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# PERFORMANCE OF RETROFIT FLAME RETENTION HEADS IN DOMESTIC OIL FURNACES

A.C.S. Hayden and R.W. Braaten
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# PERFORMANCE OF RETROFIT FLAME RETENTION HEADS IN DOMESTIC OIL FURNACES

by

A.C.S. Hayden* and R.W. Braaten*

ABSTRACT

Existing oil-fired domestic heating systems in Canada offer the potential for significant fuel savings by improving burner performance and reducing the degree of oversizing of the furnace/boiler. These actions can be achieved by retrofitting the existing oil burner with a (CSA-approved) retention head kit, coupled with downsizing of the firing rate. Temperatures measured in two warm-air furnaces, one with a stainless steel combustion chamber and the other with a ceramic combustion chamber indicate no problems should be encountered due to overheating of the combustion chamber nor primary heat exchanger, provided the stainless steel chamber is lined with ceramic fibre and the maximum allowable firing rate is reduced one size. Both of these requirements now exist in the CSA code for retrofitting retention heads.

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*Research Scientist and **Research Engineer, Canadian Combustion Research Laboratory, Energy Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa.

TABLES



FIGURES

## INTRODUCTION

Since 1971, the Canadian Combustion Research Laboratory (CCRL) has had an active program on domestic oil-fired heating equipment, both to evaluate and modify existing equipment and to develop new equipment. To this end, studies have been performed in the laboratory (1) and in the field, in a group of instrumented test homes in the Ottawa area (2).

Since 1974, a major aim of the program has been to develop technologies and strategies to reduce fuel consumption in the home by improving the efficiency of existing heating systems. Reports on CCRL field trials (2,3) show that significant potential exists for reducing domestic fuel consumption by reduction in firing rate, improvement in burner performance, use of positive chimney dampers and overnight thermostat cutback.

In particular, improvement in burner performance by reducing excess air requirements, coupled with reduction in firing rate to make the furnace/boiler more in tune with the heat demands of the house, appear to offer average fuel savings on the order of 15-20%.

This report describes laboratory tests carried out at CCRL to determine the suitability of different conventional high-pressure gun burners to improvements in performance by retrofitting a flame retention head and to determine the effect such retrofitting might have on combustion chamber and primary heat exchanger temperatures.

## TEST EQUIPMENT

Burners used for the test results reported herein were as follows: Powrmatic, Conroy WF-7000, Aero, Beech 73-C and Brock. The heads used for the test runs are those as reported on the applicable tables.

Furnaces used for the tests were a Grimsby 67-117C having a stainless steel combustion chamber and an Anthes LOD-115, having a ceramic fibre combustion chamber.

In order to measure temperature effects on internal surfaces of the Grimsby furnace, eight thermocouples were affixed to the stainless steel combustion chamber, and two to the primary heat exchanger. Location of the thermocouples is as shown in Figure 1.

Similarly, in order to measure primary heat exchanger temperatures on the Anthes furnace, three thermocouples were affixed, as shown in Figure 2.

## TEST RESULTS

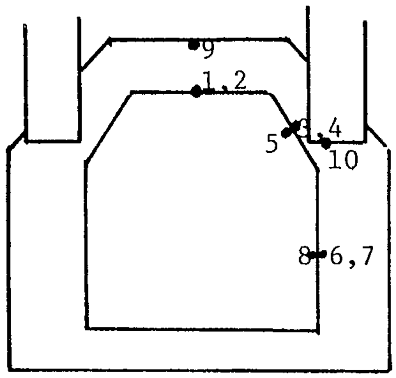
In general, reducing excess combustion air improves appliance efficiency. For a domestic oil burner, the effect can best be illustrated by the test results shown in Figure 3. With a conventional Conroy head, excess air performance, measured in terms of increasing carbon dioxide content, goes from just over 5% $CO_2$ at zero smoke number to 8% $CO_2$ at a smoke number of eight. At the same time that excess air decreases, flue gas temperature falls from 295°C to 270°C and efficiency increases from 70% to 77%. For the recommended operating smoke number of two, efficiency is about 71% for this conventional head burner.

When the burner is retrofitted with a retention head, the curve of smoke number vs excess air (i.e. $CO_2$) moves sharply to the right. At zero smoke, $CO_2$ level is now 8.5%. At an operating smoke number of two, stack temperature is down to 250°C and efficiency is increased to over 81%.

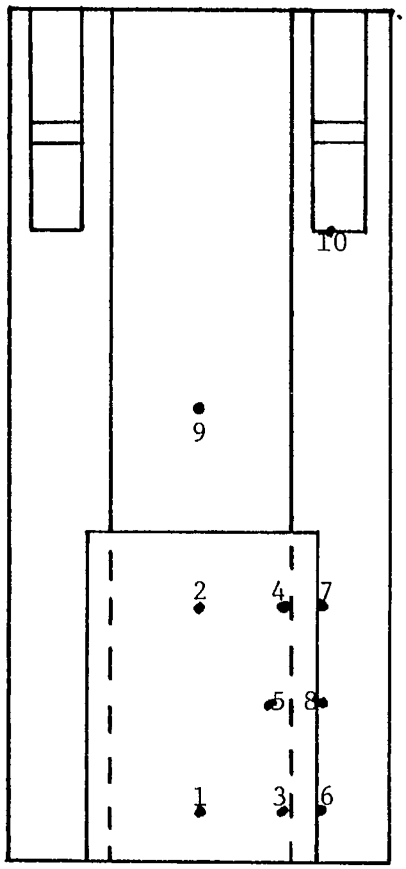
For this burner, retrofitting a retention head resulted in an increase in steady state efficiency from 71% to 81%, with a commensurate reduction in stack temperature from 290°C to 250°C.

It is interesting to note that, for the same furnace, curves of stack temperature and efficiency are effectively continuous with excess air ($CO_2$), although burner performance has changed significantly in moving from a conventional head to a retention head, as evidenced by the two curves for smoke number for the respective heads.

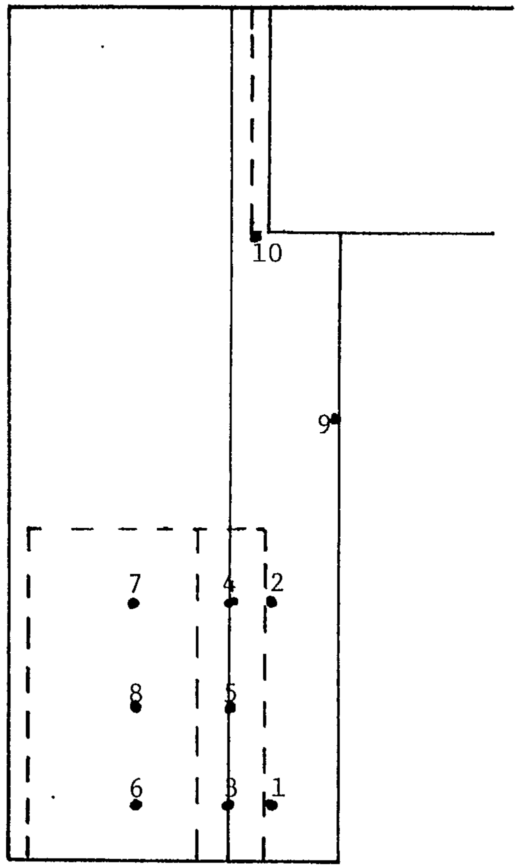
CCRL has retrofitted retention heads into sixteen instrumented homes in the Ottawa area since 1974. Furnaces/boilers involved in this retrofit have included nine different types. No evidence of failure nor overheating has occurred in these test homes. However, because of concerns expressed by other agencies, detailed measurements of combustion chamber and heat exchanger temperatures were made on the two test furnaces in the laboratory.




Top View




Front View




Side View

Figure 1 . Location of thermocouples to measure temperatures of combustion chamber and primary heat exchanger - Grimsby 67-117C oil-fired warmair furnace.

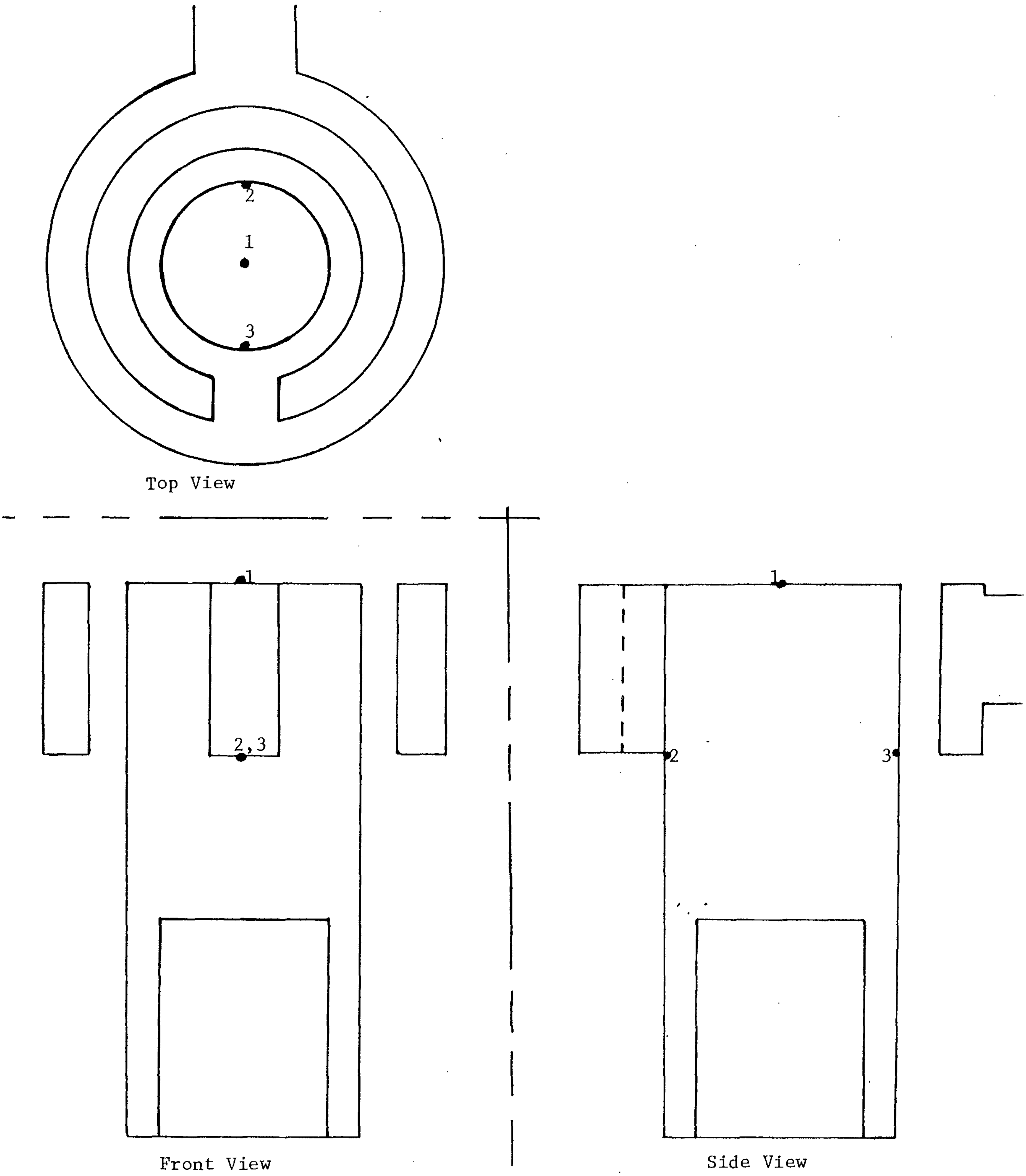



Figure 2 . Location of thermocouples to measure temperatures of primary heat exchanger - Anthes LOD-115 furnace.

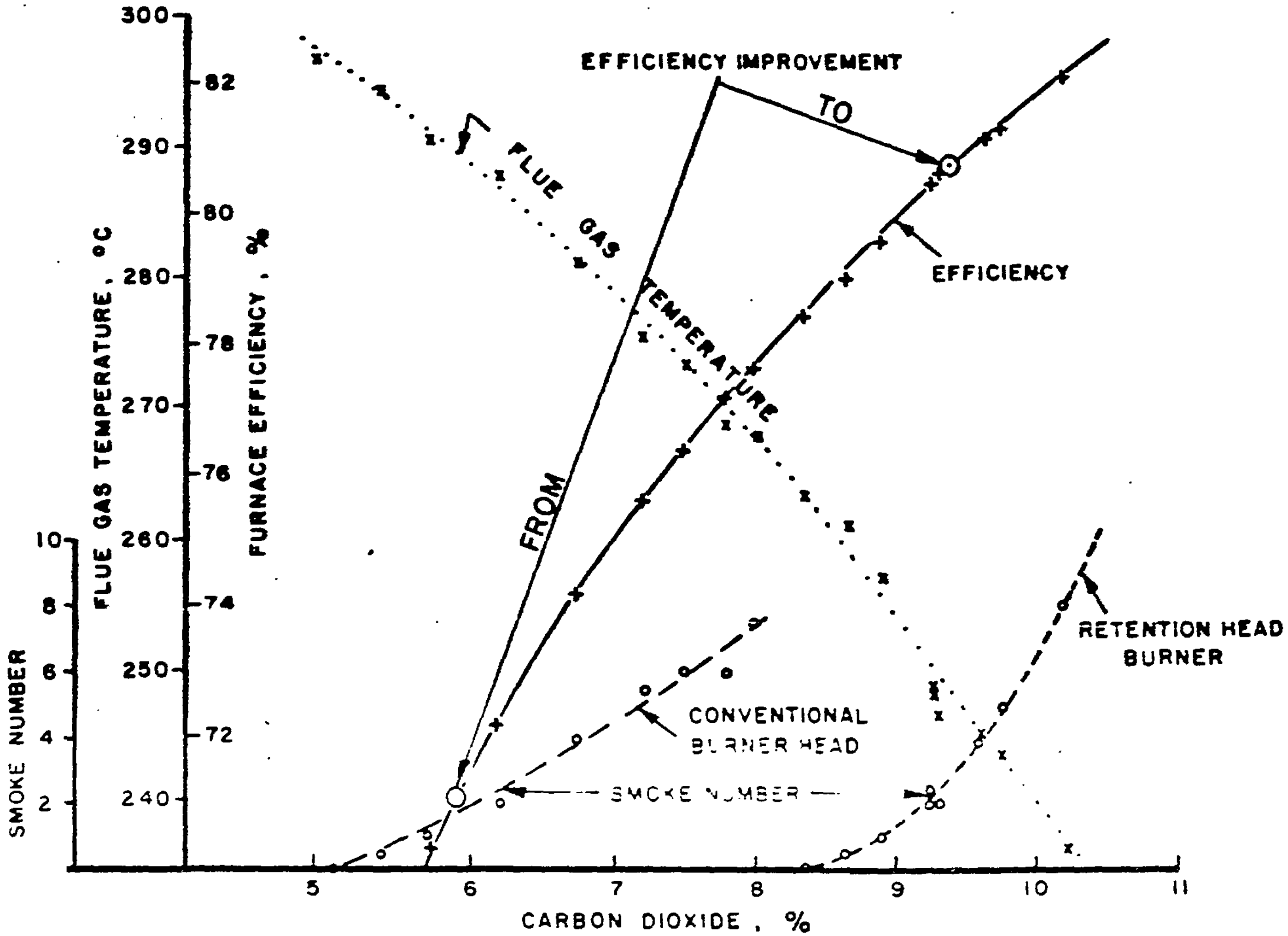



Figure Efficiency improvement of domestic oil burners when retrofitted with a retention head.

Tests were conducted in the Grimsby furnace with the stainless steel combustion chamber unlined and with a ceramic fibre liner installed.

Table 1 shows combustion chamber temperatures with a conventional head burner for three unlined conditions and seven lined conditions. The maximum metal temperature of 738°( occurred on the inner side of test point 8 with the Beach burner firing at 1.0 gph. For interest, tests with the conventional burner with the combustion chamber lined have been included. At a firing rate of 1.0 gph, the temperature at point 8 was reduced to 592°C.

Table 2 shows the comparable temperatures on the combustion chamber when the burner has been fitted with a retention head. With the combustion chamber lined as required by CSA, maximum temperatures at the same 1.0 gph firing rate are down to 639°C. At the one-size reduction in firing rate as required by CSA with the retention head, the maximum temperature is 611°C. This is 127°C lower than the temperature experienced by the chamber with the conventional burner head.

Table 3 and 4 respectively give the temperatures measured on the primary heat exchanger and in the flue gas for the above tests using conventional and retention head burners.

Results for the Grimsby furnace are summarized in Table 5. As mentioned, the metal temperature of the lined combustion chamber with the retention head is 127°C lower than for the unlined metal chamber with conventional head. Maximum primary heat exchanger temperatures for the retention head fired at one-size down fjrom conventional (i.e. down to 0.85 gph from 1.0 gph) are the same (500°C) in both cases.

Table 6 shows the results of tests conducted in the Anthese furnace, having a ceramic fibre combustion chamber, for both a conventional burner at 1.0 gph and 1.1 gph firing rates and for this burner fitted with a retention head at firing rates of 1.0 gph, 0.85 gph and 0.75 gph. Temperatures were measured at the three points on the primary heat exchanger, as well as the resultant flue gas temperature.

For the conventional burner, the maximum temperatue measured was 374°C at point 2 at the design firing rate of 1.0 gph. For the retention head, with a one-size reduction in firing rate to 0.85 gph, as required by the CSA standard, the maximum temperature measured actually decreased by 13°C, to 361°C. At the same time flue gas temperature was decreased by 41°C.

Table 1 - Combustion chamber temperatures for conventional head burners
Grimsby furnace (stainless steel chamber)

| Burner Make | Firing Rate | Chamber Condition | Combustion chamber temperatures, °C | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1. Lower Rear | 2. Upper Rear | 3. Lower Angle | 4. Upper Angle | 5. Inside Angle | 6. Lower Side | 7. Upper Side | 8. Inside Side |
| Powrmatic | 1.0 | Unlined | 568 | - | 524 | 563 | 687 | 581 | 587 | 725 |
| Beach | 1.0 | Unlined | 577 | 487 | 538 | 565 | 704 | 577 | 580 | 738 |
| Beach | 0.75 | Unlined | 524 | 490 | 530 | 542 | 618 | 538 | 525 | 662 |
| Powrmatic | 1.25 | Lined | 443 | - | 440 | 560 | 570 | 530 | 584 | 638 |
| Powrmatic | 1.1 | Lined | 458 | 413 | 436 | 556 | 553 | 486 | 541 | - |
| Powrmatic | 1.0 | Lined | 413 | 369 | 394 | 524 | 532 | 483 | 540 | 592 |
| Conroy | 1.0 | Lined | 416 | 358 | 400 | 538 | 530 | 447 | 491 | 518 |
| Powrmatic | 0.85 | Lined | 401 | 346 | 351 | 526 | 508 | 430 | 483 | - |
| Powrmatic | 0.75 | Lined | 393 | 347 | 346 | 513 | 499 | 407 | 457 | - |
| Powrmatic | 0.60 | Lined | 360 | 328 | 318 | 467 | 457 | 366 | 409 | 442 |

Table 2 - Combustion chamber temperatures for retention head burners - Grimsby furnace (stainless steel chamber)

| Burner Make | Retention Head | Firing Rate | Chamber Condition | Combustion Chamber Temperature, °C 1. Lower Rear | 2. Upper Rear | 3. Lower Angle | 4. Upper Angle | 5. Inside Angle | 6. Lower Side | 7. Upper Side | 8. Inside Side |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aero | FAFC-2 | 1.0 | Unlined | 659 | - | 656 | 660 | 850 | 629 | 604 | 752 |
| Aero | FAFC-2 | 0.85 | Unlined | 643 | - | 619 | 618 | 790 | 590 | 562 | 699 |
| Powrmatic | FAFC-2 | 1.0 | Lined | 516 | 472 | 459 | 639 | 622 | 500 | 543 | 600 |
| Brock | Brock | 1.0 | Lined | 509 | 463 | 469 | 635 | 620 | 499 | 547 | 602 |
| Powrmatic | FAFC-2 | 0.85 | Lined | 495 | 448 | 436 | 611 | 598 | 476 | 513 | - |
| Brock | Brock | 0.85 | Lined | 473 | 426 | 428 | 590 | 579 | 460 | 507 | 555 |
| Powrmatic | FAFC-2 | 0.75 | Lined | 458 | 425 | 402 | 570 | 555 | 432 | 458 | 515 |
| Brock | FAFC-2X | 0.65 | Lined | 419 | - | 371 | 510 | 515 | 388 | 435 | 496 |
| Brock | FAFC-2X | 0.50 | Lined | 367 | - | 320 | 458 | 450 | 341 | 380 | 431 |

Table 3 - Heat exchanger and flue gas temperatures using conventional burners - Grimsby warm-air furnace

| Burner Make | Firing Rate | Chamber Condition | Temperatures, °C Heat Exchanger 9. Wall | Temperatures, °C Heat Exchanger 10. Flue Exit | Temperatures, °C Flue Gas |
|---|---|---|---|---|---|
| Powrmatic | 1.0 | Unlined | 324 | 500 | 307 |
| Beach | 1.0 | Unlined | 320 | 498 | 272 |
| Beach | 0.75 | Unlined | 233 | 423 | 230 |
| Powrmatic | 1.25 | Lined | 358 | 560 | 342 |
| Powrmatic | 1.1 | Lined | 357 | 545 | 323 |
| Powrmatic | 1.0 | Lined | 316 | 507 | 314 |
| Conroy | 1.0 | Lined | 312 | 498 | 289 |
| Powrmatic | 0.85 | Lined | 312 | 480 | 271 |
| Powrmatic | 0.75 | Lined | 311 | 446 | 246 |
| Powrmatic | 0.60 | Lined | 259 | 385 | 217 |

Table 4 - Heat exchanger and flue gas temperatures using retention head burners - Grimsby warm-air furnace

| Burner Make | Retention Head | Firing Rate | Chamber Condition | Temperatures, °C Heat Exchanger 9. Wall | 10. Flue Exit | Flue Gas |
|---|---|---|---|---|---|---|
| Aero | FAFC-2 | 1.0 | Unlined | 313 | 477 | 256 |
| Aero | FAFC-2 | 0.85 | Unlined | 292 | 440 | 246 |
| Powrmatic | FAFC-2 | 1.0 | Lined | 414 | 543 | 251 |
| Brock | Brock | 1.0 | Lined | 357 | 531 | 259 |
| Powrmatic | FAFC-2 | 0.85 | Lined | 365 | 500 | 220 |
| Brock | Brock | 0.85 | Lined | 318 | 476 | 232 |
| Powrmatic | FAFC-2 | 0.75 | Lined | 311 | 433 | 208 |
| Brock | FAFC-2X | 0.65 | Lined | 266 | 400 | 202 |
| Brock | FAFC-2X | 0.50 | Lined | 208 | 334 | 202 |

Table 5 - Summary of effect of retention head on temperatures of combustion chamber and primary heat exchanger - Grimsby 67-117C furnace (stainless steel chamber)

| Burner Head | Chamber Condition | Firing Rate | Temperature, °C Combustion Chamber 1. Lower Rear | 2. Upper Rear | 3. Lower Angle | 4. Upper Angl3 | 5. Inside Angle | 6. Lower Side | 7. Upper Side | 8. Inside Side | Heat Exchanger 9. Wall | 10. Flue Exit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conventional | Unlined | 1.0 | 577 | 487 | 538 | 565 | 704 | 581 | 587 | 738 | 324 | 500 |
| Retention Head | Lined | 1.0 | 516 | 472 | 469 | 639 | 622 | 500 | 547 | 602 | 414 | 543 |
| " " | Lined | 0.85 | 495 | 448 | 436 | 611 | 598 | 476 | 513 | 555 | 365 | 500 |
| " " | Lined | 0.75 | 458 | 425 | 402 | 570 | 555 | 432 | 458 | 515 | 311 | 433 |

Table 6 - Effect of retention head on temperatures of primary heat exchanger - Anthes LOD - 115 (ceramic fibre combustion chamber)

| Burner Head | Firing Rate | Heat Exchanger Temperatures, °C 1. Outside Top | 2. Inside Front | 3. Inside Rear | Flue Gas Temperature °C |
|---|---|---|---|---|---|
| | 1.1 | 334 | 387 | 319 | 343 |
| Conventional | 1.0 | 326 | 374 | 303 | 336 |
| Retention Head | 1.0 | 361 | 398 | 357 | 317 |
| | 0.85 | 339 | 361 | 328 | 295 |
| | 0.75 | 311 | 337 | 294 | 270 |

## CONCLUSIONS

From previous papers and the tests reported herein, retention heads on domestic oil burners offer an effective means to improve steady state efficiency by decreasing excess air requirements and stack temperature.

Tests reported herein show no evidence of metal overheating when flame retention heads are retrofitted into stainless steel combustion chambers, provided such chambers are lined with a ceramic fibre metal, as required by the CSA code.

Equal or lower metal surface temperatures were measured on the primary heat exchanger of both furnaces when burners were retrofitted with a flame retention head with a one size reduction in firing rate, as required by CSA.

There is no indication of potential safety problems due to retrofitting of CSA approved retention head kits on conventional oil burners, bearing in mind that additional derating of the furnace is an essential part of the EMR oil furnace retrofit program and that servicemen are being given the technique (4) to more properly size the nozzle to meet the heat demands of the house.

At the same time, improved burner performance, when coupled with adequate decrease in firing rate, offers large potential fuel savings to homes in Canada heated with oil. The laboratory tests, together with results from sixteen instrumented test homes, demonstrated that significant energy savings can be achieved without compromising safety.

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