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SUMMARY OF TESTS MADE ON THREE DOMESTIC-TYPE WOOD-BURNING HOT WATER BOILERS

by

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Introduction

During recent years increasing attention has been paid to the use of wood for fuel in domestic heating appliances. This interest, no doubt, has resulted, to a considerable degree, from the necessity of curtailing expenditures for fuel on the part of the small consumer in both the rural and urban centres of Canada. In addition growing interest has been manifested by those operating farm woodlots as well as among lumber and pulp companies in making use of timber which is useless for lumber or pulp purposes and is often at the present time wasted.

Similar conditions are reported to exist in European countries, especially those with inadequate supplies of coal. These reports indicate that the situation in certain European countires has been so acute as to stimulate the production of wood-burning appliances designed on new principles for which high efficiencies are claimed. Neglecting stoves and small space heaters which have been previously reported upon[x] the greatest interest in wood-using furnaces of the domestic hot water type has been developed in Sweden where it is said that many ministerial and other public buildings are centrally heated with wood fuel.

x "Summary of Tests Made on Seven Wood-Burning Stoves" - mimeographed brochure available from Forest Products Laboratories, Department of Mines and Resources, Ottawa, Canada. Free on request.

As a further contribution to the study of the use of wood for fuel initiated by the Forest Products Laboratories, the Fuel Research Laboratories, Bureau of Mines, at Ottawa tested two Swedish wood-burning hot water boilers in comparison with a third boiler of Canadian manufacture. The primary objective of this cooperative investigation was to determine whether the Swedish boilers were more efficient wood burners for domestic heating purposes than the Canadian boiler when used with the same fuel for the same purpose. A secondary objective was to become familar with the new combustion features said to be incorporated in the Swedish-built equipment.

Description of Boilers

Table I lists the ratings and principal specifications of the three boilers tested; plates I, II, and III show exterior views of the respective boilers as set up for test; while figures 1, 2, and 3 give sectional views showing the gas passages, etc., for the same boilers.

Boiler No. 1, Canadian-made, is of an ordinary hot water type. It was designed as a coal burner but good results have been obtained with it when using wood. The test results given here for this boiler have been taken from a previous publication[x] and are used as a basis against which to compare the performance of the two Swedish boilers. The reader is referred to this publication[x] for detailed information regarding the set-up, methods of procedure, etc., used for tests made with this boiler.

Boilers No. 2 and 3, were made in Sweden. Both have been designed for use with wood and were particularly selected for testing because each embodied the latest combustion methods reported to be so successful in Europe. They were also comparable in size to boiler No. 1 - (See item 1, manufacturers' rating, Table 1) - an important consideration when making comparative tests of this nature. The chief feature of these boilers was the use of so-called "slow combustion". To accomplish this the boiler is made as airtight as possible and fitted with closely controlled dampers. A long travel for the products of combustion is provided within the furnace itself, thus ensuring that, as nearly as possible, complete combustion takes place before the gases escape into the chimney. These boilers have large magazines which require replenishing only two or three times a day. The burning of the solid wood is confined to a small area near the base of the magazine, but the combustion of the gases which are formed takes place in separate chambers located at the rear or sides of the fuel magazine as can be seen in the sectional views, figures 2 and 3.

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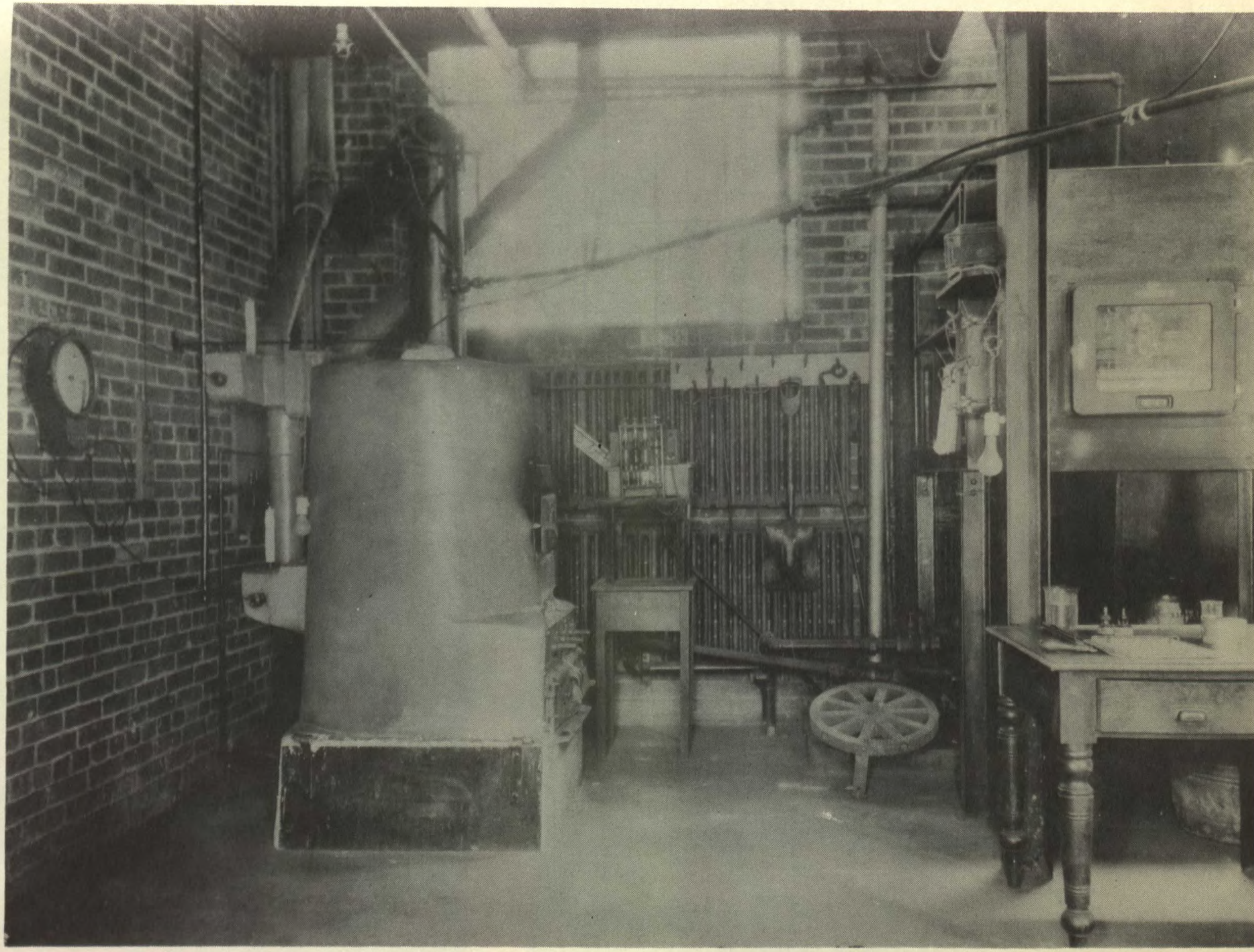
x "Wood Fuel Burning Tests" - Mines Branch Publication No. 761, available from Bureau of Mines, Department of Mines and Resources, Ottawa, Canada. Price 10 cents.

Table I

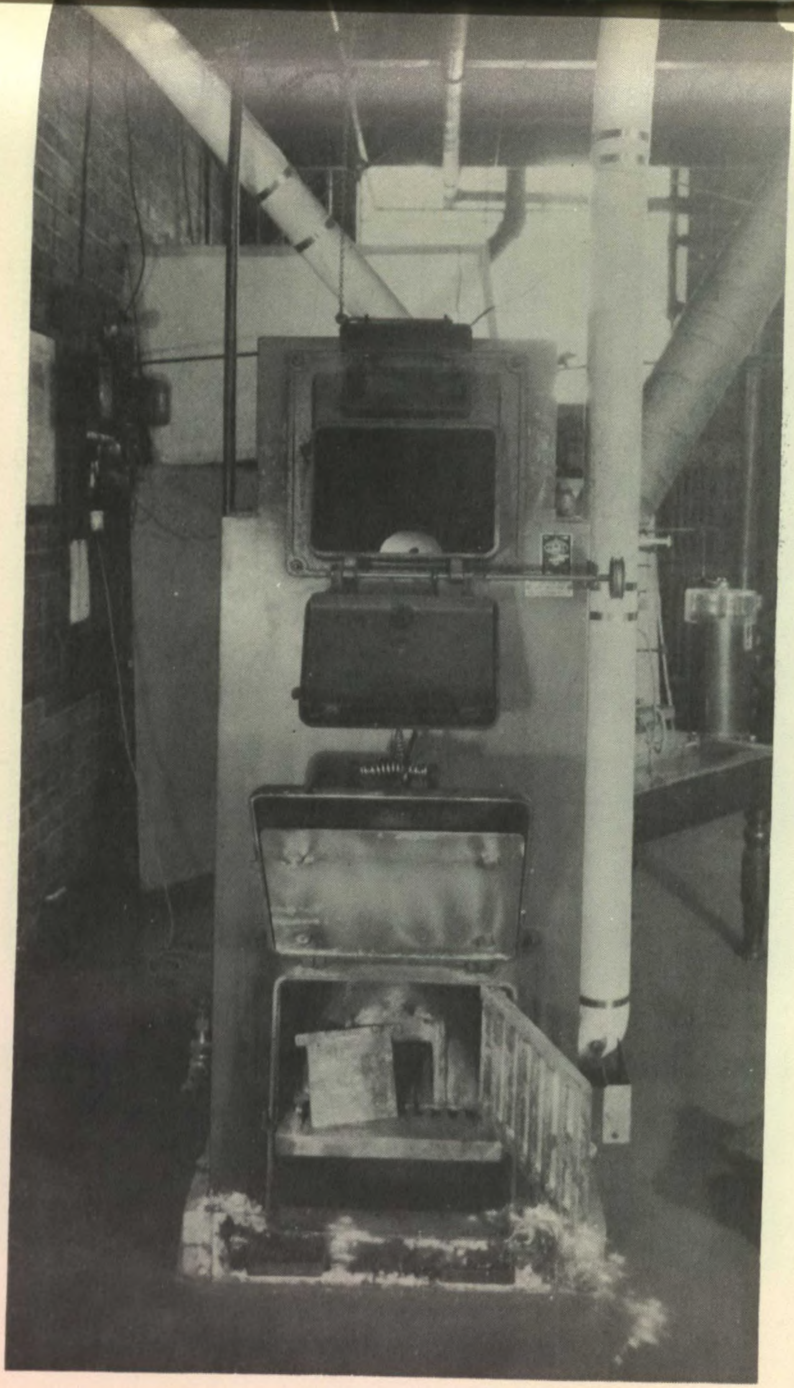
Boiler Ratings and Principal Specifications

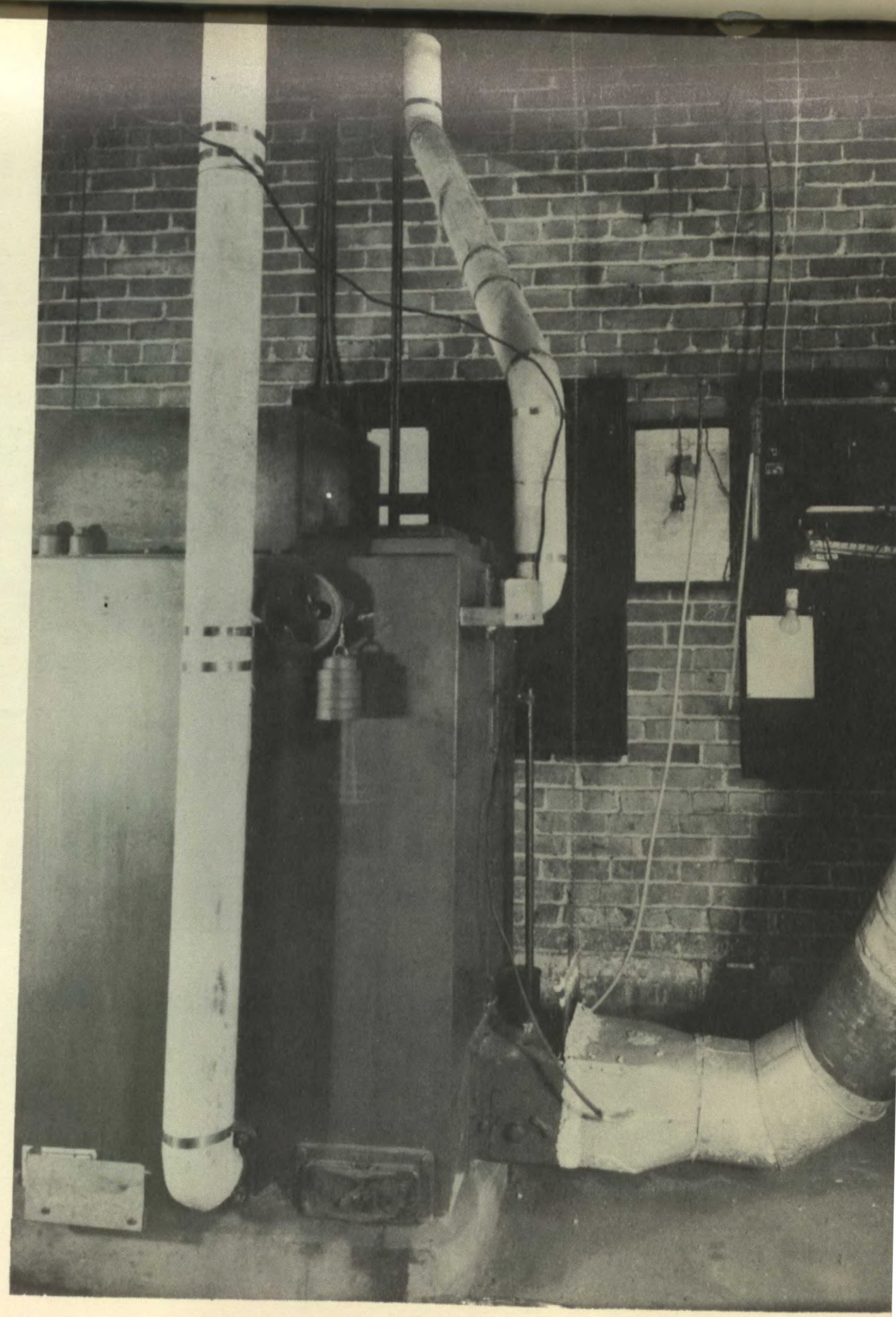
Item	Boiler No.1 Made in Canada Conventional Round Cast-Iron Type	Boiler No.2 Made in Sweden Special, down draught, Square, welded steel plate, wood boiler	Boiler no.3 Made in Sweden Special, under-burning, Square, cast, sectional wood boiler
1.- Manufacturers' rated capacity BTU/hr	132,000	138,880	124,990
2.- Average rating feet of water radiation sq.ft	880	926	833
3.- Nominal grate area sq.ft	3.4	4.5	2.9
4.- Area of heating surface sq.ft	32.4	53.8	48.4
5.- Volume of fuel magazine cu.ft	5.4 x1	12.0	8.1
6.- Gross shipping weight lb	1630	1740	2343
7.- Retail cost at Ottawa	$160.00	$305.00 x2	$265.00 x2

x1. - Volume, grate to top of firepot.
x2. - Price based on Swedish Krona at 25.77 cents.

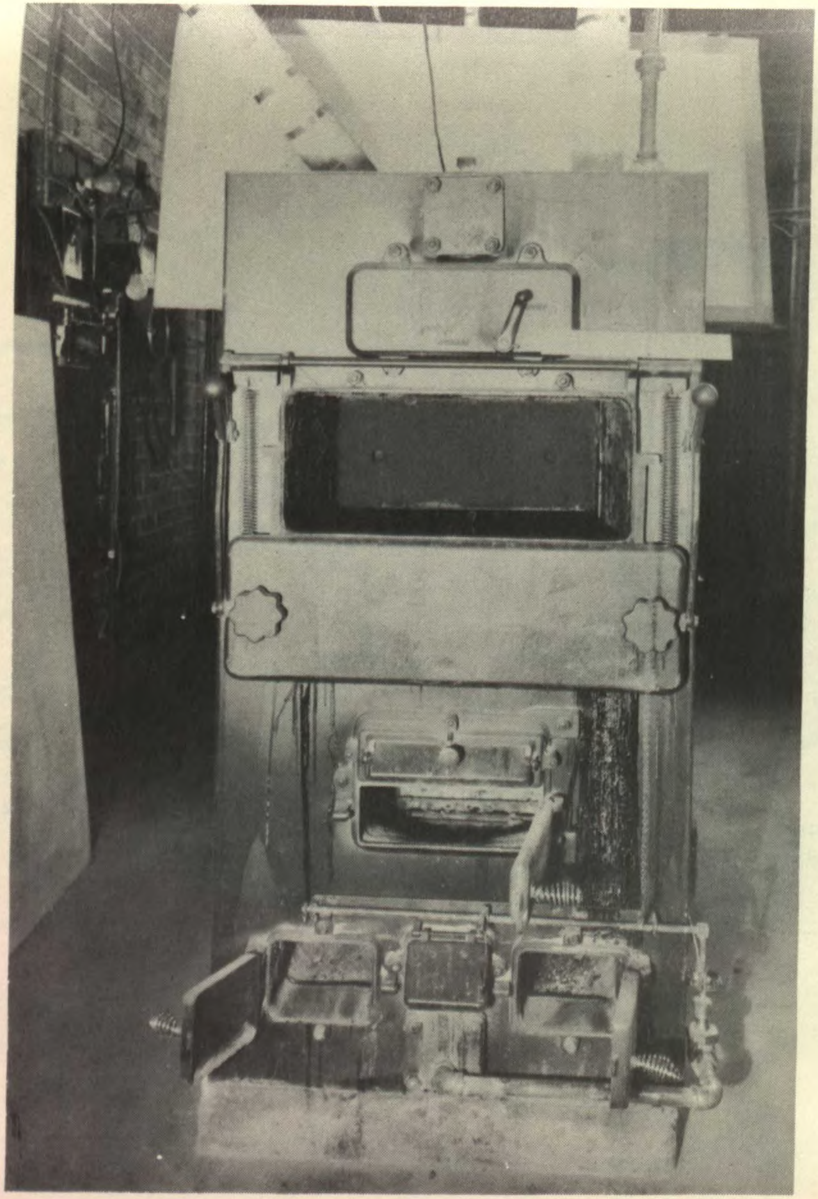


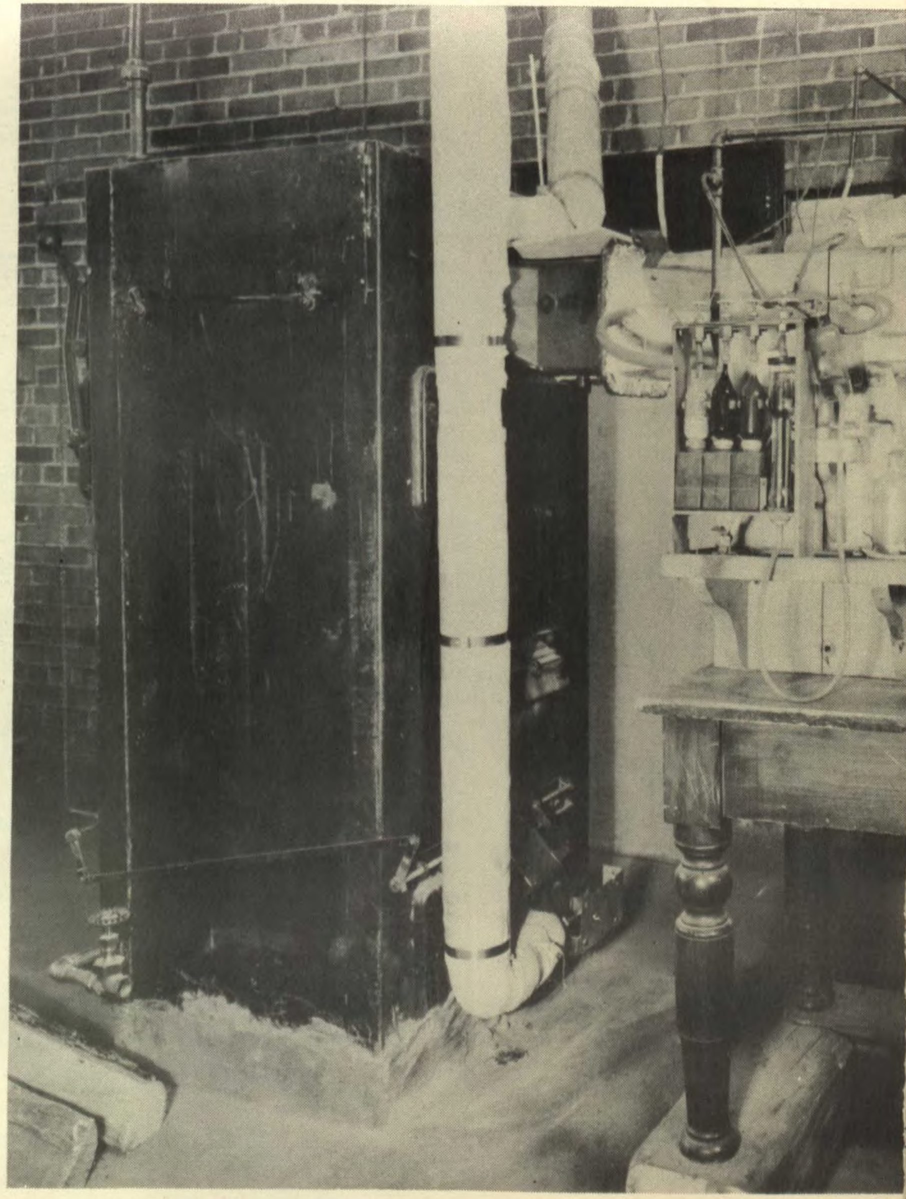
Side view Boiler No. 1





Front and Side views Boiler No. 2





Front and Side views Boiler No. 3

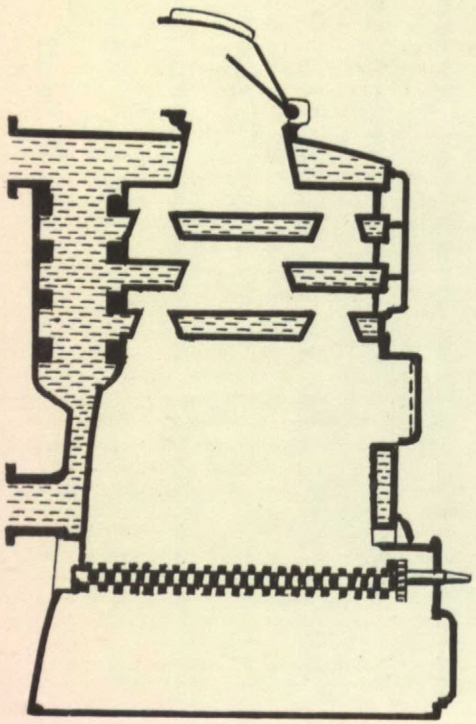


Fig. - 1

Sectional view Boiler No. 1

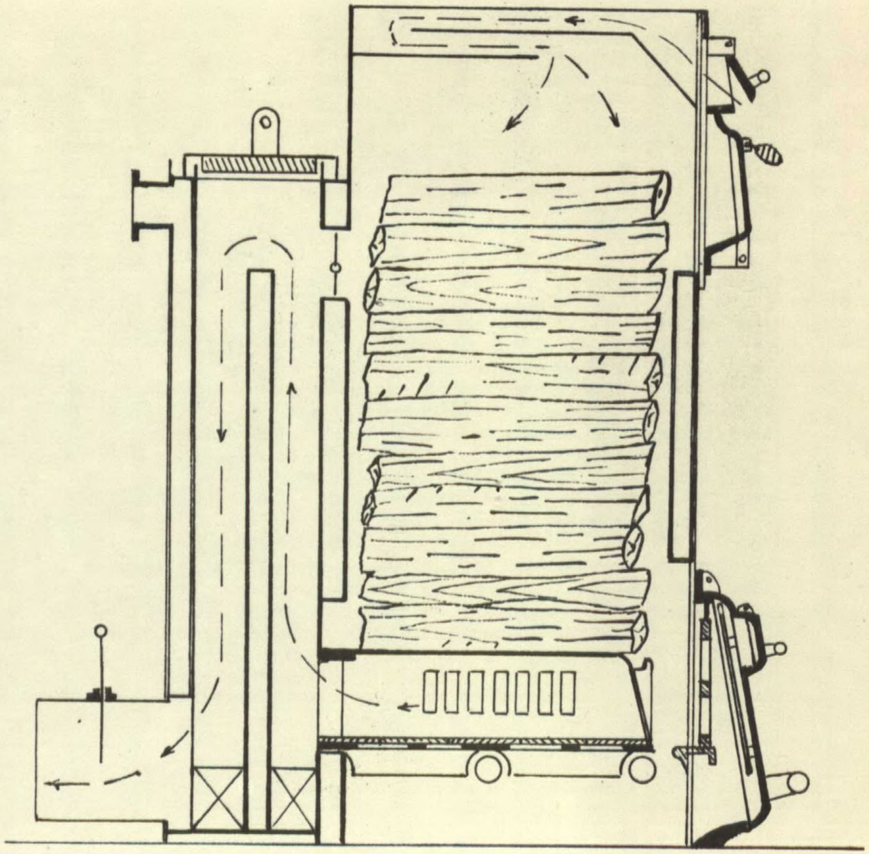


Fig. - 2

Sectional view Boiler No. 2

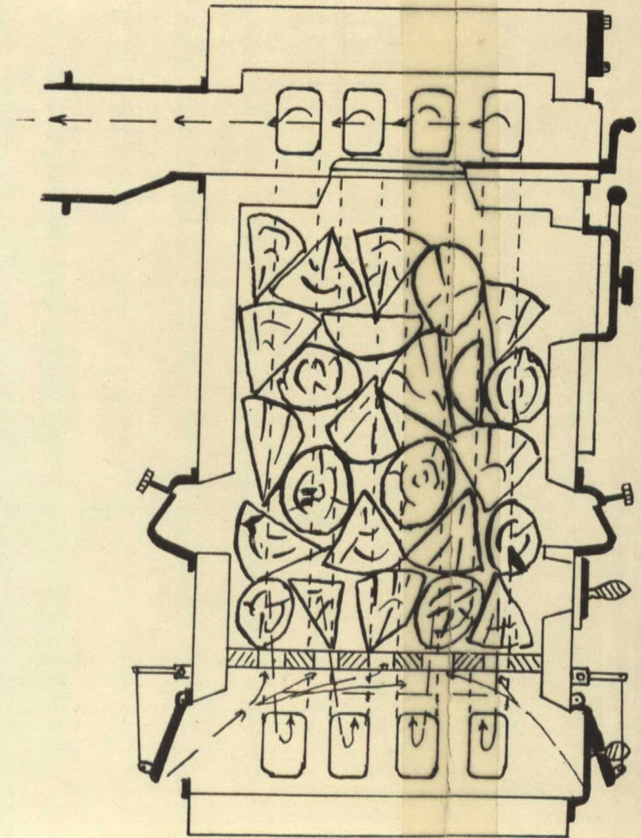


Fig. - 3

Sectional view Boiler No. 3

Method of Test

The same general test procedure was used for these tests as that described in Mines Branch Publication No. 761 to which the reader has been previously referred. Some hours before the trials were commenced the boilers were fired-up and kept in operation at a medium rate of burning until water temperature conditions were stabilized. When this point was reached the whole contents of the firepot were quickly removed, quenched, and discarded. A new fire was immediately kindled at which time the trial was officially started. Draughts were regulated in accordance with the combustion rate desired which was at an output of approximately 80 to 85 thousand B.T.U. per hour. This roughly corresponds to a constant combustion rate of 65 per cent of the boiler capacity, or in other terms a consumption of approximately 4 "standard" cords[x] of average maple firewood in a 30 day period which is about the maximum consumption to be expected for any house which these particular boilers would heat during the coldest month of the year.

Fuel was fed to the furnace magazines in pre-determined weighed quantities. A sample of the wood used for each fire-charge was taken and at the end of test was referred to the Chemical Analysis Section of the Bureau for determination as to moisture, ash, and heat content, etc. During the trials observations were made of water quantities and temperatures, draughts, flue gas temperatures, and general burning characteristics, etc., each 15 minutes and flue gas analyses were made each half-hour.

At the end of the test, water temperatures, etc., were brought to approximately the same conditions as prevailed at the start; the fire was then dumped, drawn, and quenched with dry carbon dioxide gas. The heat value of the quenched residual fire was then determined and substracted from that of the fuel fired during the test.

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x The "standard" cord is a pile of wood 4 feet wide by 4 feet deep by 8 feet long - (128 piled cubic feet). - It is a standard which may vary in respect to net weight of substance even for wood of the same species and condition, and as such is dependent as to both weight and solid volume on the local practice employed in piling and measuring as well as on shape and size of pieces, etc. The term "cord" as used herein is taken to mean 90 solid cubic feet of wood substance which has been found by experience to closely approximate 128 piled cubic feet of maple firewood.

Fuel Used

Average maple firewood, commonly termed "cordwood", cut in lengths suited to the firebox of the respective boilers was the fuel used throughout these tests. Although the wood was bought in three separate lots from wood dealers in Ottawa, careful check-up and numerous analyses established the fact that the wood for all practical purposes was uniform and of average quality throughout. Table II gives data regarding the chemical and physical properties of the wood used.

Table II

Average Chemical and Physical Properties of Wood Fuel Used for Tests

Item			Value
1. - Moisture content on original weight basis, range as fired during tests		%	15.0 to 18.7
2. - Proximate analysis dry basis	(a) ash	%	1.3
	(b) volatile matter	%	81.6
	(c) fixed carbon - (by difference)	%	17.1
3. - Ultimate analysis dry basis	(a) carbon	%	49.5
	(b) hydrogen	%	6.2
	(c) ash	%	1.3
	(d) sulphur	%	trace
	(e) nitrogen	%	0.2
	(f) oxygen - (by difference)	%	42.8
4. - Calorific value; dry, gross value		BTU/lb	8310
5. - Fuel ratio, fixed carbon/volatile matter			0.2
6. - Carbon - hydrogen ratio			8.0
7. - Bulk density[x], weight per solid cubic foot, as received		lb	45.3
8. - Solid cubic feet per cord, as received		cu.ft	90
9. - Weight per cord of 90 solid cubic feet, as received		lb	4077
10. - Size of wood fired, average length	(a) to boiler No. 1	inches	10 to 12
	(b) to boiler No. 2	inches	20 to 22
	(c) to boiler No. 3	inches	18 to 20

[x] Bulk density figures were furnished by the Forest Products Laboratories during a previous investigation at which time the properties of average maple firewood were thoroughly investigated. See Mines Branch Publication No. 761.

Results of Tests

The salient results of the tests are briefly summarized in Table III, close study of which will facilitate comparison of one boiler with another. In reviewing this table it will be noted that only one test was available for consideration with boiler No. 1, whereas the average of three repeat tests is considered for each of boilers No. 2 and 3; also that the length of all trials was 120 hours. Item 8(a) shows that the tests were made at approximately the same output with all boilers developing the same percentage of rated capacity within the limit of six as shown by item 9.

Item 2, "the interval between firings", clearly shows the effect of the large fuel magazines in the Swedish boilers which make possible fire-holding periods of three times that of the Canadian-made boiler. This is an important point as, under normal operating-conditions, the Swedish boilers would require only two or three refuelings during the course of a 24 hour day, thus permitting satisfactory overnight operations without attention.

Item 3(a) gives the amount of dry fuel burned per hour and when considered with item 8(a) definitely shows that boiler No. 1 produced the greater amount of heat with the least amount of fuel. Boiler No. 3 came second; with boiler No. 2 closely following. Items 3(b) and 8(b) give the amount of fuel burned per therm - (100,000 B.T.U.) - of useful heat delivered during the heating process and the amount of useful heat produced by each pound of fuel burned. These items also equate the boilers in the same order as given above and when taken in conjunction with fuel price and calorific value may be used to develop relative operating cost for the boilers concerned. This factor is, of course, the most important from an economic standpoint while overall thermal efficiency, (see item 10) equates the relative merits of the boilers as effective heat producers. Item 10 shows that the Canadian-made boiler was a little more efficient than either of the Swedish-made ones and that in this regard there was little to choose between the two Swedish-made boilers.

Items 4, 5, 6 and 7 are indicative of the combustion performance during the tests on the various boilers and clearly show that conditions were best for the Canadian-made boiler. The higher draught and excess air and the lower CO_2 obtaining with the Swedish boilers were unavoidable due to complex design and the more restricted furnace passages which provided for the so-called "slow combustion". These conditions were the worst with boiler No. 2 which according to manufacturer's instructions required a draught of from 3 to 5 millimeters - (0.120 to 0.200 inches water guage) - for satisfactory operation, this was necessary in order to carry the desired output as given in item 8(a). As the chimney available for these tests did not provide such a high draught, mechanical induced draught was used for the tests made on this particular boiler.

Table III

Summarized Results of Tests

Item		Result for		
		Boiler No.1 one trial	Boiler No.2 average of 3 trials	Boiler No.3 average of 3 trials
1.- Duration of trials	hrs	120	120	120
2.- Interval between firings - (average time)	hrs	2.00	5.62	6.00
3.- Dry fuel burned (a) per hour	lb	17.6	19.6	18.8
(b) per therm[x] delivered to cooling water	lb	20.59	23.64	22.76
4.- Temperature, flue gases at boiler outlet	°F	439	277	327
5.- Carbon dioxide, per cent volume in flue gases at boiler outlet	%	12.4	6.7	8.4
6.- Excess air	%	52	150	115
7.- Draught at boiler outlet	in.w.g	.012	0.146	.042
8.- Heat transmitted to cooling water				
(a) per hour	BTU/hr	85487	83093	82434
(b) per lb of dry fuel burned	BTU/hr	4856	4233	4393
9.- Percentage of rated boiler capacity developed	%	64.8	59.8	65.9
10.- Overall thermal efficiency, dry fuel basis	%	57.3	50.9	52.9

x.- Therm = 100,000 B.T.U.

Summarized Conclusions

1. The Swedish boilers were found to be not quite as efficient in the matter of heat transference as the Canadian-made boiler.

2. The Swedish boilers have better fire-holding ability than the Canadian-made boiler in the ratio of three to one, and in consequence can be operated over longer periods without attention.

3. The so-called "slow combustion" feature embodied in the Swedish boilers is conducive to tar formation within the boiler, especially at the low rates of combustion necessary in mild weather and for overnight banking, even in moderately cold weather.

4. The Swedish boilers were more carefully built and heavier, and consequently more costly than the Canadian boiler.

5. The possible draught settings with the Swedish boiler are much more numerous than for the Canadian boiler. This means that greater skill but less attention is required for their successful operation.