Peak Demand Automation DRS™

Dynamic Re-configuration of Stages, DRS™

Introduction

Dynamic Re-configuration of Stages, DRS™, is a patent pending technique to reduce the amount of energy required to heat a portable classroom. This type of classroom is also called a modular or relocatable classroom. Often these classrooms are a trailer that has been placed on the campus.

1. Dynamic Re-configuration of Stages (DRS™) reduces energy consumption by operating the inefficient electric strip heater only when it is needed, and disabling it at all other times.

2. As an additional benefit, the Peak Demand Automation system improves the air quality by operating the fan at all times during occupancy, regardless of the need for heating and cooling.

3. The Peak Demand Automation Energy Management System stores 1096 days of holidays, so complex school schedules are not a problem: no school, no AC! All holidays, breaks and summer school can be loaded years before they happen.

The attraction of relocatable classrooms is that campus expansion and contraction is easy and low cost. Should attendance increase, it is much less expensive to roll a portable classroom onto the campus and wire it for use than to build a new building. If enrollment drops, the classrooms can be sold and rolled away.

Heaters and air conditioning units must be sized to adequately heat and cool in a variety of climates, building sizes and quality of construction, including windows, leakage (infiltration) and insulation.

All electric units are used commonly in relocatable construction. While gas/electric units cost less when heating, they require that a gas line be run to the structure. This additional construction cost is unnecessary if an all electric unit is chosen because the classroom needs electricity anyway for lights and computers. A typical all electric HVAC unit is shown in figure one. The photo was taken at a classroom test site, and the unit was manufactured by the Bard Manufacturing Company of Bryan, Ohio. Their web site can be found at http://www.bardhvac.com.

Figure 1: a classroom wall-pack HVAC unit.

A typical classroom is about 900 square feet with a 9 foot ceiling. The default size for a relocatable classroom in eQuest (a US Department of Energy software program) is 31 by 31 feet. Thus the total volume of the room is 8649 ft^3 or 245 m^3 (cubic meters) of air. To raise this air mass from 40° F to a comfortable 68° degrees and to raise the temperature of all the objects in the room would take about four (4) kWh of energy. Of course the actual amount required can vary for reasons mentioned above.

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Lets assume that the wall-pack is capable of delivering 10,000 Watts of heating to the space, then the amount of time required will be about 24 minutes depending on construction.

The problem with this is that many thermostats will invoke the second stage far sooner than 24 minutes. Some thermostats will turn on the second stage immediately if the temperature difference is past a threshold of say three degrees. That means that the second stage will be turned on immediately to heat the room from 40°F to 68°F.

The first stage in these units is a heat pump capable of delivering heat efficiently into the space. A heat pump should always put more heat into the space than it requires in electric power off the grid. The second stage on these units is an electric strip heater, which has no efficiency advantage, that is the amount of heat that is pulled from the grid is exactly the same amount directed into the space.

Heat pumps and strip heaters:

A heat pump operates by pumping a fluid in a closed system and exchanging heat in that fluid by blowing air across heat exchangers through which the fluid flows. A heat pump in heating is exactly like an air conditioner except the flow is reversed. A schematic representation of a heat pump is shown in figure 2.

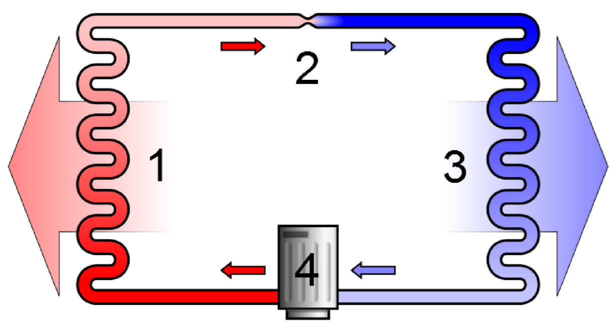

Figure 2: Schematic of a heat pump

Figure 2. shows a schematic of a heat pump pumping a fluid in a closed-circuit. The compressor at point 4 raises the pressure and hence the temperature of the gas or refrigerant and that hot gas passes into the condenser at point 1. Inside the condenser the fluid loses heat as it is exchanged with the airflow across the coils. It loses heat and remains at the same pressure as it condenses into a liquid. Once it is a liquid it passes through an expansion valve at point 2, which lowers the pressure of the liquid. The low temperature liquid is then converted to a gas by the gaining heat from a coil usually on the outside of the building. This coil will be colder than the outside air temperature, and thus heat flows into the space. This heat exchanger is also known as the evaporator. Once the refrigerant has evaporated it can be handled again by the compressor at point 4 and re-compressed, starting the cycle again.

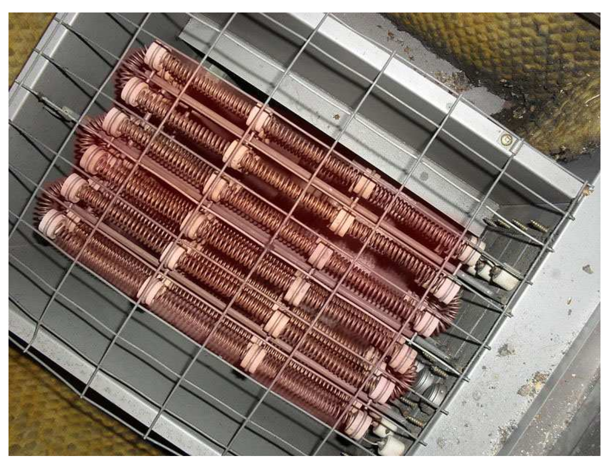
Figure 3: Picture of a resistance strip heater

The amount of electricity required in this process is the amount of electricity required to run the compressor. This energy is always less than the heat exchanged at the condenser and and evaporator coils. The efficiency of the system is expressed by the terms COP (coefficient of performance) or EER (energy efficiency ratio) and is normally in the range of 2.5 to 3.0 to 1. Simply, if the COP is three, this system can provide 3 kWh of energy into the room while only taking 1 kWh of energy off of the electric grid.

Strip heaters work by putting electricity into a resistive element. Figure 3 shows an actual photo of such a strip heater. The coils of this heater become hot and typically will glow red when this heater is active. Unlike the heat pump, there is no electrical advantage to using a heater of this type. Every kilowatt hour delivered as heat to the room requires a kilowatt hour be removed from the electric grid. Thus the heat pump is 2 ½ or three times more efficient than the strip heater. Figure 4 shows a cutaway view of a wall pack heater. For heating there are two heat exchangers, the heat pump coil and the strip heater. When cooling is required a valve reverses the refrigerant flow and the heat pump coil cools instead of heats. The strip heater is never activated.

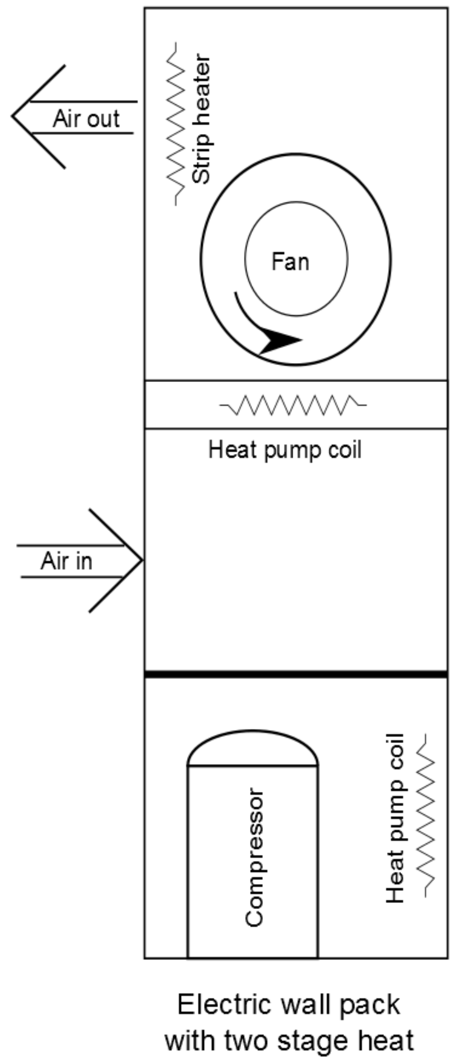

Figure 4. Cutaway picture of a Wall-pack

The effect of stratification:

ASHRAE, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, in its fundamentals handbook, suggests that excessive stratification of temperature may occur whenever the exit temperature of the duct-work is more than 15 degrees higher than the surrounding temperature. Actual measurements taken in a classroom showed that the temperature at the outlet vent of the heater was approximately 100° F with only the first stage running. With the second stage active the temperature exceeded 125° F. Very few classrooms follow the ASHRAE guidelines that heater vents be placed in evenly along the floor of the occupied space. A common solution to excess stratification is that a teacher will open doors or windows to promulgate mixing and even out the temperature throughout the space. When this occurs heat is lost out the openings.

The wall-packs offer quick heating by virtue of their two stage design. When both stages are active they are able to get heat into the space quickly. Figure 5. Shows the heat delivered by the stages and the watts used or drawn from the grid. Since the first stage is a heat pump it can deliver 10,000 Watts of heat while only drawing 3333 Watts from the grid. (I have simplified all of the numbers to make the mathematics simple) The second stage, in contrast, is a 1 to 1 conversion of energy, that is that if it is to deliver 10,000 Watts of heat it will require 10,000 Watts be drawn from the grid. If both stages are active, which is the case whenever an electronic thermostat is used, the combined output is 20,000 Watts of heat into the space while drawing 13,333 Watts from the grid. Therefore it is simply twice as efficient to put energy into the space by using the first stage heat pump only as it is by allowing the first and second stage to activate together. Put another way, the savings is 50%.

	First stage	Second Stage	Combined
Heat delivered	10000	10000	20000
Watts used	3333	10000	13333
Efficiency Watts/Watt	3	1	1.5

Figure 5: The power (heat) delivered by the stages

It gets worse:

Some units contain more than one strip heater. It is not unusual to see a large wall pack configured with a single heat pump and two separate strip heaters. It is not uncommon for thermostats to have two stages of heat, but very few have three stages so it is common for HVAC technicians to combine the strip heater stages together as at least one manufacturer recommends. This results in inefficiencies even greater than those described here.

Why not just leave the strip heater unconnected? That way the system will always run with only the most efficient heating source, the heat pump. There are two reasons. The first reason is that even in moderate climates it can get cold at night, and if the outside temperature is cold and the space is unoccupied for a period of time, as in the three-day weekend, the interior of the space could be quite cold and require an amount of energy more than usual to heat. In this case it may be necessary to activate the second stage to get the room temperature high enough so that the temperature can be comfortable for the occupants. The second reason why we would want a second stage to remain active is for occasional use at unscheduled times. This is the case when a teacher comes in on the weekend to work and needs the space heated quickly to be able to work comfortably. Typically this is done on a manual basis; the teacher will turn on the heat when they arrive.

DRS™ – how it works

DRS™

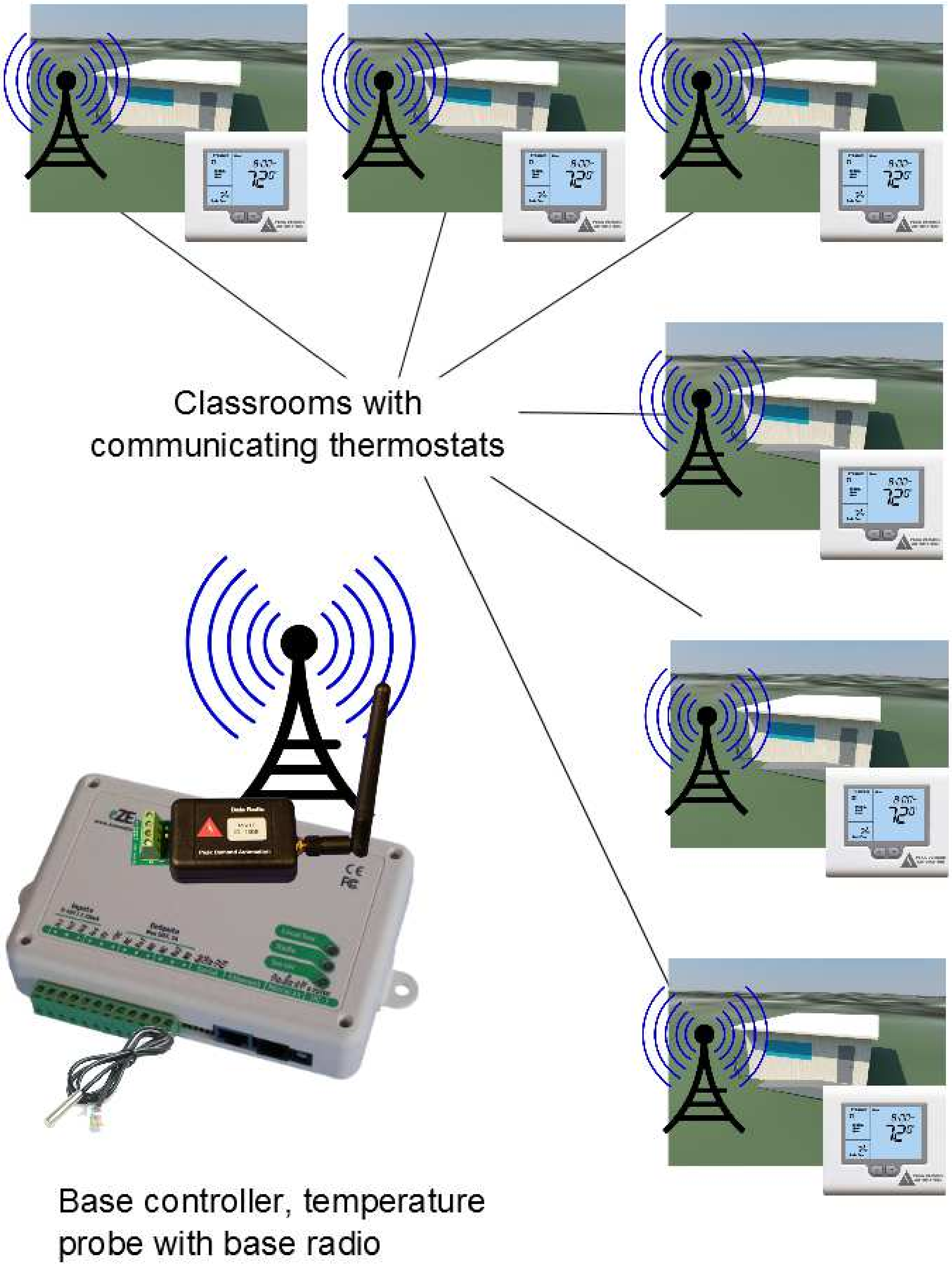

Figure 6. The Peak Demand Automation Energy Management System capable of Dynamic Reconfiguration of Stages (DRS™) and improving air quality.

Figure 6. shows a typical campus with a Peak Demand Automation Energy Management System. A central controller with an external temperature probe manages the campus by communicating with thermostats in each of the buildings, in this case portable buildings with wall packs. This communication is done digitally and can be done either by radio or with a wire. Special thermostats are used that have this communication ability built-in. This communication capability allows them to be dynamically reconfigured by sending a command to them. The central controller has a temperature probe which can be placed on the outside of the building containing the controller. The controller then measures the outside temperature at the installation constantly. It can decide whether or not it is appropriate to send a signal to each of the thermostats on campus allowing them to disable the inefficient second stage of the wall packs. In fact this is exactly how the decision is made. Currently, with the operator manual found at www.peakdemandautomation.com, the controller tests the outside air temperature each weekday at 7 AM and again at 9 AM. If the outside temperature is found to be above 40° F, the second stage will be disabled. If the temperature is below 40° F, the second stage remains enabled in order to make sure that the rooms are up to temperature in time for students. The second stage is never disabled on weekends so that a teacher operating the thermostat manually can have the full benefit of quick heating. An additional benefit of this type of system is that all of the thermostats can be commanded to turn on the fan during all occupied hours of the space. This substantially improves the air quality and reduces the CO_2 content.

Other factors which make the Peak Demand Automation system the right solution for schools

The first benefit of the Peak Demand Automation Energy Management System is lower energy consumption. There are other benefits that are obtained when the system is installed.

Low cost: Wireless technology has the lowest possible installation cost. The Peak Demand Automation Energy Management System is Internet aware, and uses the FCC approved ISM frequency band for transmitting data. This reduces the potential for interference and does not conflict with the frequencies that are typically used for Wi-Fi computer networking. Its range of operation and reliability exceeds that of similar Wi-Fi or ZigBee implementations.

Improved air quality: Without any additional hardware, measurements show substantial drops in CO_2 levels in classrooms if the fan is left running throughout all occupied periods. This is also a Title 24 requirement in California.

Relocatable: Wireless technology means that if relocatable classrooms are moved or replaced, the benefits of the Energy Management System can be realized simply by moving the thermostats, a simple job without any additional costs associated with wiring of communications lines.

Pre-programmed Holidays The Peak Demand Automation Energy Management System Stores 1096 days of holidays, so complex school schedules are not a problem: no school, no AC! Three years are stored, and no additional labor is required to operate the system.

DRS™ is a trademark of a patent pending technology from Peak Demand Automation of Carmichael, California. Companies and institutions seeking licensing and technical support for this technology should contact the company directly.