

Discussion Regarding Reporting Units for Emissions from Residential Cord-wood Burning Space-heating Appliances

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EXECUTIVE SUMMARY

Relationships between the units used for measuring and reporting emissions from U.S. EPA-regulated residential cordwood-burning (RC-B) appliances and EPA-exempted masonry heaters are discussed as well as how these relationships are affected by appliance operating conditions and combustion parameters. The primary focus of discussion is on the grams-of-emissions-per-kilogram-of-fuel-burned (g/kg) and grams-of-emissions-per-hour-of-operation (g/hr) reporting units. How these reporting units can be used to indicate relative levels of performance and how these reporting units can be appropriately applied to the type of combustion process taking place and the kind of heating appliance being used is also discussed in detail. Particular emphasis is placed on differences between EPA-regulated woodstoves which are operated by controlling combustion-air supplies and masonry heaters which are operated by controlling the size of fuel loads and the frequency of burning cycles.

Primary conclusions presented in this discussion paper are as follows:

1. The most useful and technically sound reporting unit for all RC-B appliances and masonry heaters would be grams of emissions discharged per unit of useful heat produced. These units have not been used because no verifiable measurement methods were available at the time applicable regulations were being written.
2. The g/kg and g/hr reporting units must be used with caution when applied to the performance of either the EPA-regulated RC-B appliances or the EPA-exempted masonry heaters:
 - a) G/hr can be used to indicate the performance of EPA-regulated RC-B appliances (EPA calls them affected facilities) only because of the limitations imposed by EPA's definition of RC-Bs and the specificity of the test methodology utilized to measure emissions performance. It is only because these limitations and specificity impose such a narrow range of sizes, design configurations, and test-condition operating protocols that the g/hr reporting units can be used for ranking one RC-B against another. G/hr should not, however, be used to estimate field performance of RC-B appliances.
 - b) The g/hr reporting unit is not appropriate for masonry heaters because it does not directly reflect the optimized quality of the burning process which takes place in masonry heaters. G/kg is the most useful reporting unit for masonry heaters because it does directly reflect the quality of the burning process taking place. In addition, with g/kg data and defined construction specifications, masonry heaters can be fairly ranked against one another.
 - c) Since g/kg is the most useful unit for indicating the quality of the combustion process taking place, it would also be useful for comparing the currently regulated RC-B appliances (ie, woodstoves) with masonry

heaters.

INTRODUCTION

The underlying concern of everyone involved with the issue of units for reporting pollutant emissions from residential cordwood-burning space-heating appliances (RC-B appliances for brevity) is the amount of pollutants being discharged into surrounding airsheds during any given period of time. One difficulty which emerged early in the efforts to develop RC-B emissions control and reduction regulations and also caused some controversy and confusion over the last 14 years, is the units for expressing the amount of emissions (primarily PM₁₀-particulate and carbon monoxide) being emitted by RC-B appliances. The two primary reporting-unit candidates considered since the regulation of woodstove and fireplace emissions began in the early 1980s, are:

1. The emission factor; ie, how much (mass) of pollution is discharged per mass of fuel burned, expressed in grams per kilogram (g/kg), and
2. The emission rate; ie, how much (mass) of pollution is discharged per unit of time, expressed in grams per hour (g/hr).

A third candidate, mass of pollution discharged per unit of useful room heat produced by an RC-B appliance expressed as grains per British thermal unit (gr/Btu or in SI units; grams per Megajoule (g/MJ)) had been considered in the early days of regulation development. However, because a verified method for measuring efficiency did not exist at that time and it was thought that an acceptable and accurate measurement method would be very expensive, this unit of measure never gained favor by regulators or the RC-B appliance manufacturing industry.

The basis for controversy between using either of the two primary-candidate reporting units is whether one or the other provides better information for ranking one RC-B appliance against another and/or whether one or the other provides better and more useable information for modelling the relationship between the amount of RC-B pollution being discharged into an airshed and how the RC-Bs are being operated. It would be simplified and ideal if RC-B appliances discharged pollutants at constant rates or even consistent rates for any given burn rate or heat output level. Other residential heating appliances, like oil or gas furnaces or even pellet stoves and most large combustion sources like electric power utility boilers, have controlled air supplies and fueling rates to optimize combustion processes at a "steady state". This maintains nearly constant, low pollutant emission rates over long periods of time. If RC-B appliances had steady-state combustion conditions and constant and consistent emissions rates like the gas- and oil-fired heating appliances and large power generating facilities, relatively simple calculations could be used for developing good estimates or models of airshed pollutant loading from RC-B appliances. But the fact is that no RC-B appliance discharges pollution at a constant rate from the beginning to the end of a fuel-load burn cycle or even consistent rates from one burn-rate/heat-output level to the next. As a cordwood-fuel load burns in an RC-B appliance its physical and chemical characteristics change dramatically as do the amount and the physical and chemical nature of the pollutants being discharged. Everything is always changing in a cordwood-burning appliance including other, additional, and combustion-influencing parameters like temperatures, fuel weight, and fuel-load geometry.

ANALYSIS OF RC-B EMISSIONS DYNAMICS

Figure 1 is a generalized illustration showing how particulate and carbon monoxide emission factors (g/kg) change as well as how the burn rate itself changes as one, full fuel load is burned (ie, one "burn cycle") and the appliance is operated at one air supply setting. A percentage scale is used on the y-axis to show the minimum and maximum for each graphed parameter (ie, 0 to 100% is the total range of change that take place for each of the parameters). This illustration demonstrates how each parameter changes relative to the minimums and maximums for each of the other graphed parameters.

The fuel load is ignited at 0% fuel-load consumption. The burn rate begins slow at this point but increases rapidly to a maximum fuel consumption rate (ie, kg/hr) at a point when about 50% of the fuel weight has been consumed. Emission factors (g/kg) for both particulate and CO emissions begin rising right at the point the fuel is ignited. Particulate emission factors (g/kg) increase more rapidly than the emission rate (g/hr), however, as volatile and semi-volatile materials in the fuel load are heated and vaporized by the increasing amount of heat being generated.

Because RC-B appliances are all batch-loaded fuel processors and rely on very weak naturally drafted air supplies, it is unavoidable that periods of time will occur during a burn cycle when at least some small area within the combustion zone will have imperfect combustion conditions (eg, not enough residence time or the mixing and/or temperature conditions are not optimum). State-of-the-art, low-emission RC-B appliances optimize combustion throughout the burn cycle using combustion-air distribution systems which are powered by natural draft forces. They also use enhanced firebox heat management designs for optimized thermal performance. But, even with this new technology, it is impossible without expensive auxiliary powered control designs (eg, electrically) to avoid all imperfect combustion conditions that can occur with a batch-loaded process. It is the unburned or incompletely burned volatile and semi-volatile materials resulting from these imperfect combustion conditions that escape the firebox and form particulate emissions as they cool and condense on their way up the chimney.

Analyzing Figure 1 further shows that after the particulate emission factors (g/kg) are maximum at a point when about 30% of the fuel load has been consumed, they decrease due to improving, more vigorous combustion conditions in the firebox (ie, higher temperatures and more mixing). Particulate emission factors (g/kg) then decrease rapidly after about 60% of the fuel load is consumed due to decreasing volatile and semi-volatile contents of the fuel. The point at which the volatile and semi-volatile contents of the fuel have been depleted is sometimes called the charcoal stage of a burn cycle and is characterized by low particulate emissions.

Like particulate emission factors (g/kg), CO emission factors (g/kg) increase in the early stages of the fire due to the increasing amount of fuel being burned with inadequate temperature and/or mixing conditions.

CO emissions per kilogram of fuel being burned (g/kg) start decreasing after about 40% of the fuel is consumed which is when combustion conditions begin to improve. CO emission factors (g/kg) only decrease slowly however, until a point at which the burning fuel is dominated by coals (which is characterized by both high carbon and low volatile and semi-volatile material content). At this point, there is usually sufficient temperatures for good combustion. However, inadequate air and fuel mixing becomes the dominant combustion imperfection which causes the dramatic increase in the amount of CO produced for every kilogram of fuel burned at this final part of the burn cycle.

Figure 2 has similar axis scales to those in Figure 1 except that Figure 2 shows how particulate and CO emission rates (g/hr) change during a burn cycle and, as in Figure 1, it includes a curve showing how the burn rate itself changes during one full burn cycle at a constant air supply setting. Since the emission rates are a direct function of burn rate,

ie, burn rate (kg/hr) x emission factor (g/kg) = g/hr,

changes in both the particulate and CO emission-rate curves follow changes in the burn-rate curve very closely. This emission rate graph (gr/hr) does show clearly that at the same time in the burn cycle when large changes in the amount of emissions being produced for every kilogram of fuel being burned are taking place (as shown in Figure 1), there is little evidence of improving or deteriorating combustion conditions. Figure 2 is useful however, for showing that increasing fuel consumption rates increase both CO and particulate emissions rates (g/hr).

Figure 2 also illustrates how good combustion conditions and hence, low emissions per kilogram of fuel being burned can be masked by a high burn rate: ie, lower g/kg emissions and optimum combustion conditions occur at the relatively higher burn rates but are not indicated by the g/hr curves. This is ironic because it is at the higher burn rates that the batch-loaded RC-B appliances universally have the best combustion conditions and the lowest amount of emissions per kilogram of fuel being burned. This also means that a good RC-B appliance design can consistently produce the best, optimized combustion conditions but because the stove may have a consistently high burn rate, and hence, more heat output, it can be kept from the market because of high g/hr emissions. With equal overall efficiencies and equal g/hr emission rates a high burn-rate RC-B appliance would discharge less pollution to the atmosphere than a low burn-rate RC-B appliance delivering the same amount of total heat.

Figure 3 is a graph that shows how both the PM10-particulate emission rate (g/hr) values and the emission factor (g/kg) values change as full burn-cycle burn rates change in a typical non-catalytic RC-B woodstove. The patterns shown are characteristic of all non-catalytic woodstoves with adjustable air supplies and hence, adjustable burn rates. Each data point in each curve represents a whole fuel-load burn cycle at one air supply setting. Therefore, it takes many tests to gather the data for these curves. The size of any particular stove (and hence its fuel load size) will shift the kilogram-per-hour burn rate scale right or left but the resultant emission rate and emission factor patterns will stay the same. Even poorly designed woodstoves would have the same patterns but the scale for emissions rates and emission factors on the y-axis would increase to show higher emissions at any given burn rate.

The emission rate (g/hr) curve in Figure 3 shows rapidly increasing emissions as burn rates increase in the very lowest burn-rate range below 0.4 kg/hr, followed by a continuing, although lower slope increase to the 1.0 kg burn-rate level. The g/hr then shows a decrease as the burn rate increases in the mid-ranges to 2.0 kg/hr.

The rapidly rising g/hr emissions that occur when the burn rate increases in the lowest burn-rate range below 0.4 kg/hr, are due to large relative increases in burn rate with concurrently increasing emissions reaching the atmosphere for each kilogram of fuel being burned. There is an increase in emissions discharged to the atmosphere as burn rates increase at these very low burn rates in spite of the fact that air/fuel mixing is improving and higher temperatures are being generated. This is because at the very lowest burn rates (ie, less than 0.4 kg/hr on this graph) where the worst combustion conditions occur and the maximum amount of emissions are produced in the combustion zone for every kilogram of fuel burned, some of the emissions condense and get deposited on firebox and flue pipe walls before they can be discharged to the atmosphere. This phenomenon actually results in lower emissions to the atmosphere but a higher rate of creosote deposition in the chimney. Although always present in these low burn rate ranges, the effect of creosote depositions on emissions to the atmosphere decreases as the burn rates increase from 0.

The emission factor (g/kg) curve also increases in the burn rate range below 0.4 kg/hr. Since g/kg does not have a direct mathematical relation with burn rate like the g/hr units, the increase in emissions in this burn rate range is due only to the decreasing effect of creosote deposition as the burn rate increases.

The g/kg curve decreases after the 0.4 kg/hr burn rate because the effect of better air/fuel mixing and higher temperatures decrease the amount of emissions being produced for every kilogram of fuel being burned. Although the amount of emissions per kilogram of fuel being burned decreases, the g/hr curve continues to increase above the 0.4 kg/hr burn rate due to the fact that the large relative increase in burn rate offsets the relative decrease in the amount of emissions produced for each kg of fuel burned. For example, if there is a doubling of the burn rate from 0.5 kg/hr to 1.0 kg/hr and at the same time there is a 35% decrease in emissions produced by each kilogram of fuel being burned, the g/hr emission rate still increases 30%. That is,

0.5 kg/hr burn rate x 30 g/kg emission factor = 15 g/hr emission rate,

then doubling the burn rate and decreasing the emission factor by 35% gives:

1.0 kg/hr burn rate x 19.5 g/kg emission factor = 19.5 g/hr emission rate,

which is a $((19.5-15.0)/15.0) \times 100 = 30\%$ increase in the emissions rate.

By definition and by their direct mathematical relationship, the g/hr and g/kg curves cross at the 1.0 kg/hr burn rate. After these curves cross, the decreasing g/kg emissions overcome the relative increases in burn rate which then effect a decrease in the g/hr curve. As the burn rate approaches 2.0 kg/hr the g/kg emissions decrease to a minimum due to optimized combustion conditions in the firebox. The height of the g/kg curve at the point that combustion (or more appropriately, the quality of the burn) is optimized is a function of firebox/stove design. Better designs will have lower g/kg curves in the combustion-optimization range. An important fact about this part of the g/kg curve is that the combustion-optimization segment of the curve covers a relatively large area of the mid to high burn-rate range and not the low burn- rate ranges. All EPA certified non-catalytic stoves must burn the majority of their fuel loadings in this range or they will not have a low emissions rate (ie, g/hr). It is important to note again that even if the quality of the combustion process (ie, g/kg) stays the same in these stoves, just increasing the burn rate would increase their g/hr emissions rate. It is also important to note this low emission factor part of the g/kg curve because this is the burn-rate range where masonry heaters always operate.

Masonry heaters are all designed to burn fuel at one burn rate in the mid to high combustion-optimized range to obtain the most heat production and lowest emissions possible. It must also be realized that emissions represent low combustion efficiency and lost/wasted fuel-heating potential.

The whole curve for a masonry heater would be one point or would only cover a small area in the combustion-optimized segment of the burn-rate range. This is because masonry heaters are only designed to have one burn rate. If a masonry heater firebox is designed poorly, the g/kg curve (point) would be higher in this combustion-optimized part of the curve and the curve (point) would be lower in a well designed masonry heater.

Again, by definition and because of the direct mathematical relationship between g/hr and g/kg, the g/hr curve increases throughout the combustion-optimized segment of the burn-rate range. This is due to the fact that although the g/kg curve is constant (flat) showing no change in the quality and efficiency of the combustion process taking place, merely increasing the burn rate causes the g/hr curve to increase. For example, keeping the g/kg emission factor constant while the burn rate changes from 2.5 to 4.0 kg/hr will increase the g/hr emission rate by 60%. That is,

5.5 g/kg emission factor x 2.5 kg/hr burn rate = 13.75 g/hr emission rate,

then increasing the burn rate from 2.5 to 4.0 kg/hr gives;

5.5 g/kg emission factor x 4.0 kg/hr burn rate = 22.00 g/hr emission rate,

which is a $((22.00-13.75)/13.75) \times 100 = 60\%$ increase in the emission rate.

Therefore, it can be very misleading to assess the pollution characteristics of an RC-B appliance, masonry heater or woodstove, just by only using a g/hr value. Any clean burning appliance design can have high g/hr emission rates just because it burns fuel fast. Even though they can be producing more heat with lower total emissions to the atmosphere, single burn-rate, high burn-rate appliances such as masonry heaters are viewed as high polluters when g/hr values are used for comparison to other types of appliances like adjustable burn-rate woodstoves.

To conclude the g/hr- and g/kg-curve analysis, the increase in g/kg emissions at burn rates above 4.0 kg/hr is due to decreasing combustion efficiency which is caused, in most cases, by excess combustion-air cooling or by dilution of the combustion gases given off by the heated wood before they can burn. Depending on the firebox design, the fire can also become too fuel rich because too much of the fuel load is being heated to high temperatures which creates large amounts of combustible gases without enough air for efficient combustion. In either of these cases the amount of pollution created by each kilogram of fuel increases and hence, the slope of the g/hr curve increases even more. The g/hr-curve increase progresses at a steeper slope than the g/kg curve because it is compounded by both an increasing burn rate and an increasing emission factor.

DISCUSSION and CONCLUSIONS

To get around the problems presented by the variable and constantly changing RC-B combustion and emissions parameters, the EPA and the Oregon and Colorado state certification testing programs, required that regulated RC-B appliances be tested for emissions at four different burn rates ranging from low to high. Since each test sample is taken/collected over an entire burn cycle, each test represents the average pollutant discharge that took place during the burning period for each of the four whole fuel loads. The results from each of the four separate tests are then weight-averaged together using weighting factors derived from the expected average annual residential heat demand of the average house in an average heat demand location in the U.S. Therefore, what you have at the end of this certification process is a single emission rate (in g/hr as required by EPA) for each model of RC-B appliance which indicates the average mass of pollution that can be expected to be discharged on an hourly basis when the appliance is in operation.

It is important to note in this discussion that both the g/hr and g/kg units are resultant data from certification testing of RC-B appliances. No additional testing is required to obtain either unit of measure. It's only a quirk of history that of the three options for reporting units, the EPA, and the states that have had certification programs, chose the g/hr units to establish regulatory emission limits for RC-B appliances.

The use of g/hr units started in Oregon and then was adopted by Colorado and finally by EPA. During the NSPS negotiations, there was EPA resistance to change from the units used by Oregon and Colorado even with solid technical arguments supporting change. The record of EPA's New Source Performance Standard (NSPS) negotiations with the RC-B appliance industry clearly shows that the choice for g/hr was not made without challenging comments or good alternative recommendations. EPA argued that since their goal was only to develop a reliable ranking system for comparing RC-B woodstoves to one another, the already-used g/hr units would serve that purpose and be chosen.

Clearly the most useful reporting units would have been in grams of pollutants discharged to the airshed per

unit of useful heat output from the RC-B appliance. The real advantage of this unit of measure is that it would take into account the overall thermal efficiency of the appliance. If the g/hr or g/kg test results were equal between two RC-B appliance models, the more efficient model would burn less fuel in less time to heat the same space. As mentioned above, the heat output-based emission-rate units were not used since they would require the measurement of overall thermal efficiency and EPA felt the thermal efficiency measurement methods available at the time the NSPS was being negotiated were costly and not verified enough to use in EPA's certification program.

In the determination of grams per hour (g/hr) units of emissions measurements for regulating RC-B woodstoves, it is not required by the method that the appliances provide any useful space heating. All that is needed to determine g/hr is the measurement of total exhaust-gas flow rate and the pollutant concentration; ie,

$$\text{g/m}^3 \times \text{m}^3/\text{hr} = \text{g/hr}.$$

Where: g/m³ = grams of emissions per cubic meter of flue gas. m³/hr = cubic meters of flue gas flow per hour.

Neither the concept of g/hr itself nor the test method protocols to measure g/hr emissions, require the production of any useful heat, only that the appliance be able to burn specified fuel loads within 4 prescribed burn rate categories. To emphasize, the test method does not use heat output categories, just burn rate categories.

During the New Source Performance Standards (NSPS) negotiations in 1986, the U.S. Environmental Protection Agency (EPA) decided to assume standard thermal efficiency levels for all certified RC-B appliances. Considering their objectives, this approach to efficiency is somewhat reasonable since the definition of the appliances being regulated (EPA calls them "affected facilities") imposes physical and operating specifications like air-to-fuel ratio, weight, and firebox volume limitations which when used in combination with the required burn rate categories and the emission limits, result in the approximate EPA assumed efficiency levels. This is not coincidental but an engineering fact that if all the affected- facility definition criteria, test-protocol requirements and emission limits are met, the overall efficiency levels will be close to EPA's assumed levels.

Most importantly, when discussing units of measure the unique features of RC-B woodstoves that make the g/hr units useable in the regulation of woodstove emissions are:

1. The heat output (burn rate) of the appliance is adjustable on a real time basis. If the user desires more heat, the air supply and/or fuel load is increased to increase the combustion process and if less heat is desired the air and/or fuel load is decreased, and
2. The production of heat in the firebox by the fuel-burning combustion process and the release of that heat to the surrounding space occurs at virtually the same time. There is no, or only a very small, delay between heat production by the fuel-burning process and the transfer of that heat to the space being heated. RC-B appliance firebox shells are virtually all made from either sheet metal or cast iron to accommodate this heat transfer. In either case, these high heat-conductivity materials are used because they conduct heat from the firebox to the surrounding space as quickly as possible. Because woodstoves are not designed for heat storage, there is no (or only very little) storage of heat in the mass of the appliance. Woodstoves make heat in the firebox and transfer it to the space being heated as soon as possible.

These features make the g/hr unit of measure applicable to woodstoves but applicable only because these

features are unique to woodstoves. This does not mean that g/kg or the mass of emissions per unit of useful heat output could not be used. In fact either one could be used with at least as much and more useful information being provided about the quality and efficiency of the combustion process taking place. No other appliances or source types burning any other fuel for any other reasons can reasonably use the g/hr unit alone. No matter what the source, without production or process throughput data there would always be serious potential for transferring incorrect information.

It is only because of the construction specifications imposed by EPA's NSPS woodstove definition and the emission limits imposed on the regulated woodstoves that allow the use of g/hr units. In addition, because of the definition and the emission limitations, woodstoves are, by default, regulated based on the amount of emissions produced per unit of useful heat output. This is because of the assumed efficiencies and the amount of useful heat output generated during the burning of test fuel at the rates required by the test protocols: eg, virtually all regulated non-catalytic stoves burning 1 kg/hr will produce approximately 12,500 Btu/hr of useful heat to the surrounding room, and virtually all catalytic stoves will produce approximately 14,500 Btu/hr when burning 1 kg/hr of fuel. This is because the efficiencies for all of the RC-B stoves in each category, non-catalytic and catalytic, are nearly the same.

Masonry heaters were intentionally excluded from the EPA's NSPS by EPA's specified weight criteria. EPA rationale was that masonry heaters would require time- and money-consuming development of new test method operating protocols and because of their designed, consistent high burn-rate, would be clean burning anyway and would not present problems in local airsheds. In addition, if the EPA were to regulate masonry heaters, the reporting units for emissions would have to have been changed first.

The g/hr emission rate is not useful or appropriate for masonry heaters since masonry heaters only burn fuel during a very short part of their useful heat output cycle. In addition, if masonry heaters are to be ranked or compared to woodstoves the woodstove NSPS test-method operating protocol (Method 28A, 40 CFR 60, appendix A) would have to be changed. Since the primary burn-cycle mode of operation for masonry heaters is one fuel load burned at the full-high burn rate until all the fuel is gone, the test cycle would need to include the whole cycle including start-up and complete burn down (ie, a "cold-to-cold" test-burn cycle). The test-method operating protocol would have to take into account the fact that useful heat output is produced by masonry heaters long after the fire has gone out.

Method 28A for woodstoves is a hot-to-hot test-burn cycle: a hot coal bed is established in a hot stove; a specified fuel load is then added to begin the test; and completion of the test is at the point in time when the added fuel is totally consumed back to the original, hot coal bed. This cycle is conducted at 4 different, and specified burn rates to make a complete certification test series.

It is important to realize the difference between testing an RC-B appliance using a hot-to-hot test cycle as opposed to using a cold-to-cold test cycle. In 1986, Jay Shelton of Shelton Research in Santa Fe, New Mexico did a woodstove research project for the State of Colorado and found that emissions discharged during the cold start up of a woodstove equals 50 percent of the emissions discharged during a whole hot-to-hot test cycle. This means that the standard EPA test method misses up to 33 percent of the total emissions actually discharged by a woodstove.

This is not a criticism of the method, if it is kept in mind that the method was designed to rank stoves against one another and not to simulate actual and absolute in-consumer-use emission rates. It was felt by almost all of the regulators participating in the NSPS regulation negotiations that ranking of stoves with an indicated relative emissions reduction was more important than trying to establish absolute or "real world" emission rates for certified stoves. That is, an NSPS limit of 7.5 g/hr for non-catalytic stoves was a 75 percent

reduction from the 30 g/hr which was considered by the regulators to be the emissions rate for the common "conventional" stoves in use at the time of the NSPS negotiations. The idea was that the 75 percent reduction indicated by the laboratory test method would translate to a 75 percent reduction in actual home-heating-use emissions to the atmosphere regardless of what the actual or absolute emissions rates were. The objective was to get the 75 percent reduction. There was never any attempt or wish by EPA in the NSPS negotiations to use woodstove certification emissions values for estimating or modeling airshed emissions loading rates.

On the other hand, all standardized testing performed on masonry heaters to date has sampled the whole burn cycle on a cold-to-cold basis. The Automated Woodstove Emission Sampler (AWES) used by OMNI Environmental Services in performing 'in-situ' field and laboratory sampling of masonry heaters, collects emissions samples at all times of the burn cycle, including start-up from cold (no fire) to cold, total-fuel burn-down for total sample periods of one week or more, 24 hours a day.

In conclusion, since all masonry heaters built to a masonry heater construction standard will all have essentially the same efficiency, what masonry heaters need is a reporting unit for emissions that reflects the quality of the burning process taking place inside the appliance. That is, how much pollution is created by each unit of fuel burned. And since firebox size affects the fuel load capacity and hence also affects at which burn rate combustion optimization and lowest emissions will occur, the reporting units on which masonry heaters are regulated should be g/kg. Adoption of this reporting unit would provide for a clear and concise measure of combustion quality and when combined with masonry heater design specifications, would provide for the lowest emissions per unit of useful heat produced.

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