MASONRY HEATER TEST RESULTS FROM AUSTRIA

Austria has one of the richest masonry heating traditions in the world. The only masonry heaters built in Austria are of the Grundofen (all masonry) type, and always have been. The Einsatz (metal insert) system, popular in Germany, has never made inroads here. Furthermore, Austria has an uninterupted stovebuilding tradition. Most other countries stopped building heaters during the cheap oil era, thus losing much trade-based knowledge.

Previous issues of MHA News have carried reports on Austrian activities. About three years ago, David Lyle sent in a copy of an article from "Klima und Raum", the Austrian stovebuilding and ceramics journal, that detailed the joint development of the "Bio-Firebox" by Rath Refractories and the Austrian stovemason's guild. MHA News ran a full translation, which included the North American debut of the "Top-Down" burn.

After the '92 Phoenix MHA meeting, we ran a report on our meeting with Dr. Ernst Rath, who had made a special trip to meet with the North American stovebuilding community. Dr. Rath is CEO of Austria's largest refractory company and an MHA member. He recently sent us a new batch of "K+R" issues, containing reports on recent Austrian testing.

The Austrian stovebuilder's guild has its own test facility and commissioned several test series over the last two years.

The 1991 series was prompted by the increasing concern with emissions from solid fuel burning devices. The approach was to field test 34 stoves of the Grundofen type in order to get a "snapshot" of the current situation, and generate enough data so that some meaningful conclusions could be drawn.

The results were published in the June '92 issue of K+R in an article by Dr. Herman Hofbauer. A summary follows: (translation by N. Senf)

Emissions are influenced by three factors: the appliance, the fuel and the operator. Laboratory testing only addresses one of the these, the appliance, even though fuel and operator are large factors in actual use.

The goal of the field tests was to generate representative data on emissions and efficiency for wood-fired masonry heaters.

> THE GOAL OF THE FIELD TESTS WAS TO GENERATE REPRESENTATIVE DATA ON EMISSIONS AND EFFICIENCY FOR WOOD-FIRED MASONRY HEATERS

The tests were to include a number of different Grundofen configurations, and fuelling factors were to be addressed as well. In order to meet these goals and obtain a representative sampling, an Austria-wide set of field tests of actual stoves in normal use was required.

Another deciding factor in the design of this test series was the fact that, aside from laboratory data, existing field data consisted mostly of individual tests on single stoves, and usually on extremely bad examples of the stovebuilders art. The aim of the this test series was to generate a database to serve the following purposes:

- ❑ a general purpose database for regulatory and other considerations
- ❑ a basis for overall country-wide emissions estimates
- ❑ a basis for comparison with other wood heating systems

Conducting the Tests

The choice of masonry heaters to test was done by technical representatives of the indivdual Austrian states. A uniform data form was designed and used.

Testing was done with "test-suitcases" normally used in the combustion trades for domestic heating systems. Samples were taken at the final flue run just before entry into the chimney connector. In cases were this wasn't possible, it was noted on the data form.

Tests burns were carried out by the homeowner with the homeowner's normal fuel. Various parameters such as type of ignition (top, bottom, etc.) were recorded and measurements were made at 5 minute intervals for the following:

- O_2, CO_2 and CO concentrations
- Flue Temperature

Table 1: Summary of Austria-Wide Field Test Series

Stov eNr	Desi gnkW	FBox Type	Firebox Dimensions			Fuel	Am'nt	Ignit ion	CO mg/MJ	Effic. %
			L	W	H					
1	6.5	N	70	40	75	C	15	B	1200	87
2	5.6	N	70	35	75	C	12	B	2300	79
3	7.4	N	98	37	82	C	18	B	3400	87
4	5.2	B				C	10	T	1460	86
5	5.2	N				C	10	T	2150	89
6	5.2	N				C	10	T	2230	88
7	7.5	N				B	10	T	970	77
8	4.2	N	73	55	55	C	6.5	B	1680	81
9	7.5	B	66	50	84	C	3	B	2060	73
10	7.5	B	66	50	84	C	14	T	3250	77
11	8.2	N				C	20	T	1230	80
12	6.5	N				C	10	REAR	1100	82
13	6.8	B	61	40	79	C	17	B	470	81
14	7.0	NB	50	50	60	B	10	B	1470	92
15	7.0	NB	100	37	68	B	15	B	940	83
16	4.8	N	100	35	75	C	11	B	910	85
17	4.5	N	50	40	70	C	6	B	3300	81
18		B	80	70	90	C	15	T	1060	78
19	8.0	N	60	60	45	C	15	T	11140	79
20	7.0	B	45	59	80	C	15	T	1550	94
21	7.0	B	45	59	80	C	15	T	2120	93
22	7.8	N	109	50	66	C	15	T	1400	86
23	6.0	N	70	60	75	C	15	T	1270	89
24		N	90	60	50	C	15	T	3660	80
25	6.1	N	58	54	150	C	12	T	4890	90
26	7.4	N	60	50	90	C	12	T	2640	86
27	4.2	N	50	40	70	C	10	B	3440	77
28	3.0	N	40	25	60	C	6	B	1890	75
29	7.5	N	70	50	80	C	12	T	4590	87
30	6.7	N	75	40	61	C	15	T	9960	90
31	4.5	B	45	53	42	C	8.5	T	4600	61
32	5.4	N	70	50	65	C	12.5	T	980	75
33	5.5	N	60	40	60	C	8	B	9730	93
34	4.0	B	48	45	55	C	8	B	1860	90

Notes:

Firebox: N=Normal B=Bio NB=Normal firebox with boiler section

Fuel:: C=Cordwood B=Briquettes

Inition: T=Top B=Bottom

- Excess Air
- Stack Losses

The design of the test protocol was done by the Testing Laboratory of the (Austrian) Stovemason’s Guild. The heaters were compared on the basis of average CO number and average efficiency.

The CO Emissions Factor

This serves as an indicator of combustion quality and of emissions, since the emissions of CO and hydrocarbons go hand in hand.

(editor’s note: There is no evidence that this applies to particulates also. Recent North American masonry heater testing in general has shown no correlation between CO and PM-10 in the 1-5 gm range. The 1993 Lopez Labs testing (see report elsewhere in this issue) also indicated a strong relationship between real-time hydrocarbon numbers from a gas analyzer and real-time PM numbers from a dilution tunnel.)

THE DESIGN OF THE TEST PROTOCOL WAS DONE BY THE TESTING LABORATORY OF THE (AUSTRIAN) STOVEMASON’S GUILD. THE HEATERS WERE COMPARED ON THE BASIS OF AVERAGE CO NUMBER AND AVERAGE EFFICIENCY.

CO factors are given in mg/MJ (milligrams CO per MegaJoule of heat output). This allows direct comparison with other heating systems and fuels.

Emissions and efficiencies were calculated according to the following formulas:

$$E_{CO} = \frac{\sum X_{CO}}{\eta m \sum X_{CO_2}} K \sum X_{CO_2}$$

$$K = \frac{1.250 CO_2 max \times V_{go}}{100 H_u}$$

(=approx 72 for wood @ 15% moisture)

where:

E_{CO}	mg/MJ	Emissions factor for CO (=3.6 mg/kWh)
Xco	%	CO concentration in exhaust gas
Xco_2	%	CO_2 concentration in exhaust gas
ηm		Average efficiency
CO_2max	%	Maximum CO_2 concentration
Vgo	Nm^3/kg	Stochiometric exhaust gas volume per kg of fuel (dry basis)
Hu	MJ/kg	Heating value

Average Efficiency

The average efficiency was obtained by the Siegert stack loss method. Losses due to incomplete combustion were ignored *(ie., combustion efficiency of 100% is assumed).* The average efficiency calculation also assumes that the exhaust gas rate (liters per second) is approximately constant throughout the burn.

$$\eta = 1 - qv$$

$$\eta m = \frac{\sum X_{CO_2}}{\sum X_{CO_2}}$$

where:

ηm	%	Average efficiency during one complete burn cycle
η	%	Efficiency
qv	%	Stack Loss (Siegert)
X_{CO_2}	%	CO_2 concentration in exhaust gas

The average efficiency was obtained by taking into account the complete burn cycle, from ignition to the closing of dampers. The most recent research at the Guild's test lab. indicates that this is a good approximation, and a writeup will appear elsewhere. This allows us to calculate a good approximate average efficiency number from CO and CO_2 measurements alone.

Test Results

Field tests were conducted on thirty four installations in 7 different (Austrian) states in order get a representative sample of different construction methods, rated heat outputs (ie., stove sizes), firing methods and fuel types.

Results are summarized in Table 1.

All results were used in calculating averages, including outlying data points, in order to obtain a representative sampling of existing installations. It should be stated that this test series yielded valuable data on the performance of different masonry heater types.

(Translator's note on the Great Confusion in masonry heater terminology: strictly speaking, the German-language term "Kachelofen" applies to any stove with a Kachel (=structural clay tile) facade, including a hot air convection stove with a metal insert (="Einsatz"). "Grundofen" is the generic term for an all-masonry, high mass, fast burn, heat storing stove, ie., a masonry heater as defined in draft ASTM E-06.57.07. The Einsatz is popular in Germany, but has never found favour in Austria. Therefore, in Austria the term "Kachelofen" automatically implies "Grundofen". By contrast, in Germany there is a "Kachelgrundofen" and a "Warmluftkachelofen", ie., a warm-air Kachelofen, aka. "Einsatzkachelofen". To confuse matters even more, in North America the term "Grundofen" is applied to a vaguely defined subset of masonry heater types. In Germany the term "Grundofen" would apply equally to a Finnish Contraflow, a Swedish Kakelugn or an Austrian Kachelofen. In this article, we therefore translate the Austrian term "Kachelofen" as masonry heater.)

The data generated by the test protocol allows us to draw meaningful conclusions regarding design-based causes of poor performance. In future, those stove designs that exhibited a high emissions factor will no longer be allowed by the Austrian Stovemason's Guild.

THE DATA GENERATED BY THE TEST PROTOCOL ALLOWS US TO DRAW MEANINGFUL CONCLUSIONS REGARDING DESIGN-BASED CAUSES OF POOR PERFORMANCE

If we break the results down by emission factor into 1000 mg/MJ intervals, there is a clear indication of a Gaussian (probability) distribution in the 1000 to 5000 mg/MJ range. We therefore conclude that this range depicts typical performance for the (Austrian) masonry heater. There were no values in the 5000 to 9000 mg/MJ nor in the 10,000 to 11,000 range. There were two stoves in the 9000 to 10,000 and one stove in the 11,000 to 12,000 range. Statistically, the three stoves are outlyers. It can also be stated that all three of these stoves exhibit very obvious deficiencies in their design/construction that would account for their high emission factor.

Other Conclusions

One obvious question is: how is stove performance affected by the more recently introduced design changes? A few brief conclusions are summarized below:

The so-called Bio-firebox was developed and introduced in the last few years. How did it perform? Table 3 indicates that, on average, the Bio-firebox had lower CO emissions than standard fireboxes.

Another emissions-reducing technique recommended in the last few years has been the top-down burn (ignition from the top). One surprising result from this test series was that the top-down burn performed worse than front (bottom) ignition.

A more thorough analysis yields a plausible explanation for this effect. The top-down burn results in a longer burn time, resulting in a lower burn rate (kg/hr). At rated heat output (maximum wood load), we see a positive influence, since the lower burn rate assures that there is an adequate oxygen supply during all phases of the burn.

With a partial fuel load - which is usually the case, in practice and in this test series - top ignition can result in too low a burn rate, leading to lower firebox temperatures and an adverse effect on the quality of the burn. A higher burn rate is more advantageous with partial loads, and this is achieved with bottom ignition or reloading onto a coal bed.

Wood briquettes have been available in Austria for several years, and have been recommended for masonry heater use. Tests at the Guild's labs have shown the combustion quality to be excellent. This is also confirmed by the field tests, although with only 3 data points, more testing is indicated.

Comparison with other Solid Fuel Burning Devices

Table 4 compares the woodfired Grundofen CO result (2500 mg/kg) with other systems. All values are taken from the 1988 Austrian Government Report on Energy. The data clearly shows the Grundofen to have better emissions performance than all other solid fuel domestic appliances and central heating systems. Only central heating systems for well-split wood achieve the same value. Significantly lower values are only achieved in large industrial systems.

Conclustions and Outlook

The data from this test series allows us to draw reliable conclustions about the overall performance vis-a-vis CO emissions and overall efficiency of existing Grundofen installations under typical conditions.

The test data cannot be compared with and should not be exchanged with laboratory results. Laboratory testing usually results in better numbers, since standardized fuel is burned under optimum conditions, and operator influence is factored out.

> LABORATORY TESTING USUALLY RESULTS IN BETTER NUMBERS, SINCE STANDARDIZED FUEL IS BURNED UNDER OPTIMUM CONDITIONS, AND OPERATOR INFLUENCE IS FACTORED OUT.

The advances over the last few years in continuous-burn stoves have led to demonstrably better combustion performance. With increasing environmental awareness, the Grundofen will also come under closer scrutiny and be asked to demonstrate performance improvements. Techical advances on several fronts are in the development stage, and will soon be seen in the marketplace.

Number	Carbon Monoxide mg/MJ	Efficiency %
34(all)	2850	83.3
31 (no outliers)	2130	83.0

Table 2. Average CO Emissions Factors and Efficiencies for Wood-Fired Grundkacheloefen.

(Editor's Note: European efficiency numbers in general do not reflect the boiling of water loss (see Lopez Labs report in this issue). In the 1993 Lopez Labs tests, boiling of water loss averaged 11.4 %. Also not counted in the Austrian tests were CO losses, which averaged 4.24% in the Lopez tests, nor hydrocarbon losses, which averaged 1.37%. Therefore, comparable North American numbers would be around 17.0% lower, for an Austrian average of 65.7 (all tests) or 66.0 (no outliers). Interestingly, the average from 22 tests in the '93 Lopez Labs series is 65.5% (all tests) and 66.9 (without the single underfire air test). By comparison, OMNI's EPA-audited field tests of 6 masonry heaters (42 burns total) yielded the following results: All six heaters: 59.1%; four overfire air heaters only: 60.4%; 2 underfire air heaters only: 56.5%.

	Number	Carbon Monoxide mg/MJ
Firebox		
Normal	22/25	2250/3130
Bio	9	2030
Ignition		
Top	18	2280
Bottom	13	1920
Fuel		
Wood	28	2235
Wood Briquettes	3	1130

Table 3, Influence of Various Parameters on CO Factor

A second round of testing was then carried out, and the results were reported by Dr. Hofbauer in the 10/92 issue of K+R:

OPERATOR INFLUENCE IN GRUNDOFEN EMISSIONS

by Herman Hofbauer

The Kachelofen is surely the most tradition-rich heating system that we know of. This by no means implies that it is behind the times. A comprehensive field test series was undertaken in 91/92 and reported on above. One question remained unanswered, however: How much influence does the operator have on emissions?

Introduction

The first tests series attempted to arrive at an average value for all wood-fired masonry heater emissions. The goal was to test as large and as varied a group of stoves as possible, since this reflects the real-word situation. It was found that all the masonry heaters studied were fired with 50 to 80% of their rated capacity.

A surprising result was that stoves which were used with a top-down burn had no better emissions numbers than the average.

This finding contradicts previous laboratory test results.

A SURPRISING RESULT WAS THAT STOVES WHICH WERE USED WITH A TOP-DOWN BURN HAD NO BETTER EMISSIONS NUMBERS THAN THE AVERAGE

This discrepancy became the springboard for the next series of tests.

Test Design

The goal of the second series was to determine the extent of operator influence and type of ignition on emissions performance. Four masonry heaters in the field and one in the lab were tested according to the following matrix:

	75% of max. fuel load	45% of max. fuel load
Top ignition		
Front ignition (bottom)		
Ignition from coal bed		

Fuel with 15% moisture was used for all tests. Wood size was approx. 6 x 8 x 25 cm. One heater was also tested with wood briquettes. The influence of wood moisture, fuel size and similar parameters will be the subject of a future test series. Emissions were compared on the basis of CO emissions in mg/MJ.

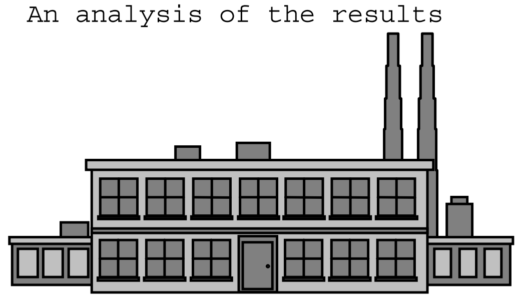
Conducting the Tests

Testing was conducted with the same protocol used in the first series of field tests. The results of the 6 matrix variants are presented in graphical form. CO emissions are indicated on the basis of the average burn rate. Average burn rate is calculated as fuel load divided by burn time.

Results

Optimum Burn Rate

An analysis of the results



shows that the different ignition schemes either increase (ignition from coal bed) or decrease (top ignition) the burn rate. A similar relationship holds for fuel load mass. A larger fuel load, all things being equal, results in a higher burn rate. The burn rate therefore includes an ignition and a fuel load component. The highest burn rate is achieved by igniting the largest fuel load on a charcoal bed, and the lowest rate results from igniting the smallest fuel load from the top.

By plotting the CO emission factor versus the burn rate, a characteristic relationship is evident and more or less pronounced depending on the appliance. Chart 1 shows this relationship for one of the four heaters. It is clear that each heater has an optimal burn rate, for which CO emissions are the lowest. A lower or higher burn rate results in higher CO. In other words, the burn becomes less than optimum.

If the burn rate is too high, then the available chimney draft is insufficient to introduce enough oxygen at the height of the burn - it's a bad burn. If the burn rate is too low, then the chimney draws too much air through the firebox, the excess air number is high, and the firebox temperature is lowered by the extra air - again resulting in less than optimum combustion.

Chart 2 is similar to chart 1 and shows the corresponding results for a masonry heater in the lab. In addition to values for cordwood are values for wood briquettes. You will note that the optimal burn rate for both fuels is practically identical. In addition, we again see evidence that CO numbers for briquettes are lower than for cordwood.

Chart 3 shows all data points for the 4 stoves that were field tested. The excess air number refers to the average excess air for the entire burn. The excess air number is actually lower during the peak of the burn and higher at either end. Plotting CO against the average excess air number, we again see a characteristic relationship that can be divided into 3 regions:

- Excess air less than 2.5:

Here there is a high probability that the peak of the burn will experience a lack of air with resulting poor combustion.

- Excess air between 2.5 and 3.5

The best combustion conditions are to be seen in this region.

- Excess air greater than 3.5

Too much excess air leads to lower combustion temperatures and a poorer burn.

The next article in this series will elaborate on these results as they relate to firebox design and optimum stove operation.

IT IS CLEAR THAT EACH HEATER HAS AN OPTIMAL BURN RATE, FOR WHICH CO EMISSIONS ARE THE LOWEST. A LOWER OR HIGHER BURN RATE RESULTS IN HIGHER CO

Optimum Excess Air Number

Chart 3 shows the relationship between combustion quality and excess air. The excess air number refers to how many more times than the theoretical (stochiometric) amount of combustion air is supplied. A theoretically complete burn with stochiometric air (excess air number = 1) would result in zero oxygen in the flue gas. Complete combustion without some excess air is impossible with almost all fuels.

(This article was continued in the 1/93 issue of K+R:

FIREBOX DIMENSIONING AND OPERATION OF LOW-EMISSIONS WOOD-FIRED MASONRY HEATERS

by Herman Hofbauer

In view of the recent research results, the next question is "How does this affect guidelines for firebox design and how does this affect the operation of masonry heaters?"

Here is a brief summary of the research results so far:

1. Every masonry heater design implies an associated optimum burn rate. This translates directly into an optimum fuel charge, since burn rate equals fuel charge divided by burn time. This follows from the fact that, with heat storage at our disposal, we don't attempt to control the burn time itself through regulating the combustion air supply. Optimized fuel charge translates into optimized combustion (low CO emissions). With a fuel charge that is higher or lower than the optimum, we are able to detect a rise in CO.

2. The conditions for an optimum burn rate are determined by the layout of the stove, particularly the firebox.

3. With an existing Grundofen, we can vary the burn rate in several ways. The most important ones are the fuel charge size and configuration, and the kindling method. Wood moisture and wood sizing are surely additonal factors. In the currentl round of testing, only the first two factors were investigated.

4. A good burn is achieved with an excess air number of 2.3 to 3.

The design goal must be to optimize the burn through design factors of firebox and heat exchange channel dimensioning, and chimney connection. This is achieved when the result is an optimized burn rate. The following discussion deals with the design factors that have to be accounted for.

Design Implications

The basis for sizing the heater is a calculation of the house or room heating load. For heater A (test results in ill xxx) we require a heat output of 5.1 kW.

In order to meet the required output, we need the following fuel charge per burn:

$$m_H = \frac{P_n t}{H_U \eta}$$

where:

m_H (kg0	wood charge per burn
P_N	rated heat output (kW)
t	heating cycle (h)
H_U (kW/kg)	heat content of fuel
η	efficiency

For heater A, these variables were given the following values:

P_N	= 5.1 kW (calculated heat load
t	= 13 h (results from medium-heavy construction style, 1 hour reserve)
H_U	= 4.028 kWh/kg
η	= 0.8

When we plug these values into the above equation, we get a fuel charge (per 13 hour heating cycle) of

$$m_{H13h} = \frac{5.1 \times 13}{4.028 \times 0.8} = 20.6\text{kg}$$

The heat load was calculated for an outside temperature of 15C. This temperature is only reached for a few days a year, and therefore the calculated output is also only required for a few days. It would therefore not make much sense to optimize the burn rate for this heat output.

The sensible thing to do is to size the heater for a smaller output, namely an output that matches the most often required heat load. Note, however, that we still need to use the 13 hour heating cycle in our calculations. Established practice (see, for example, Reference 1) is to use a size equivalent to reducing the heating cycle from 13 hours to 8. Alternatively, this can be expressed as using a size that would give us 62% of calculated full output. Using the above equation, this reduces out fuel charge from 20.6 kg to 12.7 kg.

From the viewpoint of outside temperature, we see that this amounts to saying that, on an 8 hr. heating cycle, we can cover a climate with a minimum outdoor temperature of 0C.

Burn rate should therefore become the starting point for Grundofen combustion design. The burn rate gives us the required rate of combustion air, from which follows the exhaust gas flux and which therefore gives us a rational basis for sizing and laying out firebox and exhaust gas (heat transfer) channels.

Existing guidelines in use to date have been based on accumulated trade experience, but a broad, systematic series of tests has never been undertaken until recently.

Experience has tought us that it is advantageous to burn the fuel for an eight hour heating cycle in one hour. This is how we determine our optimized burn rate. The solid line in the chart on the previous page shows this relationship, with values for four stoves. Therefore, for stove 1, our optimum burn rate is 12.7 kg/hr., as calculated in the previous example.

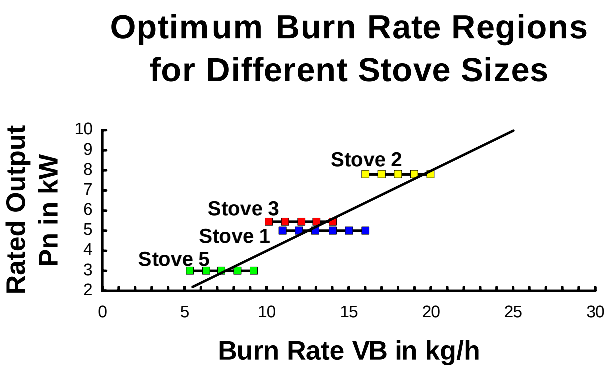
In addition, the field tests enable us to give values for optimized (minimum CO) burn rates for stoves 1 to 3 and for stove 5. These are indicated by the horizontal lines for each stove.

Inspecting the graph makes it clear that the generally accepted (trade) practice for calculating burn rates is confirmed by the tests.

In order to lay out a stove we also require the excess air number. Accepted practice is to use a value averaged over the burn cycle, in the same fashion as burn rate values. Accepted trade practice to date has been to use a value of 2.4. In figure xxx on page xxx, we see that the tests give us optimal values in the range 2.5 to 3.

In theory, we should keep the excess air number as low as possible. Less excess air gives us higher firebox temperatures, which are desirable for good combustion. Not only that, but the lower amount of dilution air reduces our stack losses, since less room air is heated to chimney temperatures and then exhausted.

One lower limit on the excess air number is the fact that during the fast gaseous combustion phase of the burn, we will get



an air starved or lean condition. This can lead to incomplete combustion and high CO emissions .The burn goes "over the edge" ("Umkippen der Verbrennung", literally "the burn tips over").

(*Editor's note: around this "critical point" in excess air number, we can get two completely different CO curves with a very slight change in air. Analytically, this is a "non-linear" condition know as a bifurcation. The road forks and the burn travels an alternate path. We can't recover the initial condition through a simple air adjustment and see a large CO spike instead. See Lopez Labs tests elsewhere in this issue. Note that the phenomenon described here is specific to fast burn, heat-storing appliances with an unregulated air supply, and shouldn't be confused with conventional stove phenomena. The solution is design-based and obvious: increase excess air.*

For regulators who are truly serious about cleaning up their air sheds, it would be appropriate to establish a separate category for high-mass heat storing appliances: Clean-burning, no fuss, systems that are site built according to well established, trade based, parametric design rules backed up by field testing. You will get a cleaner air shed by requiring trade certified installers than you will from laboratory testing of individual appliances. You also won't see any performance deterioration over time).

As mentioned, the values we use are understood to be average values, averaged over the whole burn. It should not go unmentioned here that the excess air numer is dependent on the instantaneous burn rate, and is constantly changing. If we divide the burn into three phases, we see the following typical values:

Burn Phase	Excess Air Number
Ignition	2.5-8
Main Burn	1.5-2.5
Charcoal	2.5-5

The traditionally used design value of 2.4 for excess air has been validated by the testing. For the five stoves tested from a minimum emissions standpoint, we see a small, virtually inignificant, adjustment upwards. We refer you to the Madaus book, cited above, for practical examples of design calculations.

We emphasize the point that the calculation of firebox and flue sizes is more than just one more useless task burdening the stovemason. It should be seen instead as a very effective instrument with which we can lower stove emissions.

All of the stoves tested for burn rate versus emissions show us that, when we use the optimized burn rate regimen for each stove, that they are more than capable of meeting the strict new CO emissions regulations for 1995 (1300 mg/MJ). Furthermore, this is easily achieved under field conditions, even though the regulations require "only" laboratory tests.

What this means for you

The tests series clearly demonstrates that for each heater there is an optimal burn rate (*ed: ie., an optimum fuel charge and ignition protocol*). The goal therefore has to be to operate the appliance in this region. The next step is to formulate a clear set of design guidelines encompassing the field test results.

The burn rate in a given stove can be varied to some degree by the weight of the fuel charge and the kindling method. (There are no doubt other factors, such as fuel sizing , that are outside the scope of the present test series).

We need to differentiate two cases:

- Case 1: Use with optimum amount of wood (based on stove design)

We know that the optimum fuel charge is for 60 to 65% of rated output over 13 hours, ie., rated output over 8 hours. With this optimum fuel charge, we don't see much effect of kindling method on emissions.

As mentioned earlier, it is not really a matter of one exact burn rate that we need to achieve. Rather, there is a more or less broad region in which we can get a first class burn. If we happen to use the optimum fuel charge, we find ourselves right in the center of this region. Changing the kindling method here doesn’t affect the burn enough to take us outside of this excellent burn zone. If we deviate quite a bit from the optimum fuel charge, then we need to start paying attention to the kindling method

- Case 2: Use minimum or maximum amount of wood

Maximum amount

With a maximum fuel charge, top ignition is advantageous, since it has the effect or reducing the burn rate.

Minimum amount

Here we see advantages for bottom ignition, or ignition onto a charcoal bed, since this tends to increase the burn rate.

This realization regarding kindling method is fully compatible with the field test results, which showed no advantage for top ignition. Seen from our new vantage point, we realize that the tests, on average, took place in the fairly broad optimum burn zone and therefore we would not expect top ignition to have an effect.

The goal of the field test series was to obtain real-worl numbers for masonry heaters as they are actually used every day. The results show us that typically these appliances are operated with a fuel charge that is between 45% and 75% of maximum (rated 13 hr output). This fact confirms our thesis that it is better to optimize masonry heaters for 8 hr (62%) output than for rated output.

Outlook

This test series sought answers to two questions:

1. How much effect on burn quality is there from different operating conditions as seen in actual everyday use?

2. How does commonly accepted current stove design and layout practice stack up against recent requirements to minimize emissions?

Positive Results

Variations in actual operator practice as seen in the field results in burn rate variations. In addition, kindling method can affect burn rate. Detailed measurements carried out on five different heaters showed that each heater had an optimum burn rate zone that allowed excellent combusion. However, chimney draft and flue gas channel calculations for each heater establish a design burn rate. This design value was determined for each stove, based on established historical trade practice. The data shows that these design values result in masonry heaters with low in-field CO emissions in compliance with 1995 Austrian clean air regulations. The calculated burn rates, in view of emissions performance, were therefore classed as optimum.

Stove Calculations as Insurance

Stove calculations should not be regarded by the trade as a nuisance or an inconvenience. Rather, they should rightly be viewed as insurance for maximum masonry heater performance.

References:

1.) Der Kachelgrundofen, Planung, Konstruction und Aufbau, Madaus, Chr. and Henhapl, N., published by Verlag Gustav Kopf GmbH, Box 1490,Waiblingen-Bittenfeld, Germany, 4th edition, 1992. (42.00 DM).

The only English language reference is:

Kachelgrundöfen - A Guide for the Practitioner, Heinz Maresch, 1972, 16 pages, translated by N. Senf, available from Masonry Stove Builders, RR 5, Shawville, Québec, J0X-2Y0.