

Case Studies: Infrared Heating in Industrial Applications

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ABSTRACT

Puget Sound Energy (PSE) is a utility which serves more than one million electric customers and over 700,000 natural gas customers in Washington State. PSE offers grant programs to assist customers to improve both electric and natural gas energy efficiency. Recently, the utility is looking into all directions to find opportunities to meet the aggressive goals in gas savings. One of the areas in focus is heating system for industrial facilities, an overlooked opportunity until recently. For industrial facilities in PSE service territory, heating is commonly provided by forced air unit heaters. A cost effective measure is to replace forced air unit heaters with infrared heaters. Infrared heating is nothing new but properly applying it to effectively and efficiently heat the industrial facilities requires careful engineering design and equipment selection. While energy savings are important for energy efficiency projects, accurately predicting energy saving is very difficult due to too many variables. On the operational side, infrared heating is different from forced air heating in the way of temperature setting and temperature setback. Through participating in the grant program, customers have implemented many infrared heating projects in auto service garages and industrial plants. The results of the projects are mixed in term of providing comfort environment in an efficient way. This paper will present several cases in that some are successful projects and others are not. The data that were collected from projects on the temperature measurement, the comfort conditions, and the energy usage will be included. The lessons learned will be discussed.

Introduction

Industrial plants are traditionally heated by either hot water or steam unit ventilators. When gas is readily available, gas fired unit heaters are used in place of the hot water or steam unit heaters. The way the unit heaters work is to supply hot air of 120 to 180⁰ F to the spaces. The air will then heat the space to the desired temperature for occupant comfort and process requirement in some cases. Most of the industrial plants have ceilings as high as 15 feet and up to 40 or 50 feet as in hangars. The heat will rise to the ceiling due to stratification. There are a lot of design attempts to lessen the problem by forcing air circulation either by adding ceiling fans or by introducing air at high velocity from top toward to the floor. Temperature spot checking and data logging indicate the vertical temperature variation is significant. The average temperature in the spaces is much higher than the temperature at the occupant level. This increases the overall heat loss that results in higher heating energy consumption.

The alternative way to heat the industrial plants is to use gas fired infrared (IR) heaters. Infrared heaters are not suited for all cases due to potential hazardous situations. ASHRAE Applications Handbook (ASHRAE, 2003) provides a good list of the factors that should be considered before considering infrared heating. Due to high temperature, IR heaters must not be placed where they could ignite flammable dust or vapors or decompose vapors into toxic gases. IR Heaters must be located with recommended clearances to ensure proper heat distribution. Stored materials must be kept far enough from heaters to avoid hot spots. The good application

of IR heaters would be in areas that have high a ceiling. This paper will present some case studies to demonstrate the proper application of IR heating with emphasis on energy efficiency improvement.

Overview of Infrared Heating

There are various types of gas fired IR heaters. This paper is based on experience with low intensity heaters. Figure 1 is a typical heater used in industrial applications. The major parts of the heaters are: burner, fan/vacuum pump, emitter, and reflector. The way IR heater works is very similar to lighting. The IR heating energy is transmitted from the emitter to the objects in all directions. The reflector is to focus the energy to the floor below. The comfort condition is created by direct radiation from the heater, re-radiation from floor or machinery on the floor that absorbs energy, and convection from higher temperature surrounding air to occupants. Ideally, we would like to have 100% of heat transfer in the form of radiant energy but most of the heaters have a ratio of about 35 to 55% of radiant energy to input energy according to ASHRAE (ASHRAE, 2004). Some of the energy is wasted through exhaust of combustion and the other energy is transferred to the surrounding air through convection. As comparing to gas fired forced air heaters, about 80% of the energy is transferred to air through convection.

For most of the heating needs, the goal is to maintain a comfortable working environment on the worker level. In IR heating, the space temperature can be lower than in forced air heating due to radiation from the floor and other objects in the space. Even the space temperature is controlled to the same, the average air temperature in the space is lower. This will result in lower heat loss. Although it is difficult to measure the effects of the temperature stratification on the outside air infiltration, it is possible the air infiltration is higher in forced air heating than in IR heating. To estimate the energy usage of the building, the heat loss through the envelope, the internal heat loads, and the air changes need to be estimated properly.

Figure 1: Low Intensity Gas Fired Infrared Heater



Energy Saving Estimate

Although hourly energy simulation will provide a more accurate result, analysis using bin weather data is an effective way to estimate heating energy. As in utility incentive programs, energy saving is very important. To understand the difference between forced air heating vs. IR heating, we will look at the temperature profile in the vertical spaces of the buildings. Using data loggers placed on the internal wall of the building, we indirectly record the temperature in the vertical spaces. Figure 2 shows the temperature variation in a forced air heated maintenance airplane hangar. The temperature was recorded for several weeks in the winter. Outside air

temperature is included as a reference. The data loggers were installed at 5 feet, 20 feet and 35 feet level. The ceiling height of the hangar is about 40 to 45 feet. The heaters are located at the center of the hangar at about 30 feet from the floor pointing down and continuously rotating. We can see from the data that the temperature varies significantly from the set point which is about 70 F. Since this is the hangar, the hangar door opening and the heaters operation have significant effects on the temperature. The average temperature of the spaces is at least 5 degree higher than setpoint.

Figure 2: Space Temperatures at Various Heights in a Forced Air Heated Hangar

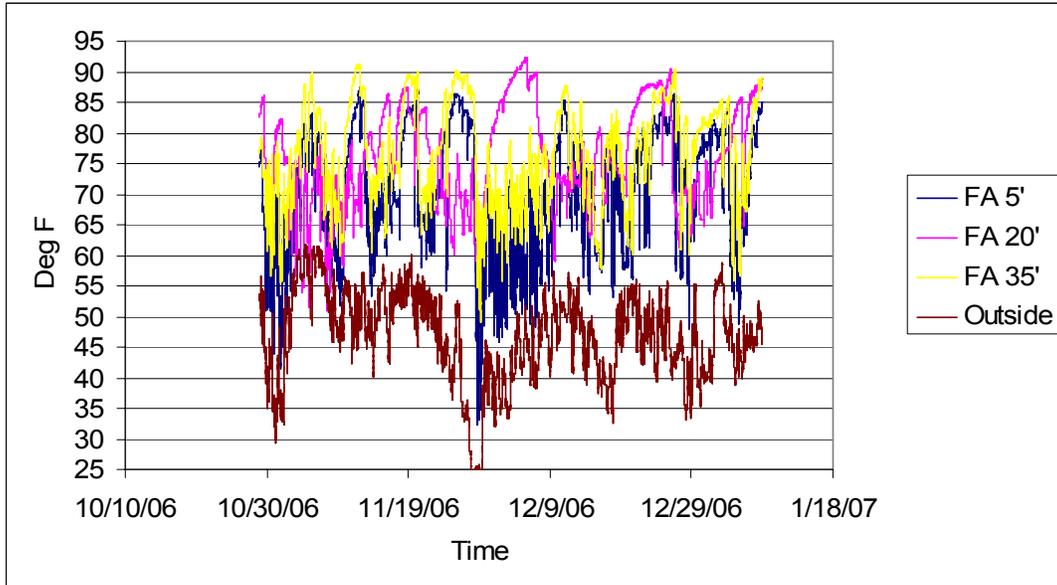
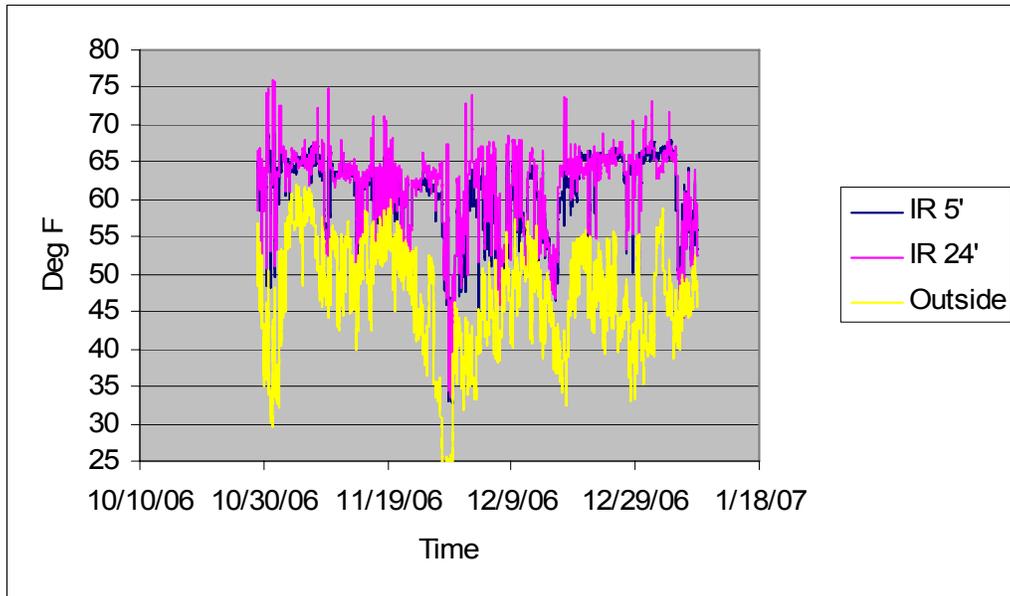


Figure 3 shows the temperature profiles in a hangar that has been converted into IR heating. The location is the same and the size and shape of the hangar are very similar. The temperature is set at about 65 F in this hangar and it is comfortable for the workers to work on the planes. The outside air temperature is included as reference. The data logging time period is exactly the same. Although the temperature fluctuated with the outside air temperature due to the capacity limitation, the temperature at 5 feet and 24 feet level is almost the same as the set point temperature. It is also important to point out that even with a 5 degree lower temperature set point, this hangar provides comfortable working environment due to the fact that the floor temperature is higher in the IR heated hangar. The added on benefit is that the airplane is also heated quickly by IR heaters after it is brought in for service.

Figure 3: Space Temperature at Various Heights in an Infrared Heated Hangar



To estimate energy savings from using IR heating vs. forced air heating, the critical element besides data on building envelope insulation and outside air ventilation and/or infiltration is the average space temperature. As demonstrated in Figures 2 & 3, the average temperature in the space can be 10 degrees difference. The temperature variation is related to the supply air temperature in the forced air situation and the design of the air distribution. The height of the ceiling also has effects on the vertical temperature variation. Through instant measurement of internal wall temperatures at various levels, it seems very common for 5 degrees increase every 10 feet vertically. So at working level of 5 feet, the temperature of 70 F will result in 76 degree at 18 feet level. As in retrofit situation, a very simple way to check is to measure the internal wall temperatures to figure out the temperature variation. Table 1 provides an example of a comparison of the service garage in the forced air heating and IR heating situation. The example is to demonstrate that the energy saving from three (3) degree difference is significant. The heating energy is calculated for each bin hours as follows:

$$Q = ((UA + 1.08 \times CFM) \times (T_o - T_i) - Q_i \times 3413) \times Hr \times \% / \text{eff} / 100,000$$

Where: Q is heating energy in Therms. UA is the building envelope thermal transmittance in Btu/F/hr. CFM is the outside air infiltration and ventilation rate in ft³/min. Hr is bin hours for the temperature. T_o is outside air temperature for the bin hours. T_i is the average inside temperature. Q_i is the total internal thermal loads (such as lighting and motor loads) in kW. % is the percentage of the time at T_i (such as % occupied hours or unoccupied hours). eff is the efficiency of the heater.

From the table, we can see the energy reduction is 23%. As we all know, the heating energy is related to a lot of factors. The real benefit from using IR heating as regarding to energy consumption is the overall space temperature that contributes to the heat loss. The energy usage is also related to the temperature setting and controls in the spaces. In forced air heating, the air temperature is much higher, so the heat loss is much higher due to air changes. The above spreadsheet assumes air changes are the same for both IR and forced air heating. The effects are estimated based on average temperature in the space. To reliably estimate the energy savings, we need to add the temperature variation in the consideration on top of the traditional energy estimates that include envelope data and internal loads. For high ceiling buildings such as in industrial setting, the temperature stratification should be carefully evaluated. Data logging is very useful in retrofit situation. The temperature stratification is insignificant in IR heating. That is why the IR heating posts energy saving potentials.

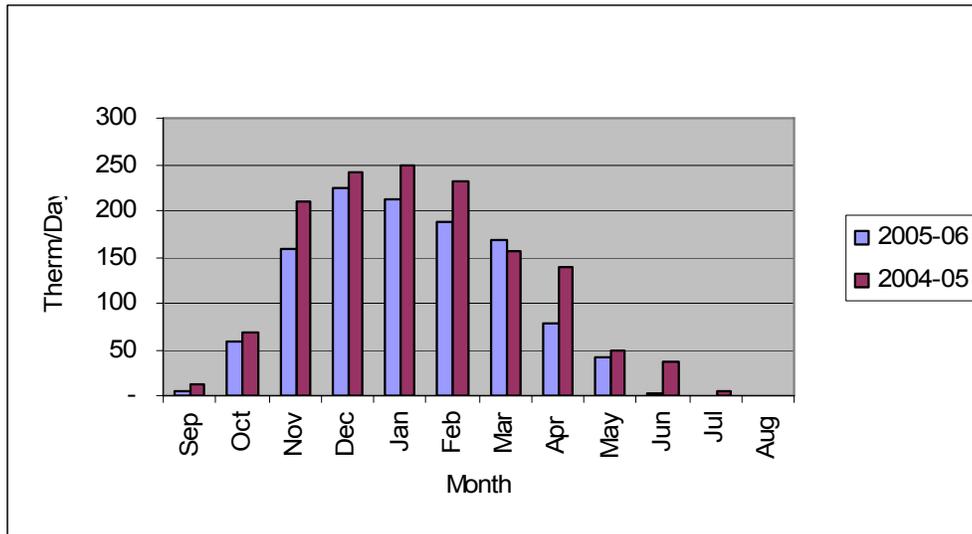
Case Studies

The proper application of IR heating depends on several factors. The best application for IR heating would be for buildings that have high ceilings and high air changes due to door opening. The buildings fit in this category include auto service garages, airplane maintenance hangars, warehouses in industrial plants and some manufacturing plants. We will look at four cases here.

Auto Services Garage

Auto services garages usually have 18 to 20-foot ceilings and have a lot of over-hang doors. Through utility's incentive program, many successful IR heating projects have been done in services garages. Traditionally auto services garages are heated by forced air gas unit heaters. The temperature inside is set at 65 F or higher. Due to door opening, it is difficult to maintain garages to a comfortable condition. The benefit of IR heating is to keep the heat on the floor and the side benefit is to quickly heat up the cars that are brought in for service. Door opening has less effect on the temperature of the spaces. Figure 4 shows billing data for a dealership in Seattle area in the pre-post installation of the IR heaters. The utility billing gas meter is for the garage only. The total usage in forced air heating is 42,000 therms/yr (\$45,000 at current rate of \$1.07/therm). The saving is 7,800 therms/yr or over \$8,300 in cost saving. The weather was colder after IR heaters were installed (4655 degree days vs. 4501). The project cost was about \$40,000 that resulted in a less than 5 years simple payback. The garage is a lot more comfortable to work in now.

Figure 4: Gas Usage Comparison Pre- and Post Infrared Heating Retrofit in Services Garage



Maintenance Airplane Hangar

Maintenance airplane hangars are good candidates for IR heating. In a sense it is like auto services garage except the ceiling is much higher and the scale is larger. The temperature data showed earlier were from a couple of military airplane hangars. The case demonstrated here is for an industrial maintenance hangar. This airplane hangar already had gas fired IR heaters, but the layout of the heaters was poorly designed. The type of emitters on the heaters was just like the sheet metal used in the HVAC ducts. The emitter was a single pass type and very long. Single pass emitters have the burner on one end and the exhaust on the other end. The problem appeared to be low temperature on section of the emitter that was far away from the burner, so most of the heat was in the form of convection. The temperature on the working level was not acceptable. Due to poor layout, a lot of radiant heat was reflected off from airplanes and never reach the ground. The heaters were retrofitted with better designed heaters that were double run and had better emitters (See Figure 1). The double run emitters have the burner and exhaust on the same end so the emitters have more uniform temperature through out. The emitter section next to the burner transfers heat to the emitter section next to the exhaust. The layout was carefully designed to make sure the emitters cover the floor space completely. This is similar to lighting design. The end result is a more comfortable working environment while reducing the energy usage. Figure 5 shows the pre- and post retrofit billing data. The saving in this case is 30% or over 18,800 therms/yr (over \$20,000 at \$1.07/therm). Figure 6 shows the heating degree days for the billing periods. The heating season in 2006 (post-installation) was colder in general comparing to heating season in 2004-05 (pre-installation.) This case indicated that proper selection and layout of the IR heaters is very important as in lighting design.

Figure 5: Gas Usage Comparison Pre- and Post Infrared Heating Retrofit in Hangar

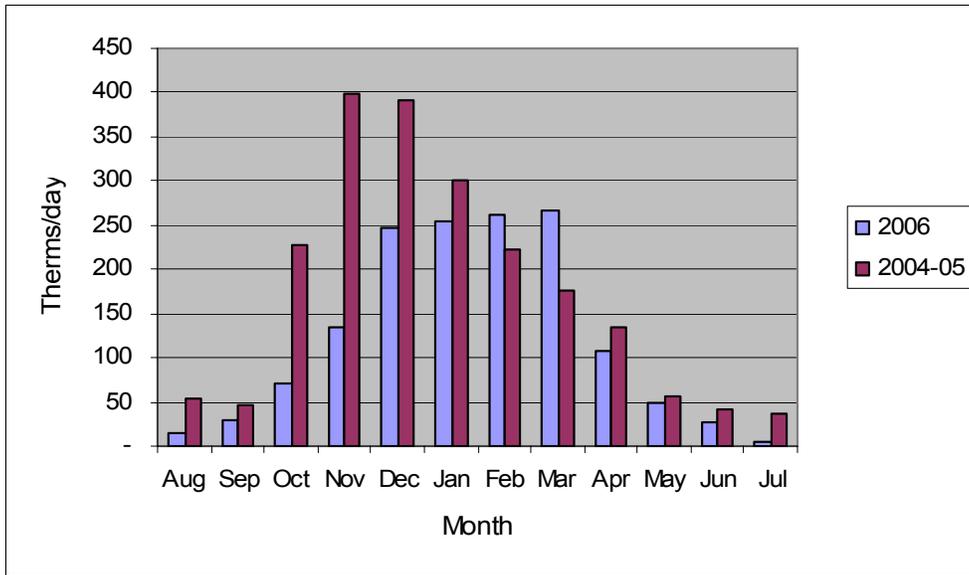
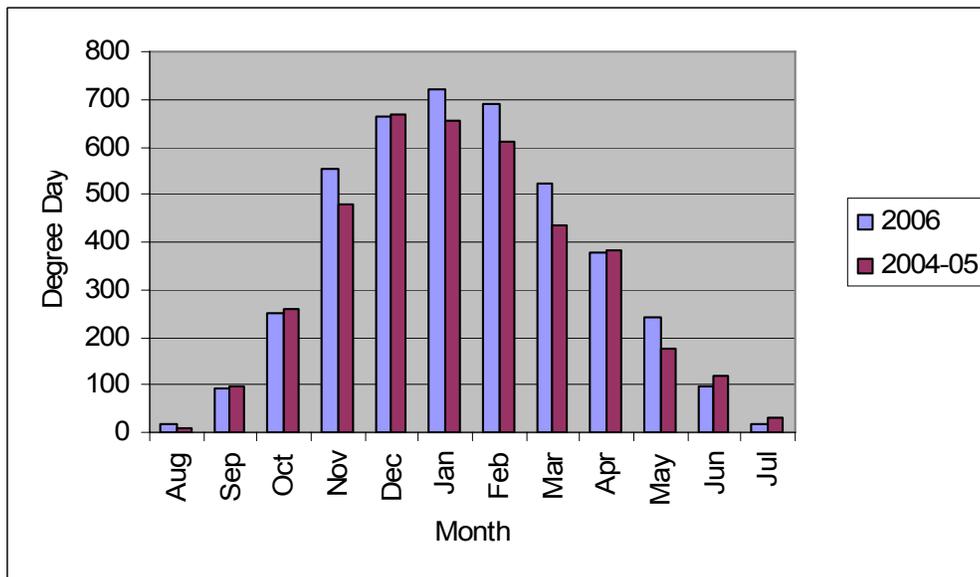


Figure 6: Heating Degree Day Comparison Pre- and Post Infrared Heating Retrofit in Hangar



Warehouse in a Furniture Plant

Warehouse is a good application if it is required to heat above 60 F. Over-hang door opening can introduce a lot of outside air into the space. Workers are packing and loading products into truck trailers during the normal operation. IR heaters can be a good application in general heating or spot heating to maintain acceptable working environment. In projects we did, the results are very good. For the case in the warehouse in a furniture plant, the gas consumption was cut from more than 10,000 therms/yr to less than 4,000/yr therms. The results include temperature setting from original 70 deg to 65 degree and night set back. The comfort level in

the warehouse is maintained with lower temperature. This case indicated that lower temperature setting is possible for IR heating.

Paper Machine Parts Manufacturer

Through utility's program, we had funded many IR heating projects. Most of the projects show significant savings. There are some projects that did not have saving due to the changes in the heating setting. That is, the existing heating was not sufficient but the new IR heating has the capacity to maintain the space temperature. Some time, the occupants still set the thermostat the same way as in the existing system. That will maintain the space temperature but the gas usage actually increases, because now we have the capacity to heat the space up. That creates a dilemma for us. If the customer just adds more forced air heaters – the low cost way, the energy usage would have been more.

There is one case that we are still trying to figure out the solution. This is a large machine shop that manufactures parts for paper machinery. The building has very little insulation and has a size of almost like a football field with about 30 to 45 feet ceiling height. The existing heaters are gas fired forced air unit heaters. The gas usage was over 70,000 therms/yr to maintain 60 degree. In a lot of time in a year when outside temperature is low, the existing heaters can not maintain 60 F. A lot of work that are performed by the workers includes handling of metal parts. IR heating appeared to be a good application. The contractor designed and installed the IR heaters. After the installation, the space temperature could not be maintained at 60 F in one area. It appears several things cause the problems: one is that the type of heaters selected is not good for the mounting height. Very long single run type of heaters (60 feet in length) were selected. The emitter temperature drops very fast to the end of the heater so the percentage of the radiant heat is small. Picture 1 shows the type of heaters installed in the spaces. Another problem is that the heat load is under-estimated. This project is one of the early projects we involved in. The customer had to put back the forced air heaters as supplement to the IR heaters that defeat the whole purpose of using IR heaters. Although the customer now have a better working environment due to IR heating on the machinery and the metal parts the workers have to handle. The gas usage increased since the IR heaters installed. The lesson learned here is that IR heating improves the efficiency of the heating system if designed and installed properly. The energy usage depends on a lot of factors such as the temperature setting and occupied hours.

Picture 1: Infrared Gas Heater Installed in Paper Machine Parts Manufacturing Plant



Summary

IR heating if applied properly will improve the efficiency of the heating system as comparing to forced air heating. The energy saving depends on a lot of factors including the temperature setting. The forced air heated spaces tend to have high temperature stratification if ceiling height is over 15 feet or more. The temperature logging and instant measurement indicate higher average space temperature in forced air heating as comparing to IR heating. We can draw conclusion as which way is more efficient but the energy usage depends both on the efficiency and the temperature setting in the spaces. IR heating provides a more effective way to heat industrial plant and commercial facilities that have high ceilings. The energy efficiency should be investigated very carefully. Proper equipment selection and layout of the IR heaters are very critical to ensure proper heating.

References

ASHRAE, 2003. ASHRAE Applications Handbook, pp 53.6 – 53.8.

ASHRAE, 2004. ASHRAE Handbook – HVAC Systems and Equipment, pp 15.2.