Masonry Heater Association Of North America NEWS

Volume 4 Number 2 SPECIAL EDITION - FEB '91

Clean Burn Breakthrough!

Austrian researcher claims "Lowest emissions ever measured for wood combustion".

A research program initiated by the Austrian stovemasons guild in 1986 is shedding light on the the recent Blacksburg masonry heater results.

A new firebox system developed under the program is now being marketed by the A. Rath Company in Vienna, a manufacturer of ceramic refractories and a major participant in the research.

Underfire air looks like one of the casualties, and environmentally aware contraflow builders will undoubtedly be designing new air systems for their fireboxes. Initial indications are that the g/hr numbers that will be realistically attainable in the field are well below 1 gram.

The new system, known as the Bio-Firebox, is reportedly very user friendly and relatively insensitive to wood moisture and fuel charge geometry.

MHA member and well-known wood heating researcher David Lyle of the Heating Research Co. in New Hampshire is responsible for breaking the news, which is reaching these shores a full three years after the initial research in Austria. About 25% of Austrian stove masons are now employing the system full time. In Austria, the Grundofen (all masonry system) is more popular than the Einsatz (metal insert) system, in contrast to neighbouring Germany.

A few days ago, MHA News received one of its regular information exchange packages from David. It included a letter and pricelist from Dr. A. Rath. founder of the company bearing his name. Dr. Rath included two magazine articles that appeared in K+R magazine, an Austrian trade publication.

Ads for the Bio-Firebox have been appearing in Kamin & Kachelofen for several months. It was easy to overlook their significance in among all of the other advertised new systems, in what surely is becoming a European clean burn frenzy.

However, reading the K+R articles quickly convinced your editor of their importance, so MHANews immediately translated them and is breaking the news in this special edition. The text of the two articles follows, so that you may form your own opinion: The first article appeared in April,1987 and the second one was published last November and detailed some very exciting new results.

Also in this issue you will find another "Technical Topics" installment, this one on the subject of combustion chemistry. This is a vital subject for every stovemason to include in his curriculum. Some of the recent clean burn breakthroughs were made by Austrian stovemasons working in the field. As we get into the exciting territory of super-clean wood combustion technology, our bag of tricks will need to include some new tools, methods, and knowledge so that we can form intelligent judgements and separate fact from fiction.

In This Issue

The new firebox

Minimizing Environmentally Harmful Emissions

K+R 4/87

by Dr. Hofer, director, Technologishes Gewerbemuseum, Vienna
(translation by N. Senf)

We have already written about this subject on several occasions and brought forth various details. Now, the time has come. More than a year has passed since we finished the research to develop a new firebox. Almost 200 test runs were made. Numerous firebox configurations were tested. The following article details the results of this research.

The environment has become the focus for the 90's. and rightly so! Everyone is now aware that industrial activity results in the consumption of raw materials and generation of waste products resulting in a degradation of the immediate and overall environment, to a greater or lesser degree. One of the major culprits is the combustion process.

An enormous amount of fuel is burned every day, whether to run industrial processes, or to generate electricity. Our vehicles burn fuel in order to transport goods and people. We burn fuel in our own cars in order to have privacy and convenience. And finally, we burn a wide range of fuels in our heating systems.

Combustion generates waste products. A minor player is ash, although it is not without problems. Considerably more difficult to deal with are the so called exhaust gases. This is unavoidable. Of even more consequence is the fact that we cannot capture them and therefore have to release them into the immediate environment, from whence they are free to travel where they may. They have the potential to cause harm, even serious harm, which we simply cannot allow.

Better yet, we can attempt to burn as cleanly as possible - this has been the goal of combustion science for a very long time. A whole plethora of methods have been developed to address this problem - a prime example being the catalytic combustor.

The main product of the stovemason is the Kachelofen. It also burns fuel, and it also is receiving very critical scrutiny from various quarters. It was therefore necessary and important to pose the question: Where do we stand with this technology? Is the Kachelofen also one of the environmental villains, or do we occupy the high ground? As a federally mandated testing organization, we started looking for a definitive answer to this question in 1985 (*editors note: this refers to the Austrian lab report that was made available through MHA member Biofire (Heinz Flurer)*). To this end, a standard Kachelofen was constructed at the testing lab. (*ed. note: by the Austrian stovemasons guild*) The testing lab carried out a series of precise tests. This allowed us to determine that the combustion technology employed in the Grundkachelofen is environmentally friendly. The rapid burning of split cordwood combined with the storage capacity of the masonry mass was, very surely and without doubt, an excellent combustion technology for wood. In 1985 it was certainly the best technology available. The burning of wood fuel in steel or cast iron stoves, or steel boilers for that matter, was not even close, either in terms of emissions or overall efficiency, as evidenced by the CO content of the flue gases.

Masonry Heater Association of North America NEWS

Vol. 4 No. 2 February 91

Published by The Masonry Heater Association of North America

ELECTED OFFICERS - 1991

President - Gordon Jones, P. Eng
Vice President - Tom Stroud
Secretary - Norbert Senf
Treasurer - Mike Homchick

Business Offices: c/o Brick Institute of America, 11490 Commerce Park Drive, Reston, Virginia, 22091, Tel.-703/620-0010

Editorial Office : c/o Masonry Stove Builders, RR 5, Shawville, Quebec, J0X 2Y0, Tel. 613/234-6208
FAX 563-9318

Membership is open to anyone with an interest in masonry heating and is subject to approval by the membership committee.

Annual membership dues:
Voting - 200.00 (US)
Associate - 50.00(US)

Now, the testing authority could have taken the view that these results were good enough. Grundkachelofen technology is without doubt better than the others; end of story. This would surely have been wrong. After consulting with experts in various fields, the technical arm of the stovemasons association decided to try to ensure the future of the trade by commissioning a series of tests that would attempt to clarify the question: are we at the limits of low emissions woodburning technology?

The research people were therefore given the following questions as a mandate:

a) Are the current regulations for firebox dimensioning and construction sufficient?

b) Can better combustion be achieved through changes in firebox construction?

To these primary goals were added two subsidiary, although not unimportant, goals:

a) An attempt to increase operator convenience by substituting the manual closing off of combustion air at the firebox door with an automatic mechanism (*ed. note: Austrian stoves do not use chimney dampers.)*

b) To address the problem of room air requirements by developing means for alternate air supply methods, e.g. outside air.

In order to carry the testing out in as thorough a manner as possible, the following strategy was developed:

1. A firebox was used that was built exactly to the then current codes - this was the baseline.

2. With this firebox, the floor was held constant and the height of the firebox was varied.

3. Using the variables above, the influence of top exit versus a rear exit firebox was probed.

4. Next, the manner of supplying combustion air was varied. Instead of the standard firebox door supply, air was supplied through slots that were installed around the perimeter of the firebox. The height of the slots was varied in addition to the various firebox heights.

During the testing, an additional set of controls was evolved:

a) Testing was done with a cold stovebody as well as a warm one.

b) The chimney draft was varied, within the limits available at the lab, from 5 - 25 Pa (0.5 - 2.5 mm H2O).

c) To this was added a variation in the size of fuel load from 10 - 25 kg. wood. It should be noted here that the design size of the firebox was held constant at 20 kg. of fuel.

d) In addition, the influence of wet versus dry wood on the combustion cycle was determined.

It is beyond the scope of this article to illustrate all of the test data. It was presented by showing the relationship of the various parameters by means of three dimensional graphs. An example is presented in Fig. 1.

However, an analysis of the data showed two very clear trends. One of them had been well known to the trade for a long time. It is the fact that the height of the firebox should not be made too small.

This principle is recognized by the stovebuilding profession in the current firebox regulations. We attempted to clarify these even further. We came to the following conclusion, through both the test results and also through direct observation of the flame pattern. The development of the flame pattern above the fuel load is somewhat cone shaped. Good combustion is most fully realized only when, as much as possible, the flame tips do not touch the firebox walls or ceiling. This of course is one way that soot can be formed. The flame cone should be able to develop itself fully in the combustion chamber without surface contact.

In order to insure that the combustion cycle can run undisturbed, the following guide for dimensioning the firebox can be used: You imagine a pyramid that sits ontop of the normal fuel load. The angle should be 15 degrees or less from vertical, and this should be measured from the long dimension of the firebox. This gives the required firebox height.

If the firebox exit is located in the sidewall, one does not need quite a much height. However, it is not correct to use the diagonal

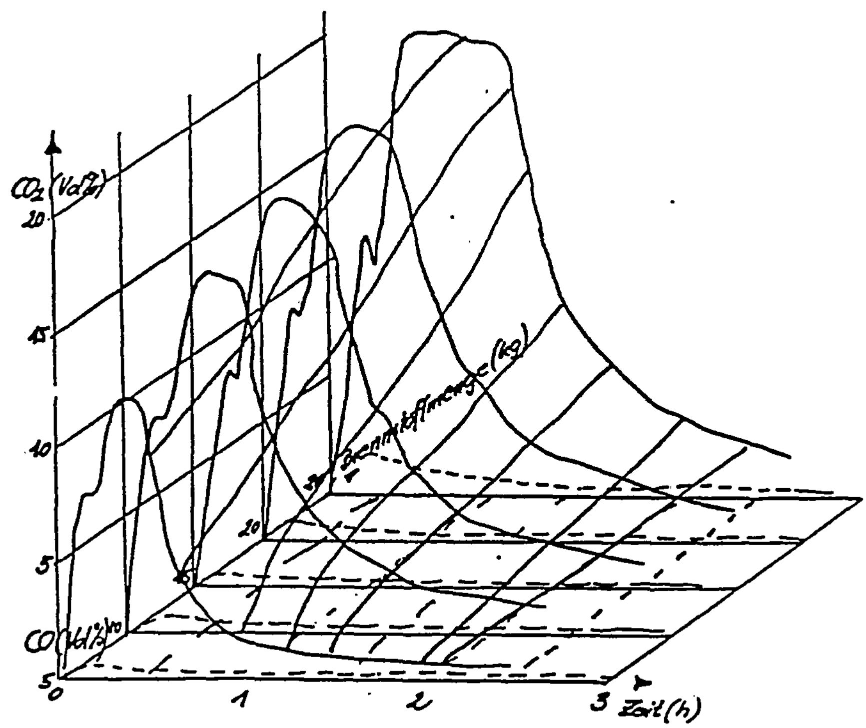


Figure 1: CO and CO_2 plotted against Time and Fuel Weight

(to the exit) as the height. Instead, take the tip of the pyramid and rotate it toward the sidewall, using a centre of rotation that coincides with the centre of the (top of the) fuel load.

The second trend that was found, and the principal result of the testing, is that the combustion air should be fed to the combustion zone from all sides. This result should also have been expected. Why? Wood combustion is an oxidizing reaction which, once initiated, prefers to proceed in a rapid and unhindered fashion. However, in order to achieve this end an adequate supply of oxygen must be close at hand. It must be situated so that it has ready access to all parts of the layered fuel load. The normal method of supplying oxygen through the firebox door surely does not meet this requirement. A perimeter supply, however, does. In addition, the combustion air is preheated, and surely this is beneficial.

It was soon discovered that it makes a difference at what height one places the slotes and what size they are. If the height is too low, then a poor burn is achieved during the start of the cycle. If the height is excessive, then problems arise towards the end of the burn since not enough air is pulled down to the level of the fuelbed.

In addition, the size of the air slots influences the overall quality of the burn. If the slots are too large, then the velocity of the incoming air is too low and doesn't penetrate to the centre of the firebox before it is overcome by the velocity head of the combustion gases. Quite a few trials were required before the optimum size could be determined.

For a new idea to be worth something, it must also translate well into practice. A lot of consultations were undertaken to determine methods that would

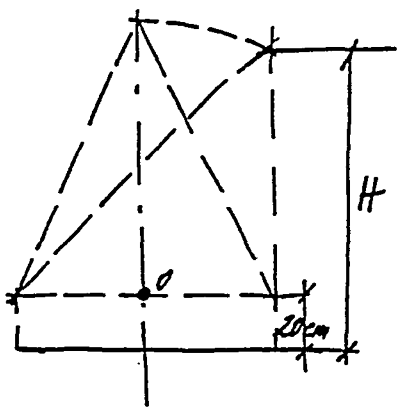


Fig. 2: Fbox height for side exit

make it possible for the stovebuilding trade to easily apply them. Another goal was to find ways that this type of firebox could easily be retrofitted to existing heaters during routine service calls. The result of these discussions is a modular "building block" system consisting of three new firebrick shapes. A bottom brick, a sidewall brick, and a backwall brick.

The system is easy to install. It can be retrofitted into existing heaters at any time. And, importantly, firebox damage can be repaired be the replacement of individual bricks.

At one point in the development it was argued that one should not incorporate the slots into the firebox walls. It was feared that ashes could enter the slots. This fear has turned out to be groundless. Ashes are easily kept out by the combustion air stream. Even if it did happen, they can easily be removed with a vacuum cleaner.

These bricks won't fit every firebox! Even this argument was given serious consideration. It turns out that the number of different firebox dimensions is small. The firebrick sizes take the standard Kachel dimensions into account. *(ed note: Kachelofen are dimensioned in multiples of the standard Kachel size)*

It would be false to declare that this new firebox system signals the end of the Kachelofen's evolution. We do, however,

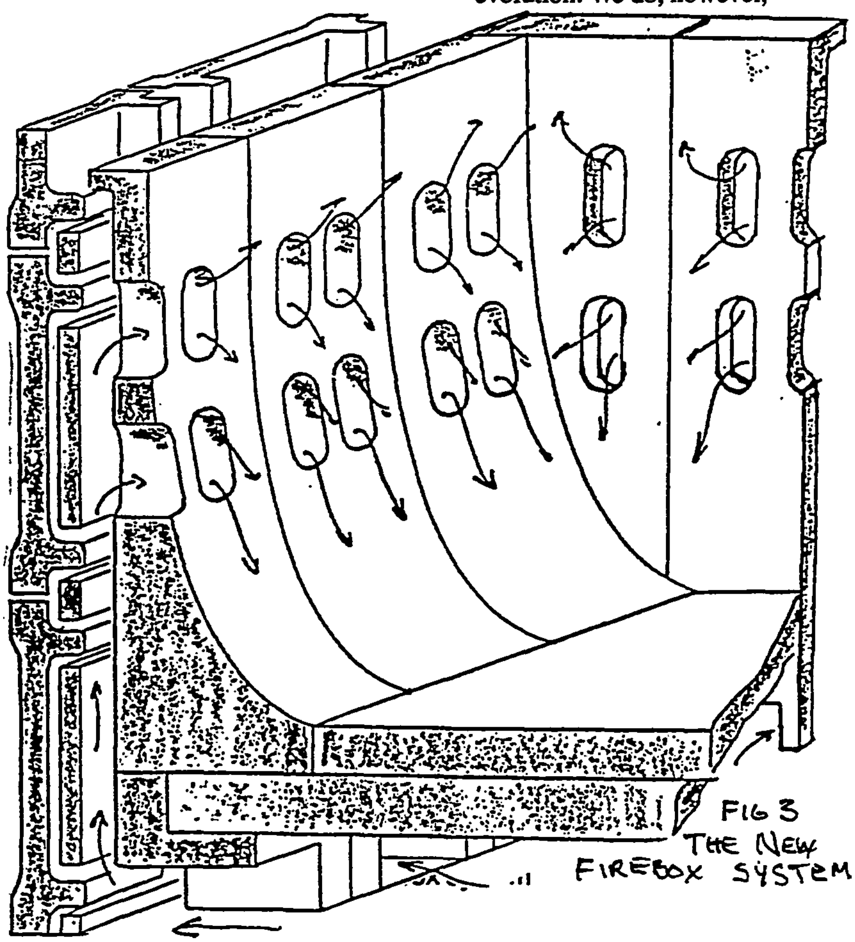
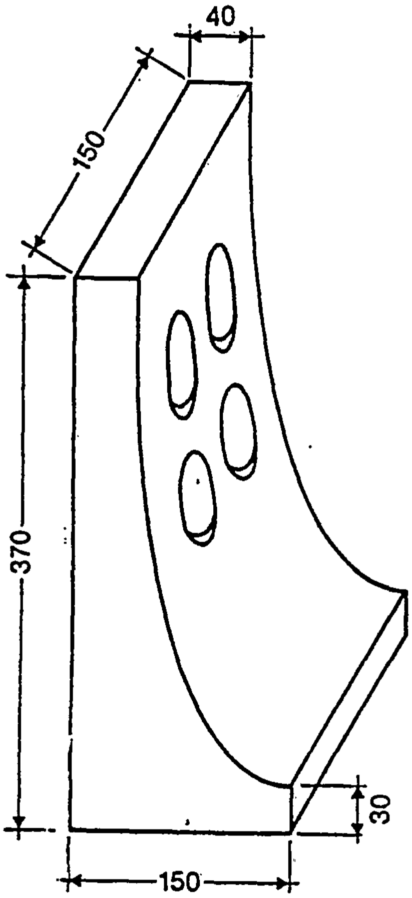
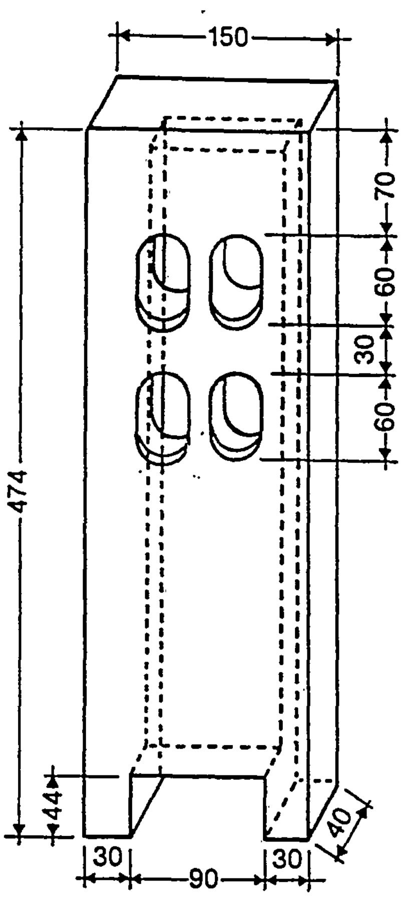
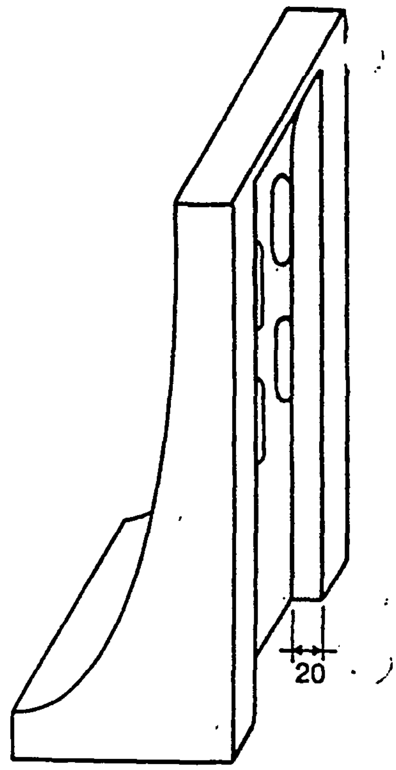
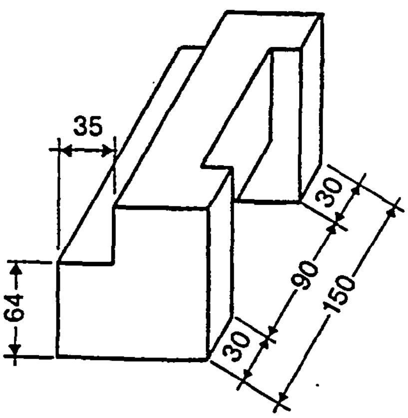


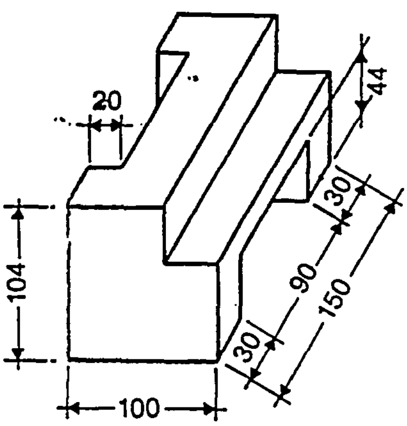
FIG 3 THE NEW FIREBOX SYSTEM







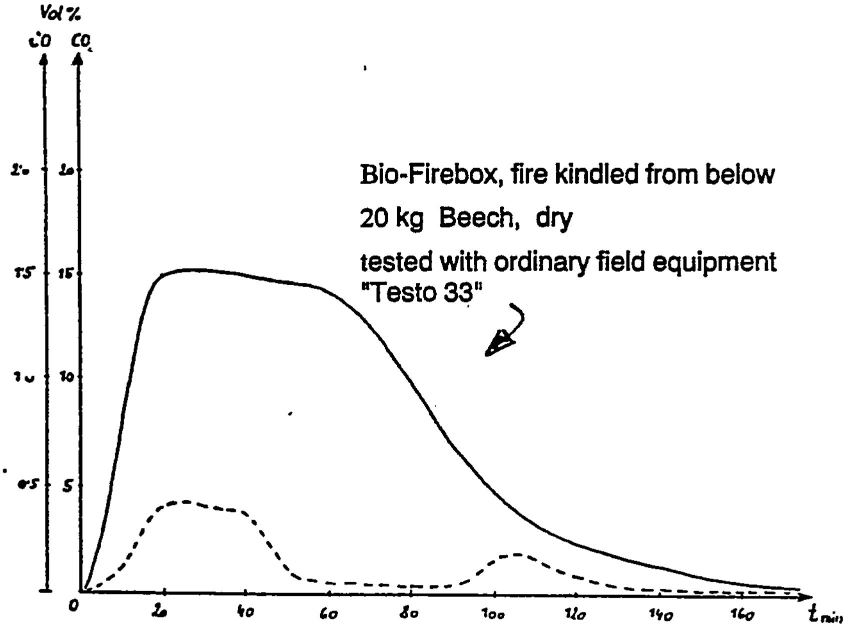


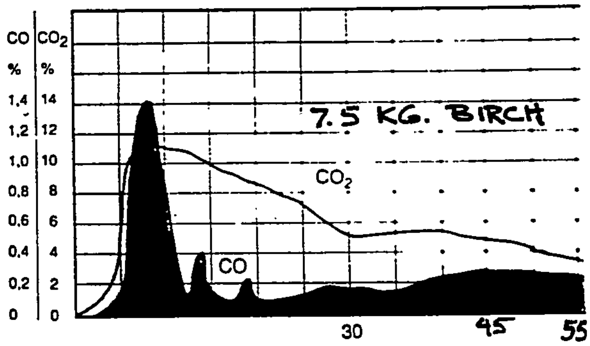


believe that this firebox construction secures for wood heat a really environmentally friendly combustion method at least into the near future. It is not necessary to use exactly the same components as these. Dr. August Rath's company, which played a signficant role in the testing program, is of course convinced of the efficacy of this system, as are the investigators. Fundamentally, however, the idea of a perimeter combustion air supply can also be implemented in other ways.

One thing can be stated with certainty. This new firebox configuration is user friendly. It is very forgiving of errors such as a clumsily stacked fuel load or the use of wet firewood. In addition, it not only points in the direction of an automatic loading door, but almost demands it. The air supply is not dependent on the door at all, and can come from anywhere in the stove. Installing an automatic damper no longer poses a problem. This is currently under co-development with Kachelofen component manufacturers.

Finally, I would like to express thanks to the research and development arms of the various companies in the industry whose financial help supported this research to a large degree. Special thanks are in order to Dr. Rath's company for participating in this project as a major partner.





Contraflow, Tampere tests

K+R November 90
Heating Technology

The Bio-Firebox: The Research Continues

Environmentally Friendly Stovebuilding

An exhibition with the theme "Environmentally Friendly Stovebuilding" took place in Salzburg on 9/11/90. Manufacturers who took part were: Rath, Kaschutz and Lohberger. Dr. Hofer, who runs the state authorized testing lab, presented a talk on this theme. Our first report is on the presentation given by Dieter Schlatzer, technical consultant to the Rath company.

We first reported on the early developments of the Bio-Firebox, which was undertaked because of environmental concerns regarding solid fuel burning, in this magazine in the early summer of 1986.

The first demonstration of this technology was at the Technical Exhibit in Bad Ischl in 1987. Some interest was generated, and a few innovative stovemasons began to experiment in the field.

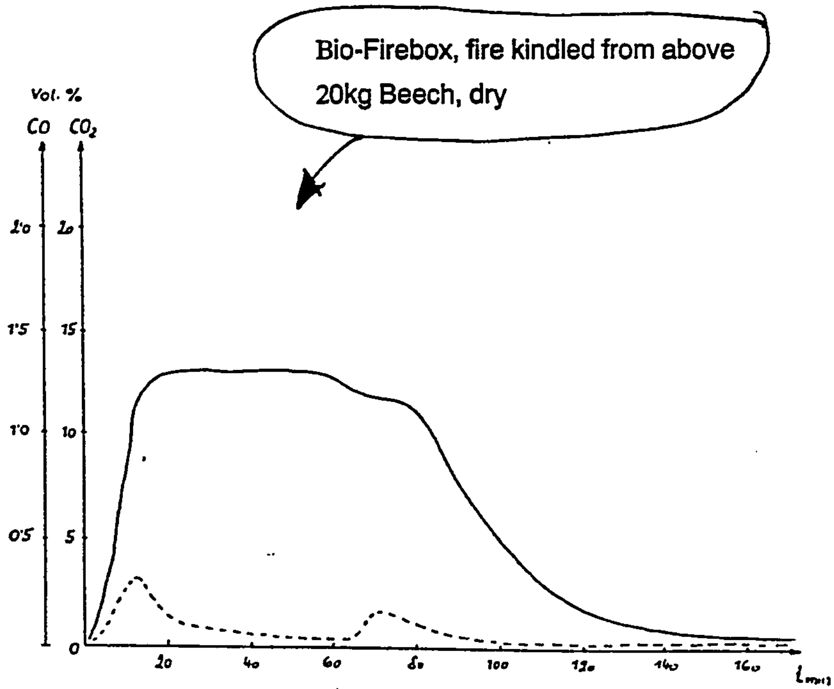
In 1988, the Rath company constucted a stove model with a Bio-Firebox at the Baubiologie *(ed note: building biology, ie., low indoor pollution housing)* annual exhibition in St. Wolfgang, and generated a lot of interest.

This demo model was then loaned to stovebuilders for exhibit at various trade shows and was thereby widely disseminated.

At the Technical Exhibit in Bad Ischl the following year, the idea of the Bio-Firebox was again brought to the attention of the stovemasons.

This Bio-Firebox has therefore been in existence for four years, and until very recently was the only Kachelgrundofen technology that allowed a drastic reduction in emissions.

About a year ago, an old technique was rediscovered by a stovemason in Vorarlberg, namely kindling the fire at the top of the fuel load. In



combination with the Bio-Firebox, this resulted in the lowest emissions that have ever been measured for wood combustions.

Almost in parallel with these developments, there were trials partly from industry and partly from the stovemason community, to commercialize an automatically closing door in order to make the stove more user friendly and also safer. These doors have now been used in Kachelofed construction for some time.

In the meantime, the whole stovebuilding supply industry has reacted, and there are now also other combustion enhancing developments on the market.

From the brief history that I have just presented, one can see that the stovebuilding supply industry has labored very hard in order to made it possible to burn wood, a renewable biological resource, in the most environmentally responsible way possible.

-"And what about the stovemason, the heating system builder, what is he doing?"

According to Dieter Schlatzer: "In my estimation, and based on trade shows, conventions, and consultations, about 25% of stovemasons are using the Bio-Firebox on a regular basis, 15% occasionally, and certainly more than 50% of the stovemasons have not used it at all yet."

What is the purpose of the Bio-Firebox, what can it do, and how is it used?

-The purpose of the Bio-Firebox is to reduce emissions to the point that all applicable new clean air standards can be met. This is done through a new combustion air supply method that has been developed only recently.

The construction of the Bio-Firebox is completely problem-free, and it can be installed into any Kachelofen form whatsoever.

Fireboxes based on this research were first put on the market by the Rath company.

-"I would like to see the CO and CO2 charts that show the difference between this new system and the conventional firebox"

-the charts speak for themselves.

Commentary

Let's start with a brief recap of North American developments: In 1981, there was a research program at Tampere University in Finland to put the contraflow heater on a rational basis. One of the main recommendations stemming from the research was the use of underfire air (a grate), where none had normally been used before. As far as I can gather, one of the origins of this was Finnish experience with large-scale wood combustion (power plants). The recommendation, basically, was - underfire air, and the more the better, combined with additional primary air directed against the front side of the fuel pile from the doors.

Most contraflow heaters have been built that way ever since. Under good conditions, they have a smoky startup phase for 5-10 minutes, and then burn without smoke, provided the fuel is dry. The fire is very spectacular, with a 5 to 6 foot flame length typical.

For the Blacksburg tests, the second unit, the contraflow, was added at the last stage to try and get as wide a range of units represented as possible. Shortly before, I had the opportunity to visit with Ernst Heuft in Surrey, and during our discussions he predicted that the overfire air unit would burn cleaner. Tom Stroud had just lent me a very authoritative book from Switzerland that state a 50/50 ratio as being good. Ernst recommended 1/3 under and 2/3 over. Skip Hayden, head of the Combustion Lab at Energy Mines and Resources Canada, also recommends against the use of underfire air. The Finns state that it is almost impossible to get the grate too big. What's a poor stovebuilder to do?

Ever since the Blacksburg results, there has been a lot of head scratching to try and figure out what was going on. The overfire air Grundofen unit from Diemeyer, Ward and Stroud came in at around 1 gram, and Masonry Stove BuildersHeat-Kit Contraflow came in at roughly 2 grams. When emissions were expressed as a factor, ie. grams per kilogram of fuel, the contraflow came out worse. Moreover, the CO emissions factor was more than double that of the Grundofen.

What was frustrating was to not have the resources to take this further, or even to be present at the lab to see how representative of real life the firing method was. Using a 16ft stack (in 80 degree weather) doesn't seem very realistic, although you don't have a choice if you want comparability with EPA.The emissions data in the report gives you an overall number, and there is no CO/CO2 curve presented to provide some clue as to what was going on. For example: is the long flue heater getting rid of some of its startup emissions as deposits in the brick channels and then burning them off later?

Many criticisms have been levelled against the dilution tunnel method. Back in the "good old" seventies and eighties, air-starved stoves belching out incredible quantities of pollutants were the norm. If you stuck a probe directly into the stack, it was very likely to get gummed up with creosote. Hence the need to dilute the smoke enough so that you could run a sample through your equipment without damage. As a result, we're now stuck with a complicated emmissions methodology for woodburning heaters

Current Masonry Heater technology is or soon will be at the point where the conventional g/hr PM methods no longer offer us much, from a cost/benefit standpoint.

If you examine the data set from Blacksburg, another feature is apparent, namely the very wide scatter of the data points. One contraflow run was at 0.5 g/hr and another one was at almost 4.5 grams. This is with standardized, dimensioned lumber fuel. What is going on here; if anything? Frustrating.

Therefore, it has been illuminating indeed to get these reports from Austria. They fill in the missing pieces of the puzzle. The day after receiving the information from David, I retrofitted the Heat-Kit in our house with a reasonable facsimile of the new system, and have run 5 test so far.

Two things are immediately noticeable. The flames are much shorter. They barely go into the upper chamber. Its a slower burn, and the coal phase lasts much longer, which will present a problem for chimney damper systems. Blue flames are visible at the air ports quite early on.

Secondly, the start up smoke from the chimney is much different. A little bit of light blue or black, hardly any smoke at all. More like a slightly rich oil burner.

Of course! Almost all of the emissions have been happening during the first tem minutes. That would explain the wide data scatter. Makes sense, because the flames at the grate are immediately quenched by the cold fuel pile, and this would make for a great sensitivity to small random changes in initial conditions.

Now for the really interesting part. A load of fuel, maple with 24% moisture content, is kindled from the top. No smoke visible from the chimney at all, even during startup! I'm in the process of building a simple sampler using a vacuum pump and a filter train to try and get some ballpark numbers, and should have some preliminary findings to present in Orlando. (We have a model of a new firebox built in the CAD system, and will be sending it out shortly to HeatKit collaborators for evaluation.)

This can also be seen from the CO/CO2 charts on page 6. The small middle graph is from the Hyytiainen/Barden book and was from the Tampere tests. Notice the pronounced CO spike at the beginning of the burn. On the Austrian charts, notice the much lower bumps in the curve, and compare the bump between the standard and the top-kindled fuel load. The lower CO2 curve on the Finnish chart also indicates more excess air, so the CO curve should actually be adjusted upward when compared with the Austrian curves, since the CO is getting diluted by more air moving through the system. Also, note the different time scale.

The CO/CO2 charts are standard fossil fuel technology, where you don't have gobs of tar to deal with. Well, neither do we. Therefore, its extremely sensible of the Europeans to use this method with woodburning as well. Grams per hour of PM exiting your stack makes sense when you're dealing with 50 or 60 grams of nasties per hour, as the airtight stoves were up until a couple of years ago. Down in the masonry heater range, standard combustion measurements make a lot more sense - they're simpler, cheaper, and they tell you what you need to know.

Dr. Jaasma's TCC (Total Combustible Carbon) method is an example along these lines. Unfortunately, the feeling in the lab community seems to be that they've already mad e the investment in dilution tunnels, and they don't want to have to start again from scratch.

While a lot of work remains to be done with conventional fireplaces, I believe that current masonry heater technology is or soon will be at the point where the convential g/hr PM methods no longer offers us much, from a cost/benefit standpoint. Once we are no longer emitting hydrocarbons, the CO/CO2 curve gives us everything we need to know.

Interestingly, the new B415 methodology being proposed at CSA in Canada, while recognizing that it has to pay lip service to EPA to be viable, uses a 3.491 g/MJoule CO factor as a parallel measure of cleanliness.

Corrections:

New address for **RON PIHL:** Cornerstone Masonry
Box 73
Pray, MT 59065
406/222-6872

FRED RICK's company is **Kachelofen Canada**, and not **Hearth Studio**. By the way, we're glad to hear that Fred is back on his feet and busy after a recent hospital stay.

MASONRY HEATER ASSOCIATION OF NORTH AMERICA

Official Membership List as of Feb. 20, 1991

Name	Company	Address	Phone	1990 Dues Paid
Jerry Frisch	Lopez Quarries	111 Barbara Lane, Everett, WA, 98203	206-353-8963	X
Mike Homchick	Masonry Construction Co	21943 21st Place S.W., Brier, WA, 98036	206-771-4175	X
Tom Stroud	Dietmeyer Ward & Stroud	P.O. Box 323, Vashon, WA, 98070	206-463-3722	X
Jerry Haupt	Kent Valley Masonry	21633 99th S., Kent, WA 98031	206-854-4930	X
Gordon Jones, P.Eng		Route 8 Box 161, Johnson City, TN, 37601	615-928-6288	X
Fred Schukal	Sleepy Hollow Chimney Sweep Supply	85 Emjay Blvd., Brentwood, NY, 11717	516-231-2333	
Mark McKusick	Hearth Warmers	RR 1 Box 36B, Colrain, MA, 01340	413-624-3363	X
Stig Karlberg	Royal Crown	333 E. State - Suite 206, Rockford, IL, 61104	815-968-2022	X
J. Patrick Manley	Brick Stove Works	374 Nelson Ridge Rd., Washington, ME, 04574	207-845-2440	X
Tom Trout	Vesta Masonry Stove Inc.	373 Old Seven Mile Ridge Rd., Burnsville, NC, 28714	704-675-5247	X
Dale Hisler	Lightning Arrow Stove Works	Box 1245, Norwich, VT, 05055	802-649-8818	
David Lyle	Heating Research Co.,	Box 300, Acworth, NH, 03601	603-835-2318	X
David Johnstone		P.O. Box 198, Errington, BC, V0R 1V0	604-248-6535	
Ernst Heuft	The Master Stove Setter	6504-134th St., Surrey, BC, V3W 4S2	604-596-2585	X
Norbert Senf	Masonry Stove Builders	RR 5, Shawville, PQ, J0X 2Y0	613-234-6208 (O) 819-647-5092 (H)	X
Ted Corvey	TULIKIVI	30 Glen Road, West Lebanon, NH, 03784	1-800-THE-FIRE 603-298-8388(NH)	X
Bob Gossett	Gossett Masonry Design	141 Sisotow Belle Lane, Yakima, WA, 98903	503-966-9683	X
George Gough	Gough Masonry Ltd.	506 John St., Sault Ste. Marie, ON, P6C 3K3	705-253-4314	X
Ulli Baumhard	Canadian Ceramic Wood Heat	R.R. 1, Sutton West, ON., L0E 1R0	416-478-8843	X
Fred Rick	Kachelofen Canada	49 Westlake Cresc., Toronto, ON, M4C 2X3	416-423-0960	X
Heinz Flurer	Biofire	3220 Melbourne, Salt Lake City, UT, 84106	801-486-0266	X
Steve Williams	Williams Masonry	P.O. Box 968, Dolores, CO, 81323	303-882-4913	X
Steve Cohan	Hot Rock Masonry	Box 247, Floyd, VA, 24091	703-789-7148, 703-745-4856	X
Douglas Hargreave	Inverness Masonry Heat	1434 Dairy Rd., Charlottesville, VA, 22903	804-979-7300, 804-979-4906	X
Brent Gabby, P.Eng	Brick Institute of America	11490 Commerce Park Drive, Reston, VA, 22091	703-620-0010	X
Rod and Aluna Zander	Artisan's Workshop	127 North Street, Goshen, CT, 06756	203-491-3091	X
Dave McGee	European Heat & Design Inc.	1918 Bisbane Street, Silver Springs, MD, 20902	703-438-0777(O) 301-593-5055(H)	X
Stan Homola	Mastercraft Masonry	P.O. Box 73,Brush Prairie,WA,98603	206-892-4381	X
Sash Stephens	Ceramic Stove Arts	1512 East Spruce Street, Seattle WA 98122	206-325-8964	X
Rudi Schongassner	Alpenofen	P.O. Box 486, Vail CO 81658	303-949-6314	X
Bill Derrick	Alternate Energy Systems	Rt.22B, Box 344, Peru, N.Y. 12972	518-643-9374	X
Steve Busch	Maine Masonry Stove Co	Box 44, Buckfield, ME, 04220	207-336-2021	X
Jonathan H. Walters	Kopp Clay Co.	P.O. Box 465, Malvern OH 44644	216-863-0111	X
	General Shale Products	P.O. Box 3547 CRS, Johnson City, TN 37601	615-282-4661	X
Patrick Solich	Bavarian Stove - Solich Masonry	424 Hickory St.,Blomfield, CO 80020		X
Steve Patzer	Patzer & Co. Masonry	3N 743, Rte 31, St. Charles, IL 60174	708-584-1081	X
Ron Pihl	Cornerstone Masonry	Box 73, Pray, MT 59065	406-222-6872	X
ASSOCIATE MEMBERS				
Erik Nilsen		RFD 1, Box 589,Dalton, NH 03561		X
Charlie Page	TESS Inc.	RR 1 Box 3 Beanville Rd, Randolph, VT, 05060	802-728-4485	X
Glen Luse	Chimney Works Inc.	1821 Liberty Drive, Williamsport, PA, 17701	717-494-1050	X
Walter Moberg	Walter Moberg Design	921 SW Morrison St. - Suite 440, Portland, OR, 97205	503-227-0547	X
Jay Hensley	SNEWS	P.O.Box 98, Wilmore, KY40390	606-858-4043	X
Mike Breault	Crocket Mountain Chimney Service	P.O. Box 693, Wilton, ME, 04294		X
Steve Bushway	Village Chimney Services	R.R. 1, Box 178-D, Cunnington, MA 01026	413-458-9660	X
Duncan MacKinnon	Duncan's Chimney & Woodstoves	32 Front St., San Rafael, CA, 94901	415-453-4644	

A Crash Course in Combustion Chemistry

PM's, POM's, PAH's, grams per hour. grams per kilogram, grams per kilojoule, micrograms per Normalized cubic meter. These are all ways of describing flue gas emissions. When reading reports from researchers in the wood combustion field, the stovemason is usually faced with technical overload. Even if he (or she) comprehends the immediate information that is presented, it isn't easy to put the information into the context of other reports that often originate in a different country with a different system of measurement and a different method for tackling the same problem.

Wood combustion is a complicated process consisting of several main chemical reactions and a very large number of intermediate reactions. Depending on the conditions in the firebox, many alternate paths are available to the reacting compounds. As you know, when wood is burned the range of possible products that can leave the stack is very wide. In primitive systems, there can also be tars that don't even make it out of the stack, but condense inside the chimney. These are aptly termed as "stinkers".

The purpose of this article is to present a basic model of combustion chemistry and terminology so that the stovemason may have a deeper understanding of what happens when wood fuel is burned in his product. We'll also try to decipher some of the information from the various lab test reports.

In the last article we learned that wood has a complicated chemistry, but that it can be broken down into an elementary analysis as follows:

Carbon	(C)	41.0%	
Hydrogen	(H_2)	4.5%	
Oxygen	(O_2)	37.0%	
Water	(H_2O)	16.0%	(Air dried)
Ash		1.5%	

The brackets give the *molecular formula*. For example, C refers to 1 *atom* of carbon and H2 refers to one *molecule* of hydrogen, which consists of two atoms. There is also about 1% Nitrogen, which we will ignore.

The *atomic weights* of the different *elements* are as follows, and refer to the atomic weight of Hydrogen, the lightest element, which is 1.

H	1
C	12
O	16

For example, from this we get the *molecular weight* of carbon dioxide, CO_2, as 44 and carbon monoxide, CO, as 28. A *mole* of CO_2 weighs 44 grams and a mole of CO weighs 28 grams. A mole is also called a *gram molecule*, and consists of 6×10^{23} molecules (known as *Avogadro's number*). Therefore, 44 grams of CO_2 and 28 grams of CO both have the same number of molecules.

During *complete combustion*, the following chemical reactions take place:

$$C + O_2 = CO_2$$

$$H_2 + \frac{1}{2}O_2 = H_2O$$

During *incomplete combustion*, we get the following:

$$C + \frac{1}{2}O_2 = CO$$

The CO can itself be combusted as follows:

$$CO + \frac{1}{2}O_2 = CO_2$$

As wood is heated, it releases *hydrocarbons* in the form of *volatiles* or gases, and they are given the general molecular formula C_mH_n. The products from complete combustion of hydrocarbons are CO_2 and H_2O (water vapor or steam).

It is the *incomplete combustion* of hydrocarbons around which the whole question of emissions revolves. Incomplete hydrocarbon combustion gives rise to carbon monoxide (CO), soot (C), free hydrogen (H_2) and numerous tars and other organic compounds.

All of these reactions are *exothermic*, ie., they result in a conversion of chemical energy into heat, namely:

1kg C + 2.67kg O_2 = 3.67kg CO_2
+ 8,000 kcal or 33,820 kJ

1kg C + 1.33kg O_2 = 2.33kg CO
+ 2,400 kcal or 10,200 kJ

1kg CO + 0.57kg O_2 = 1.57kg CO_2
+ 2,400 kcal or 10,200 kJ

1kg H_2 + 8.0kg O_2 = 9.0kg O_2
+ 34,000 kcal or 144,500 kJ

One kilocalorie equals about 4 BTU's.

Once the chemical composition of a fuel is known, the above formulas can be used to calculate the heat content.

If we oven dry the wood, then it becomes 98.5% combustibles, We've taken out the water, and everything except the ash is combustible. The elementary analysis now becomes:

C	50.0%
H_2	6.0%
O_2	42.0%
Ash	2.0%

Combustion Air

The *theoretical combustion air* requirement can be calculated from the chemical composition of the fuel.

With complete combustion and dry air:

$Air_{th} = 8.8\,C + 26.5\,H_2 - 3.3\,O_2$

Nm^3/kg, or cubic meters per kilogram of fuel, where Nm is a *normalized cubic meter*, ie., atmospheric pressure and 0 C.

Let's run through an example:

Calculate the theoretical air requirement for wood combustion as well as the actual combustion air if the exhaust gas contains 10% CO_2:

For wood with the following analysis: C = 41%, H_2 = 4.5%, O2 = 36%, N_2 = 1%, H_2O = 16%, Ash = 1.5%

$Air_{th} = 8.8 \times 0.41 + 26.5 \times 0.045 - 3.3 \times 0.36 = 3.60\ Nm^3/kg$

In reality, more than the theoretical amount of air is required, since some air passes through the firebox without taking part in the combustion. This is called *excess air.*

Excess air = CO_2max./CO_2measured

From Table 2 in Technical Topics #3, the maximum $C0_2$ possible in wood fuel flue gas is 20.9%

Our excess air is therefore n = 20.9/10 = 2.09, ie., 209% excess air.

Since the theoretical air requirement is $3.60\ Nm^3/kg$, we are actually supplying 2.09 x 3.60 = 7.55 cubic meters of air per kilogram of wood.

Lets have a look at the CO_2/CO charts on page 6. We can see that the contraflow is running at about 8% CO_2, which translates into about 275% excess air, whereas the grundofen in the top chart is running at 15% CO_2 or about 130% excess air. Note the different time scales between the underfire and overfire burns.

For both complete and incomplete combustion, the excess air numbers for wood can be obtained from the chart in Figure 8

Decreasing CO_2 content in the flue gas means more excess air, and vice versa. When the CO_2 content goes higher than 16%, emissions start to rise.

The trick is to get as high a CO2 number as you can without having the CO go up. As we can see from the combustion chemistry, CO is an indicator of incomplete combustion.

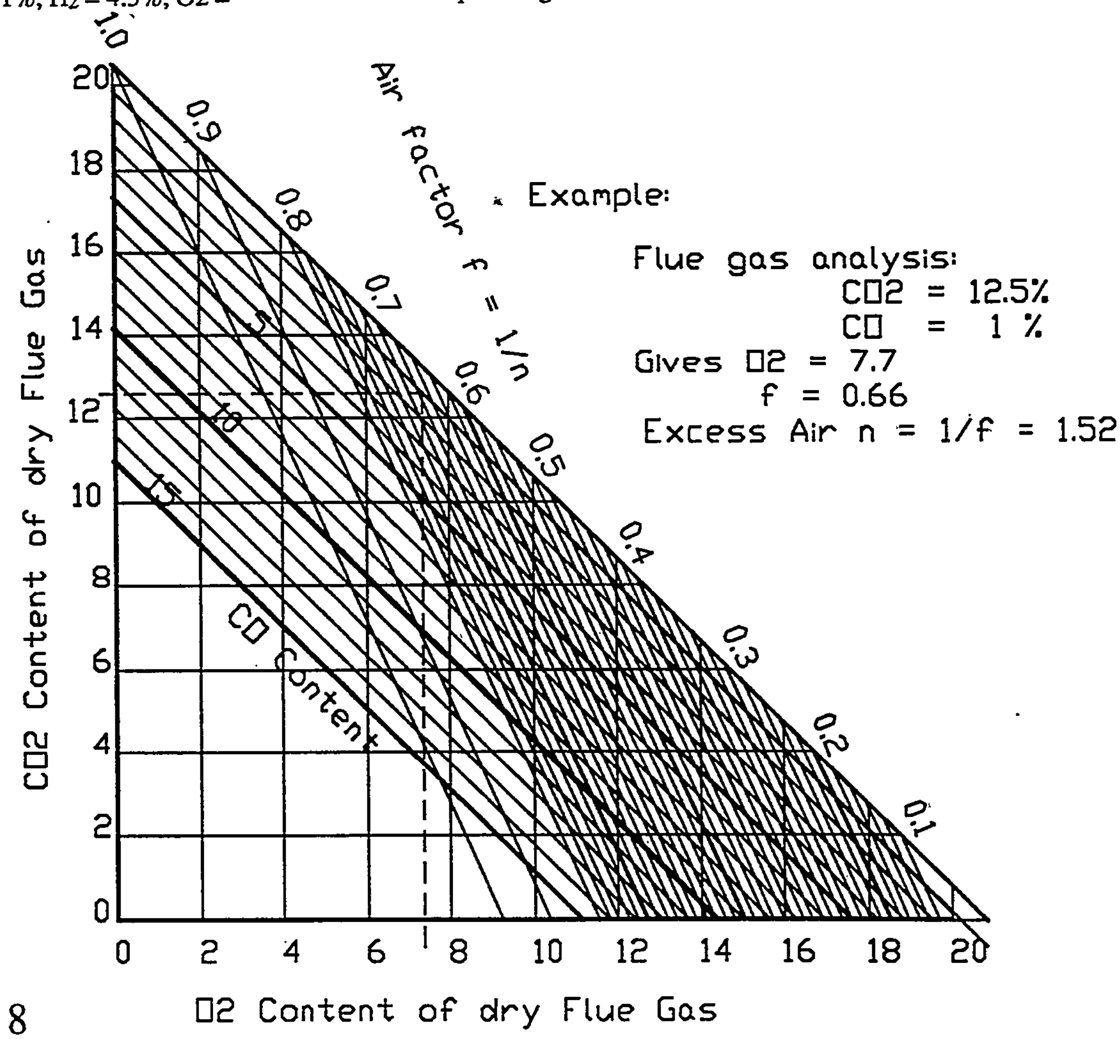


Fig. 8

Combustion Chart For Wood (CO2max 20.4%)

Letters

David Lyle sends the following report from Solid Fuel Expo '91

Have recently returned from Solid Fuel Expo '91, the seminar and trade show sponsored by the N.Y. Chimney Sweep Guild at Schenectady. **Dave Holland, Joe Austin** (Biofire) and I all gave talks there. All of us were impressed by the turnout and by the strong interest in masonry heaters among the chimney crowd.

There were some pointed questions:

--Can you acutally make any money at this?

--Are these things so clean they'll put sweeps out of business?

One sweep/reliner took what seemed to me a sensible attitude toward the first question. He said, "I'm not concerned with getting rich now building heaters. What I really want to know is, if I devote ten years to learning this (heater) business, will it pay off? Will there be more demand ten years from now? Will the ten years I've spent learning the trade, be justified?

This sweep reliner is a realist. He understands it will take years to learn what he needs to know. He already admires the masonry heater. He'll be a real asset to our business.

As for the clean-burn "problem" - we pointed out that most heater builders advise owners to heave their heater checked out each year. That can be a role for the sweep, not something that will put him out of business.

Dave Holland overheard some succinct business advice. It cropped up in a conversation between a New Sweep and an Old Sweep -- but it could as well apply to heater builders:

NS: What's the key to your success?

OD: Two words: Right decisions.

NS: How do you make right decisions?

OS: One word: Experience.

NS: But how do you get experience?

OS: Two words: Wrong decisions.

Amen.

Steve Busch of Maine Masonry Stove Co. writes:

As always - many thanks for your tireless effort in continuing to produce the MHA News.

Unfortunately, once again I find myself unable to attend the next meeting in Orlando. Maine's largest home show is that weekend in Portland & I don't feel as though I can affort to miss it. Please send my best to all who come.

Enclosed are a couple of photos for display. Corner unit with bakeoven & woodbox (soapstone trim, waterstruck brick). Also, the Pizza oven in Portlans - 2 7ft diameter domes (center arch is for access to lights & pyrometers.)

We are finally, after long struggle, ready to open up our effort on damper sales. Sold about 40 sets last year with no promotion except lugging them around to meetings. More on this will be coming your way for the summer MHA News.

Why Join MHA?

- **Receive MHA NEWS.** Be the first to learn about new developments in this exciting trade.
- **Join your peers** across this continent and be part of the action. MHA is the only organized voice in this industry today. Despite our small size, we have some impressive accomplishments under our belt. These include:
- a leading role in the recent development of a **Masonry Heater Emissions Testing Methodology** - the results allowed us to succeed in gaining a blanket certification for masonry heaters in the state of Washington.
- development of an industry consensus draft **standard (through ASTM)** for masonry heater construction
- production of a high quality generic **color brochure** for members to use in their businesses
- Association membership **certificates, jackets, T-shirts and hats**
- a successful **seminar series** at the recent annual meeting
- attend the next meeting - **April 1991, Orlando FL** - see the WHA trade show and meet with **North America's leading heater masons, manufacturers, dealers and technical experts!**

SEE YOU IN ORLANDO!

Your chance to meet and swap notes with your colleagues. A good tip or two can pay for the cost of your trip. Take a break from winter. Write it off!

- WHA is providing us with meeting rooms and a trade show booth.
- The MHA meetings will be on April 3 and 4. WHA show is April 5 to 8.
- On the MHA agenda are:
- Business Meeting - strengthen your organization by helping to set strategies and directions for the coming year This is your organization. Let it know how it can serve you better. Many hands ease the load.
- Seminar Sessions: The big hit last year. Don't miss it!
- ASTM meeting
- Masonry Caucus meeting at WHA - the wood heating industry needs your masonry expertise! Opportunities abound.
- Catch the WHA show, the wood heating industry's biggest event. See what's new, meet your suppliers in person, make profitable new contacts.

Things are a little slow right now. Have lots of pending heater sales dependent on people upscaling, & selling current house.

Tom Trout reports just returning from Blacksburg, where he, **Jerry Frish** and **Steve Cohan** built a Firecrest, a Heat-Force (Rosin design from **Greg Pettipas** in Vancouver), a Rumford and a TESS at Jaasma's lab. The TESS had a new experimental grate design. **Brent Gabby** was also in attendance for the event. Also at the lab where two Bellfires units from Sleepy Hollow - a zero clearance unit and a retrofit unit that was put into one of the masonry fireplaces from the WHA tests.

MHA's crack masonry crew built the three units, including chimneys, in 2 days.

Brent reports that **Ernst Heuft** is about to take off for Houston, where he is addressing the giant Masonry Expo on the subject of fireplaces. Brent will be there and plans to videotape the event, which should make a fine addition to MHA's educational resources.

Tom also reports that TULIKIVI has been downscaling its labour force in Schuyler, partly due to new technology and partly to the recession. Three office jobs were cut and the labor force was reduced from 65 to 39.

Tom himself has been very busy since September, with 16 heaters under his belt.

Hardware Bonanza

- Jerry Frisch sends news of a hardware sale at TULIKIVI. They are liquidating all of their "Old Model" parts. The price sheet is dated December 20. There is a 10% discount for orders of 10 or more. Here's what they've got:

04994 FIRE CHAMBER DOOR:	46	150.80
04997 FIRE CHAMBER DOOR:	160	256.56
04988 FIRE CHAMBER DOOR:	136	359.53
04988/1 SAME AS ABOVE W. ORNAMENTS	32	359.53
04801 FIRE CHAMBER DOOR	18	136.94
04999 ASH CHAMBER DOOR ALL MODELS	112	54.25
04803 COOKTOP 445X736	18	202.41
05145 GRATE 210X405	90	18.20
05054 GRATE 110X400	234	12.87
05056 GRATE	48	18.07
B1512147 GRATE 165X290	108	6.98