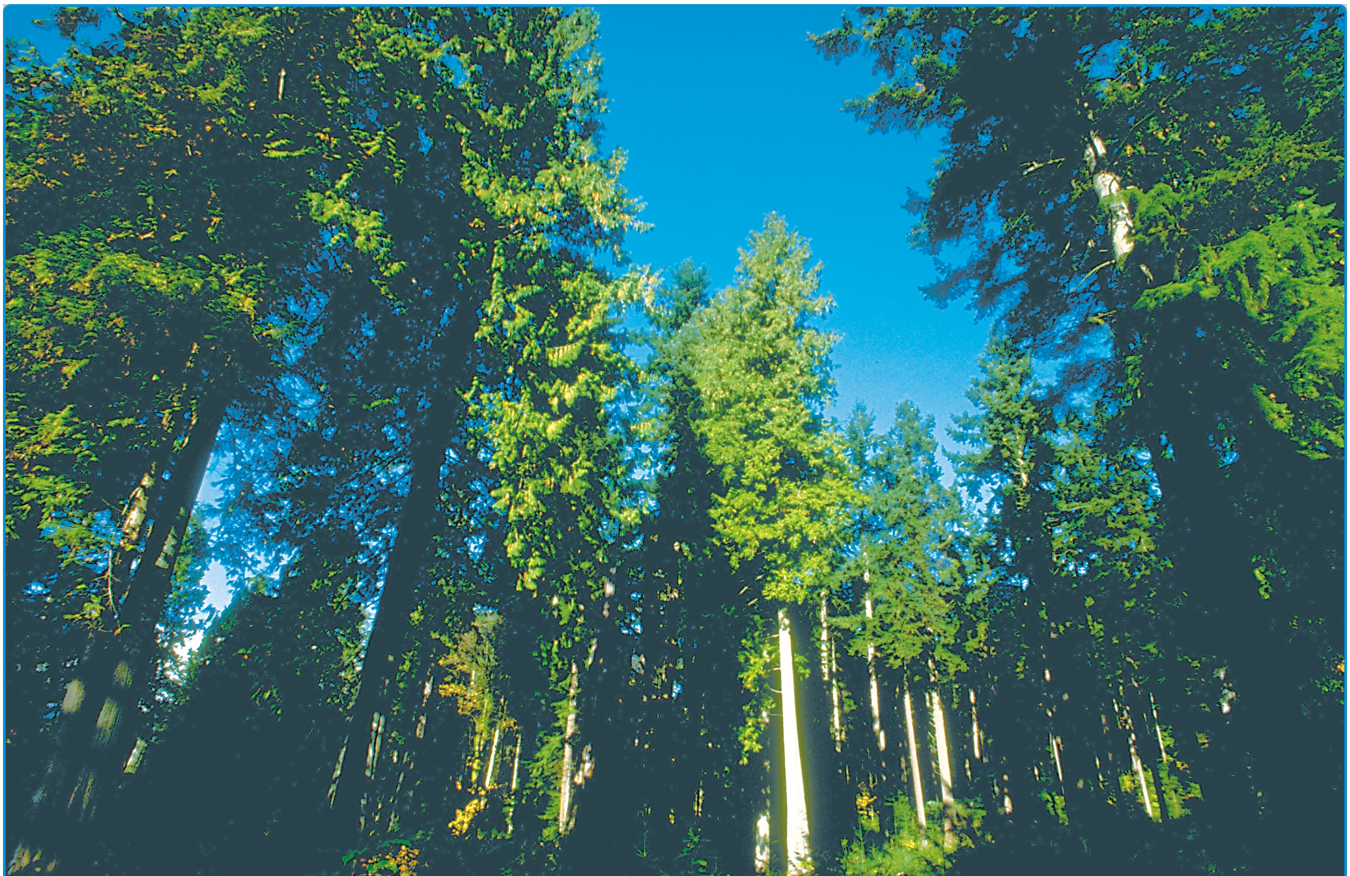
by James E. Houck, Ph.D. and Paul Tiegs, P.E

The market for wood heaters is large; new wood heaters are efficient; the problem appears to be documentation and dissemination of the facts.



WOOD: THE UNTOLD STORY

Possible regional energy shortfalls combined with spiraling fossil fuel and electricity costs suggest that a new look at wood heater efficiency and heat output is in order. Credible and realistic efficiency and heat output figures would increase hearth product sales. Consumers' interest in energy cost savings and desire for a guaranteed heat source are powerful topical market forces when future high energy costs and possible shortages are predicted almost daily by the news media. Answers to the following questions need to be provided to both consumers and energy policy planners:

- How much electric or fossil fuel energy will be saved?
- How much money will be saved?
- How long will it take to pay back the cost of the initial investment?
- What size or model heater is appropriate for a given residence in a given climate zone?

But there are two big problems. First, historically, there has not been a cost-effective, realistic method for measuring and reporting wood heater efficiency and heat output that has been generally accepted. Consequently, both generic and model-specific statements on wood heater performance have often been both misused and mistrusted. Further, because the measurement and calculation methods are inherently complex, efficiency and heat output results from different test methods are often simply misunderstood.

When it comes to wood heater efficiency and heat output, marketing "optimism" and "apples and oranges" comparisons are the norms rather than the exception. To add insult to injury, the efficiency calculation method most often used in the United States produces efficiency levels lower than the actual efficiency that can be expected from a wood heater operating under realistic in-home conditions. Similarly, the default efficiency values associated with the U.S. EPA Standards of Performance for New Stationary Sources (certification emission testing regulations), almost always utilized by wood stove manufacturers for convenience and cost savings, are based on unrealistic scenarios and are lower than what would be expected in most real-world cases.

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The second big problem is education. Few energy policy makers are familiar with the facts about wood heaters and therefore do not include wood heaters as part of their energy plans with recommendations for wood heater use disseminated to consumers. Here's a dramatic example: Among the approximately 170 pages of the May 2001 National Energy Policy report, wood heaters were covered by a single sentence, "Wood, the largest source of biomass, has been used to provide heat for thousands of years." In terms of education and promotion of wood heating, the hearth industry has dropped the ball – big time.

Wood Heater Thermal Testing – History and Methods

During the 1980s and early 1990s, a number of scholarly technical papers and reports on wood heater thermal performance were published by each of the major wood heater research organizations of the time – Shelton Research, Inc. (SRI), Virginia Polytechnic Institute (VPI), OMNI Environmental Services, Inc. (OMNI), and the Canadian Combustion Research Laboratory (CCRL). Standard methods were proposed and, in some cases, even adopted (albeit they have been largely ignored and/or are now obsolete). Organizations that were involved in the methods setting exercise included the U.S. EPA, U.S. DOE, Oregon DEQ, WHA and ASHRAE.

To further confound the current state of affairs, the only significant current wood appliance thermal performance methods, either in final or draft form, have been developed outside the United States. They include: European Committee for Standardization method CEN/prEN 13240, International Organization for Standardization method ISO/DIS 13336, Australian and New Zealand standard method AS/NZS 4012, and Canadian standard method B415.1-00. Like their predecessors, these methods have not been widely used, particularly in North America.

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So what has the alphanumeric soup of testing laboratories, organizations and test methods done for the industry? Very little. Certainly, there is a wealth of esoteric knowledge about the thermal performance of woodburning appliances. If a scientist or engineer studies the methods and reports for a couple of weeks he knows "the story." Not surprisingly, most consumers and energy policy officials don't.

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The current state of affairs also does the manufacturers of wood heaters no favors. Because there is not a uniform accepted method, the choice of which method, if any, to use is unclear and it can be difficult to respond to competitive claims. In addition, since the methods can best be described as benchmark methods which are only qualitatively related to how an appliance actually operates under real-world conditions in homes, it is difficult to use the results of the tests to demonstrate energy and cost savings. However, perhaps the biggest disservice is to the manufacturers' pocketbook. Most of the protocols are complex and expensive. They don't need to be.

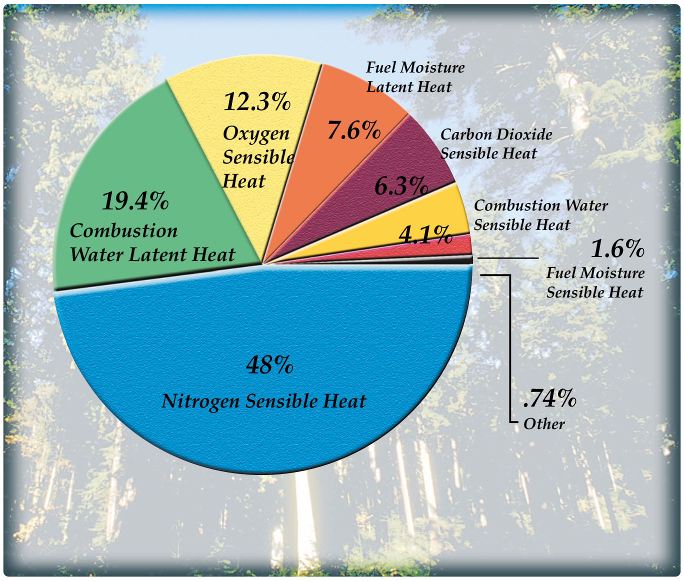
Wood Heater Thermal Testing – Theory

All significant test protocols that have been developed are variations of two basic measurement methods. These are room calorimetry and stack loss. Both are designed to ratio the amount of heat that warms the interior of the house to the amount of heat contained in the fuel. The room calorimetry method measures the amount of heat that would heat the interior of a house by making measurements in a well-insulated room. The stack loss method measures the amount of energy lost due to incomplete combustion of the fuel and the amount of energy lost up the stack; what is left is the amount that is available for heating the interior of a house.

Both the room calorimetry and stack loss methods are reasonable technical approaches. The stack loss method has a practical advantage, in that a given set-up has a more dynamic application range, i.e., it can be used on heaters with a wider range of burn rates and chimney flows. For example, it can be used on the smallest airtight wood stove or on a large furnace or open fireplace equally as well. It also has the advantage that it can be taken into homes where appliances, particularly masonry units, are installed. However, the most important advantage for the industry is that, of the two fundamental method types, it costs considerably less per test.

The overall efficiency of a wood heater, however it is measured, is the product of the combustion efficiency (sometimes called chemical efficiency) and the heat transfer efficiency. If all the carbon, hydrogen and oxygen contained in wood fuel are converted to carbon dioxide and water by combustion, then the combustion efficiency is 100 percent. This, of course, does not happen since products of incomplete combustion composed of methane, carbon monoxide, particles, and non-methane organic vapors are formed. Combustion efficiencies are, however, high as compared to heat transfer efficiencies and they are generally 90 percent or greater.

Heat transfer efficiencies relate to the amount of the heat energy produced by the combustion process that warms the interior of the home versus what is lost out the stack. Heat transfer into the home occurs in three fashions – radiative, conductive and convective transfer. Heat lost out the stack occurs by the physical transport of hot gases (including water vapor) out of the home through the chimney. These gases include air components (oxygen, nitrogen and argon), products of combustion (carbon dioxide and water), and water vapor evaporated from moisture in the fuel. The energy loss associated with the gases exiting the chimney at a temperature greater than room temperature is called sensible heat loss. The energy loss associated with the water leaving the chimney as vapor rather than liquid is called latent heat loss (see chart above).



Efficiency can be reported by two methods. One method assumes heat is available from the latent heat of water produced by combustion, and the fuel higher heating value (HHV) is used in the calculation. That is, it assumes that the 972 Btus per pound of water energy difference between water in the vapor phase and water in the liquid phase is available for heat. This method is sometimes referred to as the theoretical efficiency since water does not, in reality, leave the stack in the liquid phase but obviously in the vapor phase. If water were to condense in a wood heater stack and provide its latent heat, the creosote and condensed water would produce an untenable mess.

The second method of calculating efficiency assumes that the energy associated with the latent heat of water is not available for heat. This method is referred to as the realistic efficiency, since it describes the realistic scenario, i.e., water exiting the chimney in the vapor phase above 212˚F. The fuel lower heating value (LHV) is used in the calculation for this method.

Unfortunately, the calculation method that has been used most frequently in the United States is the theoretical method. Not only does it make a realistic assessment of energy and cost savings more clouded, but woodburning appliances are put at a perceptual disadvantage through its use. Efficiencies calculated by the theoretical method, using the same data from the same laboratory tests, are about 10 percent (not percentage values) lower than the efficiencies calculated by the realistic method. That is, a wood heater with a theoretical efficiency value of 60 percent would have a realistic efficiency value of about 66 percent. It also should be noted that the issue is further confused by the fact that the realistic not the theoretical calculation is typically used in Europe.

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Certification of Thermal Performance

Clearly, to compete in the energy conscious marketplace and to allow for the proper appliance sizing, the documentation of thermal performance is needed. This includes a common sense, realistic efficiency value, as well as heat output and burn duration characteristics for a given wood heater. The measurement and calculation of thermal performance are well understood, both in theory and in practice, hence real-world thermal efficiency information can be provided to the consumer and to the space heating/energy professional without an alphanumeric soup of test protocols.

The approach OMNI-Test Laboratories has taken is to provide thermal performance labels and associated documentation (such as for incorporation into owner manuals) for each wood heater/operation scenario tested. The key difference between the documentation of realistic thermal performance and the multiple procedures spelled out in the methods outlined by the various committees, organizations and agencies is that wood heaters are operated in the normal fashion for which they were designed rather than having artificial conditions superimposed on them. Dimensional lumber, standardized species of wood fuel, preset burn rates, etc., are not used but rather the appliances are operated under the conditions for which they were designed. Typical national or regional values for such parameters as wood fuel species, wood moisture, and stack height (draft) are selected and those conditions are spelled out in the label and associated documentation.

In some cases more than one efficiency test may be appropriate. For example, one test for hardwood and one for softwood, or an additional test for the lower draft produced by a short chimney characteristic of a mobile home may be appropriate. In any case, the objective is to provide thermal performance data from the heater operating in the fashion for which it was designed and as it will actually be used.

Another key point is that the operation of most wood heaters can be characterized as a sequence of highly variable batch processes. For air quality emission testing, this has been recognized and OMNI-Test Laboratories has developed the semi-automated Emission Source Sampler (ESS) to integrate long-term measurements from a number of batches and to get a representative average value. (The ESS has been used with the Washington State certification program and the draft Northern Sonoma County emission testing protocol.) The ESS also provides the data for thermal performance documentation.

Certified Efficiency

Document Docket No.	1176
Manufacturer:	Warm Air, Inc.
Model:	12C
Date:	08/13/01
Fuel:	Oak cordwood
Burn Rate:	1.8 dry lb/hr
Fuel Moisture:	22%DB
Heat Output Range: Btu/hr	10,000-30,000
Realistic Efficiency: (avg)	71%
Burn Duration: (avg)	10 hrs.

The Big Picture

To get the big picture for wood heaters, one needs to go beyond individual appliance efficiencies and put energy usage into perspective. Some surprising facts are revealed when energy usage on an overall home scale or on a national scale is considered. When all aspects of heating appliance use are taken into consideration, wood stoves, pellet stoves, masonry heaters and fireplace inserts replace more fossil fuel energy through their use than the comparison of appliance efficiencies alone would suggest. This is, in part, because most traditional gas and oil furnaces, which are the mainstays of home heating in the United States, have lower overall effective efficiencies than is obvious at first glance.

Without going into detailed and messy calculations, here's why: First, studies have shown that there is typically 30 to 40 percent efficiency loss due to duct work for forced air furnaces. Second, furnaces with draft hoods induce a much higher air exchange rate in a home, bringing in more cold, unheated air than airtight wood heaters. Third, most wood heaters are considered zone heaters, while gas and oil furnaces are centralized. It is generally accepted that zone heaters are, in practice, more efficient than centralized furnaces since only specific areas during specific times are heated when zone heaters are utilized, thus avoiding energy waste. In all fairness, it must be noted that new technology furnaces and home designs with furnaces can also be quite energy efficient. However, the overwhelming majority of homes and furnaces do not fall into that category.

Another surprising fact is that, on a national basis, wood heaters are even more efficient than electric heaters, which along with gas and oil furnaces are the other most common type of home heating appliance in use and have generally been viewed as very efficient. The key reason wood heaters are more efficient on the national scale is that the number of production steps to deliver a unit of space heat to the home for wood heat is fewer than for electric heat. Each production step has its inherent inefficiencies requiring investments of power to perform it.

Nearly three-quarters of all electric heat is produced by fossil fuel combustion, and over one-half is produced by coal combustion. Coal-fired power plants, which are only 30 to 40 percent efficient, and transmission line losses are estimated as being around 12 percent. When all the steps needed to deliver electricity from fossil fuel usage, including extraction, transportation and the processing of fuels, are taken into consideration, the net overall efficiency for coal, as an example, from virgin fuel in the ground to home heat, is less than 10 percent. Consequently, it is very clear that electric heat is far less efficient than wood heat on a national scale, and that in reality a lot more fossil fuel is required for electric space heating than it first appears.

With over six quadrillion Btus of energy used annually for space heating, the issue of overall home and national efficiencies should be a very important aspect of energy planning. Overall wood heater efficiency facts clearly have not been well publicized.

Opportunities

While it is said that only death and taxes are certain, the construction of new homes and the need for heat are nearly as certain. In recent years there have been more than one million new homes built annually in the United States, and there are over 100 million homes in place, virtually all of which (except for those in the state of Hawaii) require space heating. In addition to this large and regularly growing market, the wood heating industry is in a very unique and envious position due to the makeup of existing home appliance types.

There are approximately 28 million households that have woodburning fireplaces without a heating insert, and nine million households that have uncertified wood heaters (stoves and fireplace inserts). These homes provide a ready market for wood and pellet burning appliances. Energy efficient fireplace inserts can be installed and new higher efficiency, cleaner burning Phase 2 wood stoves can replace old uncertified models in these homes without remodeling costs or major home reconfiguration. In summary, the market is large; new wood heaters are efficient; the problem appears to be documentation and dissemination of the facts.

About the authors: Dr. James E. Houck is president of OMNI Consulting Services and a research scientist with over 20 years experience. Paul Tiegs is the president of OMNI- Test Laboratories and a professional engineer with over 25 years of experience. OMNI Consulting Services specializes in energy and environmental issues associated with residential heating. OMNI-Test Laboratories specializes in safety, efficiency and environmental testing of home heating appliances and fuels. Information and related studies can be obtained at www.omni-test.com.