Overall Efficiency
For
Building and Home Heating Systems

Work and Vision Statements

Monday, August 07, 2006

Why Overall Efficiency?

I have a dream. My dream is to save the world an average of 80 billion dollars in fuel bills annually. After I saw the movie, An Inconvenient Truth, I am convinced that the build up of CO2 emissions is going to be a much bigger problem then rising fuel costs. When I visited an ASHRAE conference the experts agreed. I predict that the rate of global warming will accelerate over the next few decades. We will be forced to abandon fossil fuels well before we run out of oil. The future looks like nuclear power plants providing electricity and producing hydrogen for cars and home heating fuel. Energy Efficiency is a very important project. We need to delay the time for conversion to allow our scientists and politicians to develop plans for it. Reducing CO2 emissions is more important then reducing fuel consumption. An Energy Efficiency project is a good way to accomplish both. I am in the process of developing a plan around this goal. I have personally been working on this task for a few years now and have some good ideas. This paper is actually two papers in one. First I will present a vision of the way I feel things should be. Then I will present a work statement on tasks that we as a group could work on. We are going to work towards developing a way to accurately use Overall Heating Efficiency.

I want to first talk about what sparked me to start this project. Many years ago I took a seminar on Viessmann boilers. I heard the teacher talk about some of the problems with AFUE. He said that Viessmann was much more efficient then American boilers. More efficient then the AFUE shows. He said AFUE has a lot of problems. I heard this over and over again from other sources over the years. Lately I read an article (Written by Thomas Durkin P.E., ASHRAE Journal, Vol48, July, 2006, Titled Boiler System Efficiency) on converting from Steam to Warm water heating in ten schools. Outdoor reset and condensing boilers were used. Out of ten schools the average savings was 68%. According to AFUE the savings were much less

AFUE is the standard that the DOE is trying to set for the heating industry. I feel that AFUE is not getting the job done. I have done many combustion analyses and found no correlation between AFUE and actual efficiency gains in the field. Every year millions of development dollars are spent by manufacturers to build boilers with higher AFUE numbers. I believe they are spending this money in the wrong direction. The consumer is misinformed as to what is the best choice of equipment to install into someone's home.

Buderus and Veismann pack there boilers with insulation so that they run more efficient in your home. American boilers are lightly insulated. The European manufactures also concentrate on low water temperatures. The American manufacturers don’t worry about such things. Why? Because AFUE doesn't account properly for jacket losses and AFUE is tested at 140 degree water temperature on all boilers.

I took a boiler tuning class from NCI. This class was taught by Jim Davis. I find his stuff to be revolutionary. Jim is one of my hero's. Jim taught me that the calculation used in the combustion analyzer was giving some false information. Jim taught me how to tune a boiler to run efficiently in someone’s house. He taught me the rules of combustion. The boilers are set up to run efficiently in a lab condition set up for AFUE. Set up to produce the highest AFUE numbers. Just in tuning the boiler properly, for overall efficiency, I can save clients of mine 5 to 15% in fuel bills. Jim used to tune boilers for a living. Independent Energy Auditors used to follow him up with a field calculated before and after energy analysis. Jim got paid a percentage of the savings. He made good money doing this. His stuff works. So I tune Atmospheric boilers and I see no coloration between the AFUE rating and the actual efficiency I can tune boilers to.

AFUE is tested at 140 degrees. I have learned that for every 3 degrees dropped in water temps you get 1% in energy savings. The standard boilers actually run at 180 degrees. They are much less efficient at 180 degrees then 140 degrees. They are running at roughly 10 to 15% less efficient in your home then the AFUE rating states. Condensing boilers are also tested at 140 degrees too. The condensing boilers don't even condense until less than 130 degrees. A condensing boiler hooked up to a low temp radiant system runs at much lower temps, 75 to 130 degrees sometimes if hooked with outdoor reset. In such a situation a condensing boiler runs about 10 to 30% more efficient then at AFUE conditions. But somehow AFUE has that boiler at 95% efficient at 140? I don't believe IT!! I bet at 140 a condensing boiler is much less efficient then 95%.

A friend of mine replaced his boiler which had an AFUE of 80% efficiency with a condensing boiler that had an AFUE of about 92%. He monitored his house and found HUGE SAVINGS!! Something like 60%. Yet according to AFUE he saved only about 12%.

Nothing adds up here with AFUE. I see AFUE as a HUGE PROBLEM!!

Proper Comparison is real important to technical development. I want to develop some proper comparison methods. This will allow American manufacturers to work at the right things. Like making boilers run more efficiently in your home instead of working more efficiently in some AFUE lab test.

We need some proper comparisons!!!

By measuring the overall efficiency of a house or building we can compare the efficiency of one heating system design with another heating system design. Once a comparison is made it will be known which system design is better. Performance will be able to be gauged just like using a stop watch by an auto racer. Overall efficiency is the stop watch number for our industry. Overall Efficiency is the standard that should be used for our industry.

In 1988 I won a SCCA Showroom Stock Class A Road Racing Championship. When I started running on the race track in 1985, my car was one of the slowest on the track. Everyone was passing me. I began to learn about cars and driving skills from books, technical support from manufacturers and alliances made with fellow competitors. I received a very valuable education. The value of the education was constantly measured every day by a stopwatch and other tools. Sometimes the information found in the books wasn't accurate. My most valuable tool was the stop watch. The stop watch allowed me to significantly improve my lap times around a race track. The first step in improving my lap times was comparison. I compared the changes I made on the car this week with the changes I made last month. I compared my lap times with lap times of my competitors. I measured time in certain straights and corners. Sometimes I might be faster then my competitors in a straight but slower in the corners. I then knew an area that needed improvement. Every week I became faster until three years later I was the fastest in my class. I enjoyed working on and modifying the car.

When I got older I shifted my learning abilities from cars to hydronic heating systems. I am a certified designer and installer of radiant heating systems. I enjoy working on and modifying different systems. In 2005 we won first place commercial and Best of Show in the RPA system showcase. When we won best in show we won it with the highest points total in the history of the competition. In 2004 one of our projects won first place retrofit. My pictures and CAD mechanical and electrical layouts competed with the best projects done by other Contractors and Engineers nationwide. I have learned about heating system design from books, technical support from manufacturers and networking with fellow engineers and contractors. Yet I do not know if the heating system I designed today is more efficient then the one I designed a month ago. Nor do I know if a hot air system found in my neighbors house is more efficient then the radiant system that I designed. Sure AFUE provides me with some valuable information. AFUE just measures the appliance. It doesn't take into account for my wire and piping skills. Nor does it tell me if the boiler runs inefficiently in my design because it is oversized for the house. Chimney height, design water temperatures and outdoor reset controls play a major roll in efficiency too. AFUE doesn't take any of that information into account**.** I wanted a stop watch number for our heating industry very badly. First, I searched for it everywhere. I couldn't find anything useful. So I developed one. I took all of the ingredients that I thought was needed. Then I wrote a mathematical formula. Bob Distinti, an engineer helped me. The end result was an efficiency number that can be used in the same way as a stop watch is used on the race track. We applied for a utility patent on the use of the formula in software.

How the Formulas Work

Our new standard would be Overall Efficiency. It would be based on the btu content of the heat leaving the Conditioned space of the building over a period of time divided by the btu content of the gas feeding the boiler or furnace over the same period of time. A simplified formula looks like this. Overall Efficiency provides for a valuable comparison of different heating types. With overall efficiency you can compare one heating system type such as hot air against another type such as radiant. The two systems can be compared equally. You can compare systems from different climates and different building sizes equally.

BTU content of heat leaving the conditioned
space of the building for a period
of time amounting to one year
averaged to 100,000 btu's per hour
____ = 50% Efficiency
BTU of gas entering boiler in the same period
of time averaged to 200,000 btu's per hour

Overall Efficiency can be split up into two components, boiler side efficiency and system side efficiency. A btu meter installed on the feed and return pipes directly off of the boiler splits the two measurements up. To measure boiler side efficiency install a btu meter on the outlet and inlet of the boiler or furnace and also install a flow meter into the fuel inlet for the boiler. The delta tee of the inlet and outlet of the boiler along with the flow rate over a period of time will give you the heat that the building actually used. Measure the btu content of the gas and flow rate of fuel entering the boiler. Then using the calculation below you can calculate boiler efficiency. Measuring boiler efficiency is much easier to be accurate and easier and less expensive to monitor then overall efficiency. I believe that this method of measuring boiler efficiency is much more accurate then AFUE and should replace AFUE as the new standard. Once the boiler efficiency is improved overall efficiency will be improved too.

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BTU of gas entering boiler in the same period
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The disadvantage to measuring just boiler side efficiency is that it doesn't take into account heat lost in crawl spaces or attics do to pipes or ducts not insulated.

I personally developed with help from Bob Distinti, an equation. My formula looks like this. I call it the HEF or Heating Efficiency Formula. Another name would be

Overall Efficiency Formula or OEF. We applied for a utility patent on the use of the formula in software.

$$\left(\frac{\overset{1}{\text{Heatloss}}\ (\overset{2}{\text{BTU}})}{(\text{Indoor } \underset{3}{\text{Temperature}} - \text{Outdoor } \underset{4}{\text{temperature}}) \times \underset{5}{1\text{HR}}}\right) \times \left(\frac{\overset{6}{\text{Heating}} \text{ Degree Days} \times \overset{7}{24\text{hrs}}}{\text{CCF's } \underset{8}{\text{of}} \text{ Gas} \times \underset{9}{100\text{kBTU}}}\right) = \underset{10}{\%\ \text{Efficiency}}$$

The advantage of using the above HEF formula is that you can find the heatloss of the building; the heatloss remains constant over a long period of time. Thus the heatloss only needs to be found once. The down side is modern day heatloss calculations are not accurate enough for a competitive comparison environment as will be described later in this document. The good news is that I have a few good ideas to improve the accuracy of heatloss using real time methods that will be disclosed at a later time.

1) The Heatloss information can come from a heatloss program such as Calcplus or IBR.

2) The btu’s found in the heatloss.

3) In a heatloss program this is the indoor design temperature.

4) In a heatloss program this is the outdoor design temperature.

5) A heatloss is measured in btu’s per hour. Btu/1hr. This is the hour used in the heatloss calculation.

6) The heating degree day number is added up and amount of fuel used in the same time period is shown in 8. The days can be added up for a whole year to come up with yearly efficiency or you can add up a couple of months during a season such as the fall to come up with efficiency during the fall months. Efficiency is always better during winter months then spring or fall months. By taking spring and fall snap shots you can judge the effects of different outdoor reset controls. Other forms of energy calculation such as modified degree day or Bin can also be used and entered here.

7) In the equation it is necessary to convert the days into hours to cancel out with the hour on the other side of the equation.

8) This is the amount of fuel used during the time period of the heating degree days that were added up. It could be gallons of fuel or cubic feet of gas.

9) This is the btu content found in the fuel being used.

10) The answer will be the percent of heat in the fuel that is being used by the house or building.

To demonstrate the effectiveness of this technology, we apply the HEF equation to actual trial applications.

In the first example, "Home A" with a standard boiler and baseboard heat is upgraded to a more advanced boiler with outdoor reset capabilities. Some of the baseboard heat is replaced with radiant heating. The data taken before the upgrade is:
Heatloss of structure A = 75000 BTU/hr @ 70 degrees
HDD (Heating Degree Days) = 3020 degree*days
Fuel usage in BTU (calculated from fuel bills) = 1135 CCF @100,000 BTU per ccf=113,500,000 BTU

Where HEF = (Heatloss/70)*(HDD/ Fuel usage)*2400 = 68% efficient

After the new boiler and heating system changes were installed, the tests results are
Heatloss of structure = 75,000 BTU/hr @ 70 degrees
HDD (Heating Degree Days) = 3086 degree*days
Fuel usage in BTU (calculated from fuel bills) = 937 CCF @100,000 BTU per ccf=93,750,000 BTUs

And the new HEF value is 85%. This represents a 23% saving in fuel efficiency over the period represented by the calculation. This saving correlates to $610 dollars of saved fuel expenses over the course of the year or 73 million BTUs/year.

The above HEF values are a bit on the high side due to use of industry standard tools to calculate Heatloss. These tools do not determine Heatloss from actual measurements of energy loss; instead, they are determined from tabular data. Because the results are only approximations, they are intentionally overvalued.

As an example, we chose another home (Home B) to run the HEF value against. The homeowner was not complaining about the heating expense for his home and was quite happy with his present heating system although the boiler was 40 years old and the firebox was in disrepair. The numbers for his HEF are as follows:

Heatloss of structure = 25,500 BTU/hr @ 70 degrees
HDD (Heating Degree Days) = 3142 degree*days
Fuel usage in BTU (calculated from fuel bills) = 320 gal #2l @138,500 BTU per gal=44,320,000 BTUs

The HEF value for this home is 62 %. After analysis, it was determined that the boiler was 4 times oversized (100,000 BTU/hr) for the rated heat loss of his house. Furthermore, due to being oversized, the boiler was short cycling, which further wasted energy.

With only the dataset above, it is possible to show the second homeowner that 85% is possible based on the experience from Home A. It is therefore conceivable that the second home could improve his fuel efficiency by 37%. This correlates to a reduction in fuel by about 90 gallons over the 3 months which the calculation was performed. Using $1.23 as the price per gallon (#2 oil), this works out to a savings of about $111 for the 3 months, and conservatively $270 for the entire year. It was recommended to this homeowner that a new, properly sized, boiler will pay for itself in 10 years. If the prices of heating fuels increase as projected by DOE, then the payoff will be realized sooner.

If we assume that 50% of the homes in the U.S will rate below the database average and 50 will rate above. Consequently assume that 50% of the homes below the average could improve their energy efficiency by 20%. This works out to a potential 5% overall reduction in energy assuming everyone takes advantage of the tools that we provide. Considering that the total BTUs used in residences in 2002 (http://www.eia.doe.gov/oiaf/aeo/demand.html) is 20.4 quadrillion; then this correlates to 1 quadrillion BTUs saved per year. In terms of the prices of natural gas (per BTU); this works out to 8 billion dollars per year.

Our world wide estimate crudely assumes that 1/3 or the world population (about 2.5 Bill) has a sufficient standard of living, and climate, such that the average dwelling is heated with systems similar to those in the U.S. Since 2.5 billion is 10 times the population of the U.S, we assume worldwide projections to be 10x the U.S projection. Using this crude approximation, worldwide energy savings are estimated to be 10 quadrillion BTUs per year or about 80 Billion dollars per year (in terms of the price of natural gas).

Vision Statement

I propose that we work on two primary goals. Goal number one is to develop technology around the Overall Efficiency Formulas to make using them much easier so that contractors and homeowners will use them much more regularly. One way could be to improve the accuracy of heatloss through the development of real time information. Another way could be to have monitoring equipment installed into heating systems to measure overall efficiency. Goal number two involves scientific level monitoring. A data base of many different heating systems and there corresponding OEF numbers could be created. We can develop a form to fill out describing all aspects of the heating system being entered into the data base. Categories and sub categories can be entered into the data base. These categories of overall efficiency numbers can be averaged to find out which methods of system design are more efficient. A contest can be created to build the most efficient heating system. Info and results can be entered into the data base and later shared with everyone. The winner can benefit from winning an award. Everyone else can benefit from learning new efficiency methods to use in there own future designs. Papers can be published and seminars developed and taught to other contractors, engineers and homeowners. Every year systems and technology will improve.

Is radiant heating more efficient then hot air? This is the question that will be answered by overall efficiency formulas. Improvement in efficiency will come about through competition. It is important to promote competition in developing efficient heating systems to see improvement. This is a race. This is a race to build more efficient heating systems. It is a race without a finish line. 2000 years from now people will still be improving efficiency in heating systems or at least achieving efficiency at a less expensive price. I want to create competition between radiant and hot air guys and also with radiant vrs different radiant installation methods.

Thomas Edison developed the electrical system that we know today. He developed not just the light bulb but everything else too. He developed generators, electrical meters, light bulbs, and the whole distribution system. He was at Menlo Park when he started. He had many great engineers, scientists and technicians working with him. That gave him a huge advantage. It was this collective use of great talents that got the job done. I propose that we pool our collective knowledge and work together to advance this project.

Work Statement

First Task: The place to start in this project is to build one test site and fully monitor it for a year. The goal in the beginning will not be doing proper comparisons. The goal in the beginning will be to develop the best monitoring method. To do this a smaller sample can be used such as 1 to 5 houses. Good raw data from many different sources is the best.

Second Task: After a year of monitoring the equipment should be moved to a new test site. Another of the same sized sample should be monitored.

Third Task: We take the data from the first task and examine it. We work on developing software that makes it all work together. We also make decisions as to what is best to monitor and we eliminate monitoring methods we feel are not needed. At the same time we add new monitoring methods that we feel might help the project.

Fourth Task: We move the monitoring equipment to a new site. We hook up the new software to it. We gather more funds and with a bigger budget we test a bigger sample of houses.

Fifth Task: We take the data from year two and analyze it. This keeps going year after year until we feel that we have a standardized testing method.

Sixth Task: We then create a data base type of software with different categories. We create a form to be filled out by competing installers. The different installation types are to be put into the different categories. Once multiple systems of the same type fit into the same category an average will be taken.

Seventh Task: We create a non profit organization that monitors the systems. We try and spread the system world wide. We look for grant money from all different countries. We create competitive teams. No one who monitors would also be allowed to compete because this would be a conflict of interest. A competitive team would be organized in similar fashion as a racing team. A group of engineers, scientists and contractors would get together. They would be funded by sponsors and government grants. The teams are to install the heating systems. The non Profit group would do all of the monitoring. The non profit group would also monitor older houses and such.

Eighth Task: All of the info would go into a large data base. Books and articles would be written about which designs work best. Seminars would be given. Software that is simpler and maybe not as accurate is produced and sold commercially so that non competing contractors can monitor overall efficiency in the field for a reasonable expense.

Ninth Task: Year after year everything is repeated. Future generations will use fuel more efficiency. If we switch from fossil fuels to hydrogen then we also monitor hydrogen systems too. It will be important to conserve no matter what type of fuel is used.

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