Breadth Work

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Sound Transmission through Guestroom Walls

Mechanical - Lake Source Open-Loop Geothermal Heat Pumps

Introduction

The current design for the mechanical system to heat and cool the Erie Convention Center and Sheraton Hotel uses a small central chiller and boiler plant and packaged unitary heat pumps. The public areas are heated and cooled by a constant air volume (CAV) air and fan cooling units. The entry is heated by a radiant floor because of the high infiltration from the traffic entering and exiting the hotel. Areas near large amounts of glazing are additionally heated by resistive heaters. The individual hotel rooms are controlled by air-to-air window air conditioners/heaters to ensure the comfort of the guests.

The waterfront location of the Erie Convention Center and Sheraton Hotel allows for picturesque views of the water as well as all of the other activities happening in the area from the hotel itself. This location along the water though, has an added benefit that is not being taken advantage of: the use of the water to help heat and cool the building. This can be accomplished by implementing the use of lake source open-loop geothermal heat pumps.

Geothermal Heat Pumps

An air-to-air heat pump takes the heat from one side of the loop and rejects it into the other side. Refrigerant running through the heat pump will evaporate in the evaporator coil side of the loop (the inside for cooling, and the outside for heating), extracting heat from the air. Through the expansion and cooling of the compressed refrigerant, the fluid will then condense in the condensing loop, rejecting that heat into the space. This will warm an inside space in the winter by forcing warmer air into the room, or cool an inside space during the summer by taking the heat out of the room. This process is difficult in extremely high or low outside temperatures. For cooling with high outside temperatures, it is harder to reject the heat into the air. With low outside temperatures, there is less energy to gain from the air to reject to the inside.

This difficulty can be lessened through the use of an open loop geothermal heat pump, or an air-to-water system. The heat pump process is similar to the window units, except there is air on the inside, and water from the lake, which is maintained at an average temperature, on the outside. This way, when the refrigerant evaporates on the inside, it extracts heat from the room, and rejects it into the water, which is then carried back to the lake. To warm the room, energy is taken from the water by evaporation, and is then condensed into the room, warming the inside. This system will create a large savings in energy used.

The coefficients of performance (COP) for the existing system heating and cooling and the geothermal heat pump are compared in the following table. The geothermal heat pump is four times as efficient as the existing system for heating, and over one and a half times more efficient than the existing system for cooling.

	Heating COP	Cooling COP
Existing System: air to air units	1	3
Geothermal Heat Pumps: air to water units	4	5

The following table gives the average yearly energy spent for space heating and cooling for a building used primarily for lodging. The average energy used in the Erie Convention Center and Sheraton Hotel could then be estimated using the square feet of the building. The loads that need to be met to heat and cool the building are calculated using the COP of the existing systems multiplied by the average energy spent.

Average Energy Spent for Lodging				
	ThousBTU/sq.ft.	sq. ft.	Avg. Energy Spent (BTU)	New Load (BTU)
Space Heating	22.7	132,000	2.9964E+09	2.9964E+09
Cooling	8.1	132,000	1.0692E+09	3.2076E+09

The efficiency of a system is the amount of electricity spent per the load required. The coefficient of performance of a system is 1/ efficiency. From this, the amount of electricity saved in heating and cooling can be found. The cost of electricity per kWh in Pennsylvania according to the December 2005 figures given by the EIA is $0.0873. The total amount of money saved per year is given in the following table.

Saved Electricity (BTU)		Saved Electricity (kWh)		Cost per kWh	Cost Savings per Year		
Heating	Cooling	Heating	Cooling		Heating	Cooling	Total
2.25E+09	2.57E+09	6.58E+05	7.52E+05	$0.0873	$57,482.94	$65,636.91	**$123,119.86**

A general rule of thumb is that a pump needs 3 gpm/ton of water to run efficiently. I chose a 10 HP pump that runs at a rate of 300 gpm. This translates to a consumption of power is 1HP/ton needed to run water to the building. The predicted maximum load on the pumps at any one time is 1500 gpm. This requires the need for at least five pumps to run at this rate, however, I will use two more, for a total of seven, to be conservative.

The total amount of energy it takes to pump the water from the lake is calculated to be 38,568 kWh. This additional electricity needs to be subtracted from the amount of electricity saved in order to determine the total savings excluding the pumping electricity. The cost to pump the water from the lake as well as the new total cost savings is given in the table below.

Energy spent to pump water (kWh)	cost	new total cost savings
38,568	$3,367.00	**$119,752.85**

Finally, the cost of the material and installation or labor for the new pumps, piping, excavation, and filter is estimated in order to calculate a payback period. The costs for the heat pumps of an air-to-water system are assumed to be the same for the cost of the air-to-air system. The prices out of R.S. Means for the material and labor costs for this system are included in the tables below. Since the building is located on the water, the distance from the location of the pump to the intake of the pipe in the lake is estimated at 100 linear feet. The 300 linear feet for the drilling was approximated because of the small prices given for equipment and labor costs. Assuming that the workers will work for half of the day, this 300 feet distance will cover that additional cost. The length of pipe needed is doubled to 200 linear feet because there is a pipe bringing water into the building and one pipe taking water out of the building. In addition, a diver is needed in order to make sure that the pipe is laid properly and that the strainer is in place.

Drilling			pipe		
eqpt	labor	LF	matl	labor	LF
$0.28	$0.24	300	$10.40	$10.40	200

diver	pumps (7)		Strainer (8")	
labor	matl	labor	matl	labor
$500.00	$17,150.00	$3,535.00	$2,725.00	$325.00

Total	Adjustment for location
	0.967
$28,551.00	$27,608.82

Neglecting interest, the payback period can be estimated as the first cost divided by the annual savings. This payback period for this air to water system is 0.23 years or 2.77 months. Because there is only a change from an air-to-air system to an air-to-water system, the first cost of the heat pumps will not change. With only the additional first cost of $27,608.82 in comparison to the annual savings of $119,752.85, it is clear that the open loop system is more efficient and a good investment.

Other considerations when determining whether or not to choose to use a geothermal heat pump include fouling or scaling from deposits in the lake water. This is build up on the sides of the pipe and at the intake which will increase maintenance costs when parts need to be replaced. This plan would obviously also have to be cleared with the Environmental Protection Agency, local zoning ordinance, and others who might be concerned in the area in order to remove water from the lake and deposit it back after it is used. Since the payback period is so small, these factors are considered to be negligible and an open loop system would be a better alternative.

Acoustics - Sound Transmission through Guestroom Walls

Introduction

One major concern in hotels is the transmission of sound in between guestrooms. While it is assumed that the architects design for this issue, the actual study or result is not given. Comfort of the guests during their stay in the Erie Convention Center and Sheraton Hotel is vital to the success of the hotel. Because of this, it is important to make sure that the acoustics of the guestrooms are appropriate. This breadth study will calculate the total absorption of a typical guestroom of Type 'A'. Using this and the transmission loss between two adjacent rooms of Type 'A', it can be determined whether or not the construction of the walls between the rooms is acoustically acceptable to block out the noise of humans talking in an adjacent room.

Transmission Loss and Sound Absorption

Two adjacent typical guestrooms of Type 'A' were analyzed to check for these acoustics requirements. The floor plans, along with the window dimensions for this room are shown in Figure 12.

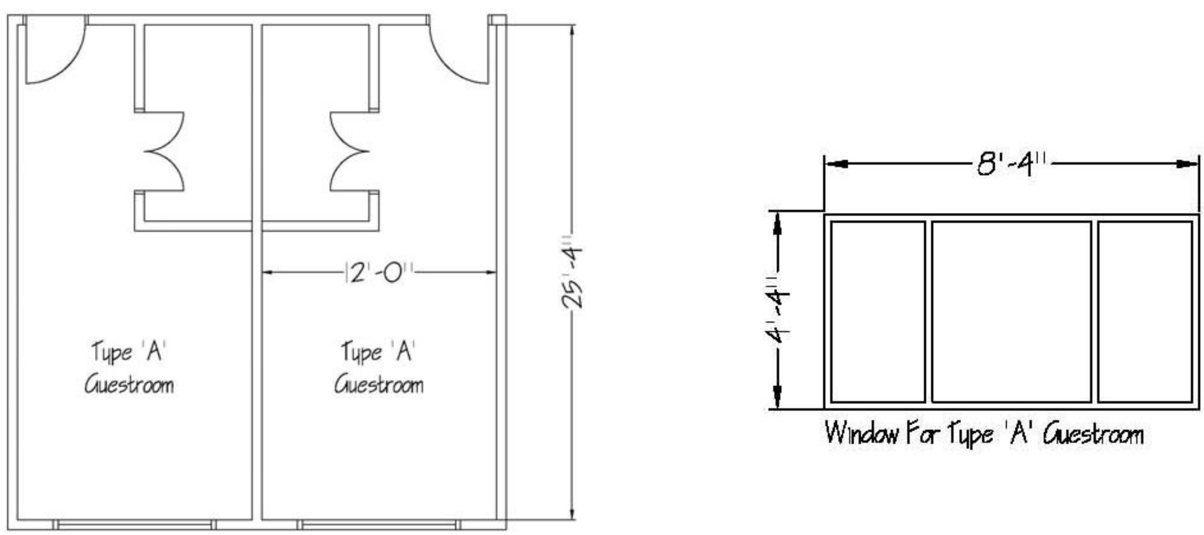

Figure 12: Two adjacent guestrooms of Type 'A' are shown and dimensioned above. These dimensions, along with the window dimensions, will be used to estimate the sound transmission loss between the rooms.

The construction detail given in the architectural drawings shows that the wall in between guestrooms is constructed with two layers of 5/8" gypsum board (on each side), 3-5/8" metal studs, and 3" of fiberglass insulation. The sound transmission loss (TL) for various frequencies is given in the following table.

Sound Transmission Loss (TL) for Frequencies (Hz)						
STC	**125**	**250**	**500**	**1000**	**2000**	**4000**
57	38	52	59	60	56	62

The materials used in the room have different absorption coefficients depending on how porous the materials are. The sound absorptions and their corresponding surface areas for all surfaces of a room of Type 'A', including, walls, ceiling, floor, windows, and curtain are found in the tables below.

Sound Absorption Coefficients - α for Frequencies (Hz)						
Material	**125**	**250**	**500**	**1000**	**2000**	**4000**
(2) 5/8" gyp. Bd. On each side of 3-5/8" studs + fiberglass	0.1	0.07	0.05	0.05	0.04	0.04
Ceiling- CMU (painted)	0.1	0.05	0.06	0.07	0.09	0.08
Carpet, heavy, foam-backed	0.08	0.24	0.57	0.69	0.71	0.73
Glass Window	0.35	0.25	0.18	0.12	0.07	0.04
Fabric, 10 oz. velour, straight	0.03	0.04	0.11	0.17	0.24	0.35

Surface Areas (ft^2)			
Material	**length**	**height**	**Area**
Wall 1	25.33	9	227.97
Wall 2	12	9	71.93
Wall 3	25.33	9	227.97
Wall 4	12	9	108.00
Ceiling	25.33	12	303.96
Floor	25.33	12	303.96
Window	8.33	4.33	36.07
Fabric	8.33	4.33	36.07
		Σ=	1315.93

To determine whether the noise reduction in between rooms will be enough, we will consider one of the rooms to be a source, with people talking, and the other room to be a receiving room, the room in question. Using the surface areas and sound absorption coefficients found in the previous tables, the average sound absorption of the receiving room can be calculated for various frequencies, using the following equation: $A_{rec}=\Sigma(S\alpha)/\Sigma S$. A_{rec} is the area of the receiving room, Σ(Sα) is the sum of the individual surface areas for a material times the absorption coefficients of that material, and Σ S is the total surface area of the room. The results for the average sound absorption are given in the table below.

Average Absorption Coefficient of Receiving Room					
125	250	500	1000	2000	4000
0.1003	0.1088	0.1776	0.2077	0.2126	0.2171

Noise reduction is the change in sound pressure level of noise, and in this case, it is concerned with the reduction between a wall separating two guest rooms. Using the transmission loss through the wall, the area of the wall separating the space as well as the average absorption of the receiving room, the noise reduction can be found. The results are shown below.

Noise Reduction (NR) Between Rooms (dB)					
125	250	500	1000	2000	4000
36	50	59	61	57	63

The following two tables give the sound pressure level in the source room due to people talking at either a normal level, or in a raised voice. Subtracting the noise reduction through the wall will give the sound pressure level in the receiving room.

Voice Lp (Source Room)						
	125	250	500	1000	2000	4000
Normal Voice	53	59	63	58	50	47
Raised Voice	50	55	58	49	46	41

Lp (Receiving Room)						
	125	250	500	1000	2000	4000
Normal Voice	17	9	4	-3	-7	-16
Raised Voice	14	5	-1	-12	-11	-22

For people in the receiving room to not be able to hear noise from the adjacent room, the ambient sound in the receiving room needs to be approximately 5 dB above the sound pressure level in receiving room. Assuming that a window air conditioning unit provides the background noise, it can be seen by comparing the table below with the previous table, that the noise reduction in between walls is adequate.

Window AC Unit Sound Pressure - 5dB					
125	250	500	1000	2000	4000
59	60	51	48	53	39

In addition to the material construction of the wall, other construction techniques can be implemented to achieve positive results. The use of an acoustical sealant at the base of the wall can prevent sound from traveling through air space at the bottom of the wall. Also, because precast concrete planks are used, there is not an air plenum in between rooms. This eliminates the possibility of sound transmission through this area from one room to another.

I have concluded that the acoustic performance in between guestrooms is acceptable for the guest's comfort. It was assumed that the source from the source room was people talking, however there could be other noises such as a television or radio turned on in addition. The noise reduction is so great, however, that these effects can be assumed to be negligible. Also, if the window air conditioning/heating unit is not turned on, there is a lack of ambient noise caused by the fan. In this case, there is a possibility of low frequency sound transmission through the walls, in which case a murmur could be heard.