FURNACE ALERT COMBUSTION BACKDRAFT INDICATOR

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FIELD EVALUATION OF FURNACE ALERT COMBUSTION BACKDRAFT INDICATOR PERFORMANCE

POST-TEST REPORT

Conducted under HTIP File No. 6521-24/85, for Canada Mortgage and Housing Corporation

Introduction

This post-test report completes the schedule of tasks outlined under HTIP File No. 6521-24/85 for field testing and evaluation of the FURNACE ALERT Combustion Backdraft Indicator. Previous reports have described the test procedure and selection of test sites. This report presents the field data collected, complete with analysis and evaluation of the performance of the FURNACE ALERT Combustion Backdraft Indicator. A separately bound Appendix contains a brief summary of the testing procedure, and the full set of field data and temperature profiles collected during the field test program.

The incentive for this work was the need to develop a simple means by which homeowners and researchers alike could detect the occurrence of prolonged exhaust gas backdrafting from naturally aspirated gas furnaces. Previously conducted research has shown that the conventional naturally aspirated gas furnace does not have the ability to exhaust its spent fumes under conditions of negative indoor pressures. While the degree of negative indoor pressure required to cause a backdrafting conditon varies depending upon home style, outdoor conditions, and furnace type, it has been shown that in many cases the operation of a fireplace or exhaust fan can cause the critical depressurization leading to venting failure of the furnace system. In other cases, if the furnace chimney becomes chilled, the naturally aspirated gas furnace may not be able to overcome the weight of the cold column of air in the chimney, again leading to venting failure. Therefore, the FURNACE ALERT Combustion Backdraft Indicator was developed as one means of detecting the occurrence of these prolonged exhaust gas backdrafts.

This project has focussed on the conventional gas furnace. The FURNACE ALERT Combustion Backdraft Indicator has been designed for usage on the conventional gas furnace, and not others, for a number of reasons. Firstly, the gas furnace exhaust products tend to be more difficult to detect by common sensing means, such as sight or smell. Oil or fireplace combustion products generally produce visible particulate matter or a detectable odour. Therefore, the greater need is to detect the gas furnace combustion gas backdraft, because of its more elusive qualities. Secondly, the standard open draft diverter chamber offers the lowest restriction to backdrafting flows from the furnace, making this type of furnace the most suspect in regard to failure

due to negative pressures occurring within the house relative to outdoors. Finally, while it is acknowledged that detection of backdrafting exhaust streams from conversion burners would be worthwhile, the absence of a defined backdraft pathway has made development of a simple backdraft indicator more difficult. Often the backdraft port is very small, an inspection port, which tends to develop high local temperatures during normal operation, precluding the easy application of the FURNACE ALERT technology. Future endeavours may yield a solution to the conversion burner backdraft detection problem. Therefore, for the remainder of this report, only the conventional naturally aspirated gas furnace shall be examined.

As a subset to this field testing evaluation, a request was made to also test the efficacy of the FURNACE ALERT Combustion Backdraft Indicator in detecting combustion exhaust gas backdrafting from naturally aspirated gas domestic hot water heaters. Three such installations were examined and are reported upon in a second section of this report.

The FURNACE ALERT Combustion Backdraft Indicator has been designed to detect extended exhaust gas backdrafting from naturally aspirated gas furnaces, as opposed to the detection of spillage. Research to-date indicates that spillage is not a stable condition and does not generally persist for more than about 1-2 minutes. Should the detection of spillage become desirable, the FURNACE ALERT technology can be utilized by selecting a different temperature threshold point and relocating the indicator to the upper edges of the vertical draft chamber opening. However, in some cases a combustion backdraft might occur such that a spillage indicator would not register the occurrence (due to local cooling along the upper draft chamber opening). In other cases, the effects of automatic flue damper closure, or furnace spillage at start-up could lead to an increased incidence of false alarms. This is not to say that the detection of spillage is not desirable. Rather, the detection of an extended backdraft condition, which can be caused by insufficient air supply to the furnace or a blocked chimney, may be more meaningful to the general user of such a detection means. Assuming that regular maintenance of gas furnaces can prevent problems related to chimney blockage and other furnace equipment problems, the addition of the FURNACE ALERT combustion backdraft indicator combined with increased home occupant awareness of their gas furnace should serve to increase home occupant safety to an acceptable level. Therefore, the detection of spillage conditions is not the focus of this report, although much of the data contained within this report does offer a basis for examining the spillage issue from a research viewpoint.

The field data will be presented and evaluated on a site by site basis, followed by a general analysis of the overall

testing program and efficacy of the FURNACE ALERT Combustion Backdraft Indicator. The data collected from each test site will be presented as follows:

1. Presentation of Test Site Location Data
2. Presentation of Field Testing Data
3. Analysis of FURNACE ALERT Combustion Backdraft Indicator performance.
4. Summary of findings from testing.

FIELD TEST DATA - PRESENTATION AND ANALYSIS

1. HTIP #001 - 6 HEXHAM ROAD TEST SITE

Testing was conducted on November 16, 1985. Outdoor winds were 28 Kmh from the East, outdoor temperature was -3 degrees Celsius. The house is a split level design, with exterior chimney, one fireplace and one kitchen range hood type exhaust fan.

Test data is contained in the Testing Data Appendix under HTIP #001. Photographs of the furnace installation and exterior house construction are provided.

Table One details the time response of the FURNACE ALERT Combustion Backdraft Indicator under the various backdrafting conditions.

The average time to response was 79.3 seconds. The maximum time to response was 111 seconds. The minimum time to response was 62 seconds.

This furnace has an automatic flue damper. No residual heating effects were observed at the shallow low center probe location that might cause false alarms for the FURNACE ALERT Combustion Backdraft Indicator.

During test #2, the flue began to recover with proper flow, and then a backdraft condition resumed. Because of the instability in the backdraft (attributed to the high outdoor winds during this testing), the response time of the FURNACE ALERT Combustion Backdraft Indicator was longer than average, or 111 seconds.

Tests #3 and #4 involved more stable backdrafts.

During test #5 some initial spillage occurred, for approximately 30 seconds, followed by proper chimney and flue venting. The FURNACE ALERT Combustion Backdraft Indicator did not register during this temporary condition.

Test #6 was similar to test #5, with approximately 30 seconds of backdrafting followed by spillage which lasted for approxmately 200 seconds from furnace start up, at which time

TABLE ONE

FOCI FIELD DATA ANALYSIS PROGRAM

TEST #	TIME TO BARE LABEL CHANGE (650) (SEC)	TIME OF FURNACE ALERT CHANGE START (SEC)	TIME OF FURNACE ALERT CHANGE TOTAL (SEC)	DURATION TO CHANGE (AVERAGED TIME) FROM B.DRAFT START (SEC)	FROM >650 POINT (SEC)	BACKDRAFT INTENSITY RATING FULL, MED WEAK, NONE TEMPORARY
1	X	X	X	X	X	NONE
2	10	107	115	111	101	WEAK
3	10	60	65	62.5	52.5	MED
4	11	59	65	62	51	MED
5	12	X	X	X	X	TEMP
6	11	X	X	X	X	TEMP
7	14	67	70	68.5	54.5	MED
8	15	90	95	92.5	77.5	FULL
9	X	X	X	X	X	TEMP
10	X	X	X	X	X	TEMP
AVERAGE		76.6	82	79.3	67.3	
MAXIMUM		107	115	111	101	

FULL: STRONG OR CONSISTENT BACKDRAFT
MED: STABLE BACKDRAFT WITHOUT EXCESSIVE REVERSE FLUE FLOW
WEAK: BACKDRAFT WITH SPORADIC PARTIAL VENT RE-ESTABLISHMENTS
NONE: NO BACKDRAFT
TEMP: INITIAL BACKDRAFT FOLLOWED BY VENT RE-ESTABLISHMENT

proper chimney and flue venting occurred. Again, the FURNACE ALERT Combustion Backdraft Indicator did not register this temporary backdrafting condition.

A relatively stable backdraft occurred during test #7, with a marginal flue recovery over a 10 second period at 50 seconds from furnace start up. The FURNACE ALERT Combustion Backdraft Indicator registered the backdraft after 68.5 seconds.

During test #8 a full backdraft occurred. Response time was slightly longer, 92.5 seconds, due to the initial cooling effect of the backdrafting air flow.

During tests #9 and #10 a temporary backdraft occurred (45-60 seconds in test #9, about 30 seconds in test #10), followed by proper chimney and flue venting. In both cases, the FURNACE ALERT Combustion Backdraft Indicator did not register a backdraft condition.

Testing at this field site indicates that the FURNACE ALERT Combustion Backdraft Indicator will not register a backdraft of temporary stature (less than 45- 60 seconds), but does register positively an extended backdraft that persists for more than, on average, 79.3 seconds. As the backdraft becomes less stable, the response time for the FURNACE ALERT Combustion Backdraft Indicator increases, due to reduced heating of the indicator surface.

2. HTIP #002 - 1 BANKVIEW TEST SITE

Testing was conducted on November 23, 1985. Outdoor winds were 4 Kmh from the South, outdoor temperature was 0 degrees Celsius. The house is a bungalow design, with exterior chimney, one fireplace, one kitchen range hood type exhaust fan and one standard bathroom exhaust fan.

Test data is contained in the Testing Data Appendix under HTIP #002. Photographs of the furnace installation and exterior house construction are provided.

Table Two details the time response of the FURNACE ALERT Combustion Backdraft Indicator under the various backdrafting conditions.

The average time to response was 102 seconds. The maximum time to response was 113 seconds. The minimum time to response was 90 seconds.

This furnace has an automatic flue damper. No residual heating effects were observed at the shallow low center probe location that might cause false alarms for the FURNACE ALERT Combustion Backdraft Indicator.

Consistent and stable backdrafts were observed for tests #2

TABLE TWO

FOOD TEST #	TIME TO BARE LABEL CHANGE (ESC) (SEC)	FIELD DATA TIME OF FURNACE ALERT CHANGE START (SEC)	TIME OF FURNACE ALERT CHANGE TOTAL (SEC)	ANALYSIS PROGRAM DURATION TO CHANGE (AVERAGED TIME) FROM B.DRAFT START (SEC)	FROM /65C POINT (SEC)	EACH DRAFT INTENSITY RATING FULL, MED WEAK, NONE TEMPORARY
1	X	X	X	X	X	NONE
2	17	98	106	102	85	MED
3	18	100	108	104	86	MED
4	15	94	114	104	89	MED
5	15	90	108	99	84	MED
6	22	105	121	113	91	MED
7	14	90	107	98.5	84.5	MED
8	17	100	115	107.5	90.5	MED
9	15	90	102	96	81	MED
10	14	88	92	90	76	MED
11	15	70	X			TEMP
AVERAGE		92.5	[illegible]	[illegible]	[illegible]	
[illegible]		105	[illegible]	113	91	

[illegible]
[illegible]
[illegible]
[illegible]

to #10 inclusive. During test #11, in which only the house fireplace was operating, a basement window was opened at discrete intervals so as to determine the amount of extra ventilation required in the house to facilitate proper furnace exhaust product venting. After 40 seconds a basement window next to the furnace was opened 1", followed by opening the window 2" at 60 seconds (at which time vent re-establishment occurred). Note that during this latter test the fresh air intake pipe was open, as well as a 4" round dryer vent pipe, but neither was sufficient to meet the combined air supply requirements of the fireplace and furnace systems.

(Point of Interest: Test #6 indicates one of the difficulties in measuring backdrafts while also measuring for spillage. A full backdraft occurs during this test. However, the shallow high right probe temperature does not reach 60 degrees Celsius during the backdraft (and rises to approximately 70 degrees Celsius as the damper closes on furnace shut down). In order to detect backdrafts with some level of confidence a FURNACE ALERT Combustion Backdraft Indicator located at the upper right hand corner of the vertical draft opening would have to be designed with a lower threshold temperature (more in the range of about 40 degrees Celsius), which would lead to greater chances for false alarms.)

Testing at this field site indicates that the FURNACE ALERT Combustion Backdraft Indicator will not register a backdraft of temporary stature (less than 70 seconds - actual critical time for registration as indicator began to darken), but does register positively an extended backdraft that persists for more than 70 seconds, and on average, 79.3 seconds. While the degree of backdraft likely varied (house conditions ranged from operation of fireplace and 2 exhaust fans through to operation of fireplace only), the response time of the FURNACE ALERT Combustion Backdraft Indicator remained relatively constant in the range of 90 to 113 seconds.

3. HTIP #003 - 6 MANCIL DRIVE

Testing was conducted on November 24, 1985. Outdoor winds were 20 Kmh from the North-West, outdoor temperature was +1 degrees Celsius. The house is a two storey design (with side split living room on first level), with exterior chimney, one fireplace, one kitchen range hood type exhaust fan and two bathroom exhaust fans.

Test data is contained in the Testing Data Appendix under HTIP #003. Photographs of the furnace installation and exterior house construction are provided.

Table Three details the time response of the FURNACE ALERT Combustion Backdraft Indicator under the various backdrafting

conditions.

The average time to response was 100 seconds. The maximum time to response was 165 seconds. The minimum time to response was 63 seconds.

This furnace does not have an automatic flue damper.

It was noted that during a long furnace cyle (600 seconds), the temperatures along the lower front edge of the vertical draft opening began to rise slightly from 20 degrees Celsius to 40 degrees Celsius. The FURNACE ALERT Combustion Backdraft Indicator threshold temperature is sufficiently high enough to avoid false alarms from this temperature rise, but the observed temperature rise does establish a lower temperature threshold level which must be avoided to prevent false alarm occurrence.

Test #2 was conducted with all exhaust capacity in the home in operation, with the furnace blower door slightly open, fireplace burning, and the hot water tank flue was closed off for the test. A full backdraft occurred with registration by the FURNACE ALERT Combustion Backdraft indicator after 120 seconds from furnace start up. From the recorded data it is observed that the temperature rise at the central region in the vertical draft opening area is suppressed by the cooler backdrafting chimney air flow. However, as the furnace begins to warm up the temperature at the shallow low center location rises, reaching 125 degrees Celsius after approximately 100 seconds of furnace operation.

During test #3, under similar conditons, the temperature rose more quickly at the shallow low center probe location - resulting in a slightly more rapid registration of the backdraft (after 80 seconds). The outdoor wind may have reduced the amount of backdrafting flow during this test, leading to less cooling influence in the draft chamber and more rapid heating of the indicator sensing zone.

Test #4 was similar to test #2. Test #5 was similar to tests #2 and #3.

Test #6 was similar only the clothes dryer was also turned on, although the furnace blower door is closed for tests #5 through #11. The temperature at the shallow low center probe does not rise as quickly as in previous tests resulting in the slower response of the FURNACE ALERT Combustion Backdraft Indicator (144 seconds). The wind may have decreased during this test leading to a greater backdrafting flow and resulting depression of temperatures in the draft chamber.

Test #7 was similar to test #6, with a response time of 165 seconds.

For the remaining tests #8 - #11, various exhaust appliances

TABLE THREE

FIELD DATA ANALYSIS PROGRAM

	TIME TO BASE LABEL CHANGE (SEC)	TIME OF FURNACE ALERT CHANGE START (SEC)	TIME OF FURNACE ALERT CHANGE TOTAL (SEC)	DURATION TO CHANGE (AVERAGED TIME, FROM B.DRAFT START (SEC)	FROM 1ST POINT (SEC)	BACKDRAFT INTENSITY RATING FULL, MED WEAK, NONE TEMPORARY
1						NONE
2		120	125	122.5	122.5	FULL
3		80	85	82.5	82.5	FULL
4	62	100	106	104	42	FULL
5	36	80	90	85	49	MED
6	74	130	158	144	110	FULL
7	26	160	170	165	139	FULL
8	14	60	85	72.5	58.5	MED
9	14	60	65	62.5	48.5	MED
10	18	86	94	91	73	MED
11	16	70	75	72.5	56.5	TEMP
AVERAGE		94.8	105.5	100.15	78.15	
MAXIMUM		160	170	165	139	

L: STRONG OR CONSISTENT BACKDRAFT
MED: STABLE BACKDRAFT WITHOUT EXCESSIVE REVERSE FLUE FLOW
WEAK: BACKDRAFT WITH SPORADIC PARTIAL VENT RE-ESTABLISHMENTS
NONE: NO BACKDRAFT
TEMP: INITIAL BACKDRAFT FOLLOWED BY VENT RE-ESTABLISHMENT

were turned off for each test. The backdraft intensity decreases and the response time of the FURNACE ALERT Combustion Backdraft Indicator begins to increase, reaching a limit of 63 seconds during test #9.

Note that during test #10, in which a stable backdraft occurred, only the fireplace was in operation. After 160 seconds of backdraft, a basement window was opened 1" - the backdraft continued. After approximately 260 seconds the window was opened approximately 2 inches at which time vent re-estabishment occurred. At the 160 seconds mark some vent re-establishment does occur, leading to a rise in the flue temperature, but full vent re-establishment does not occur until the window is opened the full 2 inches. The temperature profile data also indicates that during partial vent re-establishment the central region of the draft chamber experiences the greatest temperature rise. The lower edges of the draft chamber begin to cool off, and the upper edges of the vertical draft chamber opening experience elevated temperatures.

During the final test, #11, a central vacuum was operated in conjunction with the fireplace (now growing weak) and the clothes dryer. A backdraft occurs. At the 75 second point the vacuum was switched off, which has a small effect on the backdraft condition; draft chamber temperatures rise at the deeper probe locations suggesting that the backdraft has in fact lessened in intensity. After 120 seconds the dryer is also turned off. This action leads to vent re-establishment.

Testing at this field site indicates that the FURNACE ALERT Combustion Backdraft Indicator will register a combustion exhaust gas backdraft that persists for more than, on average, 100 seconds. In cases where the backdrafting chimney flow is great, or the furnace warm up time is longer (as with a larger type gas furnace), the response time for the FURNACE ALERT Combustion Backdraft Indicator increases. At this test site, the longest response time recorded was approximately 165 seconds.

4. HTIP #004 - 1145 PLANTE

Testing was conducted on December 8, 1985. Outdoor winds were 9 Kmh from the West, outdoor temperature was 0 degrees Celsius. The house is a side split design, with exterior chimney, one fireplace, one kitchen range hood and one bathroom exhaust fan.

Test data is contained in the Testing Data Appendix under HTIP #004. Photographs of the furnace installation and exterior house construction are provided.

Table Four details the time response of the FURNACE ALERT Combustion Backdraft Indicator under the various backdrafting

conditions.

The average time to response was 44 seconds. The maximum time to response was 47.5 seconds. The minimum time to response was 42.5 seconds.

This furnace has an automatic flue damper. No residual heating effects were observed at the shallow low center probe location that might cause false alarms for the FURNACE ALERT Combustion Backdraft Indicator.

During the first test run, #1, intended to outline the base case normal operating temperature profiles for the furnace, it was noticed that the initial start-up puff led to an elevated temperature at the shallow high probe locations (rose to approximately 70 degrees Celsius for approximately 30 seconds) and a rise of approximately 10 degrees Celsius (to 30 degress Celsius for approximately 25 seconds) at the shallow low center probe location.

Tests #2 - #7 inclusive show a series of full backdraft conditions, with relatively similar temperature profiles and FURNACE ALERT Combustion Backdraft Indicator response times of approximately 45 seconds.

Test #8 involved a temporary backdraft followed by vent re-establishment. The backdraft condition persists for approximately 35-40 seconds only. The FURNACE ALERT Combustion Backdraft Indicator does not fully register the temporary backdraft condition. Approximately 50% of the sensor material changes from white to black during the test. The vent re-establishment occurs as the indoor depressurization sources have been decreased (only the fireplace and one exhaust fan are in operation for this test).

During test #9, the fireplace and two exhaust fans are in operation, again leading to a stable backdraft condition, similar to that observed during tests #2 - #7. During this test the shallow low left probe temperature rises to 160 degrees Celsius, the shallow low right probe temperature rises to only 40-50 degrees Celsius. The shallow center probe temperature rises to 130 degrees Celsius. This indicates a bias towards the left side of the draft chamber for elevated temperatures during the backdrafting condition.

Test #10 commences with the flue in a warm condition, with the fireplace and two exhaust fans in operation. A short spillage is observed followed by vent re-establishment after approximately 75 seconds. The flue temperature rises steadily after furnace start up.

Testing at this field site indicates that the FURNACE ALERT Combustion Backdraft Indicator will not register a backdraft unless it persists for at least 30-40 seconds, but does register positively an extended backdraft that persists for

TABLE FOUR

FC04 FIELD DATA ANALYSIS PROGRAM

TEST #	TIME TO BARE LABEL CHANGE (65C) (SEC)	TIME OF FURNACE ALERT CHANGE START (SEC)	TIME OF FURNACE ALERT CHANGE TOTAL (SEC)	DURATION TO CHANGE (AVERAGED TIME) FROM B.DRAFT START (SEC)	FROM >65C POINT (SEC)	BACKDRAFT INTENSITY RATING FULL, MED WEAK, NONE TEMPORARY
1	X	X	X	X	X	NONE
2	7	45	50	47.5	40.5	FULL
3	10	43	49	46	36	FULL
4	11	40	44	42	31	FULL
5	11	40	45	42.5	31.5	FULL
6	8	41	44	42.5	34.5	FULL
7	10	41	44	42.5	32.5	MED
8	X	X	X	X	X	TEMP
9	9	40	45	42.5	33.5	MED
10	X	X	X	X	X	
11	X	X	X	X	X	
AVERAGE		41.42857	45.85714	43.64286	34.21429	
MAXIMUM		45	50	47.5	40.5	

L: STRONG OR CONSISTENT BACKDRAFT
MED: STABLE BACKDRAFT WITHOUT EXCESSIVE REVERSE FLUE FLOW
WEAK: BACKDRAFT WITH SPORADIC PARTIAL VENT RE-ESTABLISHMENTS
NONE: NO BACKDRAFT
TEMP: INITIAL BACKDRAFT FOLLOWED BY VENT RE-ESTABLISHMENT

more than, on average, 44 seconds. This is the most rapid response time that is observed with the FURNACE ALERT Combustion Backdraft Indicator, and may be due to the rate at which the furnace combustion temperature rises after furnace start up. During the base case run, the furnace combustion exit temperature reaches 200 degrees Celsius almost immediately, and rises to over 300 degrees Celsius after approximately 120 seconds of furnace operation.

The final test, #10, shows that the FURNACE ALERT Combustion Backdraft Indicator does not register a backdraft during the temporary start up spillage.

5. HTIP #005 - 1403 BORTOLOTTI CRES.

Testing was conducted on December 11, 1985. Outdoor winds were 11 Kmh from the North, outdoor temperature was -6 degrees Celsius. The house is a 2 storey design, with exterior chimney, one fireplace, one kitchen range hood type exhaust fan and two bathroom exhaust fans.

Test data is contained in the Testing Data Appendix under HTIP #005. Photographs of the furnace installation and exterior house construction are provided.

Table Five details the time response of the FURNACE ALERT Combustion Backdraft Indicator under the various backdrafting conditions.

The average time to response was 127 seconds. The maximum time to response was 225 seconds. The minimum time to response was 66 seconds.

This furnace is not equipped with an automatic flue damper.

A wide range of response times were observed at this test site. For the first 7 tests, the blower door cover was open, furnace room closed and partially sealed, fireplace in operation, in conjunction with operation of all exhaust fans in the house. This led to positive backdrafting conditions. Consequently, the temperature rise in the draft chamber was slower due to the volume of backdrafting cold chimney air. However, as the furnace cycle continues the heat output from the furnace increases leading to higher temperatures in the indicator sensing zone and subsequent registration of the backdraft. These observations hold for tests #2 - #5.

Beginning with test #5, and continuing with test #6, the furnace room is slowly unsealed, reducing the magnitude of the backdrafting flow (by virtue of the reduced negative pressure in the furnace room). The response time of the FURNACE ALERT Combustion Backdraft Indicator begins to shorten, to 119 seconds in this test #6.

TABLE FIVE

TEST #	TIME TO BARE LABEL CHANGE (65C) (SEC)	FIELD DATA ANALYSIS PROGRAM TIME OF FURNACE ALERT CHANGE START (SEC)	TIME OF FURNACE ALERT CHANGE TOTAL (SEC)	DURATION TO CHANGE (AVERAGED TIME) FROM B.DRAFT START (SEC)	FROM >65C POINT (SEC)	BACKDRAFT INTENSITY RATING FULL, MED WEAK, NONE TEMPORARY
1	X	X	X	X	X	NONE
2	45	120	122	121	76	FULL
3	107	218	221	219.5	112.5	FULL
4	65	145	154	149.5	84.5	FULL
5	130	222	227	224.5	94.5	FULL
6	23	115	122	118.5	90.5	MED
7	25	88	95	91.5	66.5	MED
8	21	82	91	86.5	65.5	MED
9	14	65	70	67.5	53.5	MED
10	15	62	70	66	51	MED
11	12	X	X	X	X	TEMP
AVERAGE		124.1111	130.2222	127.1667	77.16667	
MAXIMUM		222	227	224.5	112.5	

FULL: STRONG OR CONSISTENT BACKDRAFT
MED: STABLE BACKDRAFT WITHOUT EXCESSIVE REVERSE FLUE FLOW
WEAK: BACKDRAFT WITH SPORADIC PARTIAL VENT RE-ESTABLISHMEN
NONE: NO BACKDRAFT
TEMP: INITIAL BACKDRAFT FOLLOWED BY VENT RE-ESTABLISHMENT

As the furnace room is finally unsealed, and the furnace blower door closed off, the combustion backdrafts become less intense leading to less cool air flowing into the draft chamber area. The FURNACE ALERT Combustion Backdraft Indicator response times are closer to 70-90 seconds for the last 4 backdraft tests (#7 - #10).

During test #10, the blower door cover is closed, furnace room open, and only the fireplace is in operation. However, the chimney is cold from the previous testing, and backdrafting continues to occur during furnace operation. The response time for the FURNACE ALERT Combustion Backdraft Indicator during this test is 66 seconds. Note that the fireplace intensity has decreased during this test.

Test #11 is conducted with only a smouldering fire remaining. A short backdraft occurs, followed by vent re-establishment. The short backdraft persists for approximately 25 seconds, followed by vent re-establishment. The FURNACE ALERT Combustion Backdraft Indicator does not register the temporary backdraft condition.

Testing at this field site indicates that the FURNACE ALERT Combustion Backdraft Indicator does not register a backdraft of temporary stature (less than approximately 30 seconds), but does register positively an extended backdraft that persists for more than approximately 65 seconds for a regular backdraft (without altering indoor sealing and furnace blower door), or for more than, on average, 127 seconds, for a strong backdraft (blower door cover open, sealed furnace room). As the backdraft intensity increases, the time response of the FURNACE ALERT Combustion Backdraft Indicator lengthens due to cooling effects from the backdrafting flow.

6. HTIP #006 - 660 CHAPMAN

Testing was conducted on December 15, 1985. Outdoor winds were 16 Kmh from the South-West, outdoor temperature was -6 degrees Celsius. The house is a side split design, with exterior chimney, one fireplace and one kitchen fan.

Test data is contained in the Testing Data Appendix under HTIP #006. Photographs of the furnace installation and exterior house construction are provided.

Table Six details the time response of the FURNACE ALERT Combustion Backdraft Indicator under various backdrafting conditions.

The average time to response was 176 seconds. The maximum time to response was 369 seconds (cycling between backdraft and vent re-establishment and spillage due to outdoor wind gusts). The minimum time to response was 117 seconds.

This furnace has an automatic flue damper. No residual heating effects were observed at the shallow low center probe location that might cause false alarms for the FURNACE ALERT Combustion Backdraft Indicator.

Test #2 involves a stable backdraft. Response time is 150 seconds. This backdraft is induced by operating the fireplace, kitchen fan, and opening the cover to the furnace fan blower (basement door closed).

During test #3, very unstable flue flow occurs, cycling from backdrafting flow to re-establishment to backdraft. Consequently, a stable backdraft does not occur. However, as the furnace cycle evolves, the furnace combustion exit temperature continues to rise, such that the temperature during each backdraft cycle increases at the indicator sensing zone. After 260 seconds a backdraft of sufficient duration occurs to cause the FURNACE ALERT Combustion Backdraft Indicator to register the backdraft. This test, #3, was conducted with only the fireplace burning and the kitchen fan in operation (furnace blower cover is on), so that the degree of depressurization in the house is less than during test #2. This leads to the contention between the indoor depressurization sources and the suction created by the outdoor wind gusts (which lead to the temporary vent re-establishment conditions).

During test #4, a more stable backdraft again occurs (the furnace blower door has now been opened approximately 10%), with a resulting indicator response time of 106 seconds.

Similar observations are made during tests #5 - #7, although in test #7 the furnace blower door is again closed. During test #7, a very slight vent re-establishment begins to occur, followed by resumption of stable backdrafting. This leads to a slightly longer response time for the FURNACE ALERT Combustion Backdraft Indicator of 137 seconds.

During test #8, cycling again occurs between backdrafting and proper vent establishment. However, towards the end of the cycle a backdraft condition persists from 300 - 400 seconds, leading to registration of the backdraft on the FURNACE ALERT Combustion Backdraft Indicator. (In these specific cases where contention between outdoor winds and indoor depressurization sources leads to cycling between backdrafting and vent establishment, the temperature probes located along the upper edge of the draft chamber measure a more constant temperature rise. A spillage type indicator would be useful to register these specific events.)

During test #9, the furnace blower door is opened again about 10%, which leads to a more stable backdraft condition, and a resulting response time of 100 seconds for the FURNACE ALERT Combustion Backdraft Indicator.

TABLE SIX

FIELD DATA ANALYSIS PROGRAM

TEST #	TIME TO BARE LABEL CHANGE (65C) (SEC)	TIME OF FURNACE ALERT CHANGE START (SEC)	TIME OF FURNACE ALERT CHANGE TOTAL (SEC)	DURATION: TO CHANGE (AVERAGED TIME) FROM B.DRAFT START (SEC)	FROM >65C POINT (SEC)	BACKDRAFT INTENSITY RATING FULL, MED WEAK, NONE TEMPORARY
1	X	X	X	X	X	NONE
2	44	150	165	157.5	113.5	FULL
3	40	260	265	262.5	222.5	WEAK
4	30	106	128	117	87	MED
5	25	110	125	117.5	92.5	MED
6	27	125	140	132.5	105.5	MED
7	27	137	147	142	115	MED
8	50	360	377	368.5	318.5	WEAK
9	27	100	123	111.5	64.5	MED
10	X	X	X	X	X	TEMP
11	X	X	X	X	X	
AVERAGE		168.5	183.75	176.125	142.375	
MAXIMUM		360	377	368.5	318.5	

FULL: STRONG OR CONSISTENT BACKDRAFT
MED: STABLE BACKDRAFT WITHOUT EXCESSIVE REVERSE FLUE FLOW
WEAK: BACKDRAFT WITH SPORADIC PARTIAL VENT RE-ESTABLISHMENTS
NONE: NO BACKDRAFT
TEMP: INITIAL BACKDRAFT FOLLOWED BY VENT RE-ESTABLISHMENT

For the final test, #10, only the fireplace is in operation, and the fresh air inlet for the furnace is open (as it has been for tests #9 and #10). A short backdraft occurs for approximately 25 seconds followed by normal chimney and flue flow. The FURNACE ALERT Combustion Backdraft Indicator does not register during this temporary backdraft condition.

Testing at this field site indicates that the FURNACE ALERT Combustion Backdraft Indicator does not register a backdraft of temporary nature, either at furnace start up, or during a situation in which backdrafts of limited duration occur followed by vent re-establishment (as in the case of contention between outdoor winds and the indoor depressurization sources). The FURNACE ALERT Combustion Backdraft Indicator does register a backdraft that persists for more than approximately 100 seconds. In the cases of contention between the outdoor wind and indoor depressurization sources leading to erratic chimney flows, both +ve and -ve, as the furnace cycle proceeds the furnace combustion exit temperature continues to increase. A backdraft that occurs later on in the furnace cycle does lead to registration of the backdraft on the FURNACE ALERT Combustion Backdraft Indicator as long as the backdraft persists for a minimum period of time, which, in the case of test #8, was approximately 60 seconds (Backdraft begins at 300 seconds - registration occurs at 360 seconds).

7. HTIP #007 - 44 RIDGEFIELD CRES

Testing was conducted on December 18, 1985. Outdoor winds were 7 Kmh from the North-West, outdoor temperature was -22 degrees Celsius and falling during the testing period. The house is a standard bungalow construction with an exterior chimney, one fireplace, two bathroom fans and one high capacity in-wall kitchen fan. (The home residents mentioned that operation of the in-wall kitchen fan used to backdraft an oil furnace that had been subsequently replaced by the gas furnace - which they also knew would backdraft if the in-wall fan was operated.)

Test data is contained in the Testing Data Appendix under HTIP #007. A photograph of the furnace installation is provided. A photograph of the exterior house construction is not available, but the house is a standard bungalow construction of 1960's vintage.

Table Seven details the time response of the FURNACE ALERT Combustion Backdraft Indicator under the various backdrafting conditions. Note that in this house, when the high capacity fan was operating, the volume of backdrafting air was so great that the temperature rise in the draft chamber was not sufficient to lead to registration of the backdraft condition by the FURNACE ALERT Combustion Backdraft Indicator. During operation of the in-wall fan while the furnace was operating,

a forcefull backdraft was observed, evidenced by chilling of the floor in front of the draft chamber opening on the furnace.

In those cases where a backdraft occurred and the in-wall fan was not operating, the average time to response was 153 seconds (comprised of three readings, 148 seconds, 178 seconds, and 133 seconds). Each of the test runs is detailed below.

This furnace has an automatic flue damper. No residual heating effects were observed at the shallow low center probe location that might cause false alarms for the FURNACE ALERT Combustion Backdraft Indicator.

During test #2, the in-wall fans was operated in conjunction with the 2 bathroom fans, fireplace and the furnace blower door was opened. The resulting flue temperature was sub-zero (visual reading from data logger reporting screen indicated a -8 degree Celsius backdraft flow at 2 feet above the draft chamber). The shallow low center probe temperature rose to 60 degrees before the furnace cycle was ceased after 300 seconds of operation. The FURNACE ALERT Combustion Backdraft Indicator did not register this backdraft condition, due to the high volume of backdrafting air introduced into the draft chamber.

This test indicates a limiting condition for the normal operation of the FURNACE ALERT Combustion Backdraft Indicator. If the backdrafting flow is very large, the temperature at the indicator sensing zone does not increase sufficiently to register a backdraft. This raises an interesting issue in that during a high volume backdraft condition, there is substantial air change occurring within the building envelope, and the furnace is being surrounded by considerable amounts of fresh outdoor air. It is unlikley that carbon monoxide would be produced under such conditions, and the degree of dilution of the exhaust stream is very large. However, the venting failure is clearly a situation that should be made known to the home occupant. The FURNACE ALERT Combustion Backdraft Indicator does register backdrafts caused by different depressurization sources as in tests #4, #9 and #10.

The sensitivity of the FURNACE ALERT Combustion Backdraft Indicator could be increased slightly, by selecting a lower threshold temperature. However, other tests reported upon in this report suggest that lowering the temperature would lead to too great a risk of false alarms being registered. In the case of the Lennox Conservator furnace, the reponse time is approximately 45 seconds. Lowering the threshold temperature would begin to jeopardize effective operation of the indicator on such a furnace.

It is suggested that home owners who install high capacity

TABLE SEVEN

FIELD DATA ANALYSIS PROGRAM

TEST #	TIME TO FARE LABEL CHANGE (65C) (SEC)	TIME OF FURNACE ALERT CHANGE START (SEC)	TIME OF FURNACE ALERT CHANGE TOTAL (SEC)	DURATION TO CHANGE (AVERAGED TIME) FROM B.DRAFT START (SEC)	FROM >65C POINT (SEC)	BACKDRAFT INTENSIT. RATING FULL, MED WEAK, NONE TEMPORAR.
1	X	X	X	X	X	NONE
2	X	X	X	X	X	FULL*
3	260	X	X	X	X	FULL*
4	18	130	165	147.5	129.5	FULL
5	14	X	X	X	X	TEMP
6	X	X	X	X	X	NONE
7	X	X	X	X	X	NONE
8	190	X	X	X	X	FULL*
9	77	160	195	177.5	100.5	FULL
10	20	122	144	133	113	FULL
11	X	X	X	X	X	
AVERAGE		137.3333	168	152.6667	114.3333	
MAXIMUM		160	195	177.5	129.5	

FULL*: HIGH VOLUME BACKDRAFT CAUSED BY OPERATION OF LARGE EXHAUST FANS
FULL: STRONG OR CONSISTENT BACKDRAFT
MED: STABLE BACKDRAFT WITHOUT EXCESSIVE REVERSE FLUE FLOW
WEAK: BACKDRAFT WITH SPORADIC PARTIAL VENT RE-ESTABLISHMENTS
NONE: NO BACKDRAFT
TEMP: INITIAL BACKDRAFT FOLLOWED BY VENT RE-ESTABLISHMENT

venting equipment in their homes are the exception. Further, in the case of this test case, the home owners were aware that the fan capacity was very large and would lead to backdrafting of combustion appliances in their home such as the furnace and fireplace. While this situation is not ideal, the FURNACE ALERT Combustion Backdraft Indicator can only be used as an aid to increasing safety in the home, and is not a final solution, as pointed out by this specific case.

Test #3 was similar to test #2, although a slight darkening of the FURNACE ALERT Combustion Backdraft Indicator was noticed, indicating that this situation is just on the limit of detection by the indicator.

For test #4, only the fireplace is operated. The FURNACE ALERT Combustion Backdraft Indicator registers the backdraft after 130 seconds.

Test #4 is repeated, only in this test, #5, the fireplace doors have been closed. A backdraft occurs for approximately 120 seconds. The FURNACE ALERT Combustion Backdraft Indicator does not register this temporary backdraft. Note that in other cases where the temperature at the shallow low center probe behaves as indicated in this test, the indicator does register the backdraft if it persists for more than approximately 60 seconds. Because the backdrafting flow is very cold (-22 degrees Celsius outdoors), some cooling of the indicator substrate may be occurring at the point of attachment to the furnace leading to the slightly longer response time (130 seconds in test #4).

For tests #6 and #7 the fireplace doors have been closed and the fire is at a smouldering stage. One and two exhaust fans alone were operated. In either case, no backdraft occurred.

For test #8, the in-wall high capacity exhaust fan is again utilized, leading to a similar high flow backdraft as observed in the initial tests.

(The shallow high probes experience higher temperatures during these high volume backdrafts. In cases where high volume exhaust capacity exists, utilization of two FURNACE ALERT Combustion Backdraft Indicators might be considered, with one being located along the upper edge of the vertical draft chamber opening and utilizing a higher threshold temperature sensor.)

In test #9, the high capacity fan was operated for the first 60 seconds of furnace operation, and then turned off. This lead to the occurrence of a stable backdraft, but reduced backdrafting flow once the fan was turned off. Response time of the FURNACE ALERT Combuston Backdraft Indicator was 160 seconds.

In test #10, the high capacity fan was operated before the furnace was turned on, to ensure that the chimney was kept cold. However, as the furnace was turned on the fan was turned off. A stable backdraft occurred with the FURNACE ALERT-Combustion Backdraft Indicator registering the backdraft after 122 seconds.

Summary of FURNACE ALERT Combustion Backdraft Indicator Field Testing

The field testing has shown that the response time for the FURNACE ALERT Combustion Backdraft Indicator varies according to the intensity of the backdraft, temperature of the backdraft flow, furnace heating time constants and other variables which affect the stability of the backdraft such as varying indoor depressurization levels and outdoor wind conditions. However, for most backdraft conditions that will occur in the average household, the response time varies between approximately 45 seconds and 2 minutes. In cases where the backdraft is especially strong, as in sealed furnace rooms with open furnace blower covers, the response time rose to as high as 265 seconds. A limiting condition does exist in homes equipped with high capacity ventilation systems (in-wall high volume flow exhaust fans, for example), whereby the backdrafting flow (on cold days) will lead to substantial cooling in the draft chamber and prevent registration of the backdraft by the FURNACE ALERT Combustion Backdraft Indicator.

However, the selection of location and threshold temperature is such that false alarms are not likely to occur with the FURNACE ALERT Combustion Backdraft Indicator. Therefore, a positive registration on the indicator, according to this test data, is evidence that a problem does exist with backdrafting that merits attention, before more serious problems occur. In order to increase sensitivity to allow for greater ability of detecting high volume flow backdrafts, little leeway is available. However, it may prove possible to lower the temperature threshold slightly and increase the thermal buffering effect. This would provide greater sensitivity while offsetting the risk of more false alarm occurrences. The basic limit in reducing the temperature threshold is with larger furnaces with longer operating cycles (ie. the ICG with temperature rise to 40C over the operating cycle during normal operation).

In summary, the present design operates well for the majority of situations that are likely to occur. Multiple label systems would be the most effective next step if additional detection capabilities are called for by the affected public.

FIELD TEST - DOMESTIC HOT WATER GAS HEATERS

Three domestic hot water tanks were monitored to determine the ability of the FURNACE ALERT Combustion Backdraft Indicator to detect backdrafts from these devices. Each hot water tank heater was a naturally aspirated type, with a conical vent hood located just above the top of the hot water tank horizontal surface.

Based on this field testing program, the domestic hot water tanks observed were all very similar in design. The GSW Gulfstream type appears to be a very popular model. In all cases, the draft diverter opening was located in the same location as mentioned above. However, the vertical opening distance did vary from system to system, although within a range of approximately +/- 1-2 inches.

The FURNACE ALERT Combustion Backdraft Indicator was placed across the draft diverter opening of each of the hot water heaters, with the sensor material facing upwards, and positioned such that the sensor material was farthest away from the draft diverter opening. In effect, the label substrate formed a bridge from the outside upper lip of the draft diverter cone, across the draft diverter opening ring, to the top surface of the hot water tank. It was found that this configuration was optimal because backdrafting exhaust gases would tend to collect under the surface of the indicator substrate surface, leading to positive registrations of the backdrafts.

Based on observations during the testing, the heat flux that results from a backdrafting gas hot water heater is rather intense, in comparison to gas furnace backdrafts. Many gas hot water heaters utilize burners with approximately 30,000 BTU/hr of heat output. If the exhaust stream is backdrafting out of the relatively small draft opening area, the heat flux is concentrated around the draft diverter opening area. In the case of hot water tank draft diverter openings with larger vertical distance between the base of the hot water tank and the top conical cover of the draft diverter opening, the backdrafting heat flow would tend to rise upwards after passing beyond the confines of the draft diverter opening's upper surface.

Therefore, by utilizing the FURNACE ALERT Combustion Backdraft Indicator substrate to act as a bridge across the opening, the backdrafting exhaust flow was channelled along the surface of the substrate surface, allowing for registration of the backdraft even in cases where the distance between the hot water tank surface and upper confines of the draft diverter opening was relatively large.

The backdrafts that did occur were observed to be rather stable, and quite forcefull in terms of the temperature rise that occurred near the draft diverter opening. As a result,

a few tests on each gas hot water tank were sufficient to observe the behaviour of the backdraft and reaction of the FURNACE ALERT Combustion Backdraft Indicator. Consequently, two or three tests were conducted on each gas hot water tank.

The next section details the testing conducted on each of the three gas hot water tank installations.

1. Tank #1 - 1 BANKVIEW

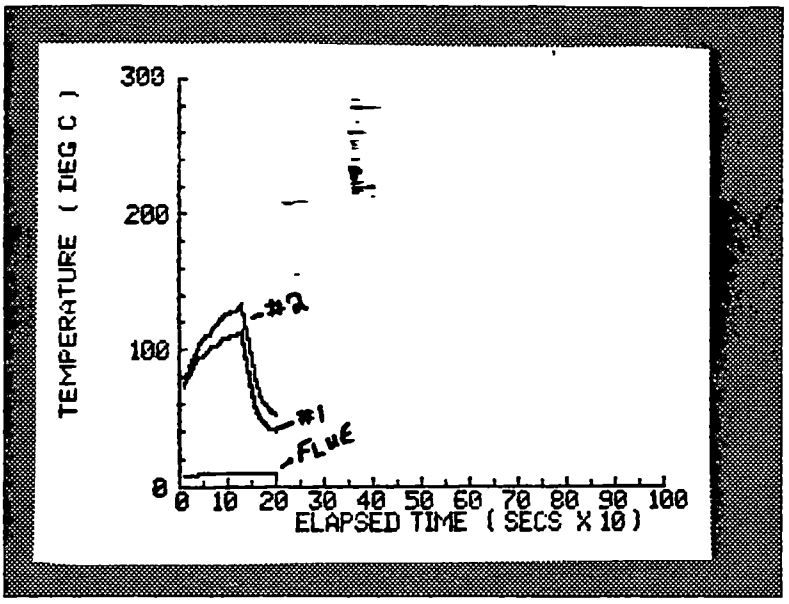
The naturally aspirated gas hot water heater utilized the same flue as the naturally aspirated gas furnace.

Probes were located at three locations surrounding the draft diverter opening. One temperature probe was located at the edge of the draft diverter opening, just near the hot water supply pipe. A second temperature probe was located approximately 1.25 inches away from the draft diverter opening edge, and just above the top surface of the hot water tank. A third probe was located near the cold water supply pipe, and also approximately 1 inch away from the draft diverter opening edge. The combustion exit temperature probe was located diametrically opposed from the second temperature probe. The resulting array of 4 temperature probes roughly encircled the draft diverter opening. The flue temperature probe was located in the flue pipe a short distance from the draft diverter opening assembly.

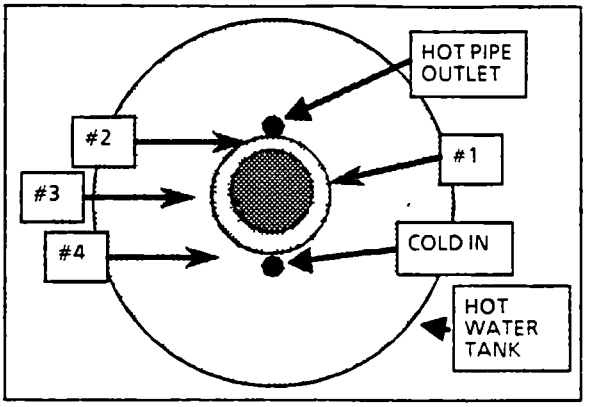
During the first test, the flue temperature probe recorded a temperature of approximately 10 degrees Celsius, indicating the occurrence of a backdrafting flow. All four temperature probes recorded similar temperatures, starting at between 60 and 80 degrees Celsius at gas hot water tank start up (this was controlled by adjusting the thermostat mounted on the gas hot water tank burner control), and rising to between 110 and 140 degrees Celsius after approximately 150 seconds of operation. (See Graph Series A, #1, #2 and #3 for the actual temperature profiles recorded)

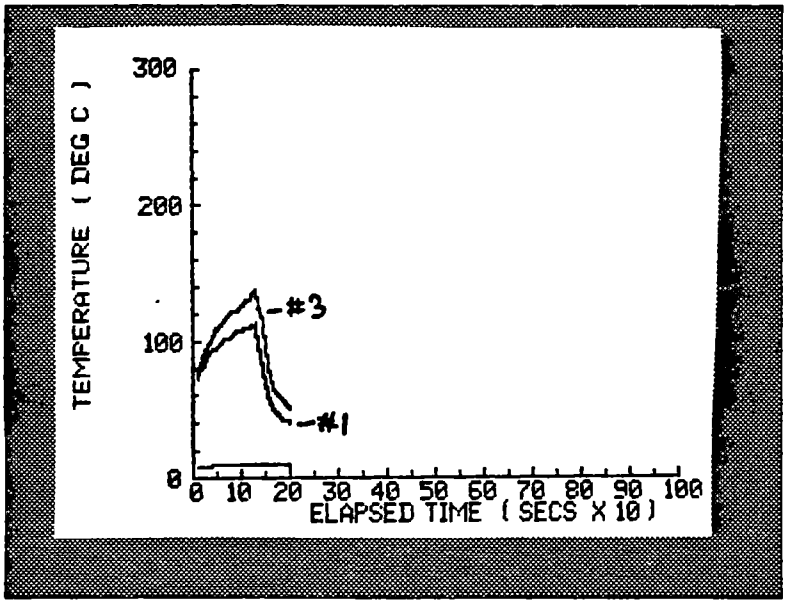
After approximately 45 seconds from gas hot water tank burner start up, a bare temperature sensing label changed black (suspended on a thin wire above the draft opening area - about 1-2 inches from the actual opening). The FURNACE ALERT Combustion Backdraft Indicator registered the backdraft after approximately 60 seconds. Because of the positive exhaust flow out of the draft diverter opening during the backdraft, the FURNACE ALERT Combustion Backdraft Indicator registered the backdraft with a very short time between beginning of registration and total registration (fully black).

During test #2, a backdraft occurred for the first 40-50 seconds, followed by vent re-establishment. The first temperature probe profile shows an initial temperature of approximately 50 degrees Celsius, rising to 80-90 degress

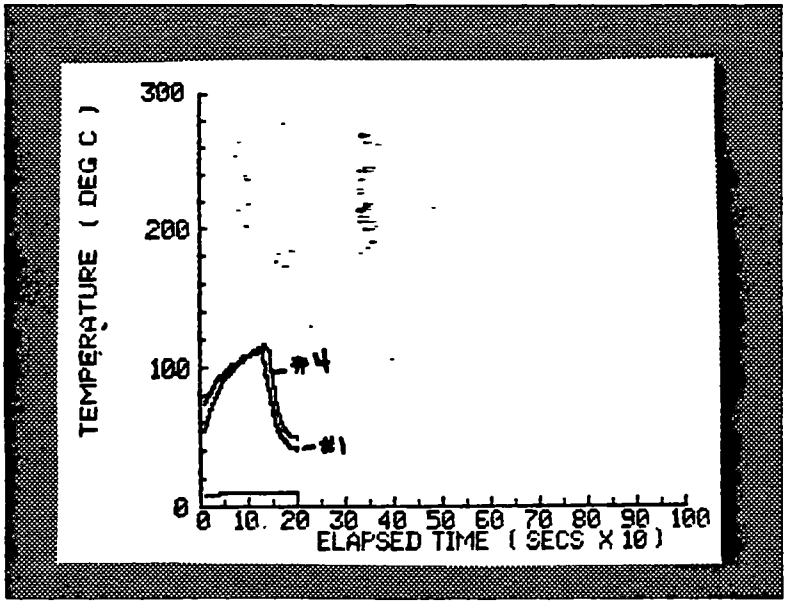


GRAPH #1

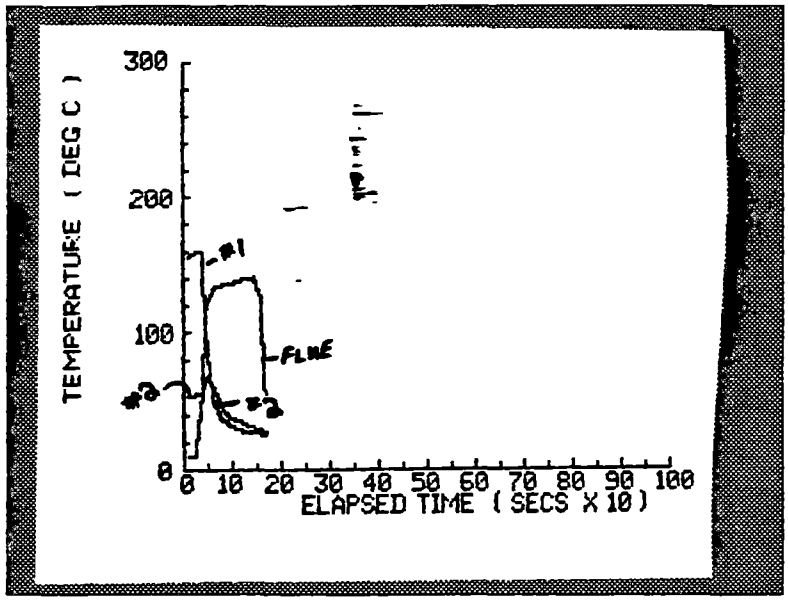




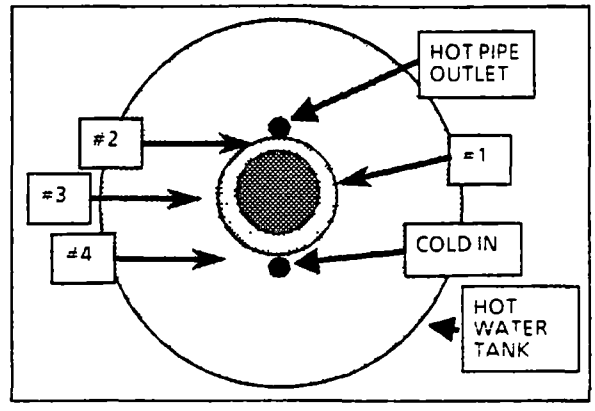
GRAPH #2

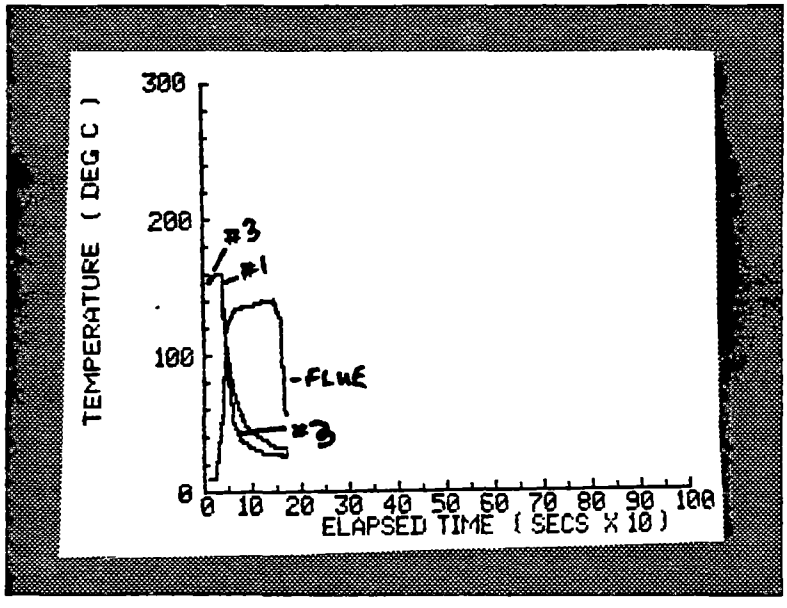


GRAPH #3

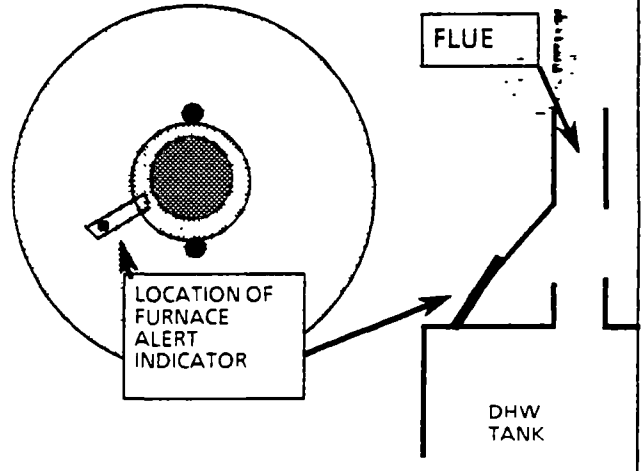


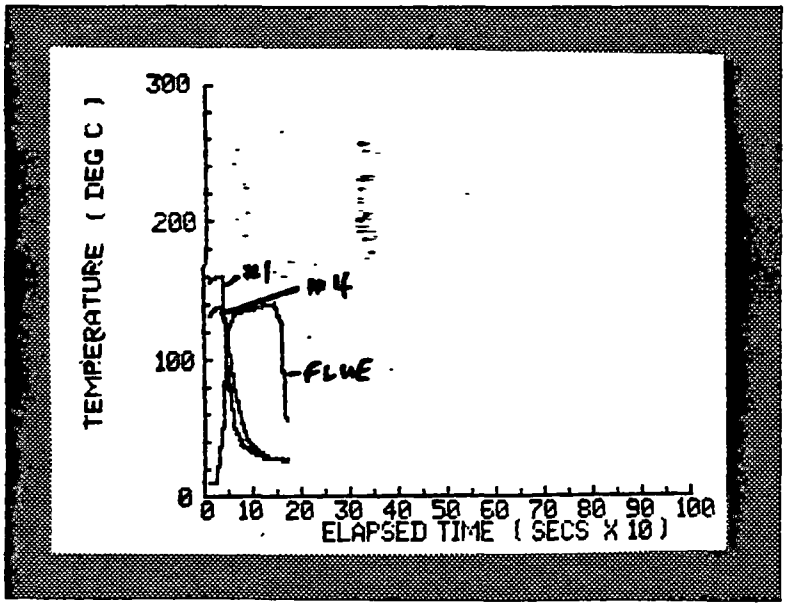
GRAPH #1 - TEST #2





GRAPH #2





GRAPH #3

Celsius after approximately 50 seconds, followed by a decay to approximately 35 degrees Celsius after 100 seconds of gas hot water tank operation. The second, third and fourth probes followed higher temperature profiles, beginning at between 150 and 160 degrees Celsius, and holding at those levels until approximately 50 seconds at which time they also drop down to approximately 40 degrees Celsis after 100 seconds of gas hot water tank operation. During this test, the FURNACE ALERT Combustion Backdraft Indicator registered the backdraft after approximately 60 seconds from gas hot water tank start up.

Although vent re-estabishment began to occur after approximately 50 seconds, the temperature levels surrounding the draft diverter opening did not drop below the threshold temperature of the FURNACE ALERT Combustion Backdraft Indicator until approximately 60 - 70 seconds from gas hot water tank start up, resulting in the positive registration of the backdraft by the FURNACE ALERT Combustion Backdraft Indicator.

In both cases, the FURNACE ALERT Combustion Backdraft Indicator registered the gas hot water tank backdraft after approximately 60 seconds of backdrafting. Note that in the case of test #2, vent re-establishment occurred, and the temperature at the probe locations dropped to approximately 40 degrees Celsius, suggesting that under normal operation the temperature surrounding the draft diverter opening would be in the 20-40 degrees Celsius range.

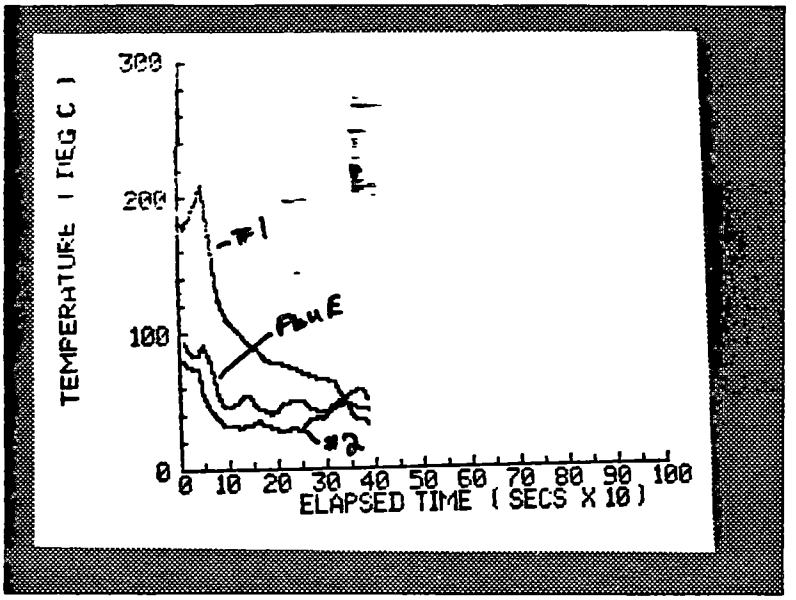
2. Tank #2 - 6 MANCIL DRIVE

This naturally aspirated gas hot water heater utilized the same chimney as the naturally aspirated gas furnace. The hot water system was a GSW Gulfstream unit.

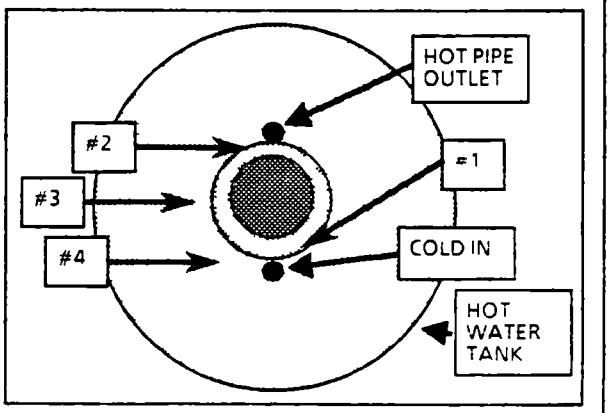
Again, four temperature probes were utilized during the test. Probes #1 and #2 were located opposite each other, and right on the edge of the draft diverter opening. Probes #3 and #4 were located along the same side of the draft diverter opening, and positioned about 1-2 inches away from the draft diverter opening.

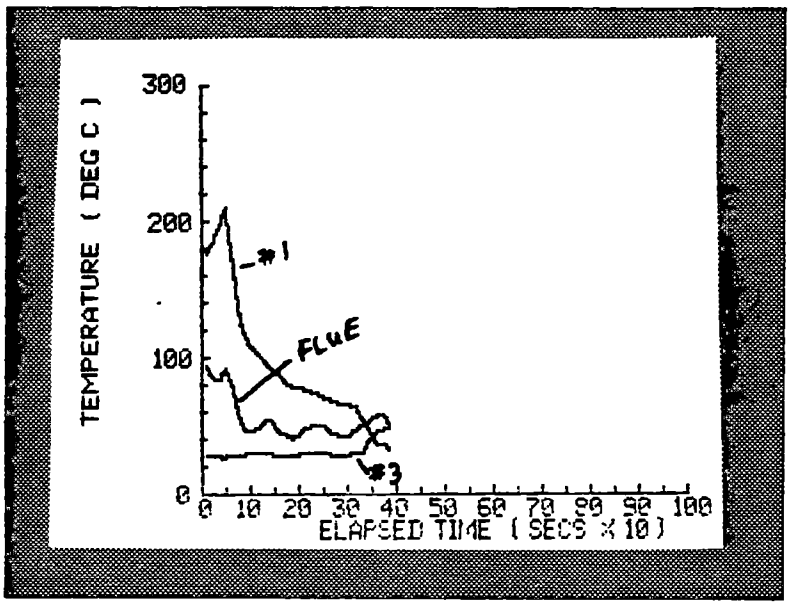
During both tests no backdraft occurred. (See Graph Series B - #1, #2 and #3). In both cases the two temperature probes located 1-2 inches away from the draft diverter opening did not experience high temperatures, although the steady temperature level was higher than ambient, approximately 25 degrees Celsius during the first test, and approximately 30-45 degrees Celsius during the second test.

While this test did not provide additional information regarding the performance of the FURNACE ALERT Combustion

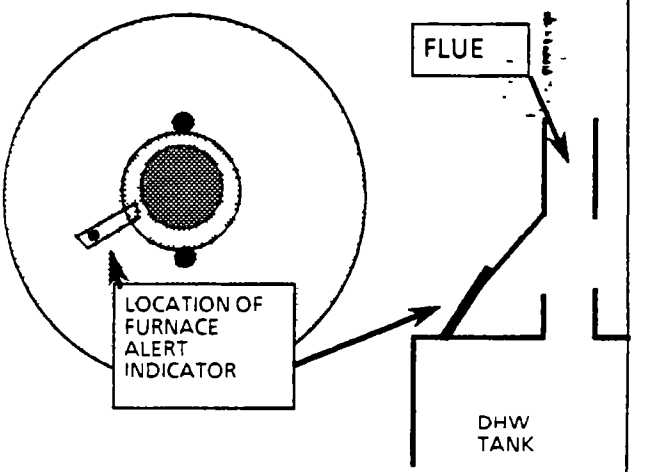


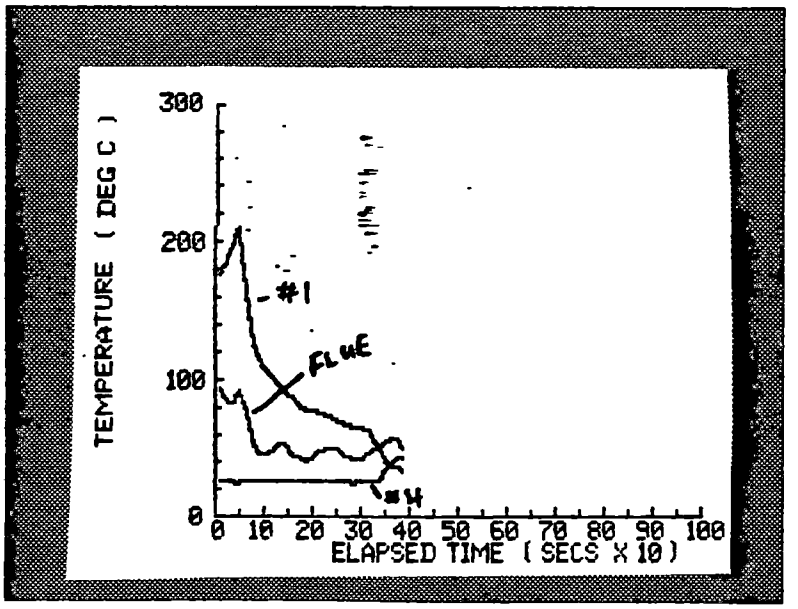
GRAPH #1 - TEST #1



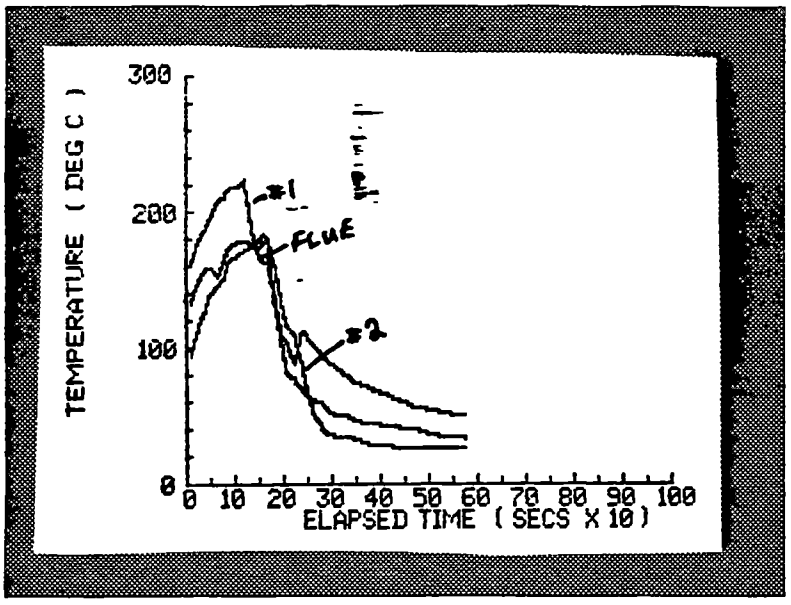


GRAPH #2

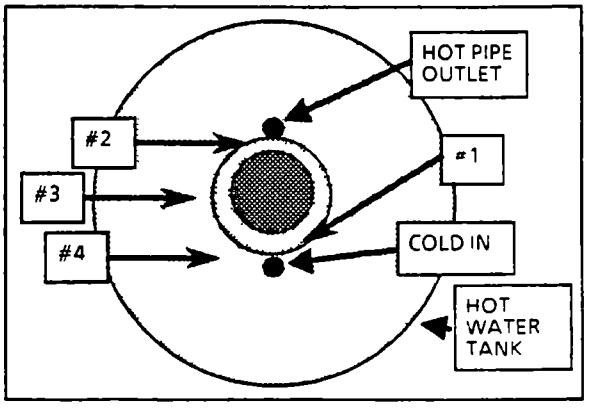


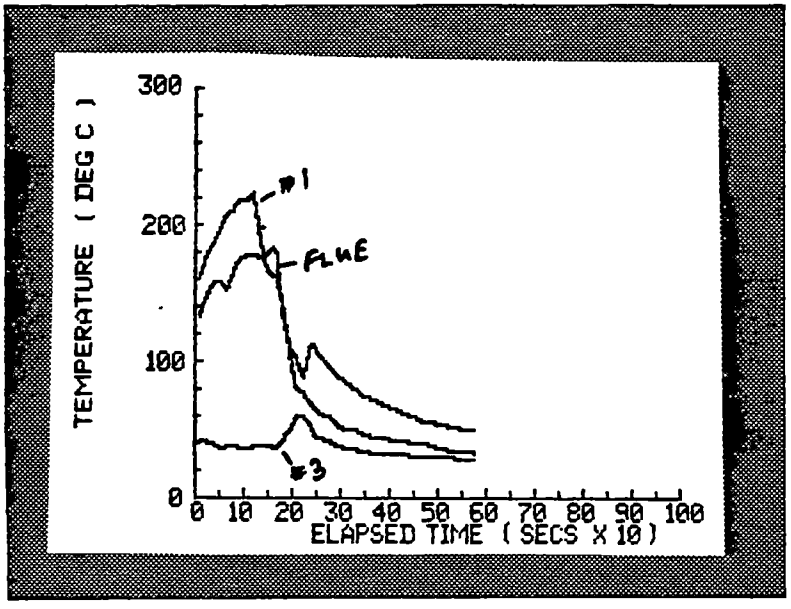


GRAPH #3

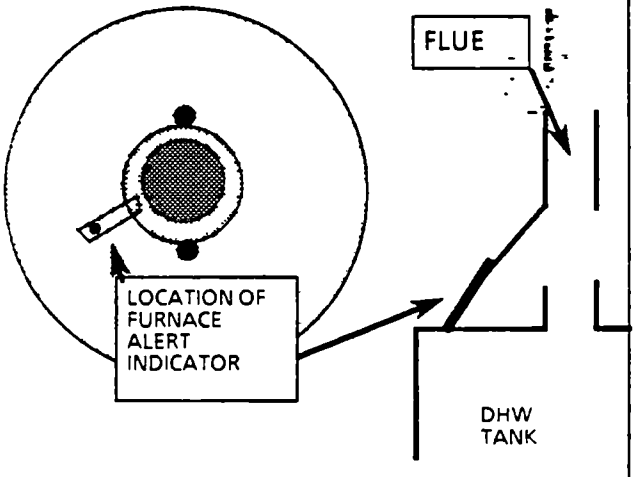


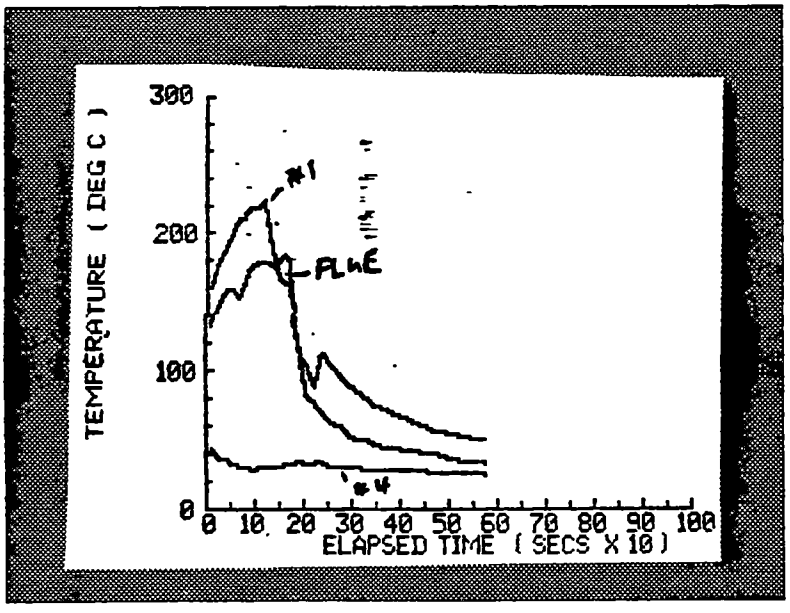
GRAPH #1 - TEST #2





GRAPH #2





GRAPH #3

Backdraft Indicator, it did outline some of the baseline operating conditions experienced with this second gas hot water tank.

The third and final gas hot water tank testing builds upon this second test, with another series of backdraft tests that result in similar response data as experienced in the first backdraft tests.

3. Tank #3 - 1145 Plante

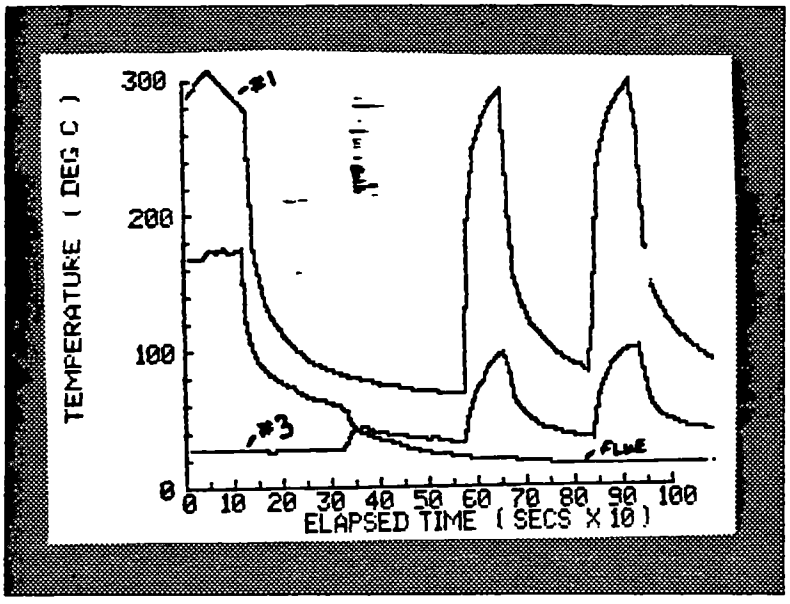
This naturally aspirated gas hot water heater utilized the same chimney as the naturally aspirated gas furnace. The backdrafts were induced by operating the house fireplace, two exhaust fans, opening the furnace fan blower cover and closing the furnace room door. The result was stable backdrafting during tests #2 and #3.

The first test (See Graph C1 - note that the data-logger was run continuously during three tests so that the temperture profiles are all recorded on one series of graphs) outlines the baseline conditions during normal gas hot water heater operation.

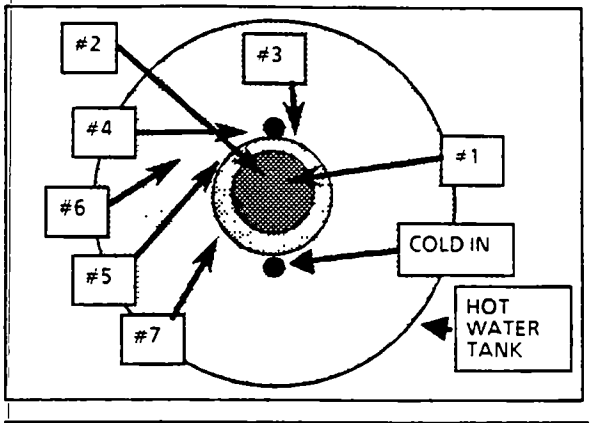
The combustion exit probe and very deep center probes were located in the pathway of the exiting combustion exhaust gases within the venting pipe. Consequently, they both exhibit similar temperature profiles, rising to approximately 240-300 degrees Celsius during each operation cycle. The flue exit temperature is approximately 170 degrees Celsius during the first operation cycle, and falls to approximately 20 degrees Celsius during the following two backdraft test cycles.

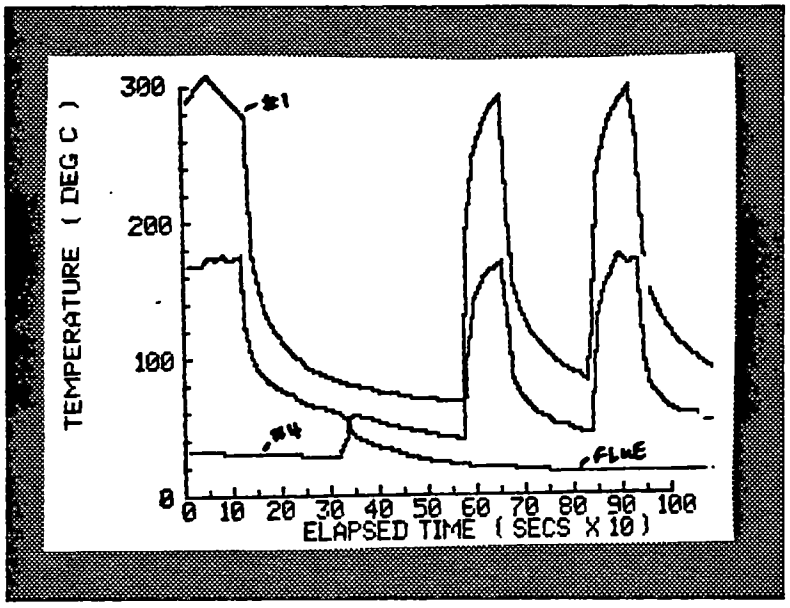
Five other temperature probes were utilized during this test series. Four of the test probes were located around the draft diverter opening over approximately one quarter of the circumference of the draft diverter opening. A fifth test probe was located just beyond the edge of the FURNACE ALERT Combustion Backdraft Indicator, which was placed across the opening of the draft diverter.

During the second test, a stable backdraft was observed (flue temperature approximately 20 degree Celsius). The FURNACE ALERT Combustion Backdraft Indicator registered the backdraft after approximately 59 seconds. The first four temperature probes (all located approximately 1-2 inches away from the draft opening) indicated temperatures ranging from 100 to 170 degrees Celsius. The fifth temperature probe registered only a slight temperature rise to approximately 35 degrees Celsius. This suggests that as the distance increases from the draft diverter opening to any test probe location, the temperature experienced at that location falls off quite rapidly with farther placements. However, the FURNACE ALERT

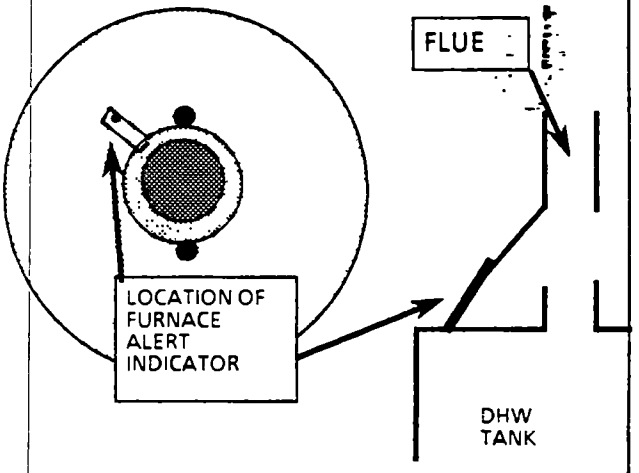


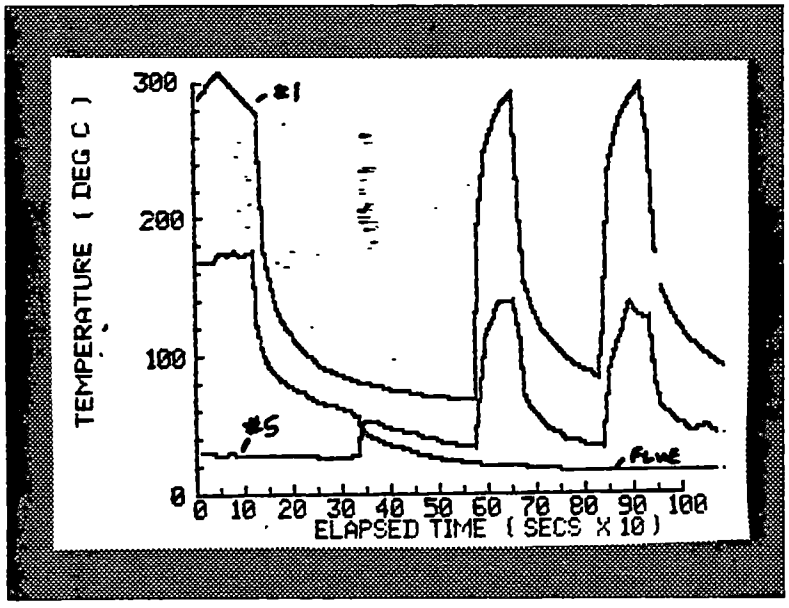
GRAPH #1 - TEST #1-3



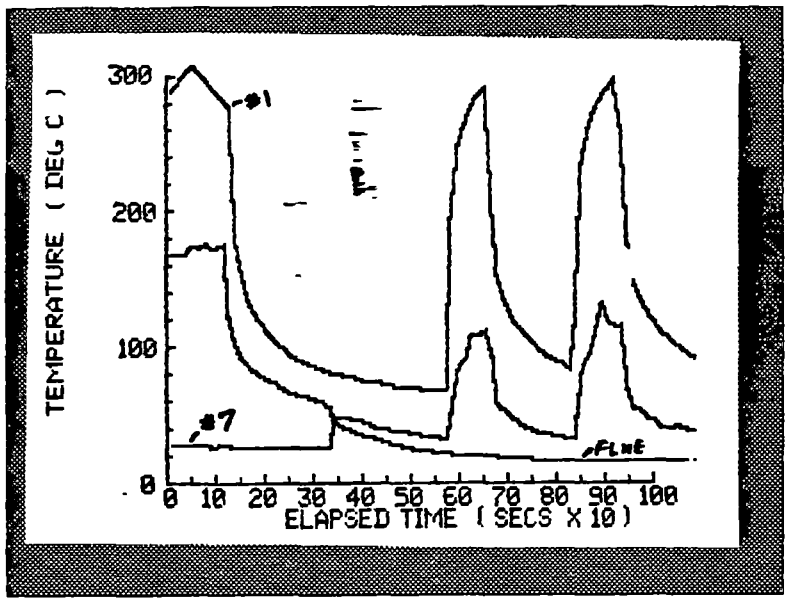


GRAPH #2

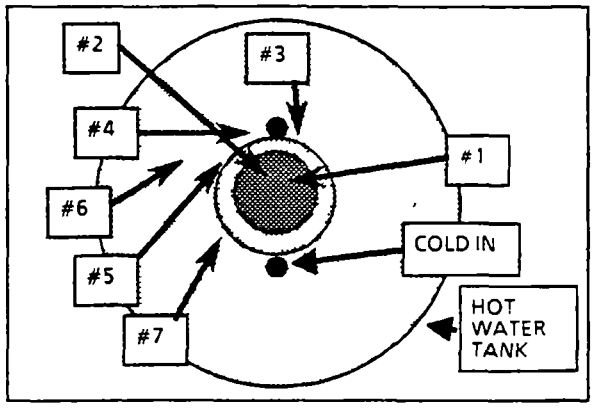


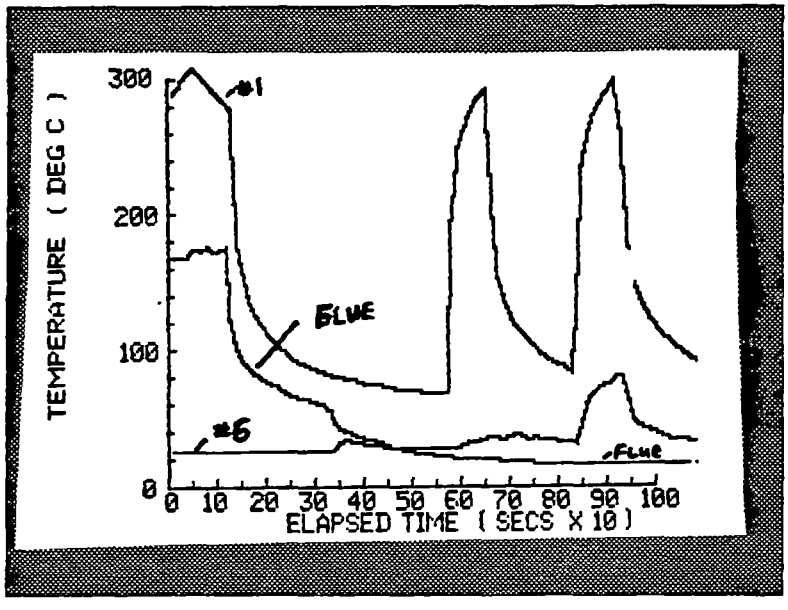


GRAPH #3

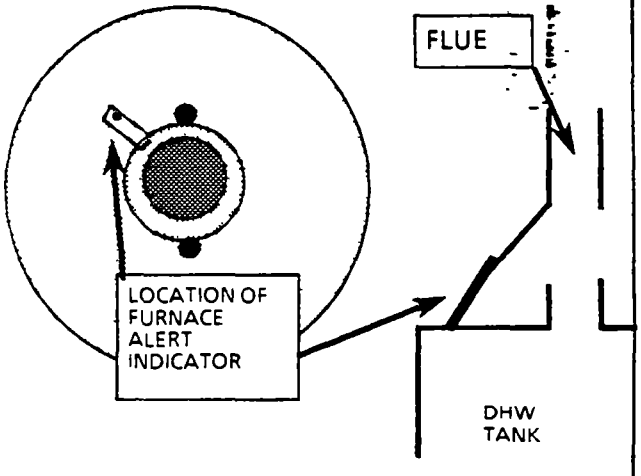


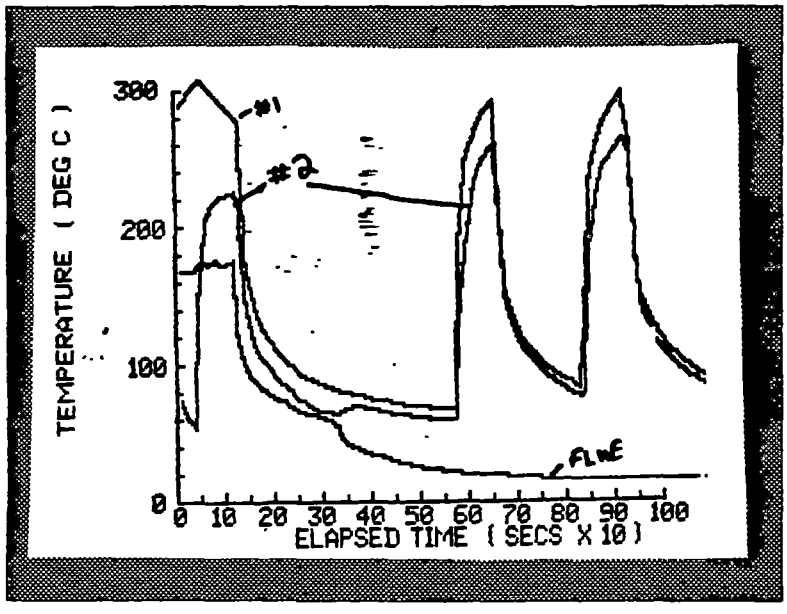
GRAPH #4 - TEST #1-3





GRAPH #5





GRAPH #6

Combustion Backdraft Indicator, when placed such that the substrate material bridges across the draft diverter opening, registers the backdraft. By locating the indicator substrate across the opening, backdrafting exhaust flow is channelled along the surface of the indicator, leading to positive registration of an exhaust gas backdraft.

During the third test, the FURNACE ALERT Combustion Backdraft Indicator registered a backdraft after approximately 75 seconds (initial colour change at 52 seconds, final at 85 seconds). Again, the response time was relatively constant with other tests conducted. Note that during this third test cycle, all probe locations experienced similar temperatures as during test #2 except for the fifth temperature probe located furthest from the draft diverter opening. The temperature measured at this probe was approximately 80 degrees Celsius.

Summary of Gas Hot Water Tank Testing

While the relative number of tests was somewhat less than those conducted for the gas furnaces, the backdrafts measured from the naturally aspirated gas hot water heaters were more consistent. On average the FURNACE ALERT Combustion Backdraft Indicator, when positioned such the indicator bridged across the draft diverter opening, registered a backdraft after approximately 60 seconds of backdrafting. The baseline temperature profiles suggest that false alarms would not occur, although the normal operating temperatures did rise to nearly 50 degree Celsius.

It is also important to note that the combustion exit temperatures rose to over 300 degrees Celsius. Attachment of the FURNACE ALERT Combustion Backdraft Indicator to the upper lip of the draft diverter assembly might be less than positive as temperatures rise to these levels. Therefore, the FURNACE ALERT Combustion Backdraft Indicator would be best placed bridging the draft diverter opening such that it is self supporting, without the need for adhesive attachment. The indicator should be placed with the sensor dot located furthest away from the draft diverter opening, sensor dot positioned upwards.

While these tests suggest that the FURNACE ALERT Combustion Backdraft Indicator provides positive registration of a combustion backdraft from the hot water heater, the testing sample was relatively small. Additional testing would be recommended before establishing final performance criteria for the FURNACE ALERT Combustion Backdraft Indicator when used to detect backdrafting from naturally aspirated gas hot water heaters.

CONCLUSIONS

The FURNACE ALERT Combustion Backdraft Indicator provides for positive registration of exhaust gas backdrafts on both naturally aspirated gas furnaces and naturally aspirated domestic hot water heaters. Under conditions likely to occur in households, the response time for registering a backdraft ranged from between 45 seconds and approximately 2 minutes. In some cases, such as during erratic backdrafting caused by outdoor wind effects combined with indoor exhaust fan and fireplace operation, the response time will be drawn out because a stable exhaust gas backdraft does not occur. A limited condition on registration of a backdraft was observed in the case of one test home equipped with a very high exhaust capacity. During operation of powerful exhaust fans, the furnace backdrafted such that the backdrafting air flow volume was very large, leading to an inability of the FURNACE ALERT Combustion Backdraft Indicator to register the backdraft. However, such circumstances are likely to occur somewhat infrequently, and when they do, the homeowners may be aware of the potential effects of operating such powerful exhaust equipment. While a backdraft under these conditions is not desirable, the high air change rate in the house would tend to dilute the combustion products, and reduce the degree of hazard.

The field testing program suggests that the FURNACE ALERT Combustion Indicator, when utilized in a sensible fashion as a means of increasing safety in the household, is an effectual means of detecting combustion exhaust gas backdrafting from naturally aspirated gas furnaces (and naturally aspirated gas hot water heaters - based on more limited data).