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Challenges and Methods of Estimating a Conceptual HVAC Design

ABSTRACT

In any conceptual HVAC design, estimators are faced with the challenge of trying to capture all of the pieces that complete a system. The difficulty in this can be that they there is limited information for the estimator to fully complete an estimate. The only way to accurately complete an estimate is for an estimator to use past experience.

Using previous completed jobs as a template can help an estimator determine how to approach the estimate. Another advantage of having this experience is knowing the order in which the HVAC components should be taken off, since one item will affect how another is quantified. Past jobs will help an estimator determine how much ductwork is needed based on square meter calculation, or how much piping will be needed for each piece of equipment.

The contents of this paper will discuss the major components of a HVAC system and the difficulties and methods in determining quantity with limited specifications and information. There are three major cost components that make up a mechanical system. These include equipment, piping, and ductwork. These three items will be discussed in detail on how their design and layout can impact cost and how to determine what is actually needed to complete the system with little information. Only the most common HVAC designs will be identified in this technical paper.

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INTRODUCTION

Estimating a conceptual HVAC system can prove to be difficult, especially if drawings are not yet designed. Many factors have to be considered when trying to visualize how a HVAC system will be built. In many cases when trying to estimate a project that has not yet been completed, an estimator essentially has to become an engineer. Use of experience and knowledge is needed to complete a design that is incomplete.

Thirteen years of experience as an estimator has given me the opportunity to work on many different types projects where the HVAC was not yet designed. It has given me the chance to see different engineered systems and how they are used. Working with these different systems has helped me accurately put together cost estimates with little information. This experience and knowledge proves to be useful, especially if architects are uncertain that a specific design will work and be with-in a project budget. HVAC costs can often be one of the most expensive internal components of a project. Being able to fully understand and estimate its value, can make an estimator very beneficial to a project that is still in the early stages of design.

HVAC EQUIPMENT

The most complex and expensive component of a mechanical system is the equipment. In any commercial project the goal of the mechanical equipment system is to heat and cool the building the most efficient and cost effective way. The first thing an estimator must establish is what type of mechanical system is being used. Most of the time big components of equipment will be listed and sized in the narrative. The challenge to the estimator is that not all of the smaller equipment will be shown to complete the system.

Two things to always consider when doing an HVAC estimate is: what type of equipment will heat and cool a building and, what type of equipment will supply and exhaust the air. These two components are different in nature, but act as one to complete a system. In the following paragraphs, I will explain how using information obtained from the narrative or architect will help an estimator. This information will include size of the building, number of rooms, function of the building, and what type of major HVAC equipment will be used. It will also help an estimator identify additional equipment that will be needed and the quantities. This will insure that the estimator has effectively put together a complete system and all of the components are captured.

MAIN HEATING EQUIPMENT

The method used to heat and cool a building is to supply hot and cold water to the air supply equipment coils. Heat for the HVAC system can be achieved two different ways. The most cost effective system is to use steam to heat the water. This is assuming steam utilized comes from an existing steam plant which is commonly found on large university sites or large medical facilities. Steam is used to heat water through the use of a heat exchanger and estimators must be aware that a pressure reducing station will be required if this system is used. Figure 1 (steam heat exchanger) is an example of how a steam heat exchanger works.

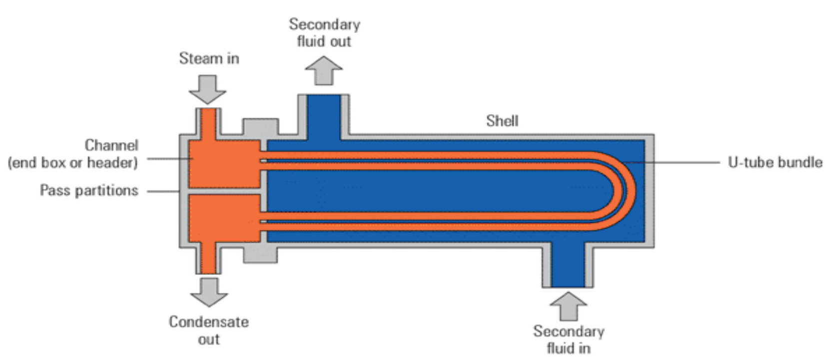

Figure 1 Steam Heat Exchanger

The second most common way to heat water is through the use of boilers. Boilers can be heated by the use of electricity, coal, steam, or gas. Depending on the size of the building, the most common method in commercial construction is the use of a gas boiler. Typically, any building over 1,859 square meters uses gas because it provides benefits such as cost and heating efficiency.

Figure 2 (gas fired boiler) shows how water enters a boiler and is heated.

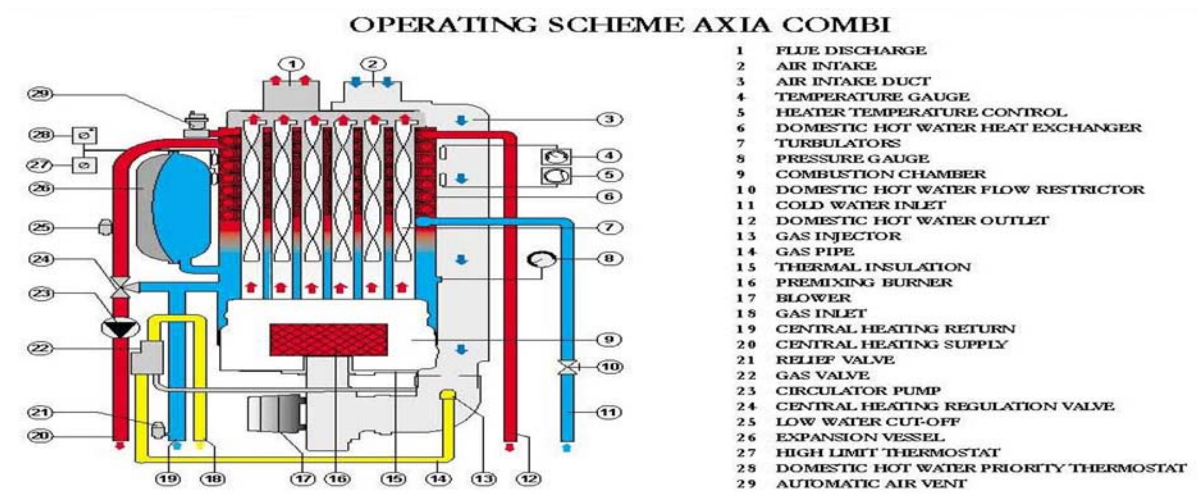

Figure 2 Gas Fired Boiler

MAIN COOLING EQUIPMENT

Cooling a building works in the same manner as heating, except the equipment will cool the water instead of heat it. The most typical way to cool water is through the use of a chiller. There are two different types of chillers. The first is a water- cooled chiller and is commonly used in buildings over 1,858 square meters and has become a common practice in commercial construction. An estimator must be aware that if a water-cooled chiller is used, than a cooling tower must also be utilized on the roof. Water-cooled chillers produce higher tonnage (cooling capacity) at lower costs per ton, creating energy efficiency.

The second type of chiller is an air cooled chiller. Though this type of chiller is not as effective as a water cooled chiller, it can be used when there is limited space inside a building. Air cooled chillers can typically be found in smaller office buildings and generally cost less, however they carry a higher energy cost. Figure 3 (water-cooled chiller) is an example of how a cooling tower helps release heat from the water to help cool the chiller.

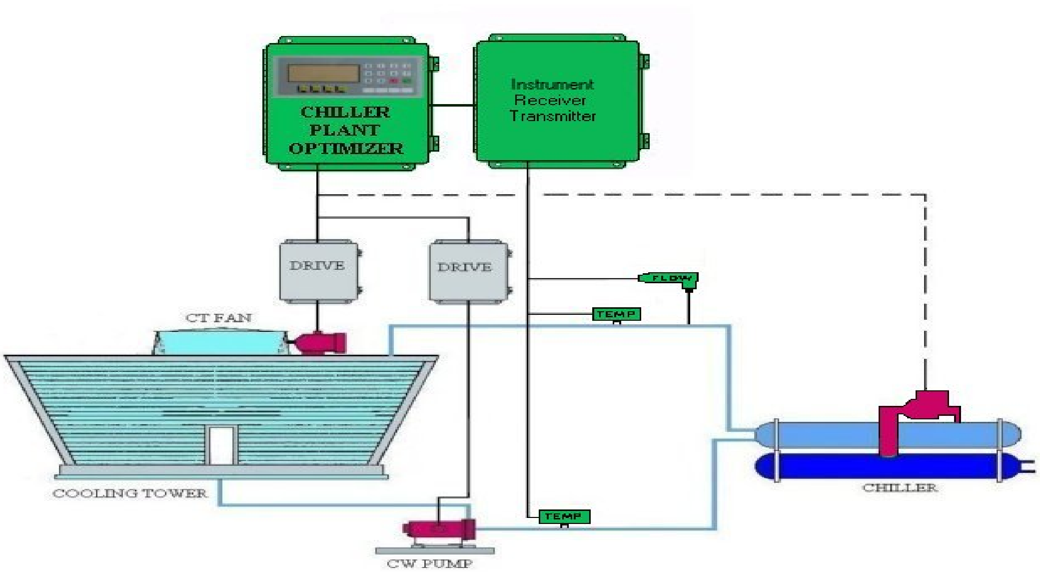

Figure 3 Water-Cooled Chiller

PUMPS

An estimator must be aware that for every piece of heating or cooling equipment, there is a pump that is needed to distribute water from the equipment to the heating and cooling coils of the air distribution equipment. This information may not always be communicated to the estimator. These pumps can vary in size depending on the size and load requirements. Typically two main primary pumps and a recirculation pump for each of the heating and cooling system will be needed. The main pumps will feed the majority of the system while the recirculation pump will help maintain the pressure of the system and return the water to be heated or cooled again. Along with the pumps, the estimator must allow for an air separator and an expansion tank for each system.

MAIN AIR SUPPLY EQUIPMENT

The most common piece of equipment that will supply air to a building is called an air handling unit. This is almost always used in a commercial building. The purpose of this piece of equipment is to move air from outside to inside a building and to heat and cool air through the use of hot and cold water coils. It also takes the exhausted air from the building back out into the atmosphere. An estimator will need to be aware there could be an energy recovery wheel that is included with the air handling unit. This recovers heat from the exhausted air and reuses it to save energy. Energy recovery wheels can often be expensive so an estimator must ask if it will be part of the air handling unit system. Figure 4 (air handling unit) is an example of how air will pass over the coils, thus transferring hot or cold water coils to the air.

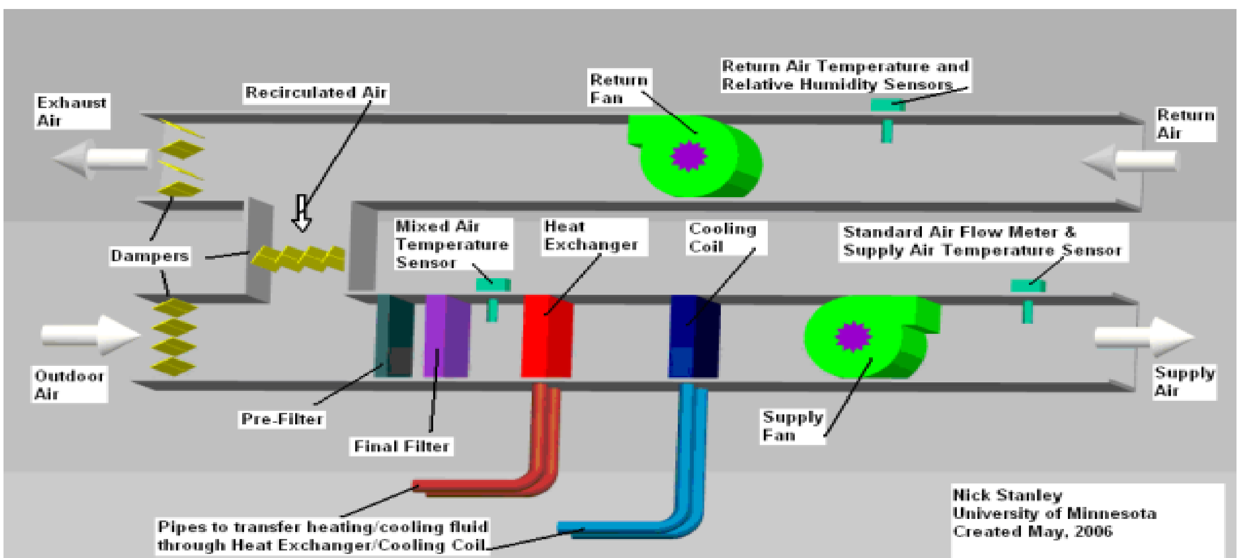

Figure 4 Air Handing Unit

VARIABLE AIR VOLUME BOXES

A list of the major pieces of equipment is typically what the estimator will be given before the start of an estimate, however smaller pieces of equipment that are used to help enhance the system may not. These pieces of equipment may not be shown on schematic design drawings and will have to be included based on the building type and the number of rooms. One of the most common methods to help enhance a system is to install variable air volume boxes (VAV boxes). These are small boxes that are installed in between the ductwork. Variable air volume boxes come with different internals depending on the buildings needs. Table 1 (variable air volume box variations) shows the different variations of these VAV boxes and the most common ones used for different types of buildings. Typically there is one for every two rooms. So if an estimator knows the number of rooms and the buildings use, one can accurately calculate the type of VAV box and the number of boxes that will be needed.

Common in small labs where airflow control is needed	**Common in buildings 929 square meter or bigger**	**Commonly used in labs, where temperature control is needed**	**Most common in smaller buildings, 929 square meter or less**
VAV box with fan only	VAV box with fan and hot water reheat coil	VAV box with fan, hot water reheat coil and cooling coil	VAV box with fan and electric reheat coil.

Table 1- Variable Air Volume Box Variations

SUPPLEMENTAL HEATING AND COOLING EQUIPMENT

It is common in buildings to have some areas that do not receive enough heat through the central heating, or that there simply is not enough insulation to contain the heat. To help supplement heat in these areas, small heaters are used. These include fan coil units, unit heaters, and cabinet unit heaters. These act in the same way as variable air volume boxes, however, they are not connected to the ductwork and can be placed anywhere in a building. These pieces of equipment can also be heated through the use of hot water pipes or through electric coils. Electric coils are the most common method used since it saves cost by eliminating having to run pipes to these units.

Common places to place such equipment are in areas such as stairwells, mechanical rooms, and entrances to buildings. An estimator must be aware that if a building has an elevator, than the building will also have an elevator machine room. This room houses all the elevator's equipments. This equipment tends to get very hot and requires the use of a split system air conditioning unit to help cool down the room. This unit is very similar to what is used in residential homes, but not as big. It consists of an outside condenser, inside fan unit that has cooling coils inside it and piping between the two.

HVAC EQUIPMENT OVERVIEW

Now that all of the components of the HVAC equipment have been covered and it is understood how they function, one can see there are many different variations and combinations of equipment that can be used to complete a system. Table 2 (example of building equipment) shows how an estimator can decide what other pieces of equipment will be utilized depending on building size, type, and number of rooms. As stated earlier, the designer has the ability to choose which system will be used. Being able to identify the smaller pieces of equipment and knowing the different setups will help an estimator ask the question, "What type of system are we using?"

2,787 square meter office building, 100 rooms, 2 elevators, 2 mechanical rooms, 3 entrances	**Quantity (each)**
Air handling units	2
Water cooled chiller with cooling tower	1
Boiler	2
Hot water pumps	3
Chilled water pumps	3
Expansion tank and air separator	2
VAV box with hot water reheat	50
Unit heaters for mechanical rooms	4
Split system AC unit for elevator machine room	2
Cabinet unit heaters for entrances	3

Table 2-Example of Building Equipment

EQUIPMENT PIPING

The second component of HVAC equipment system is the piping that is needed to carry hot and cold water to equipment coils. An estimator has to accurately calculate the quantity of piping that is needed. Again, past experience will help an estimator accomplish this challenge. In every HVAC system, there is a hot and cold water system. For each system there will need to be a supply and return pipe. This means for every piece of heating and cooling equipment, there are two pipes going to it. An estimator has to be aware that some pieces of air-supply equipment have both hot and cold water running to it, so it will require two sets of piping.

QUANTIFYING PIPING

In order for an estimator to take off the quantity of pipe needed, one would have already established the equipment used to heat and cool the water, and the equipment needed to supply the water to the air distribution system. For example, an estimator would have already known if the variable air volume boxes would be using electric reheat coils or hot water coils. Once an estimator has the equipment quantity, an average length can be taken for each piece of equipment depending on the building size. Buildings less than 929 square meters will have an average length of 18.3 meters per set of pipe. Remember, there is supply and return piping for each hot and cold water supply. Any building over 929 square meters, 30 meters will be used. However, if the supply air equipment contains more than one coil, this number will be doubled. Table 3 (piping quantities) is an example of a building equipment list taken from table 2. This will show the number of coils and pipes going to each piece of equipment and the average length that can be used to help an estimator come up with an accurate quantity.

2,787 square meter office building, 100 rooms, 2 elevators, 2 mechanical rooms, 3 entrances.	Quantity of equipment	Number of heating and cooling coils	Number of sets of pipes going to equipment	Total meters of pipe Quantity x sets of piping x 30 meters
Air handling unit	2	2	2	122
Water cooled chiller with cooling tower	1	0	1	30
Boiler	2	0	1	60
Hot water pumps	3	0	1	91
Chilled water pumps	3	0	1	91
Expansion tank and air separator	2	0	1	60
VAV box with hot water reheat	50	1	1	1524
Hot water unit heaters for mechanical rooms	4	1	1	122
Split system AC unit for elevator machine room	2	1	1	60
Electric cabinet unit heaters for entrances	3	0	0	0

Table 3-Piping Quantities

DUCTWORK

All projects require the use of ductwork to distribute and return air throughout a building from the air handling units. An estimator that has worked on past projects that have been built can accurately quantify the amount of duct needed when it is not shown. Since duct is priced per kilogram, using past jobs will allow an estimator to figure out the kilograms of duct that will be required for a specific building type by dividing the square meter of the building by the number of kilograms. For example: a 1,858 square meter office building that was completed last year required 10,000 kilograms of ductwork. So that equates to 5.38 kilograms of ductwork per square meter for a similar job.

DUCTWORK INSULATION

After an estimator calculates the kilograms of ductwork, one has to multiply the kilograms of duct by 70% to obtain the surface area of insulation. This is not a mathematical approach to the quantity of duct insulation, just a proven method amongst estimators. Like the ductwork, this is where an estimator's past experience is useful.

DUCTWORK MATERIAL

When quantifying ductwork, an estimator has to keep in mind that there can be different types of material used. Typically, ductwork is made out of galvanized metal. Laboratories required the use of stainless steel ductwork. Stainless steel ductwork is used when there are chemicals in the air that are being exhaust. One example of this would be exhausted air from a fume hood. When estimating a laboratory, using 15% of the total duct will allow for enough stainless steel ductwork.

AIR DEVICES

In every building, there are diffusers, registers, and grills used in the ceiling for the ductwork to connect to within the rooms. There is an easy method in quantifying these devices since they will not be shown. Typically every room will have two diffusers, one for the supply duct and one for the exhaust. An estimator can easily get the number of diffusers by multiplying the number of rooms the building has by two. This will include corridors, mechanical rooms, and electrical rooms.

CALCULATIONS

As you can see, the challenge for an estimator to accurately quantify the air distribution system is that they would have had to work on an identical building to obtain these calculations. Using these calculations and methods can help an estimator complete the air distribution system before it has ever been designed. Table 3 (air distribution calculation) shows a comparison of different building types and the amount of duct and accessories required per square foot. One will notice that a laboratory will require more duct than a typical office building.

Building Type	Kilograms of ductwork Per square meter	Kilograms of ductwork	Material of ductwork	Square meter of ductwork insulation, pounds x .7	Number of registers/grill
929 square meter office building, 23 rooms	5.38	5,000	Galvanized	3,500	92 ea
1,858 square meter lab facility, 50 rooms	6.84	12,708	85% Galvanized 15% Stainless Steel	8,895	100 ea
3251 square meter student dorm building, 300 rooms	4.89	15,913	Galvanized	11,139	600 ea

Table 4- Air Distribution calculations

CONCLUSION

Estimating a conceptual HVAC design can prove to be challenging. There are many methods estimators have adopted over the years to help accurately complete a system with limited information. HVAC equipment is one of the most important components in the system since it tends to have the highest overall cost. Making sure an estimator has quantified all of these pieces is important since the other components such as piping are impacted by these quantities. Since the equipment affects the quantity of the piping, the equipment should be the first item that an estimator focuses on. After the equipment that will be used is established, an estimator can accurately quantify the meters of pipe needed using the methods disused in this paper. Knowing the type of building and how it will be used is very helpful to the estimate since this influences the amount of duct that will be required. Estimators with past experience, as well as using the techniques and methods discussed, can help provide accuracy when trying to estimate quantities for a conceptual HVAC design.

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