EMISSIONS STATUS

OF LARGE WOODSTOVES

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Summary

New woodstoves technologies have reduced pollutant emissions by a factor of 10. There is no pollution requirement for woodstoves in Canada, mainly due to the lack of interest of environment ministries. Canadian manufacturers who want to certify their products to a low-emissions standard must go to the United States. The American EPA has spearheaded the development of low-emissions stoves by imposing a strict ceiling on particulate emissions.

One problem with the EPA standard is that it does not include central heating systems (furnaces) and, with present day technology, it eliminates appliances with high outputs and overnight burns. Many Canadian homes still need that output but homeowners would appreciate appliances with lower emissions. There is presently no incentive to produce such appliances for the Canadian market. There are two reasons for this: first, the demand is low and will not foster the payback required by any R&D program and second, there is no legal requirement to produce low-emission, high-output woodburning furnaces.

This research shows that while it would be difficult to improve high output central heating systems to the level of the EPA stove standard, it would not require a major R&D program to reduce these emissions by a factor of 2 or 3.

This research demonstrates the absence of "high-output" clean burning appliances for residential heating. During this project IRTA demonstrated the possibility of considerably lowering emissions from large appliances.

Résumé

Les nouvelles technologies touchant les poêles à bois ont permis de réduire les émissions de polluants par un facteur de 10. Au Canada, la pollution par les poêles à bois n'est aucunement réglementée, principalement à cause du peu d'intérêt manifesté par les ministères de l'Environnement. Aussi, les fabricants canadiens qui désirent faire homologuer leurs produits par rapport aux normes d'émissions doivent se rendre aux États-Unis. L'agence américaine de protection de l'environnement (EPA) a été à l'origine de la mise au point des poêles à faible émission, en imposant un plafond rigoureux sur les émissions particulaires.

La norme de l'EPA présente toutefois un problème : elle n'inclut pas les installations de chauffage central (générateurs d'air chaud) et, compte tenu de la technologie actuelle, elle élimine les appareils à haute puissance capables d'une durée de huit heures. De nombreuses habitations canadiennes ont toujours besoin de cette puissance, mais des appareils moins polluants seraient appréciés. À l'heure actuelle, on n'incite aucun fabricant à produire ce genre d'appareil pour le marché canadien. Deux raisons expliquent cette situation. D'abord, la demande est faible et ne justifierait pas le coût d'un programme de recherche. Ensuite, il n'y a rien dans la loi qui rend obligatoire la production de générateurs d'air chaud au bois à haute puissance et à faibles émissions.

Cette recherche montre qu'il serait certes ardu d'améliorer les appareils de chauffage central à haute puissance pour qu'elles respectent les limites de l'EPA mais qu'un investissement mineur en recherche et développement pourrait réduire les émissions par un facteur de 2 ou 3.

Cette recherche démontre en outre l'inexistence d'appareils domestiques de chauffage au bois à grande puissance rencontrant les normes de l'EPA. L'IRTA a établi, durant ses travaux, qu'il était possible de réduire considérablement les émissions produites par les gros appareils.

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EMISSIONS STATUS OF LARGE WOODSTOVES

Charles LeMay, IRTA

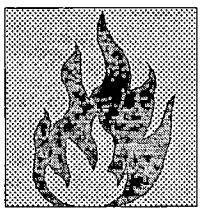
INTRODUCTION:

Over the past 10 years tremendous technological advances have been made in the production of small and medium-sized clean-burning wood stoves, but there has been no development of low cost, clean-burning appliances large enough to heat a typical rural home, either large stove or central wood-fired systems. A high percentage of such homes are occupied by low income families. If emissions-control regulations are mandated to ban the sale of large but dirty appliances, many rural home owners will eventually be forced to revert to the dirty, unsafe and cheap oil-drum stove assembled in a local shop. There is also a need for large clean appliances in the higher price range, but that is not the current concern.

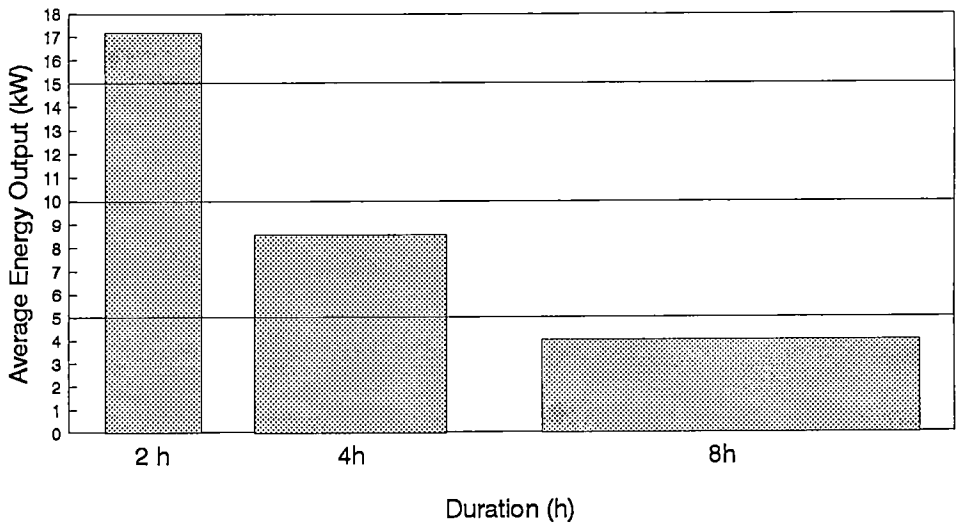
CMHC provided a grant to IRTA to obtain an accurate assessment of the emissions rates of large residential appliances currently on the market. Among other things, IRTA was to test three relatively large EPA-certified stoves, and one imported furnace.

Heat requirement of Canadian homes:

Some R2000 houses might get through a winter with a 5 kW heating system, but many older homes, especially in rural Canada need closer to 20 kW. While some existing wood stoves and furnaces may be able to achieve this output, most appliances certified to American EPA emissions requirements do not approach this heating capacity, and if they do, it is for very short periods and often accompanied by structural damage. Houses with high energy requirements require large but clean-burning appliances.



When you have this much energy available in a wood stove, you can spread it over 2 to 8 hours. The more you spread it the lower the average output. To have more output over a long period of time, you need a larger firebox. The dilemma: with current technology larger fireboxes mean increased emissions!



Required woodstove volumes

To obtain a steady 15 kW output, we must burn more than 4 kg/h of wood at 65% efficiency. At a hardwood **loading** density of 200 g/l (12 lb/cu ft) this burn consumes an effective firebox fuel volume of over 20 litres per hour. It requires a firebox volume of more than 160 litres (5½ cu. ft.) to last through an 8-hour night[1].

[1] Most wood heat users are accustomed to temperature variations and have grown to expect somewhat lower temperatures when they get up in the morning or when they return from work. Because of this, many of them are satisfied with a 125-litre appliance (4.5 ft^3), provided it is capable of "instant" output that will rapidly heat the house.

New technologies

Ten years ago, by today's standards, all woodstoves produced unacceptable levels of air pollutants. Most of those woodburning appliances are still in use. New technologies have drastically reduced emission levels, often by a factor of 10. These new technologies involve the use of catalytic combustors or of sophisticated combustion systems. Unfortunately, at this time, the available non-catalytic systems are not suitable for fire chambers larger than 85 litres (3 cu. ft.) and catalytic systems are limited (amongst other things) by catalyst surface area which translates into dollars. A 14 cm (5½ inch) cylindrical catalytic combustor, 5 cm thick with 6-mm cells, will accommodate at most a 3 kg/h burn rate without damaging surfaces and/or producing unacceptable emission levels. Such a catalyst adds some $200 to $300 to the price of a basic stove and much more to a large furnace.

A recent study conducted on behalf of CMHC demonstrated that indoor air pollution is considerably lower from typical (small) EPA-certified stoves (that support flames even at low burn rates) than from conventional stoves. Unfortunately, typical uncertified large stoves (firebox over 3 cubic feet) lose their flames at low heat outputs, and have high emissions. Such appliances are responsible for a considerable portion of the indoor air pollution from wood combustion in Canada.

Most high-tech appliances have been developed to meet the American EPA standard which now allows 7.5 g/h of particulate emissions[2]. Some states (Washington) are now imposing a ceiling of 4.5 g/h. This type of emission regulation dictates the same ceiling on all appliances, regardless of the amount of heat produced. A house could have two woodstoves with combined emissions of 15 g/h but it could not have a single woodstove that produces 8 g/h, even if it had double the heat output!

The CSA B415-M92, Performance Standard for Solid Fuel Burning Appliances (now in draft) relates to appliances having up to 1 MBtu/h input based on the heat potential of the fuel input. In the lower heat input range, B415 emissions limits correspond to EPA limits. However, to satisfy the need to regulate emissions from appliances having burn rates greater than 5 kg/h, draft B415 also establishes a particulate emissions ceiling of 0.096 g/MJ of heat input. That is, the emissions limit is based on the heat potential of the fuel input, not on the period of time. There is no need to relate emissions to appliance efficiency. The following graphs illustrate the two types of limits that were accepted. Both limits meet at the 5 kg/h point. The lower limit (up to 5 kg/h) is a flat line on the g/h scale while the other is a flat line on the g/MJ scale.

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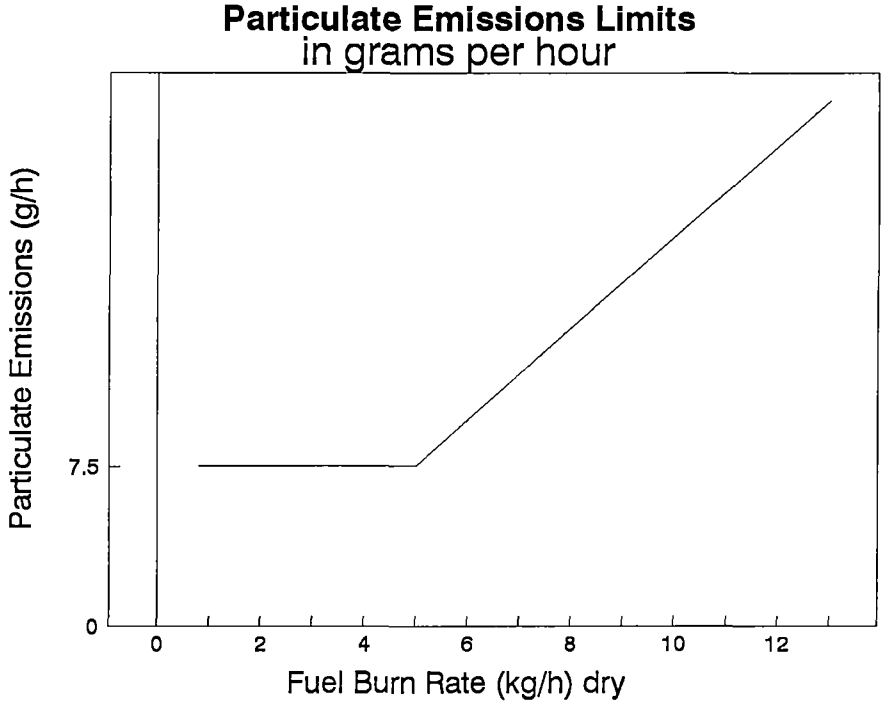
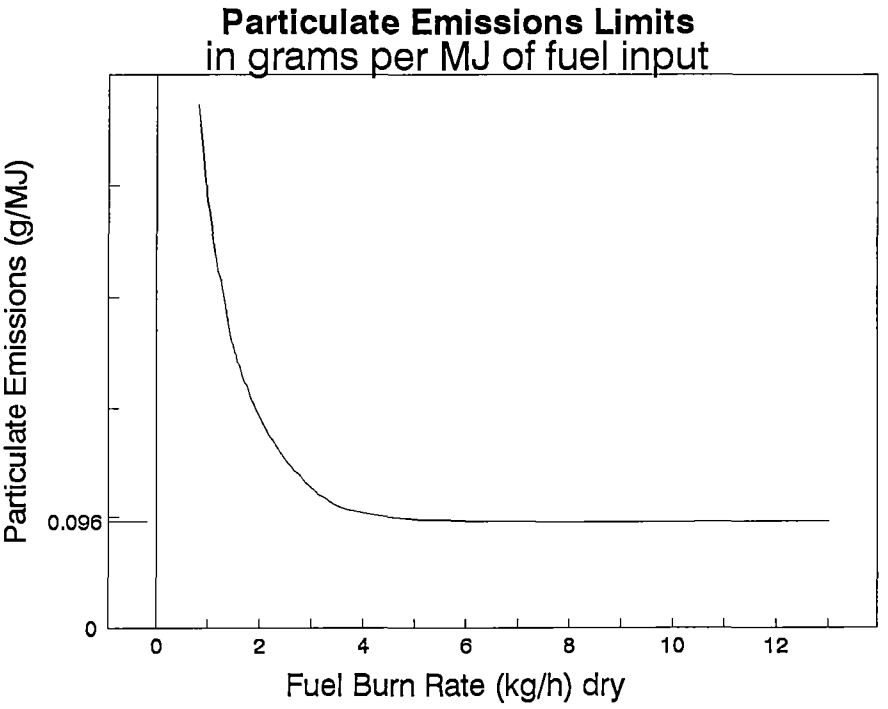
[2] These particulate emissions can be roughly defined as that part of wood smoke that will be collected on a 0.3 micrometre filter, at room temperature. The measurement is the weighted average of 4 burns: a high burn at maximum rate, a low burn below 1 kg/h and two medium burns.





Both these graphs represent the same limits. The difference is in the way they are are expressed, i.e. in average grams per hour or in grams of particulate emissions per MJ of fuel energy input.

Objective

The main objective of this research is to provide guidelines to the CSA B415 committee and to manufacturers in relation to the large stoves and wood-fired central heating systems that are needed to provide affordable, high-output wood-heating equipment that minimizes indoor and outdoor air pollution. IRTA agreed to:

1 Test three large stoves and one furnace to determine their particulate emission levels

2 Relate these results to typical emission levels for the various types of wood-burning appliances currently sold in Canada

3 Make recommendations to the CSA B415 technical committee

4 Provide design guidelines for wood-burning appliances in the 17 to 23 kW range.

Methodology:

1) Field "survey"

Before doing this research, we met with several dealers and appliance manufacturers to identify their concerns regarding the need for, and performance requirements of, larger appliances. It was clear that they had no major problems with smaller EPA-certified units once it was recognized that most are slow-burners and are incapable of high instantaneous heat output. Dealers were quick to point out the largest available EPA-certified stoves. On the other hand, they were almost embarrassed to identify the best available technology for the "large farmhouse". The appliances they showed in this category are robust and capable of supplying the required heat output. However it takes knowledgeable woodstove users to operate them well with no major creosote problems in the winter, and in mild weather this is almost impossible.

Based on these discussions, we selected the following EPA-certified Canadian-made woodstoves for detailed study: the Seefire 2100S, the Regency R6 and the Haugh's Cabot Elite. The Clayton 5.6 (imported from the USA) was selected as a typical medium-sized central heating system.

2) Performance testing

Using the CSA B415 methodology, we tested the 4 chosen appliances. Also, we borrowed data from previous IRTA testing of a Canadian catalytic furnace and a particulate-fuel-burning appliance. Since the older data were based on earlier versions of CSA B415, slight disparities are possible and the comparisons are approximate. Since the older records did

not include particulate emissions testing, we have provided CO measurements[3] for these furnaces to give some indication of comparative emissions levels.

With regard to our testing of EPA-certified stoves, we think our results approximate the EPA results. If any major divergence is observed, this report does not intend to question original EPA results.

Results and observations:

Table I

	Firebox volume (litres)	Approximate[4] average emissions (g/h)	Official EPA emissions (g/h)	EPA certified	EPA output rating MJ/h (kW)	Satisfies CSA B415
Seefire 2100S	71	6.5	3.2	yes	11.6 - 32.8 (3.2 - 9.1)	yes
Regency R6	49	9.5	3.9	yes[5]	12.1 - 62.2 (3.4 - 17.3)	no
Haugh's Cabot Elite	38	4.5	4.4	yes	11.9 - 36.4 (3.3 - 10.1)	yes
Clayton 5.6 (1)	117	100	---	no	---	no
Clayton 5.6 (2)	117	30	---	no	---	no
Cat-furn	129	3.0	---	no	---	yes

[3] CO measurements track particulate measurements although the relationship between them is appliance dependent.

[4] These appliances were not pushed to minimum limits specified by EPA. We therefore cannot apply the EPA weighted average calculation.

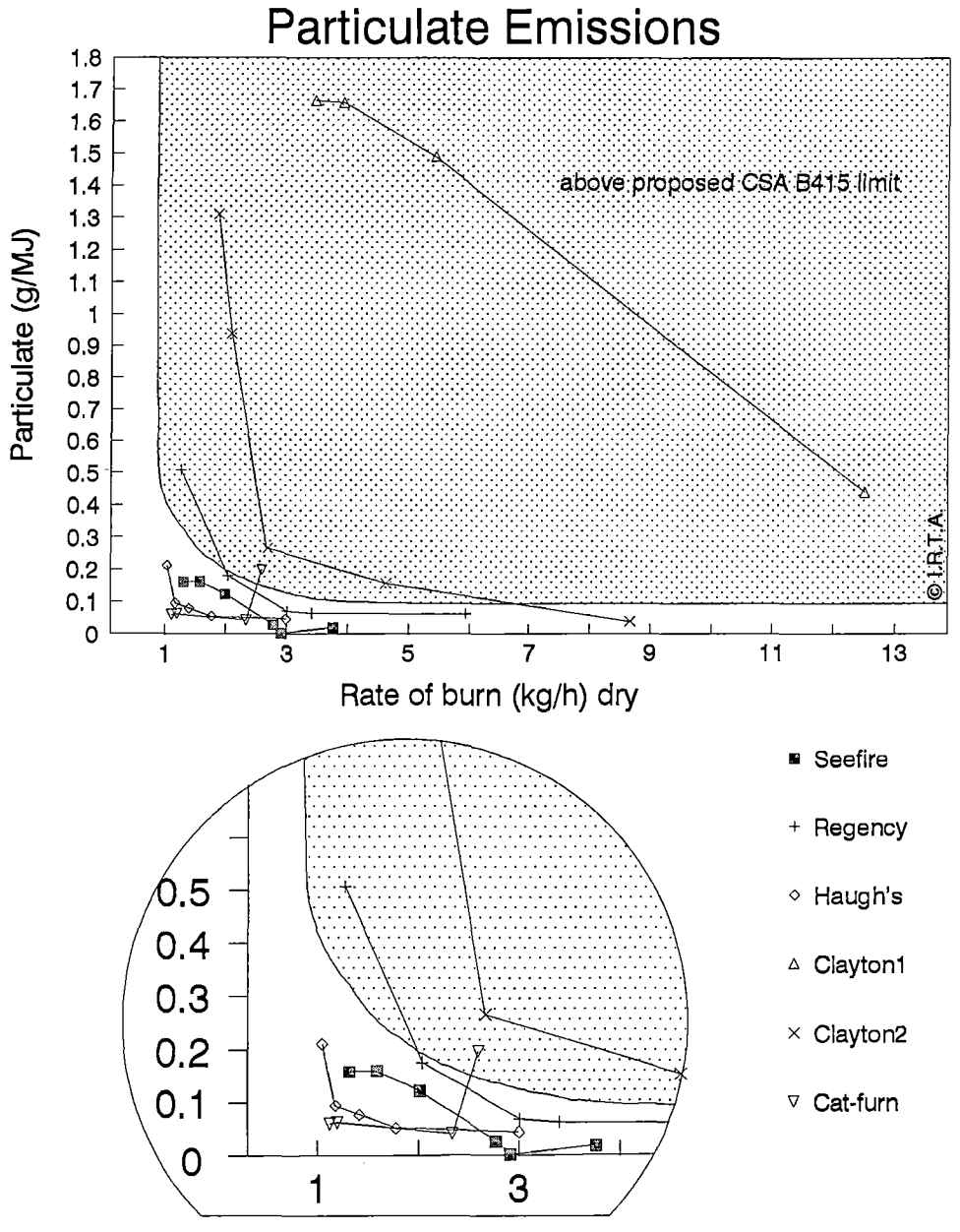
[5] We doubt that this particular unit would have passed EPA.

Table II

Fuel (wet kg)	Length of burn (h)	Dry fuel (kg)	Dry fuel (kg/h)	Rate of energy output (MJ/h(kW))	Particulates (g/MJ input)	Particulates EPA[6] (g/h)
Seefire						
8.23	5.15	6.75	1.31	16.9 (4.7)	0.162	5.99
7.72	4.00	6.33	1.58	20.4 (5.7)	0.163	7.04
7.55	3.10	6.19	2.00	25.7 (7.1)	0.125	6.85
7.40	2.08	6.07	2.92	35.7 (10.4)	0.004	0.51
Regency						
5.65	3.67	4.63	1.26	16.2 (4.5)	0.509	15.03
5.80	2.33	4.75	2.04	26.3 (7.3)	0.179	9.41
5.50	1.50	4.51	3.01	38.7 (10.7)	0.071	6.01
5.30	1.28	4.36	3.41	43.8 (12.2)	0.064	6.13
5.65	0.78	4.63	5.94	76.4 (21.2)	0.063	9.61
Haugh's						
4.30	3.38	3.52	1.04	13.4 (3.7)	0.212	6.20
4.10	2.87	3.36	1.17	15.1 (4.2)	0.096	3.52
4.15	2.43	3.40	1.40	18.0 (5.0)	0.080	3.51
4.00	1.85	3.28	1.77	22.8 (6.3)	0.055	3.16
3.90	1.07	3.20	2.99	38.5 (10.7)	0.047	4.27
Clayton 1						
14.25	3.37	11.68	3.47	44.6 (12.4)	1.665	92.92
14.05	2.93	11.52	3.93	50.6 (14.1)	1.660	102.89
14.10	2.12	11.56	5.45	70.2 (19.5)	1.489	123.37
14.04	0.92	11.51	12.51	161.0 (44.7)	0.439	89.13
Clayton 2						
13.90	6.00	11.39	1.90	24.4 (6.8)	1.311	46.25
14.25	5.53	11.68	2.11	27.2 (7.5)	0.938	38.25
13.10	4.00	10.73	2.68	34.5 (9.6)	0.266	16.40
12.60	2.23	10.33	4.62	59.5 (16.5)	0.157	16.61
13.05	1.23	10.70	8.67	111.6 (31.0)	0.039	8.81
Clayton 2						
13.79	10.10	11.27	1.12	14.4 (4.0)	0.061	2.35
13.86	9.47	11.40	1.20	15.5 (4.3)	0.063	2.56
16.02	5.62	13.16	2.34	30.1 (8.4)	0.043	3.24
14.24	4.53	11.74	2.59	33.4 (9.3)	0.199	12.54

[6] At this time, EPA imposes a correction factor on dilution tunnel measurements.

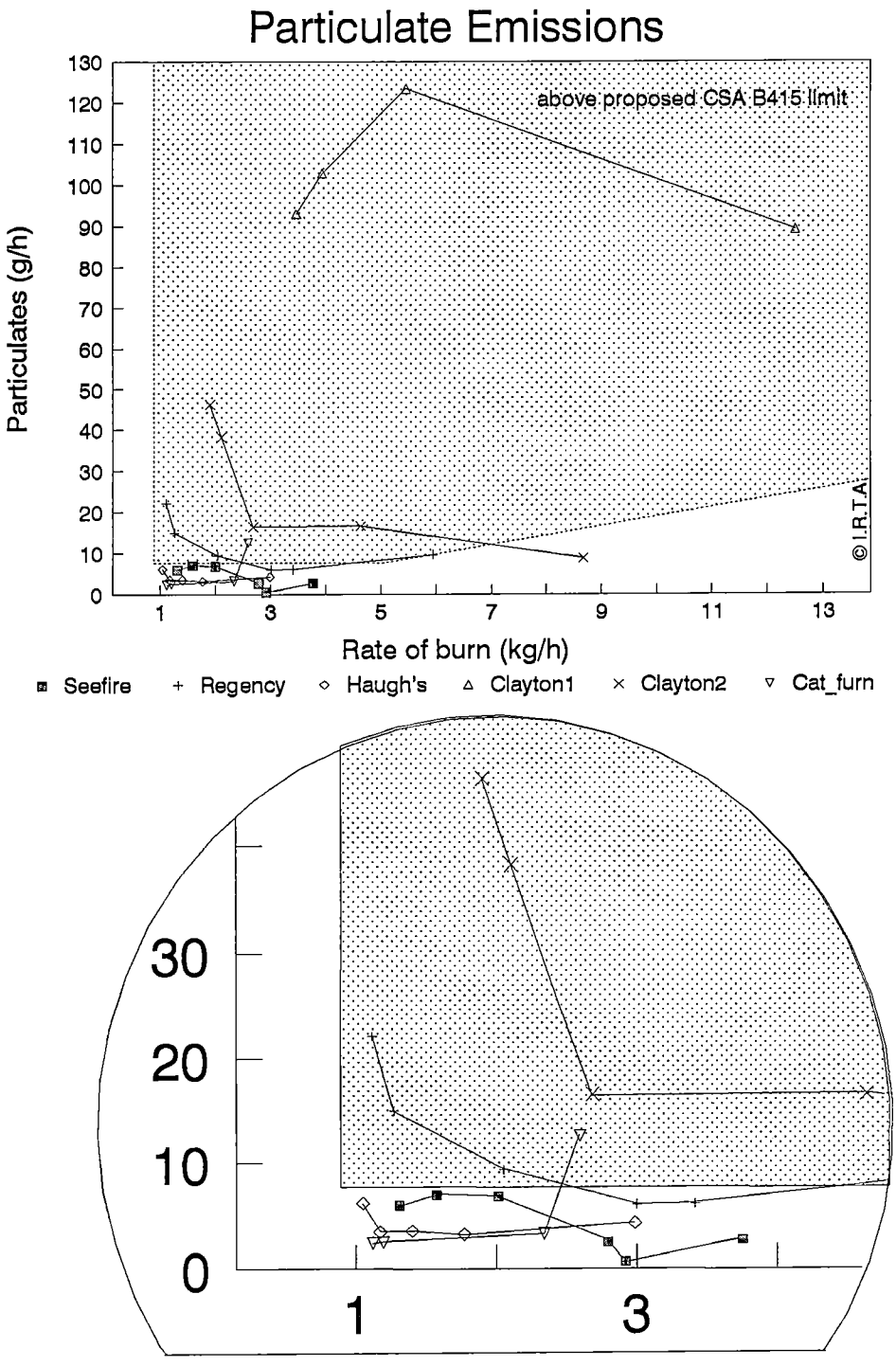
Figure 1. Particulate emissions in g/MJ fuel energy input



It can easily be observed that the Clayton 1 furnace is not in the same category as the three woodstoves, the catalytic furnace or the particulate fuel burner. It is also evident that the modifications made to the Clayton (Clayton 2) have radically improved its performance. However, it exceeds the proposed CSA B415 ceiling of 0.096 g/MJ.

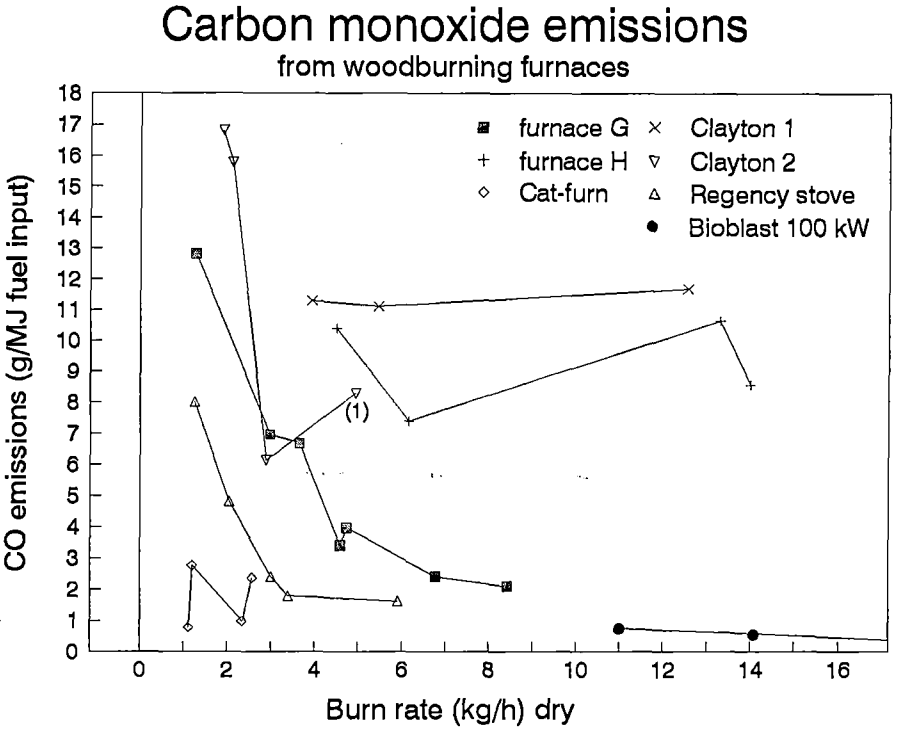
It should be noted that, for most appliances, the emissions level decreases as the burn rate increases; however, emissions from the catalytic furnace rise sharply after a certain burn rate is reached, indicating the catalyst becomes overtaxed.

Figure 2. Particulate emissions in g/h



With an average emissions ceiling of 7.5 g/h, even the improved Clayton 2, is well above the limit.

Figure 3. Carbon monoxide emissions of furnaces



(1) Increase in under-fire air

Particulate fuel burners, such as the Bioblast, can provide both the high output and the clean burn required. The catalytic wood furnace (Cat-furn) can provide a very clean lengthy burn (more than 12 hours) but it cannot reach the high outputs we are considering in this study.

Poor combustion (characterized here by high CO level below 3 kg/h) can be noted in relation to the Clayton 2 and the Regency.

Supplementary observations:

All appliances meeting EPA limits have smaller firebox volumes than are necessary for houses with a large heat demand. The non-cat furnace, although it is not covered by EPA regulations, is very far from meeting current stove emissions limits either before and after alteration.

Modifications to the non-cat furnace not only reduced CO and particulate levels in the chimney, but they also reduced enormously the open-door spillage of the appliance into the room. Prior to these modification, we considered this appliance to have an intolerably high level of open-door spillage. After modification, although some spillage persisted, it was definitely acceptable. The modification would not likely increase manufacturing costs by more than $100.

Although 40% of dwellings in Canada have a wood burning appliance, we might consider marginal the 4.6% households who use wood for primary heating. It is less marginal when you consider that 23% of Newfoundlanders use wood as primary heating. However, a low income earner who is responsible for one of the 437,000 households that use wood for primary heating, does not consider himself a marginal statistic. This citizen needs an **affordable, safe and potentially low emissions** appliance, with the qualifications in that order. If environmental issues push governments into banning the sale of large, dirty appliances, and if governments cannot afford to support research for larger, clean-burning appliances, then many rural low-income families sill revert to the cheap, reliable and totally unsafe 45-gallon drum stove. This is not progress.

Recommendations:

1) That the proposed CSA B415 Performance Standard for Solid Fuel Burning Appliances include a category for central heating systems corresponding to the **best available technology** for roundwood fired appliances. It is clear that no existing roundwood-fired appliances with outputs in the 15 kW range can presently meet the suggested limit of 0.096 mg/MJ input. We believe that in that output range, 0.200 g/MJ would be a good starting point. Progress in R&D will only be made if initial goals are realistic and affordable. Higher goals can be fixed once initial progress is made.

2) If governments decide to legislate the sale of cleaner wood-burning central heating appliances, they should provide funding to manufacturers to develop and certify large, clean, affordable systems.

3) Since the market for central heating systems is small and barely sustains a few manufacturers, the development of an improved roundwood-burning furnace fire chamber could be done by funding a group of manufacturers to develop a single fire chamber. This fire chamber could then be clad as seen fit by each particular manufacturer.

4) Emissions controls should not impose unnecessary and unrealistic limits in rural areas where pollution is not a major concern. Come of the rural poor do not have the resources to upgrade their wood-burning system.

5) Stove manufacturers looking for existing models to inspire their R&D effort should not rely blindly on EPA certification data. They should test the proposed "model" before using it as a starting point for their own development.

6) CMHC should continue to encourage energy-efficient rural housing. This will reduce the heat demand, and lower emissions by reducing fuel consumption.

7) The publication of CSA B415-M92 should be expedited; it is the basic tool for both emissions regulators and appliance R&D.

Note: at the May 16/91 meeting of the B415 Committee, it was decided to publish B415.1 (for stoves) in 1992, and probably B415.2 (for central systems) in 1993.

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Appendix 1 Statistical Summary: Woodburning in Canada

(figures in 000's of households)

	Total Dwellings	Total Single Family Dwellings	Households with Fireplaces	Households Using Wood for Primary Heating	Households Using Wood for Suppl. Heating	Total Households Using Wood for Heating	% of Single Family Dwellings Using Wood for Heating	Total Households With Wood Heaters or Fireplaces	% of Dwellings With Wood Heaters or Fireplaces
Canada	9,477	6,406	2,291	437	1,025	1,462	23%	3,753	40%
Nfld	167	150	23	38	27	65	43%	88	53%
P.E.I.	44	36	5	8	11	19	53%	24	53%
N.S.	309	244	63	37	58	95	39%	158	51%
N.B.	242	197	31	47	54	101	51%	132	55%
Québec	2,511	1,269	386	127	389	516	41%	902	36%
Ontario	3,408	2,406	878	89	269	358	15%	1,236	36%
Man.	383	288	58	10	29	39	14%	97	25%
Sask.	358	297	65	10	18	28	9%	93	26%
Alberta	865	659	236	6	32	38	6%	274	32%
B.C.	1,189	860	546	65	137	202	23%	748	63%