used for conditioning air for only the particular floor of the building on which it is located. Please refer to the following figures for an illustration of this concept. In these basic and simplified examples, you should be able to see why additional equipment would be needed in order to truly supply the appropriate air for each room to be considered comfortable for the occupants.



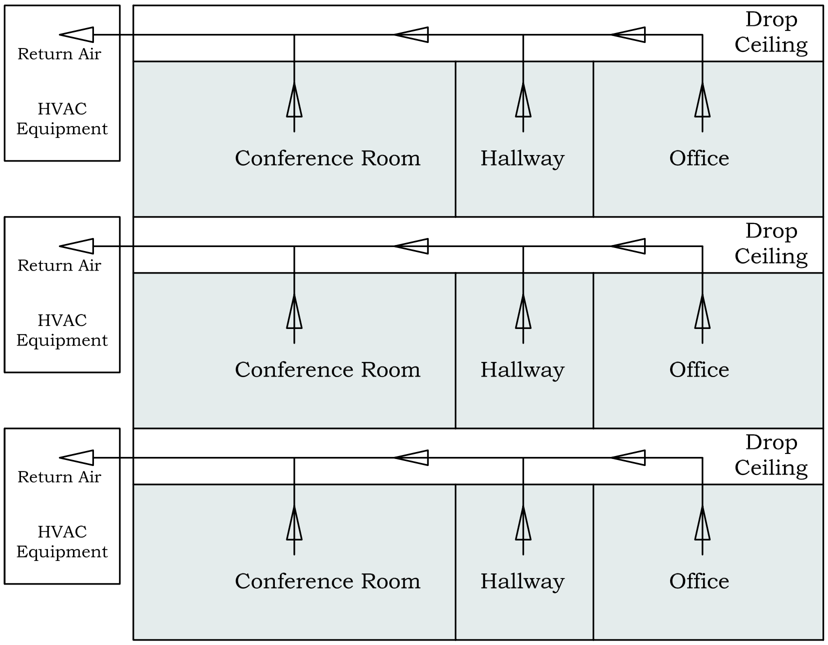
This figure represents a simplified 3 story building with a large rooftop HVAC system being used to gather air from required building spaces. This could indicate that the main HVAC system is responsible for gathering and mixing air at different temperatures and then conditioning this air to some pre-determined set values.

Of course, we all know that individuals located within these spaces will likely want different air temperatures for different levels of comfort. This would become evident in each room as some of them could have windows or many other possible influences which would affect how the supply air should be conditioned for each space.

In this basic and simplified example, one should be able to see why additional equipment would be needed to truly supply the appropriate air for each room to be considered comfortable for the occupants.

Fig. 2

Note: This is an extreme simplified example of a building and therefore all possible rooms are not shown, such as restrooms, stairwells, closets, utility rooms etc.



This figure represents the same simplified 3 story building except there is an HVAC system being used to gather air from required building spaces on each floor. This could indicate that each floor has a main HVAC system that is responsible for gathering and mixing air at different temperatures and then conditioning this air to some predetermined set values.

Again we all know that individuals located within these spaces will likely want different air temperatures for different levels of comfort. Also, certain rooms could have windows or many other possible influences which would affect how the supply air should be conditioned for each space. One such example could be how many people were in each room at one time, such as the conference room. The more people in the room, the more the room could naturally heat up and require supply air be conditioned differently, for comfort.

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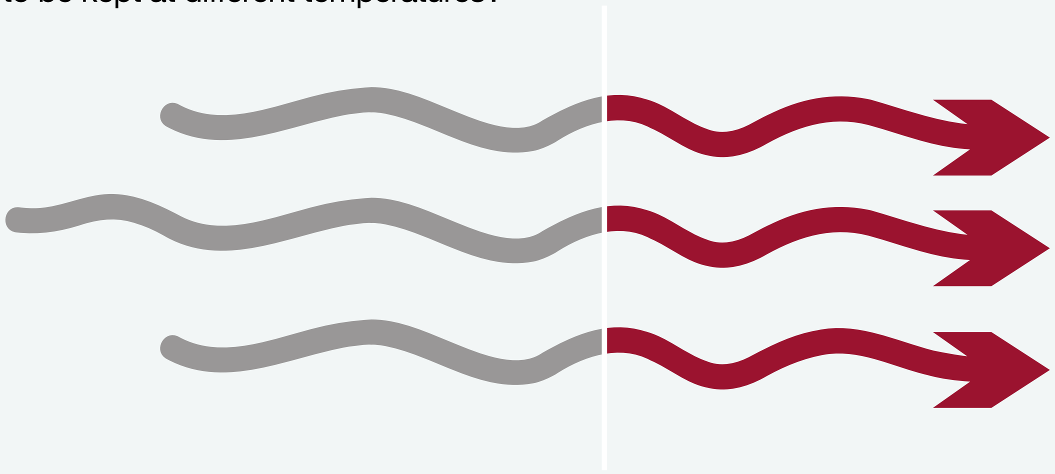
As before, one should be able to see why additional equipment would be needed to truly supply the appropriate air for each room to be considered comfortable for the occupants.

In carefully reviewing the previous (basic) examples for possible building HVAC equipment usage, it should appear clear, that to provide the desired level of air comfort for the many rooms, additional equipment would be required.

For this discussion, suppose that the outdoor temperature is at the freezing level, and therefore heating the air would naturally be something required to make the conditioned spaces for comfortable. Then ask yourself, how could this be done in a manner that allows all rooms to be kept at different temperatures?

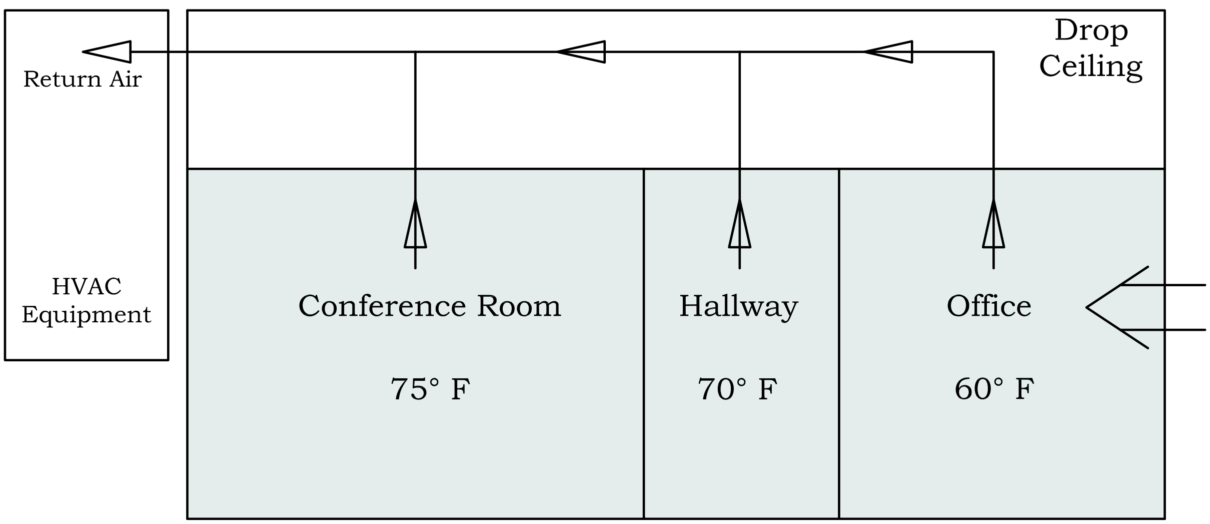


One possible answer could be to provide an Electric duct heater to supply specific predetermined zoned areas at certain levels in the building. The Kw needed for a “duct heater” in this case may be larger than in cases were more heaters are used. Although this might allow the system to keep the room temperatures closer to the desired value, it may not provide enough heat in certain areas that could remain cooler in the building. Therefore, suppose you provide an Electric duct heater for each room you want to remain conditioned and heated comfortably. The Kw for the multiple “duct heaters” used in this case would likely end up much smaller due to being used for smaller overall areas.

If we consider one room as an example and further assume that this room has one air duct that is used to draw air out of the room (return air) and one air duct to supply air into the room (supply air), we can conceptualize a possible solution. The figure shown below is intended to illustrate the basic principle being discussed. When reviewing this figure, please keep in mind that the main HVAC equipment would be gathering return air from all rooms to which it may be attached. Further, keep in mind that this return air would be made up of air being drawn from rooms which are all (likely) at different temperatures, but none of which would be at the outdoor freezing air temperature.

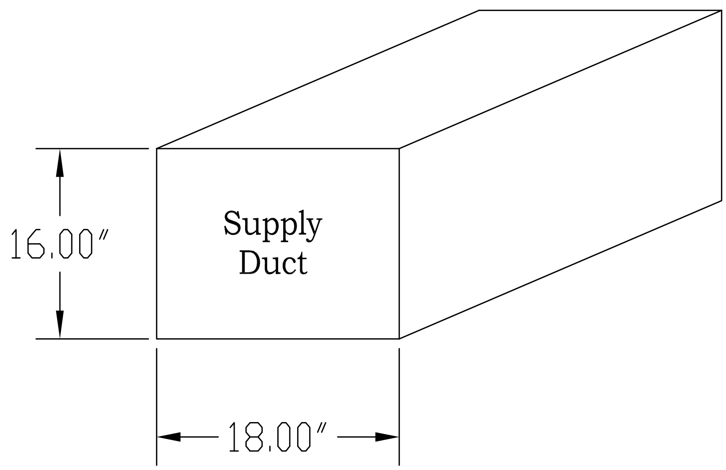
Consider a system in which the main HVAC unit may contain a larger Electric heater, used to temper air to a pre-set value. This would be of great value to the system since the additional heaters would then only have to be used to further refine the air temperature as it is being supplied to the rooms.

What if this office is on the ground floor, located on a shaded side of the building, and has a cold draft coming through a leaking window? As you can see the temperature of possible supply air would be made up of the 3 rooms shown and the leaking office would seem to always be colder than the other rooms.



As shown above, this office is always colder than the other areas in the building and since the HVAC system is only supplying air that is a mixture of the 3 rooms shown, the office will continue to be colder although the employee in this office would like to keep the room at 75° F rather than the colder 60° F. What could be done to eliminate this problem?

You call a Mechanical contractor and he determines that this cold office has 2 different air ducts located in the room. One air duct is used to draw air out and return it to the HVAC equipment where it is mixed with air from other rooms and redistributed to the cold office through the second air duct, lets call this duct the supply duct. The contractor measures this supply duct and determines that it is 16 inches high and 18 inches wide.



The contractor tells you that he could check into sizing and installing an Electric duct heater. This “duct heater” would be mounted inside the supply duct and be connected to a thermostat he could locate on the wall in your office. Certainly, you think this is a good idea and you would be more comfortable in your office. So, you ask your boss if the company would be willing to buy this duct heater and have it installed in the supply duct providing conditioned air to your office. Your boss tells you to ask the contractor if the main HVAC equipment (currently supplying the entire building floor) has an electric heater that can be used to warm your office. The contractor says, yes the HVAC equipment has an electric heater but it is not the same thing as a “duct heater”. He tells you that the HVAC equipment manufacturer makes the electric heater (custom built) and is designed to be used and located only inside this specific HVAC equipment. He calls this an “electric heat kit” or a “packaged electric heater” and tells you that the heater in your floor’s HVAC equipment is the largest heater that can be installed inside that particular size and brand.

The contractor tells your boss the same thing and your boss asks the contractor to size and quote a “duct heater” that can be installed in the supply air duct for your office and to mount a thermostat in your office so you can adjust the setting to give you the comfort level you need. The contractor says he will bring his equipment and get started.

The Mechanical contractor begins by making a list of information he will need. The contractor will be responsible for ensuring the “duct heater” is sized properly and installed per the heater manufacturer’s recommendations.

Here is his basic list of information:

1. The office supply duct measures 16 inches high by 18 inches wide

2. Since “duct heaters” must be installed at least 4 feet downstream from an air handler, the contractor ensures that the area he intends to place the heater into is not to close to the HVAC equipment. One reason he tells you this is important is that he wants to be able to be sure that air is flowing evenly over the entire face of the “duct heater”. He tells you that if the airflow is not even over the face of the heater, that parts of the element wire will run much hotter where there is less airflow. This could cause the “duct heater” to run too hot and burn out quickly since the air is not being properly applied. He also says this could cause the “duct heater” to stop heating automatically, because the heat may not be flowing through the supply duct as it was intended. This could overheat the safety limit switches which turn the heater off. So, if uneven air is flowing over the “duct heater”, it will not work properly or safely.

3. While the HVAC system is running, the contractor then checks the airspeed coming through the supply duct and determines that the airspeed is 600 feet per minute and is at a temperature of 72° F.

4. From his experience in sizing heating loads, the contractor determines that you will need around a 7.0kw “duct heater” to account for the size and losses in your office and still maintain the temperature you want.

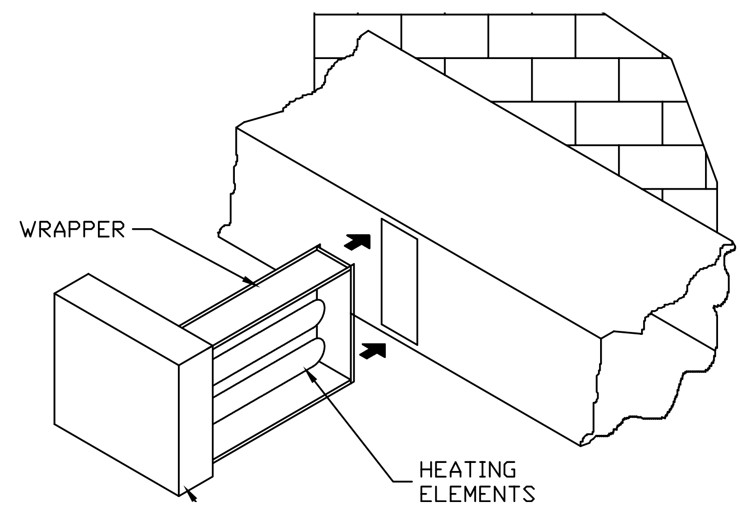
5. The contractor also determines that he can easily provide wiring from a power source of 240 volts single phase.

6. The contractor also tells you that since the “duct heater” is not a part of the HVAC equipment, you will need the heater to be supplied with what is called an airflow switch. He tells you that this airflow switch (which is installed in the heater at the factory) will sense when there is a pressure difference inside the “duct heater” control box and in the supply duct. What this means is that the heater with the airflow switch is not meant to come on, unless there is air flowing through the duct. He says this is very important since the “duct heater” is a stand-alone device and must have airflow provided from some separate source, the HVAC equipment in this case. So, in this case, the HVAC equipment is providing airflow at 600 feet per minute and air at a temperature of 72° F. The “duct heater” is to be used to increase the air temperature that is being supplied to your office.

7. More recommendations from the contractor are that the “duct heater” should be ordered with a disconnect switch and power fusing as well. He says this will provide the heater supply wiring with fused protection, so if the heater has a short the fuse will turn the power off and not continue to supply power to a heater with a problem. Also, the disconnect switch will not allow the service people to open the heater control box without the power being disconnected. He says this disconnect has to be turned off before the heater door will open and that this switch turns the supply power to the unit off.

He also says the system will be much easier for him to install with the disconnect switch already in the “duct heater” since if it were not he would have to mount a separate disconnect switch anyway, so the service people have an easy and noticeable way to turn the heater off before opening the control box door. He also says the “duct heater” manufacturer can install this disconnect switch for less money, therefore saving you money on the overall installation cost.

8. When the contractor inspects the area where he intends mounting the “duct heater” he sees that the duct is running along the edge of an interior wall and he cannot access one side of the duct. He also says that is not a problem since he intends ordering what is called a “slip-in” heater. An appropriate size hole is cut in the duct, from one side only and the heater section containing the heating elements simply slides into the hole and the control box is sealed and fastened to the duct.



9. One last thing the contractor does is to ensure that the location where he intends to mount the “duct heater” is at least 2 feet away from the turn in the supply duct used to allow the air to turn and flow down into your office. He says that one reason for this is so the downturn in the duct does not cause the air flowing across the heater to become uneven and he already told you how important even airflow is across the entire heater.

You ask the contractor, what about the thermostat you need on the wall in your office. The contractor tells you he intends using what is called a 2 stage thermostat to control when the “duct heater” is to come on. Therefore he intends ordering a 2 stage heater, which means that the 7.0kw heater would come on 3.Skw at a time. So, if the thermostat temperature you set indicates that your office is not extremely cold and the thermostat turns on only one stage of the “duct heater”, then only 3.Skw would come on and warm your office. However, if the temperature is much colder (and the thermostat is not satisfied) this thermostat can demand more heat, then both stages could come on and you would have (2) 3.Skw stages running in the “duct heater”, for a total of 7.0kw.

You tell the contractor he has been extremely helpful but you are curious about how he knows that he can put a 7.0kw heater in the supply duct to your office. He tells you he will show you some of his calculations.

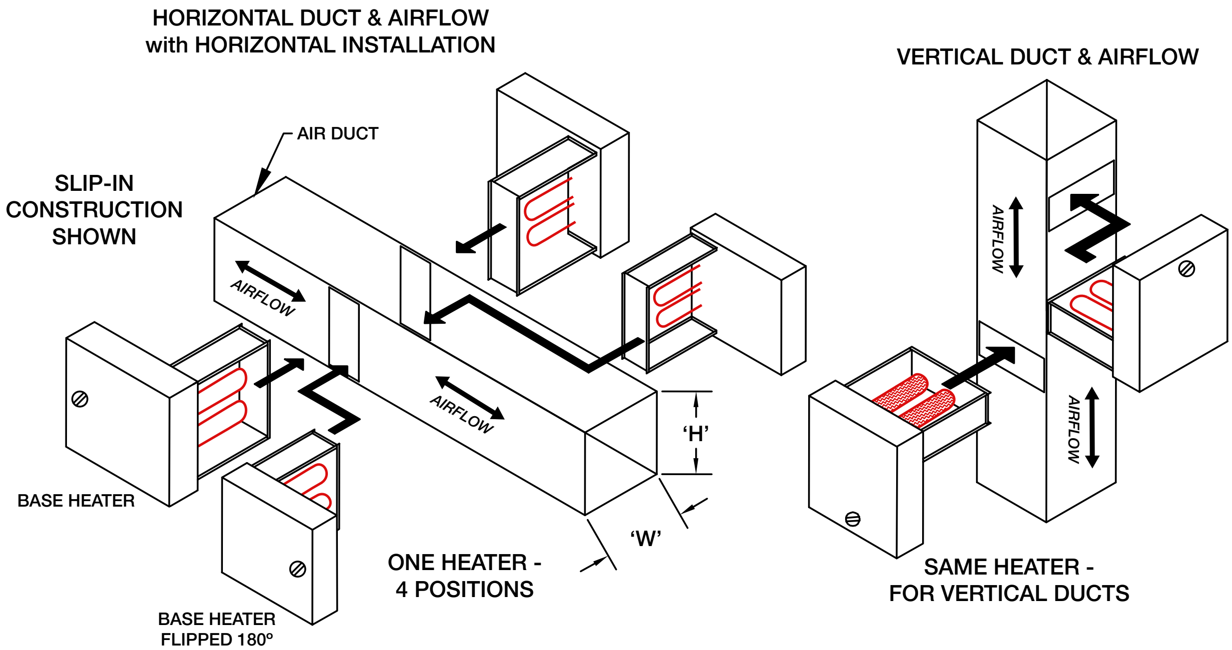
He gives you some possible steps as shown below:

1. He measured the duct and it was as we said previously 16 inches high and 18 inches wide. So he can calculate how many square feet of area is inside the duct.

$$\text{DUCT AREA} = \frac{(16.0 \times 18.0)}{144} = 2.0 \text{ SQUARE FEET}$$

2. Since he intends to put 7.0kw (or 7000 watts) in the supply duct, he can figure how much Kw per square foot will actually be inside this duct.

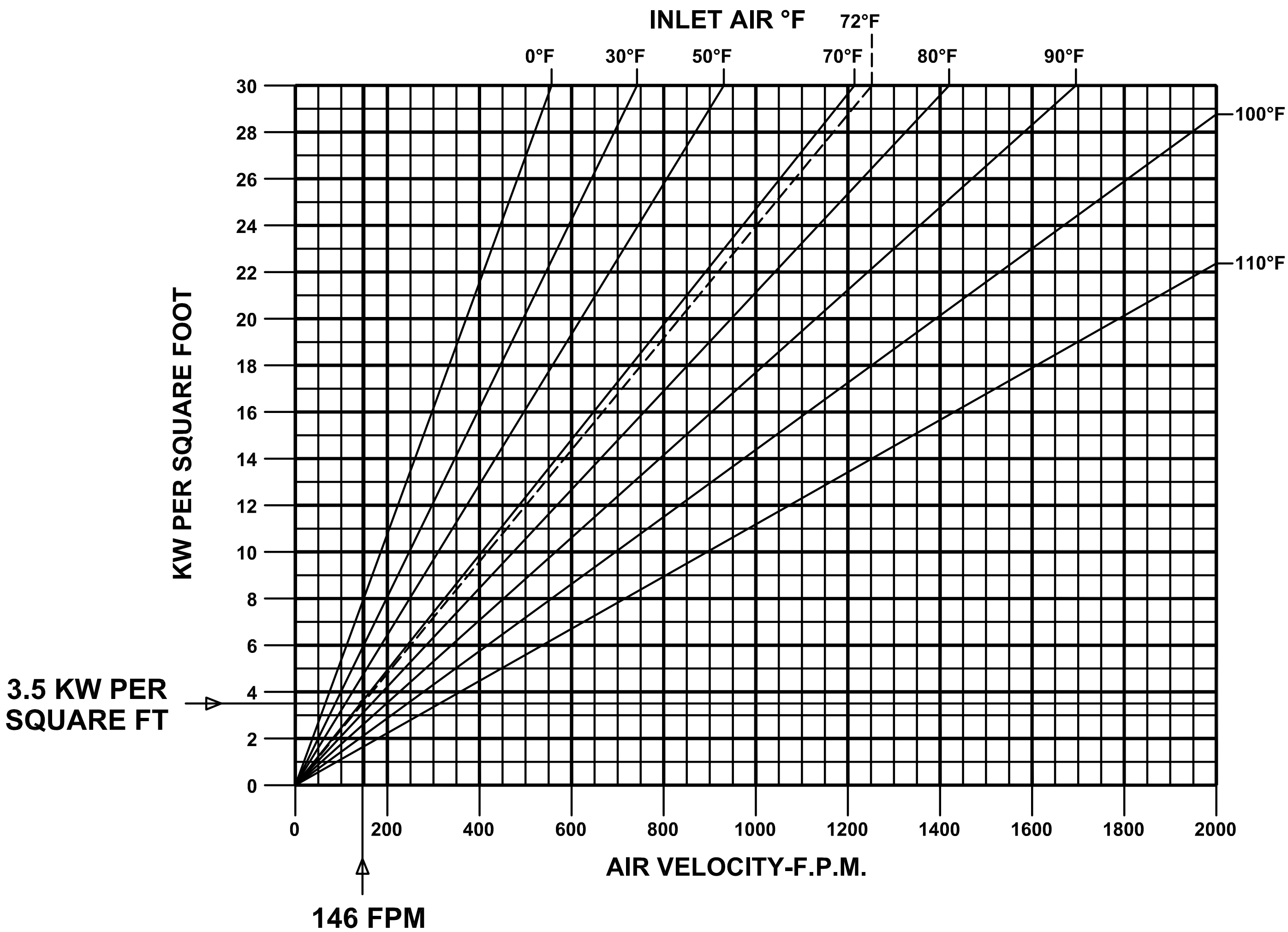
$$\text{WATTS PER SQUARE FOOT} = \frac{(7.0 \text{ Kw})}{2.0 \text{ SQUARE FEET}} = \begin{matrix}\text{3.5 Kw PER} \\ \text{SQUARE FOOT}\end{matrix}$$



3. He has a Tutco "Duct Heater" catalog and in this catalog, there is a chart which will give you an estimate as to what your airspeed needs to be through the "duct heater" depending upon how many watts per square foot you have and what the temperature of the air is flowing over the heater.

You tell him you remember him saying that the airspeed was 600 feet per minute and the air temperature was 72° F.

The contractor tells you (you are correct) and with the calculation made, now you also know that since your duct is 16 inches high and 18 inches wide, that you are attempting to put 3.5 Kw per square foot inside the duct. See the chart on the next page and check to see if you have enough airflow over the face of the heater, please remember that the airflow must be at least this minimum value at any point across the entire face of the "duct heater". Also note, these values can be easily determined by using the simple Calculator located on the Tutco website.



The chart indicates that with 3.5 Kw per square foot, that a minimum of 146 feet per minute airspeed is required at any point in the duct and over the face of the “duct heater”. Also, please notice that since the inlet air is 72° F, you can estimate the line location on the graph that is slightly greater than 70°F. This intersection point tells you that since you actually have 600 feet per minute airspeed, then you should have enough air to satisfy the “duct heater” requirements, as long as the air is evenly distributed.

Please note:

If you do not have access to the Tutco charted data and you simply want a rough estimate for minimum airflow in this case, you can use the simplified equation below. Please understand this is an estimate but may be a helpful estimation.

$$\text{CFM/Kw MIN.} = \frac{3150}{(148 - \text{INLET AIR}\ ^{o}\text{F})}$$

$$= \frac{3150}{(148 - 72^{o}\text{ F})}$$

$$\text{CFM/Kw MIN.} = 41.5$$

So: If the minimum CFM/Kw is estimated to be 41.5 then we can easily further estimate the following,

$$\text{CFM MIN.} = 41.5 \text{ x } 7.0 \text{ Kw}$$

$$= 291 \text{ CFM FOR } 148^{o}\text{F OUTLET AIR}$$

Please understand this is simply an estimation for the very minimum airflow, under the conditions given. When using this CFM value the Outlet Air °F will be estimated at ~ 148°F. So, for the Outlet Air °F you need you will need to apply more airflow than this estimated value.

Consider this:

Let's see how this estimation compares to the values found using the charted data.

$$\text{CHARTED DATA} - \text{CFM} = \text{FPM x } 2\text{FT}^{2}$$

$$= 146 \text{ x } 2$$

$$= 292 \text{ CFM}$$

As you can easily see the estimate and the Charted data values are very close and so there is value in the ability to estimate min. CFM value.

You understand this but for clarity, you ask, if the air temperature going into the "duct heater" is 72° F and the heater is running with all 7.0kw on, What should be the approximate temperature of the air when it is exiting this heater at the value of 600 FPM?

4. The contractor says, this is a very good question and he tells you that to determine this value, it depends upon exactly what you are trying to heat up. You laugh and say you are trying to heat the air up correct? He says yes, the air is what you are trying to heat, but air has certain physical properties that have to be considered to determine how much warmer the "duct heater" will make this air. He goes on to tell you that if you focus on the density of the air you are trying to heat and relative humidity, you should begin to understand how this is related to the temperature increase you need.

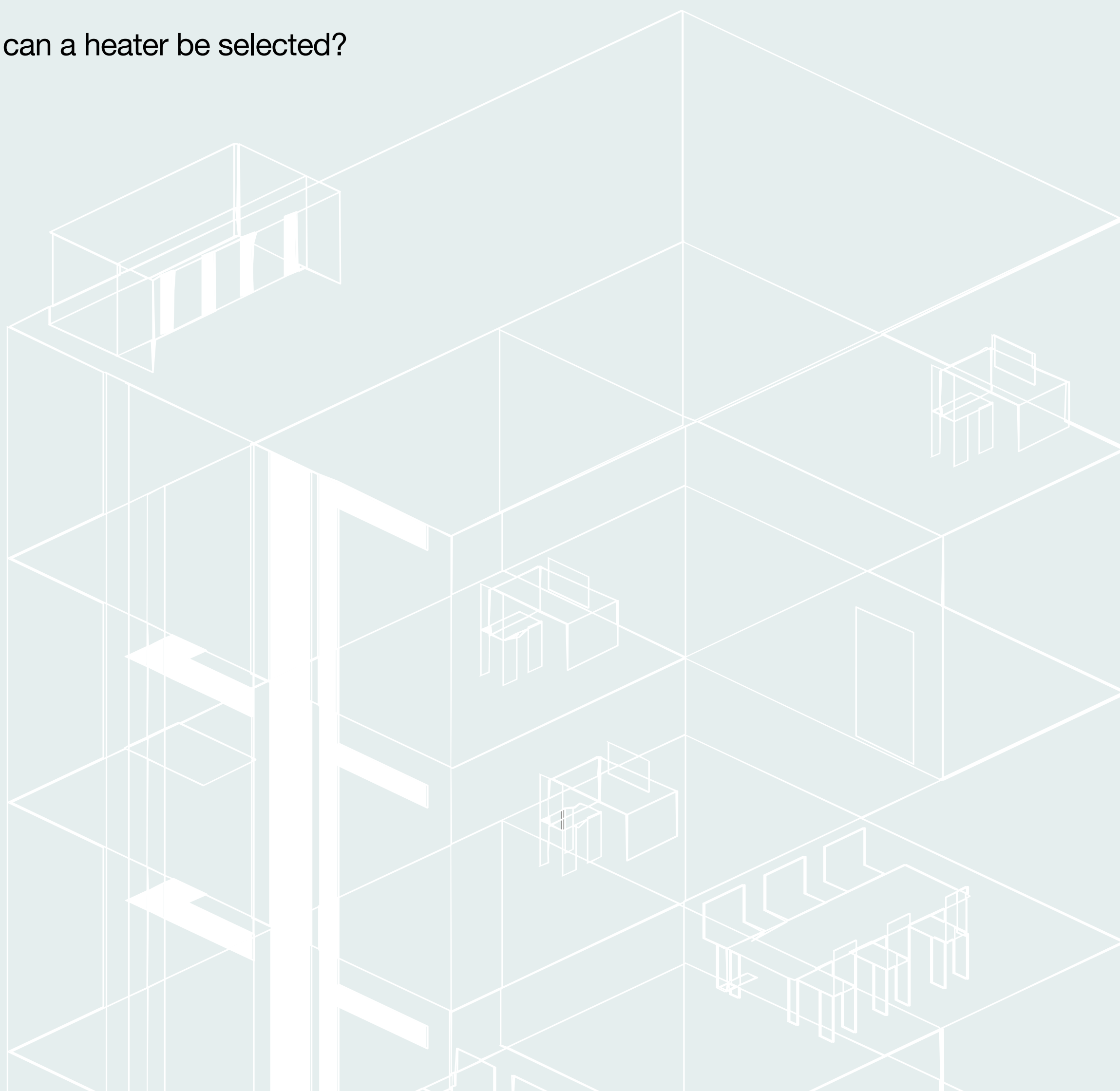
What could affect the air density?

-The elevation as related to sea level: As the elevation above sea level increases, the less dense air becomes.

-The amount of water vapor in the air: As the relative humidity increases, the amount of water vapor present increases. Therefore the higher relative humidity becomes and the more saturated air is with water vapor, the less dense the air becomes for a specific volume.

-The temperature of the air: As the temperature of air is increased it will become less dense.

The contractor tells you that if he had to consider, measure, and use all the influences at the same time to determine the required Kw, he would never get his job done. He also says that if he was truly going to calculate the exact Kw requirement based on CFM and temperature rise (using all other influences) he would have to re-calculate as the heater was actually running. He says that elevation certainly effects the air density and the Kw needed to heat air. However, he also says that since relative humidity also affects the air density, then to be exact you would have to consider the following things at the same time and re-calculate as they are changing. With moist air you are actually heating both air and water vapor and as you drive moisture from the air, the density changes, and thus the exact calculation changes. Further, as you heat the air the density changes, and as you apply these heaters at different elevations, your density changes, and thus the exact calculation changes. These items are certainly not every influence that affects the exact heat calculations, so it gets more and more complicated to be exact. So, if it is this complicated to be exact, how can a heater be selected?



Kw and Temperature rise estimates:

Since the installation of each of these type “duct heaters” can vary so much and have so many influences (as you now know), it should become apparent that the “duct heater” manufacturer could not possibly size the heaters for the end-user or the contractor. So, the contractor must calculate the heat losses and determine which influences he feels will affect the heater performance. After having done this he will determine the Kw needed to do the job. He must also, be responsible for ensuring that the proper amount of airflow is present and evenly distributed over the entire face of the heater.

1. The contractor can assume that the air being heated is “dry air”, at least at the point the “duct heater” is installed. Meaning relative humidity will not be used as an influence, which makes estimates easier.

2. Another estimation could be that as a general rule the air density could be approximated based upon the temperature of standard “dry air” at 70° F. This means you could use the value of (0.075 lbs/cubic foot) for the density of air at sea level.

3. Using these assumptions and estimations you could derive an easy formula to help estimate the possible temperature rise that may be created with the Kw and CFM you will have available. Please see the formula below.

$$TR = \frac{Kw \times 3150}{CFM}$$

$$TR = \text{(TEMPERATURE RISE)} = (\text{OUTLET AIR } ^{o}F - \text{INLET AIR } ^{o}F)$$

The contractor says this is a good basic approximation that he can use to get some idea if he has asked for enough Kw. He also says that since this approximation was made at sea level (where the air density is greater than at higher elevations) he can be sure that if he installs the heater at a higher elevation, he should have enough Kw to do the job. Since the heater is going to be controlled by the wall thermostat, the heater will simply heat the air to the thermostat temperature setting and then turn off anyway.

4. Back to the exiting air temperature question: Using this equation you can get the estimate for the exiting air temperature you might expect from the "duct heater". First, you need to calculate the airflow CFM.

$$\begin{aligned} \textbf{CFM} &= \textbf{AIR SPEED x DUCT AREA} \\ &= \textbf{600 FPM x 2 SQUARE FEET} \\ \textbf{CFM} &= \textbf{1200} \end{aligned}$$

Using the estimation equation you can determine the following exit air temperature that might be expected, leaving the "duct heater".

$$TR = \frac{Kw \times 3150}{CFM} = \frac{7.0 \times 3150}{1200}$$

$$TR = 18^{o}F$$

So, if the inlet air temperature was 72° F, then the exit temperature could be expected to be around 72° F + 18° F = 90° F.

The contractor tells you that he has determined the Kw he thinks will be sufficient to keep your office warm and that the installation can be done per the manufacturer's requirements, he can now order the "duct heater" and install it when it is received. He tells you that the information shown in the following list is all he needs to supply the "duct heater" manufacturer to build the heater he needs.

Information needed to order the "Duct heater":

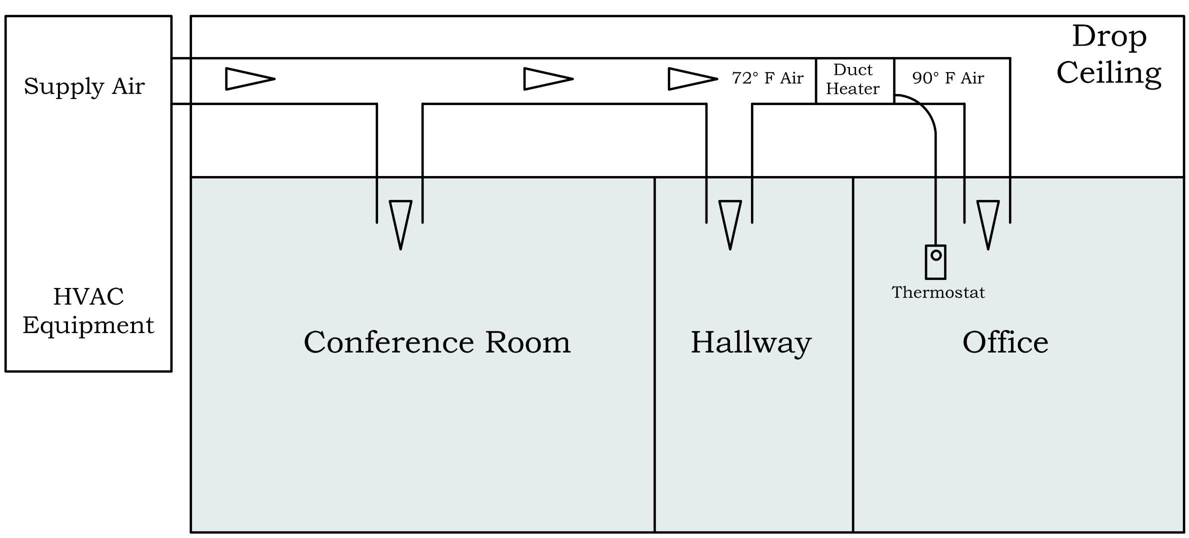
- The heater should be a "Slip-in" type or "S" type "duct heater"
- 7.0kw
- 240 volts 1 phase supply power
- 2 stages are required
- Control voltage of 24 volts
- Heater "H" height required = 16.0 (the duct height)
- Heater "W" width required = 18.0 (the duct width)

***Heater should also contain the following factory-installed accessories:**

- Airflow switch
- Door interlocking disconnect switch
- Power fusing
- Control transformer

Looking at the contractor's list you say, what is a control transformer, and why are you ordering a control voltage of 24? He tells you that it will be easier and less expensive for him to allow the "duct heater" manufacturer to install the control transformer needed to power the heater contactors. He says he could buy and install it himself but really has no place to mount this device himself. You ask, why can't you install it inside the "duct heater" control box when you get the heater? He says the heater manufacturer does not allow field-installed items to be added to the heater control box and the thermostat I plan to use if very basic and does not need to be powered anyway. This thermostat is simply being used as a switch to control each heat stage. The "duct heater" must-have contactors installed which are used to turn the heat stages on and off. These contractors must have power applied and the easiest and least expensive way to provide this is to let the heater manufacturer size, install, and wire this device. Certainly, there are other options for control voltages available, but the 24-volt controls are likely the most used in industry and it is cheaper and easier to have the "duct heater" company install the transformer.

After the "duct heater" is installed, you thank the contractor and tell him later that it is very comfortable in your office since he installed the new "duct heater". See the simple description of the "duct heater" installation shown below.



Additional Information:

As mentioned before, if you do not have access to the Tu.tea charted data and you simply want rough estimates for minimum values or approximate values, consider the following equation.

ESTIMATE

$$\text{CFM/Kw} = \frac{3150}{\Delta T\ ^{\circ}F}$$

Example:

Let us say you want to use the estimation equation to help your understanding of how much Kw you may need for a specific application.

The requirements are; L:\T = 20°F and you have CFM = 950

Using the estimation equation.

$$\text{CFM/Kw} = \frac{3150\ /\ 20^{\circ}F}{= 157.5}$$

Since you have 950 CFM you simply divide as follows 950 / 157.5 = 6.0

After dividing you can see you will need about 6.0 Kw to get a L:\T = 20°F under these conditions, this is a very simple estimation.

Note: This equation can be used for many related calculations and estimations. Simply rearrange the equation and solve it for a simple estimation value.

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ESTIMATE

$$\text{MIN. CFM} = \frac{\text{Kw} \times 3150}{(148 - \text{INLET AIR } ^{o}\text{F})}$$

; when Kw and Inlet Air °Fare known

ESTIMATE

$$\text{REQUIRED CFM} = \frac{\text{Kw} \times 3150}{(\text{OUTLET AIR } ^{o}\text{F} - \text{INLET AIR } ^{o}\text{F})}$$

; when Kw, Inlet & Outlet Air °F are known

ESTIMATE

$$\text{OUTLET AIR } ^{o}\text{F} = \frac{\text{Kw} \times 3150}{\text{CFM}} + \text{INLET AIR } ^{o}\text{F}$$

; when Kw, Inlet Air °F & CFM are known

ESTIMATE

$$\text{Kw} = \frac{\text{CFM} \times \Delta\text{T } ^{o}\text{F}}{3150}$$

; when CFM & ΔT °F are known

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