Residential Combustion Venting Failure - A Systems Approach

Project 5

Remedial Measures for Gas-fired Appliances

RESIDENTIAL COMBUSTION VENTING FAILURE

A SYSTEMS APPROACH

FINAL TECHNICAL REPORT

PROJECT 5

REMEDIAL MEASURES FOR GAS-FIRED APPLIANCES

Prepared for:

The Research Division

Policy Development and Research Sector

Canada Mortgage and Housing Corporation

Prepared by:

Scanada Consultants Limited

Scanada Sheltair Consortium

July 17, 1987

Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

The legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

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This publication is one of the many items of information published by CMHC with the assistance of federal funds.

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ABSTRACT

A research project was conducted to find and evaluate remedial measures for combustion venting problems with gas-fired appliances. It was hoped to find measures that held promise for near- to mid-term commercialization. The project was one three projects conducted by a multi-disciplinary team of scientists and engineers to investigate combustion venting remedial measures for several types of combustion appliances. The research represents one sub-project in an overall project to investigate residential combustion venting failure.
Three remedial measures for gas-fired appliances were evaluated and were found to hold varying degrees of promise for near- to mid-term commercialization. The measures evaluated were temperature-dependent spill switches, a prototype draft assisting chamber and a draft inducing fan. No attempts were made to evaluate issues such as long term durability, or compliancies with codes and standards.

This project was funded by the Canada Mortgage and Housing Corporation and the Panel for Energy Research and Development (PERD), but the views expressed are the personal views of the authors, and neither the Corporation nor PERD accepts responsibility for them.

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EXECUTIVE SUMMARY

This project summarizes the findings of an effort to evaluate remedial measures for gas-fired appliances experiencing combustion venting problems. This remedial measures research is one of seven sub-projects of an overall project entitled -

RESIDENTIAL COMBUSTION VENTING FAILURE - A SYSTEMS APPROACH

Following a literature search to identify potential remedial measures, two or three measures which had promise of being ready for commercialization in the near- to mid-term were selected and research or development work required to bring such commercialization closer to fruition was conducted.

The findings of the literature search identified three measures that held promise for near- to mid-term commercialization. These were -

- *the spillage advisor (alarm),*
- *the retrofit draft-inducing fan, and*
- *the draft-assisting chamber.*

Spillage Advisor

The concept here is not a single device but a range of devices which depend on a temperature-activated switch - a "spill switch" - for triggering. The objective of the testing was to evaluate spill switches with two different trigger temperatures at various locations in the dilution port of a naturally aspirated gas furnace to determine their effectiveness and consistency in detecting prolonged spillage of combustion products. No attempt was made to measure the effectiveness of any warning or fail-safe devices that the spill switches might be used with, since design of these is a fairly straightforward electric/electronic circuit problem once an effective sensing element has been chosen.

The results of the tests indicated that the time required to trigger a switch varied depending on its triggering temperature, its placement in the dilution port and the level of house depressurization. It was concluded that it should be possible to develop a number of different devices to warn of the occurrence of abnormal combustion products spillage from a naturally aspirating gas furnace or to somehow alter the operation of the furnace (e.g. turn it off or activate a draft inducer) when such spillage occurs. These devices could all be triggered by a temperature sensitive switch (spill switch) of the Thermodisc type, which has been shown to react consistently to spillage incidents.

Draft-inducing Fan (draft inducer)

A number of retrofit draft-inducing fans are commercially available but there is little objective data on their performance and effectiveness in correcting combustion venting problems.

The draft inducer increased the level of house depressurization required to cause irreversible spillage in the test furnace-chimney system from 7 Pa to over 20 Pa. It may have increased it even more, but this was the highest level of depressurization attainable with the blower door used.

The draft inducing fan therefore appears to be a very effective remedial measure for use with gas furnaces experiencing combustion venting problems.

Draft-assisting Chamber (DAC)

The "draft-assisting chamber" is a proprietary device that becomes part of the venting system of a naturally aspirating combustion appliance. It is intended to fulfill two functions -

- *Contain initial spilled combustion products until proper draft is established.*
- *Assist in the initiation of proper upward flue flow in a stalled or backdrafting situation yet have no effect during normal flue operation.*

The prototype "draft-assisting chamber" evaluated in these tests was found to be an effective remedial measure for containing spillage of combustion products from the dilution opening of naturally aspirating gas furnaces in houses where combustion venting is a minor problem. However, the prototype tested did not improve the house depressurization limit significantly.

INTRODUCTION

This report describes one of seven sub-projects of an overall project entitled -

RESIDENTIAL COMBUSTION VENTING FAILURE - A SYSTEMS APPROACH

- which was carried out for Canada Mortgage and Housing Corporation by the Scanada Sheltair Consortium Inc. A summary of the overall project is provided in Appendix A.

This is one of several final reports on the fifth sub-project, "Remedial Measures", which was concerned with research on remedial measures for various types of combustion equipment experiencing combustion venting problems. This report deals with remedial measures for gas-fired appliances.

This project was designed to focus on those remedial measures that promised to be simple, cost-effective and widely applicable to houses experiencing typical combustion venting failures. In order to identify measures meeting these criteria, a literature search was undertaken. This literature search and its results are described in Appendix B, which also provides the rationale for choosing the three measures which were finally included in this research. These three measures were:

1) Warning and fail-safe devices, that if successful, can be interfaced with appropriate electronics to either alert home-owners or shut down the appliance in the event of an incident of spillage or backdrafting.

2) A "draft-assisting chamber" designed to contain and reverse combustion gases spilling out the dilution port.

3) A draft-inducing fan designed to increase draft in chimneys where buoyancy of the combustion products alone is not sufficient to overcome negative house pressure.

This report summarizes the test protocol adopted for each of these measures and the results of the tests.

DESCRIPTION OF THE REMEDIAL MEASURES

Alarm/Fail-Safe Devices

The concept here is not a single device but a range of devices which depend on a temperature-activated switch - a "spill switch" - for triggering. The objective of the testing was to evaluate spill switches of two different sensitivities at various locations in the dilution port to determine their effectiveness and consistency in detecting prolonged spillage of combustion products. No attempt was made to measure the effectiveness of any warning or fail-safe devices that the spill switches might be used with, since design of these is a fairly straightforward electric/electronic circuit problem once an effective sensing element has been chosen.

The spill switches selected for testing were based on the "Thermodisc", a commercially available temperature triggered switch used in various appliances as a high-limit or low-limit control. It is available in a number of configurations:

- close on rise
- open on rise
- close on fall
- open on fall

- and with a number of different triggering temperatures.

The switches used in the present testing are based on the Thermodisc 10H Series Controls. These switches are open-on-rise, single-pole/single-throw linear limit thermostats that provide continuous thermal sensing along a fluid filled copper capillary sensing tube. On temperature rise, the fluid in the capillary tube expands causing a diaphragm in the switch to snap at a pre-calibrated temperature, opening electrical contacts. The capillary tube allows the temperature sensing to be remote from the actual switch location. Automatic reset switches were used in the testing although manual reset is also available.

The switches used in the testing had the following characteristics.[1]

1) Switch 1 - Length: 62 cm. Open on rise at 80.5°C ± 5.5°C. Close at 73.3°C.

2) Switch 2 - Length: 43 cm. Open on rise at 73.3°C ± 8.3°C. Close at 43.3°C.

A product brochure outlining the features of the Thermodisc 10H series is included in Appendix C.

Draft-Assisting Chamber

The "draft-assisting chamber" is a proprietary device that becomes part of the venting system of a naturally aspirating combustion appliance. It is intended to function in two ways -

- Contain initial spilled combustion products until proper draft is established.

- Assist in the initiation of proper upward flue flow in a stalled or backdrafting situation yet have no effect during normal flue operation. Thus it is not intended to interfere with the normal combustion process or efficiency.

This proprietary chamber is not yet commercially available but it is easily fabricated without special tooling or equipment, as was the prototype tested.

Draft-Inducing Fan

A number of retrofit draft-inducing fans are commercially available but there is little objective data on their performance and effectiveness in correcting combustion venting problems. The fan chosen for testing was the Model DI-1 manufactured by the Field Controls Company in North Carolina. It is a paddle-wheel type fan which mounts in the side of the vent connector (flue pipe) and extends just over 25 mm

1 All reported temperatures are exact conversions from Imperial specifications.

into the flow path. There are thus 95 mm of a 120 mm diameter pipe that are not obstructed by the device. It is powered by a 32 Watt, 0.4 Amp. AC motor.

Product literature describing the draft inducer tested is included in Appendix D.

TEST HOUSE

All devices were tested on an atmospheric gas furnace installed in an unoccupied show home built by Valecraft Homes in Orleans, Ontario. This house was loaned to Scanada for these tests. The house is a two storey, standard wood frame house. An airtightness test following the CGSB standard yielded the following results:

Air changes per hour at 50 Pa test pressure: 5.5
Equivalent Leakage Area: 0.11 m^2
$C =$ 55 L/s Pa^n $n =$ 0.696

This house has no known combustion ventilation problems. The vertical centre of leakage was determined by measuring inside/outside pressure differentials at a second floor window, a first floor window and a basement window, with the furnace flue blocked and under calm conditions with a 20°C inside/outside temperature difference. It was found to be located at about the level of the second storey floor.

The furnace is a York model UGR forced air furnace with input capacity of 23 kW (80,000 btuh).

The house also has a gas-fired DHW heater; however the section of the vent connector to which it was connected, was removed and replaced by a piece of straight pipe for the duration of the testing. This was done to eliminate the added complication of the second flue connection and thus simplify analysis of the results.

The cooperation of Valecraft Homes in making this house available is gratefully acknowledged.

OVERVIEW OF THE TESTING APPROACH

For the "draft-assisting chamber" and the draft-inducing fan, the objective was to obtain characteristic curves of house depressurization versus combustion products spillage duration for the furnace/flue/house system as found and with each of the devices fitted. This was achieved by installing a blower door in an entrance doorway and repeating the following procedure many times at several levels of depressurization:

- depressurize the house with the furnace at standby
- turn on the furnace and measure the time it takes to initiate proper flue flow.

The whole process was conducted with the furnace as found and then repeated with the draft-assisting chamber installed and again with the draft inducer installed.

The evaluation of the spill switches had several objectives. These were to determine -

- What conditions lead to the switches being activated or failing to be activated. This data would provide a baseline of data defining what conditions activate the switch whereupon more rigorous testing could be done.

- The effect of location on the duration of spillage required to activate the switches. These tests were design to help optimize the location of the switches.

- If severe backdrafting might delay activation of the switches due to cool outdoor air diluting combustion gases passing over the switches. Thus only severe backdrafting cases would be considered here.

- The effect of the two different lengths and temperature limits on duration of spillage required to activate the switches. Comparison of the performance of the two switches under identical conditions was sought here.

To meet the above objectives, two series of tests were conducted. The first set of tests focused on evaluating the switches at a given location under various degrees of spillage including prolonged spillage for more than three minutes. The two switches were tested simultaneously and were conducted in parallel with spillage tests for the furnace as found.

In the second series of tests, both switches were evaluated under more extreme spillage and backdrafting conditions at three vertical locations and four levels of depressurization, the minimum level being the house depressurization limit of the house.

The switches were not connected to any warning or fail safe devices, they were simply connected to a 120 volt relay which was in turn connected to the data-logging equipment (described in the next section) so that the time of triggering would be recorded.

TEST EQUIPMENT

Virtually all data generated in the testing was automatically recorded by a microcomputer-controlled data-logging system made up of the following components:

- Microcomputer
  COMPAQ portable MS-DOS computer with 256K RAM, two floppy disk drives and clock card.

- Data-logger (A to D converter, multiplexer)
  Sciemetrics Instruments Model 8082A Electronic Measurement System with 64 analog channels and 16 digital channels.

- Control Program
  Compiled BASIC program written by Scanada for customized processing of the data including periodic storage of data on diskette. This program interfaces with the overall system control software provided by Sciemetrics. An important feature of this program is that it uses the computer keyboard space bar as a status switch and records the time at which the space bar is pressed by the operator. Thus the space bar and the operator can stand in as a status switch for recording phenomena that are easier to sense visually than electronically, such as reversal of flow at the dilution port.

  The program was able to scan all channels used in this testing approximately once every 2 seconds.

- Temperature Sensors
  J type thermocouples capable of measuring temperatures in the range 0°C to 760°C with an accuracy of 0.1°C.
- Status Switches
  120 volt relay to detect opening of the spill switch.
  24 volt relay to detect whether the furnace is on or off.

- Differential Pressure Transducers
  A Setra Model 261 differential pressure transducer was used to convert pressure signals from pressure taps to equivalent voltage signals. This transducer outputs a 0 - 5 V linear signal proportional to 0 - 25 Pa. The pressure transducer was used in determining the location of the vertical centre of leakage of the house.

- Blower Door

  A Retrotec Model RDF 001 door fan was used to depressurize the house during the first series of tests. An Infiltec model R-1 door fan was used during the second series of tests. Both fans have a capacity of 2400 L/s at 50 Pa, a control module which allows manual adjustment of flow and two Magnahelic pressure gauges for measurement of inside/outside pressure difference and fan flow. Four outside pressure taps were located on the four faces of the house and joined to a pressure averaging box as per the CGSB airtightness test standard.

- Wind Anemometer

  A Bacharach Model MRF FLORITE air velocity meter was used to measure wind velocity at the site.

DETAILED TEST PROCEDURES

Task 1: Combustion venting characteristics of the house/furnace/flue system as found

1.1 Set up data-logging equipment, connect all sensors and status switches. Deploy temperature sensors as follows:

- o 9 in a 3 X 3 grid in dilution port (see Figure 1)
- o 1 in furnace breaching
- o 1 in bottom of flue
- o 1 in main floor room air
- o 1 in basement room air
- o 1 in exterior air (outdoors)

1.2 Ensure the furnace has not operated for at least 20 minutes so that the flue and heat exchanger will have cooled to ambient conditions.

1.3 Turn furnace on and, using smoke pencils, observe direction of flow at the dilution port and note duration of any spillage, pressing the computer keyboard space bar when any reversal occurs.

1.4 Once full upward flue flow is established, turn off furnace and allow to cool for at least 10 minutes.

1.5 Depressurize the house using an airtightness testing blower door, recording inside/outside pressure difference and fan flow.

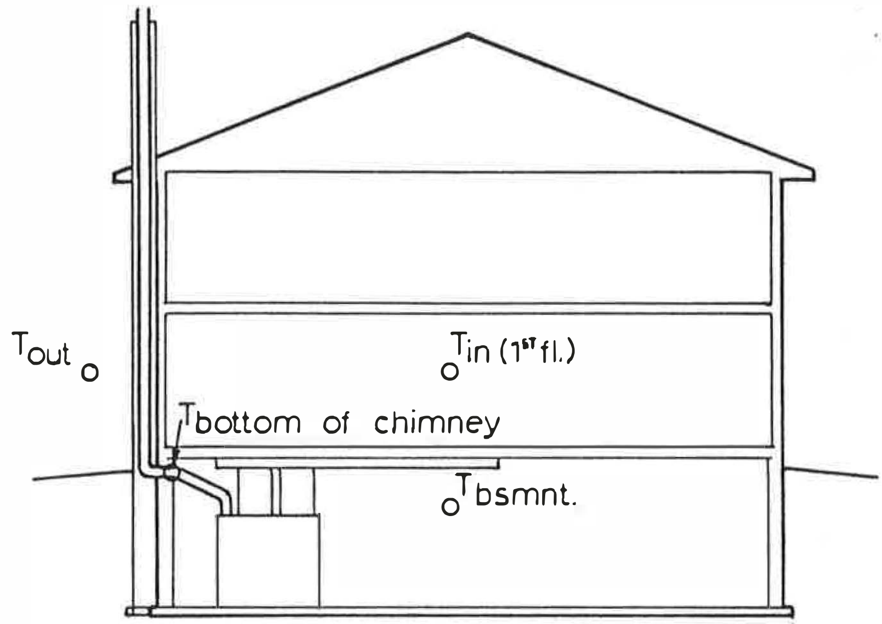
1.6 Repeat 1.3 to 1.4

1.7 Repeat 1.3 to 1.5 at increasing levels of depressurization up to 15 Pa or until spillage duration exceeds 3 minutes.

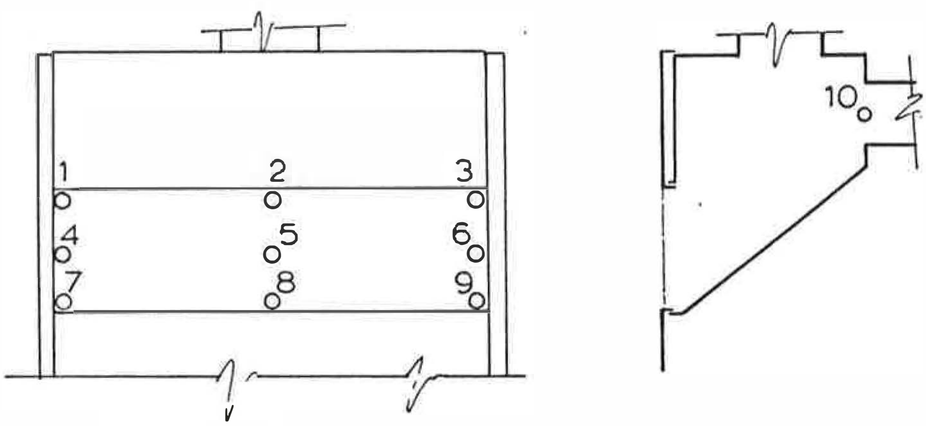
1.8 Repeat 1.2 to 1.7 in their entirety to ensure repeatability of the results.

1.9 Following another cool-down period of at least 10 minutes, run the furnace until flue gas temperature reaches equilibrium (or near equilibrium) then turn the furnace off. Record temperatures throughout the heat-up period and for at least 10 minutes after shut off.

The essential information derived in Task 1 was the data on depressurization level versus duration of spillage and the basic characterization of the house/furnace/flue system as found which was provided by the heat-up/cool-down test (Step 1.9).



SECTION THROUGH HOUSE



DILUTION OPENING

FIGURE 1: Location of temperature sensors

Task 2: Combustion venting characteristics of the house/furnace/flue system with "Draft-Assisting Chamber" installed

The procedure in Task 2 was essentially the same as in Task 1 with the exception that 6 of the 9 temperature sensors previously located in the furnace dilution port were deployed throughout the "draft-assisting chamber" to allow tracking of the movement of the combustion products through the chamber and measurement of the retention time of the chamber (see Figure 2).

The three remaining sensors in the dilution port served to provide a frame of reference to compare spillage results of for the furnace as found to spillage results with the "Draft-Assisting Chamber".

Two series of tests were conducted with the draft-assisting chamber installed. In the first series, the gaps between the furnace casing and the internal dilution air passageway were not sealed. This configuration would result in a minimum of interference with the existing design of the dilution port. In the second series of tests these gaps were sealed.

The important information derived from Task 2 were the data on depressurization levels versus time for the system to initiate upward flue flow, and the characterization of the house/furnace/flue system, as now modified, provided by the heat-up/cool-down test. In addition, temperatures recorded within the "draft-assisting chamber" indicated whether flow out the bottom of the chamber consisted of combustion products or air displaced from the chamber by accumulating combustion products. Thus it was possible to identify the level of depressurization necessary to cause spillage of combustion products into the furnace room.

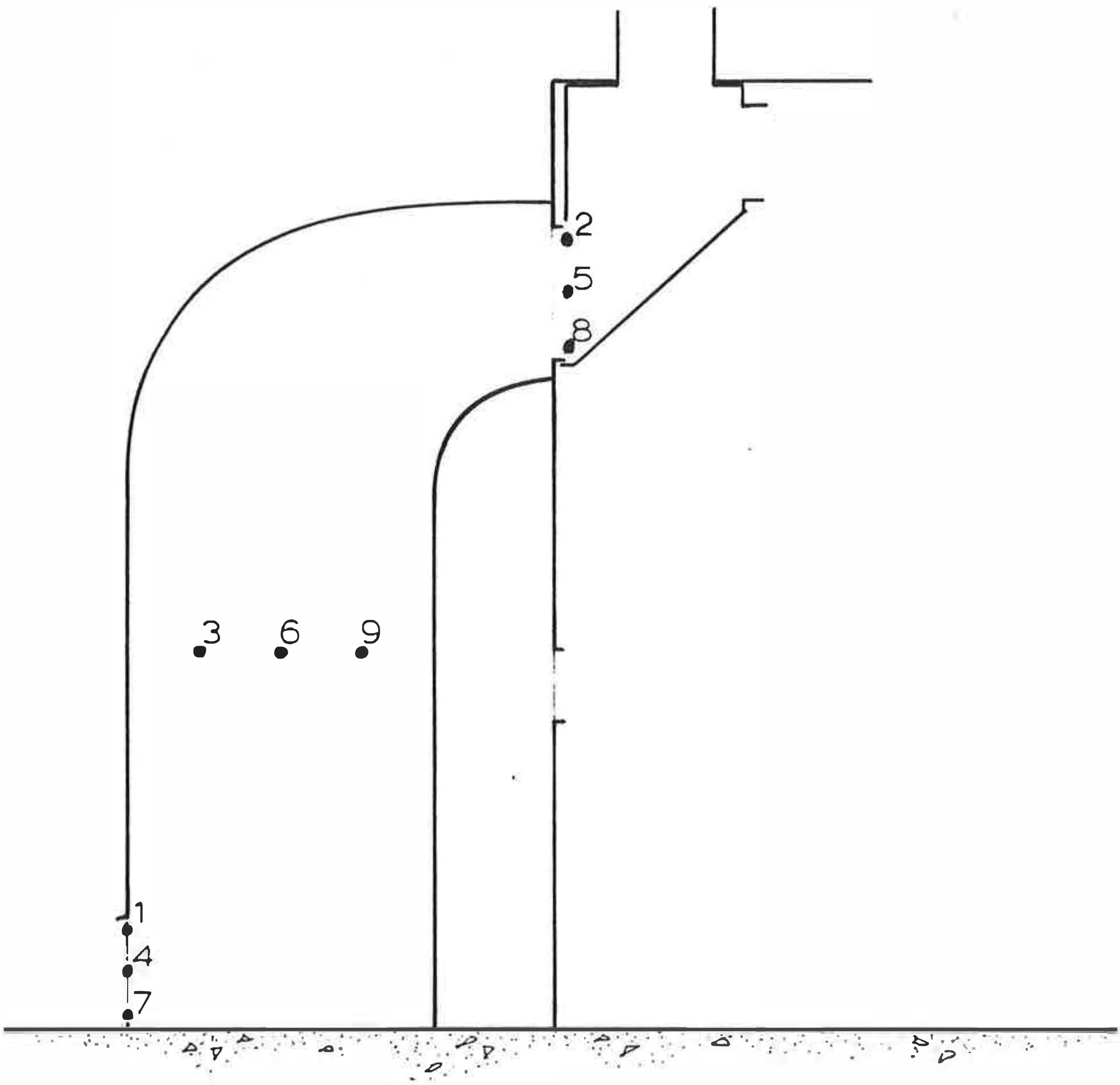


FIGURE 2: Location of temperature sensors in the draft-assisting chamber

Task 3: Combustion venting characteristics of the house/furnace flue system with draft inducer installed

The test procedure for Task 3 was identical to that used in Task 1.

The draft inducer was wired to turn on simultaneously with furnace start-up.

Two series of tests were conducted - one with the draft inducer operating and a second with the draft inducer installed but not operating. The latter tests were done to determine if the protrusion of the fan into the vent connector (flue pipe) would make the system any more prone to venting failure if the fan should fail.

Again, the important information derived from Task 3 was the data on depressurization level versus duration of spillage and the characterization of the house/furnace/flue system, as now modified, provided by the heat-up/cool-down test.

Task 4: Effectiveness and consistency of the spill switches

During the first series of tests, both switches were placed horizontally approximately 12 mm from the top lip of the dilution opening and in the plane of the opening. The time to activate the switch was measured in conditions of minor spillage to severe backdrafting. The actual location of the switches relative to the top lip of the dilution opening is a compromise between recommendations provided by Moffatt of Sheltair (derived from thermal mapping of the dilution opening) and preliminary recommendations in a CGA report (Reference 1).

In the second series of tests, the test protocol was expanded to include three vertical locations. These were:

1) 12 mm from the top lip of the dilution opening
2) halfway between the top and bottom of the dilution opening
3) 12 mm from the bottom lip of the dilution opening.

In the second series of tests, the switches were recessed 6 mm into the dilution opening. The time to activate each of the switches was recorded for depressurization levels from the house depressurization limit up to twice that level. All the switch arrangements are shown in Figure 3.

The arrangement of temperature sensors in the dilution port was designed to complement the test locations of the switches.

Since the spill switches were connected directly to the data-logger, the time of switch activation relative to furnace start-up was automatically recorded and stored on disk for each test.
Since temperature sensors were located adjacent to the capillary tubes, the average temperature along the tube at the instant each switch was activated was also recorded.

Thus the essential information derived in this task is the time at which each switch was activated and the temperature distribution along its capillary tube for several different locations.

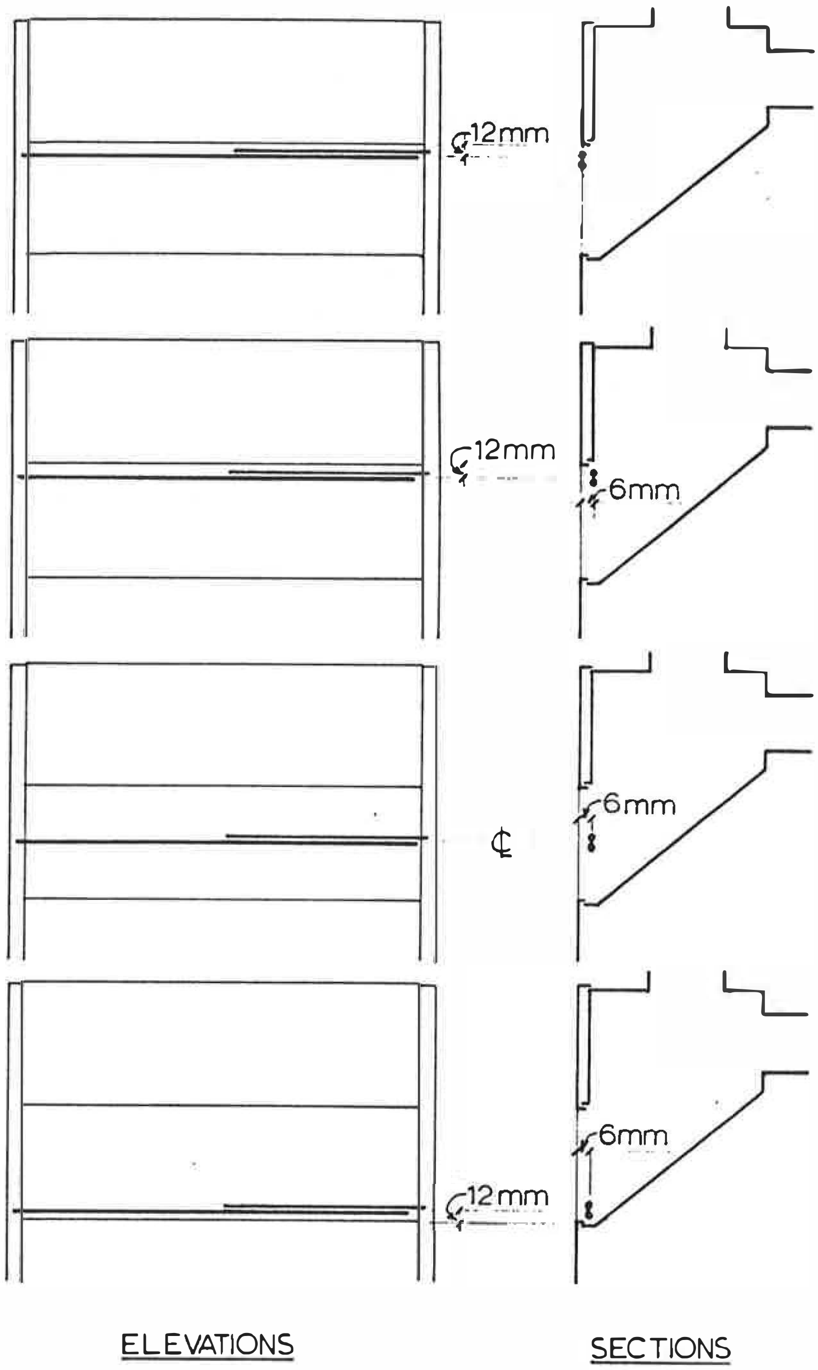


FIGURE 3: Placement of spill switches

RESULTS

Ambient Conditions

The first phase of tests was performed over a 12 hour period from 22:00 March 27,1986 to 10:00 March 28,1986.

Periodic measurements of wind indicated calm conditions throughout the tests.

Outdoor temperature was a constant 0°C throughout the tests. Basement temperatures ranged from 15°C to 16°C while main floor temperatures ranged between 17°C and 18°C. Although not recorded, second floor temperatures were estimated to be about 20°C.

The second phase of tests was performed over a 12 hour period from 22:00 April 14,1986 to 10:00 April 15, 1986.

Periodic measurements of wind indicated generally calm conditions although sporadic instances of light breezes were observed. Maximum gust of 2.5 m/s (9 km/hr) were recorded.

Outdoor temperatures were 5°C at the beginning of the test dropping to a minimum of about 2.5°C in the early morning hours. Basement temperatures ranged from 15°C to 16°C while main floor temperatures ranged between 17°C to 19°C. Again, second floor temperatures were not recorded but were estimated to be about 20°C.

House/Furnace/Flue System as Found

Spillage of combustibles was determined by the technician using a smoke pencil to visually assess the direction of flow at the dilution opening. This technique combined with the keyboard status switch operated by the second technician (in response to commands from the first technician) proved to be an effective method of recording the approximate duration of spillage for each test. Later analysis of the temperature profiles around the dilution opening helped to validate those spillage times in tests where the technician was unsure of the actual duration of spillage.

In general, at higher levels of depressurization (i.e. greater than 5 Pa), the temperature in the dilution opening responded to incidents of spillage by rising sharply when the furnace was turned on. Once positive draft was established the temperatures around the dilution opening were observed to drop quickly in response to cooler air from the basement entering the dilution opening. Sensors along the vertical midline of the dilution opening showed the most sensitivity to the flow patterns in the dilution opening.

The results show that duration of spillage as measured by temperatures at the dilution opening was longer than reported by the technician. Differences of between two to four seconds were observed at the higher levels of depressurization (i.e. greater than 5 Pa). This is not surprising since the technician would tend to respond to the initial stalling of outward flow but the temperatures would not change until actual reversal took place. In several instances the technician suggested that the reversal of spillage might have been longer than he first reported.

At low levels of depressurization, the rise in temperature around the dilution opening was small and radiative effects from the furnace itself made it difficult to pinpoint the exact moment of flow reversal. Temperatures remained relatively steady following furnace turn-on although over time the trend was a gradual drop in temperature. In these instances, spillage times recorded by the technician in the field were relied on exclusively. The difference between the technician's estimate and actual spillage is probably small anyway considering the duration of spillage at these level is short (less than two seconds).

Figure 4 is a plot of spillage duration versus level of depressurization for the house/furnace/flue system as found. Raw data is included in Appendix E.

Two sets of data are plotted for the two series of tests done to check on repeatability of results. It can be seen that the two sets of data are quite close. The discrepancies which do exist are quite consistent with the expected accuracy of the test method.

The transition from apparently reversible flow to apparently irreversible backdrafting was quite sharp and occurred at about 7.5 Pa ± 0.5 Pa. Thus, for this series of tests, under the given indoor-outdoor conditions, the House Depressurization Limit (HDL) for this house can be said to be about 7.5 Pa.

Figure 5 is a plot of the flue gas temperature at the furnace breeching and at the chimney base versus time for the heat-up/cool-down test of the house/furnace/flue system as found. This plot is similar to many others we have seen with the exception of an apparently erratic temperature response as the system approached steady state. The exact nature of this behaviour is not quite clear and we are unable to speculate as to the exact cause at this time. Despite this minor anomaly, the plot still satisfactorily describes the house/ furnace/flue system as found and provides a suitable baseline upon which to compare steady state performance of the other remedial measures.

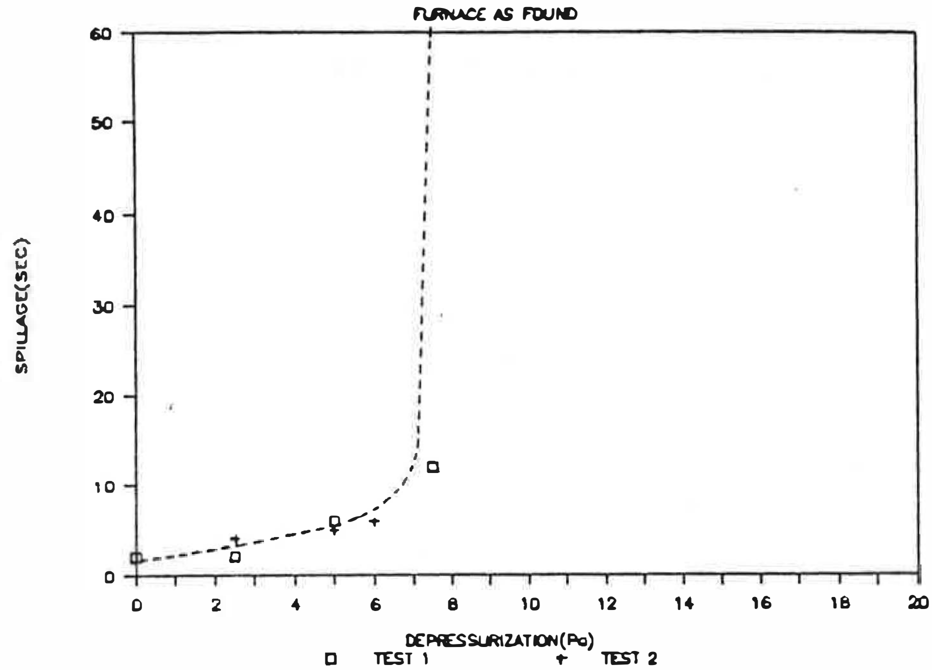


FIGURE 4: Depressurization vs. spillage: furnace as found

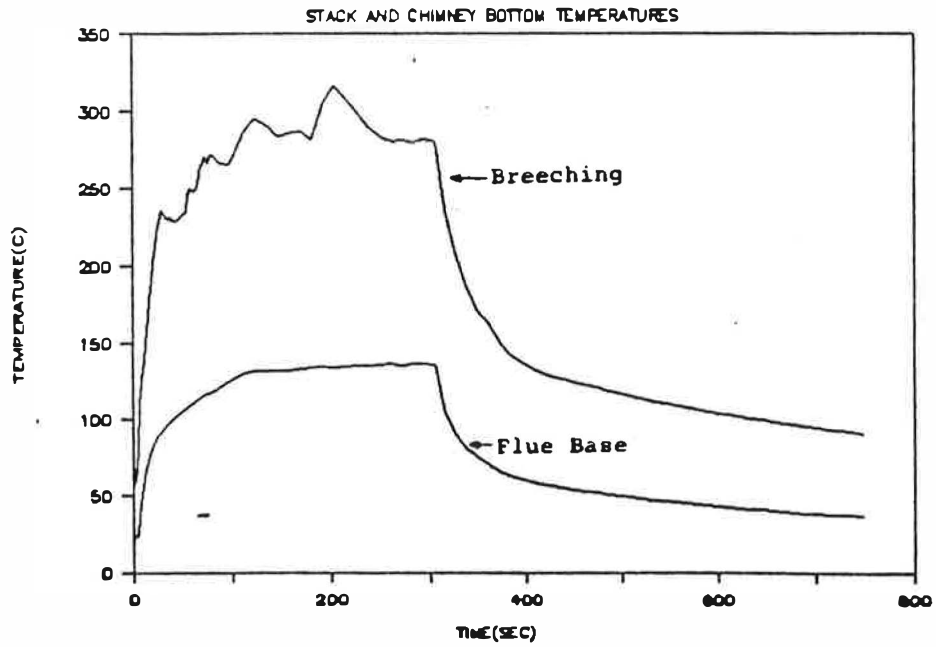


FIGURE 5: Heat-up/cool-down test: furnace as found

House/Furnace/Flue System with "Draft-Assisting Chamber" Installed

The evaluation of the "draft-assisting chamber" comprised two phases of testing. The first phase of testing was performed during the first series of tests on March 27/28, 1986. In this phase of testing, the "draft-assisting chamber" was installed but the existing gaps between the dilution box and the furnace casing were left unsealed. The second phase of testing was performed during the second series of tests on April 14/15, 1986. For these tests, the casing/dilution box gaps were sealed.

Evaluation of the performance of the "draft-assisting chamber" in containing and reversing flow out of the dilution port requires a more rigid definition of spillage than that used in describing the performance of the furnace as found. Without the draft-assisting chamber in place, it can be assumed that any flow out the dilution port contains combustion products when the furnace is operating, and thus outward or reverse flow is synonymous with spillage of combustion products. With the "draft-assisting chamber" installed, the interface between the furnace and the room air becomes the bottom opening of the chamber (1 m below the furnace dilution port for the prototype tested) rather than the furnace dilution port. Detection of reverse flow at the bottom opening of the "draft-assisting chamber" does not necessarily imply spillage of combustion products; rather, it may mean displacement of ambient air in the chamber by combustion products accumulating within it. Thus spillage for this configuration is defined as spillage of combustion products out the bottom opening of the "draft-assisting chamber"

rather than simply reverse flow at that point. Here, the measurements of temperatures within the chamber provided the additional data needed to distinguish between reverse flow of air and actual spillage of combustion products.
Therefore, with the "draft-assisting chamber" installed, two events were watched for. These were -

- initiation of upward draft, as indicated by direction of flow at the bottom opening of the draft-assisting chamber, and

- spillage of combustion products as indicated by direction of flow at the bottom opening of the draft-assisting chamber and by temperature of that flow.

It was found that the "time to initiate upward draft" was about the same with or without the "draft-assisting chamber". This is shown in Figure 6A.

On examining Figure 6A, it is apparent that, with the casing/dilution box gaps unsealed, the incorporation of this particular prototype "draft-assisting chamber" has not significantly improved the time required to initiate upward draft compared to results for the furnace as found. At best, it has increased the house depressurization limit by about 0.5 Pa, an insignificant amount given the accuracy of the measuring device (± 0.5 Pa).

However, the system did, in fact perform significantly differently with the "draft-assisting chamber" in place in that there was no spillage of combustion products until the HDL was reached. This is shown by the right-angled duration of spillage line in Figure 6B. The vertical separation between this line and the curve for the furnace as found represents the benefit of the chamber in containing the spilled combustion products.

Figures 7A and 7B are plots similar to Figures 6A and 6B but for the second phase of testing the casing/dilution box gaps were sealed. Note that a new plot for the furnace "as found" is shown. The data for this plot was collected on the same night and just preceding the second evaluation of the draft-assisting chamber.

For a given level of depressurization, much longer times to initiate upward draft were recorded for both the furnace as found and with the draft-assisting chamber installed, compared to the first series of tests (Figures 6A and 6B). This is probably due to the different ambient conditions which prevailed. Although this may make it difficult to compare the first series of tests with the second series of tests, the comparisons of the performance of system to that of the furnace as found is valid.

Again, as observed in the first series of tests, the prototype "draft-assisting chamber" resulted in little significant improvement in the house depressurization limit. It was increased by about 1 Pa from 7.5 Pa to 8.5 Pa.

The ability of this prototype to contain spilled combustion products is again evident. Combustion products spilled from the furnace dilution opening were contained in the chamber until proper draft was initiated. However, once the house depressurization limit was exceeded by one additional Pascal, the system failed completely and was unable to initiate proper draft.

An interesting condition was observed at a depressurization level of 8 Pa. The technician observing flow at the bottom opening of the "draft-assisting chamber" reported the flow fluctuating from outward to inward. Simultaneously, another observer noted that the sides of the chamber were alternating from hot-to-the-touch to cold-to-the-touch. This see-saw condition lasted 36 seconds before full upward draft was finally established. During this time no spillage of combustion products was detected at the chamber opening. The temperature profiles for this example are shown in Figure 8A. For comparison the temperature profiles for a similar test where the flow reversal occurred after only 10 seconds is shown in Figure 8B.

Figures 9A and 9B superimpose the heat-up/cool-down test results with the draft-assisting chamber installed (no house depressurization) on those for the system as found. It is clear that the prototype did not show a detectable effect on operation of the furnace/flue system during normal operating conditions (i.e. no house depressurization).

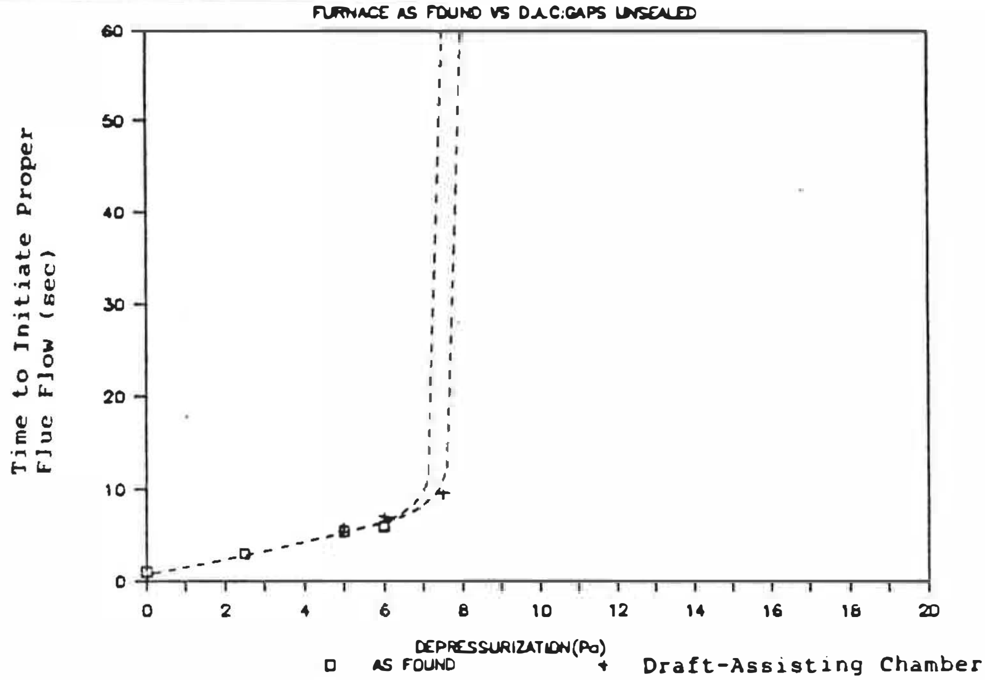


FIGURE 6A: Depressurization vs. time to initiate proper flue flow - furnace as found vs furnace with draft-assisting chamber: gaps unsealed

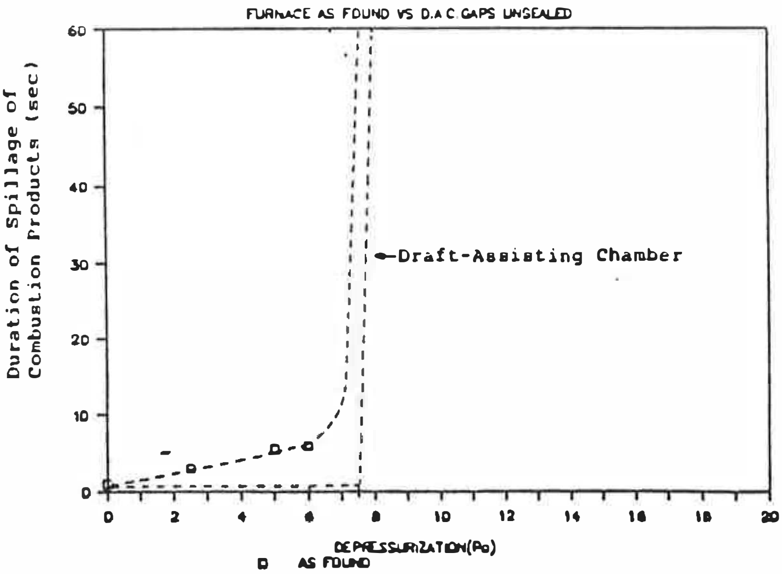


FIGURE 6B: Depressurization vs. spillage of combustion products at system opening - furnace as found vs. furnace with draft-assisting chamber: gaps unsealed

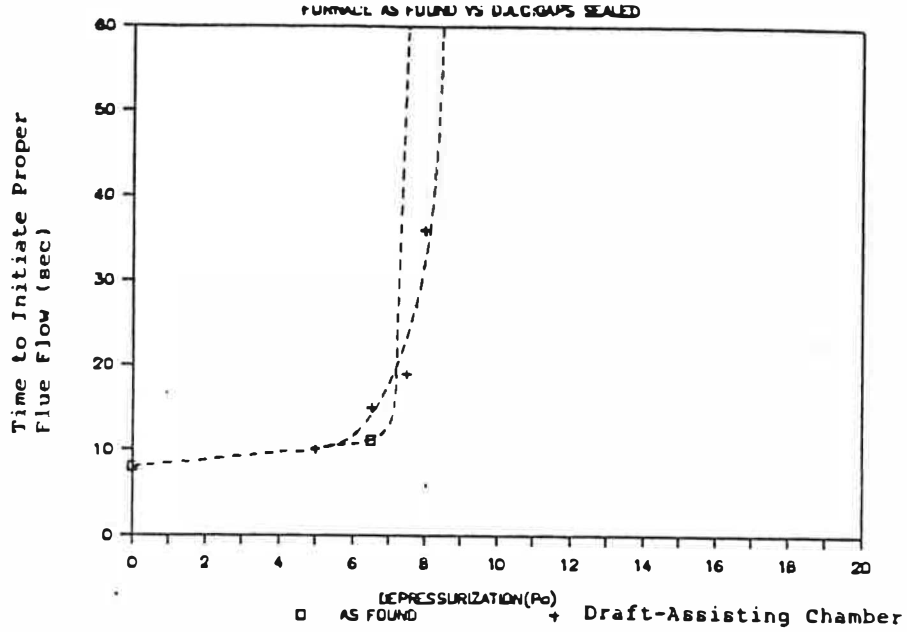


FIGURE 7A: Depressurization vs. time to initiate proper flue flow - furnace as found vs. furnace with draft-assisting chamber: gaps sealed

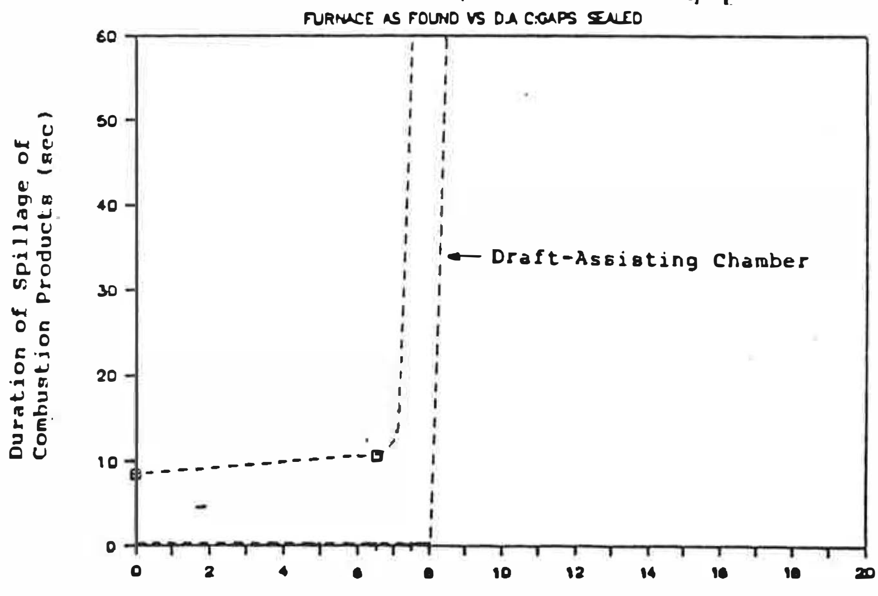


FIGURE 7B: Depressurization vs. Spillage of Combustion Products at System Opening - Furnace as Found vs. Furnace with Draft-Assisting Chamber: Gaps Sealed

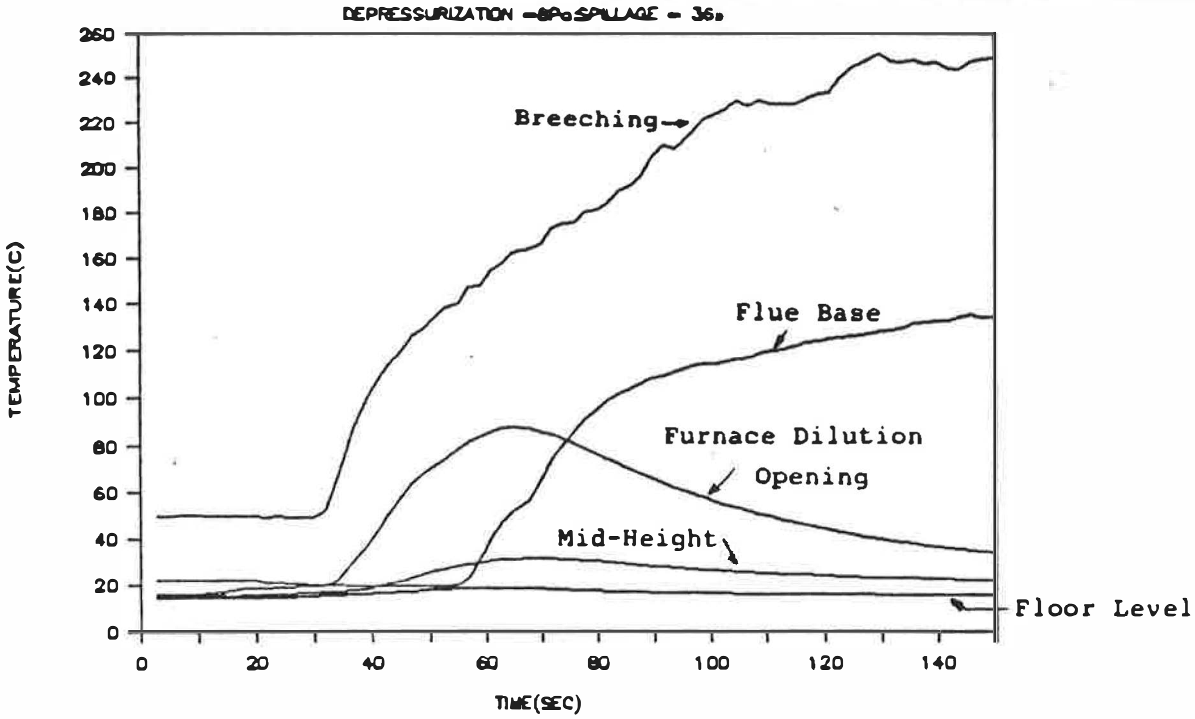


FIGURE 8A: Temperature profiles along draft-assisting chamber: gaps sealed - ΔP = 7.5 Pa

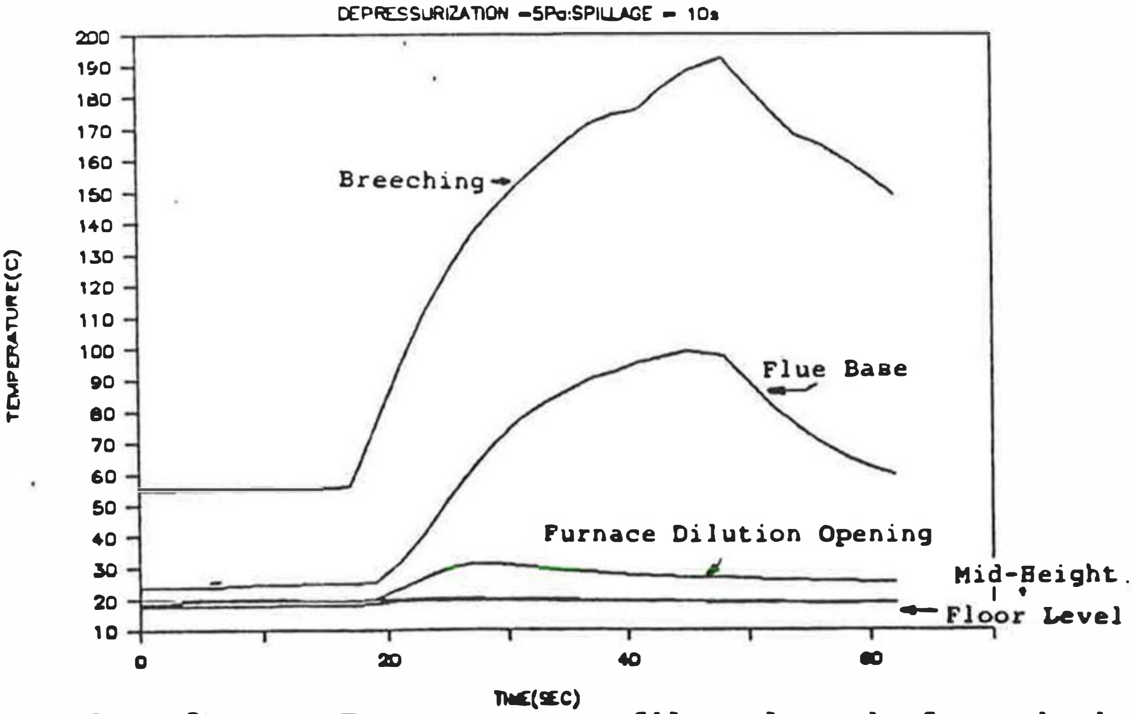


FIGURE 8B: Temperature profiles along draft-assisting chamber: gaps sealed - ΔP = 5 Pa

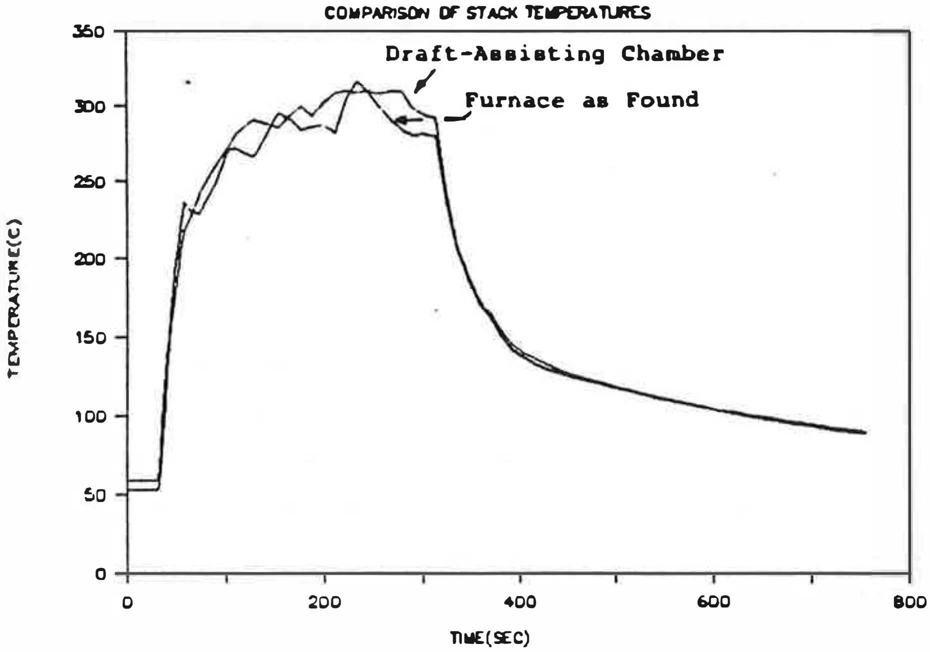


FIGURE 9A: Heat-up/cool-down test: stack temperatures - furnace with draft-assisting chamber (D.A.C.) vs. furnace as found

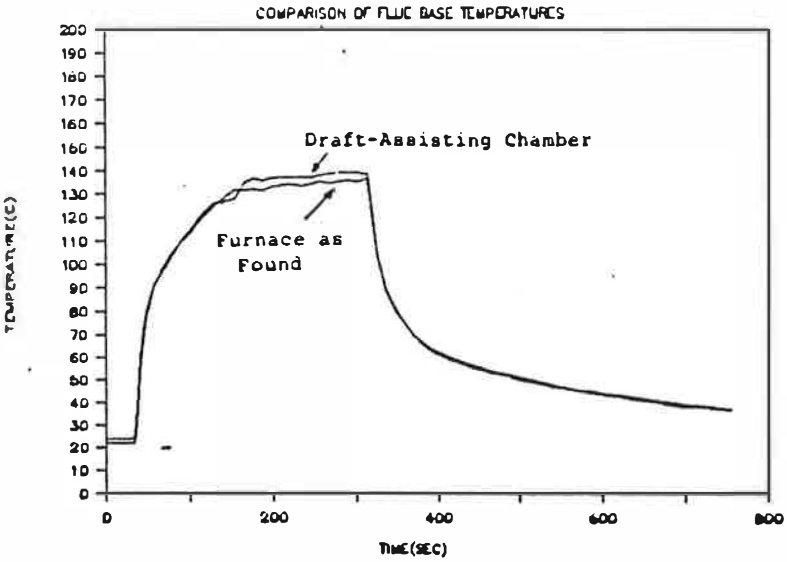


FIGURE 9B: Heat-up/cool-down test: temperatures at chimney bottom - furnace with draft-assisting chamber vs. furnace as found

House/Furnace/Flue System with Draft Inducer Installed

Figure 10 is a plot of duration of spillage versus level of depressurization for the system with the draft inducer installed superimposed on the plot for the system as found.

It is apparent that incorporation of the draft inducer has increased the level of depressurization required to cause any given spillage duration dramatically. For example, at 20 Pa depressurization (the maximum that could be achieved with the blower door available) spillage lasted only 45 seconds. This may have been close to the upper limit of depressurization for the draft inducer. Nevertheless, this is clearly more than adequate for all but the worst conceivable cases of house depressurization.

Due to the limitations of the blower door used, it was not possible to positively determine the change in the House Depressurization Limit caused by the installation of the draft inducer. We can only say that it was increased from 7.5 Pa to more than 20 Pa.

Figure 11 is a superimposition of the heat-up/cool-down test results with the draft inducer installed on those for the system as found. It is clear that the draft inducer has no detectable effect on the normal operation of the furnace/flue system.

It was noted that operation of the draft inducer added 1 to 2 Pa to the house depressurization.

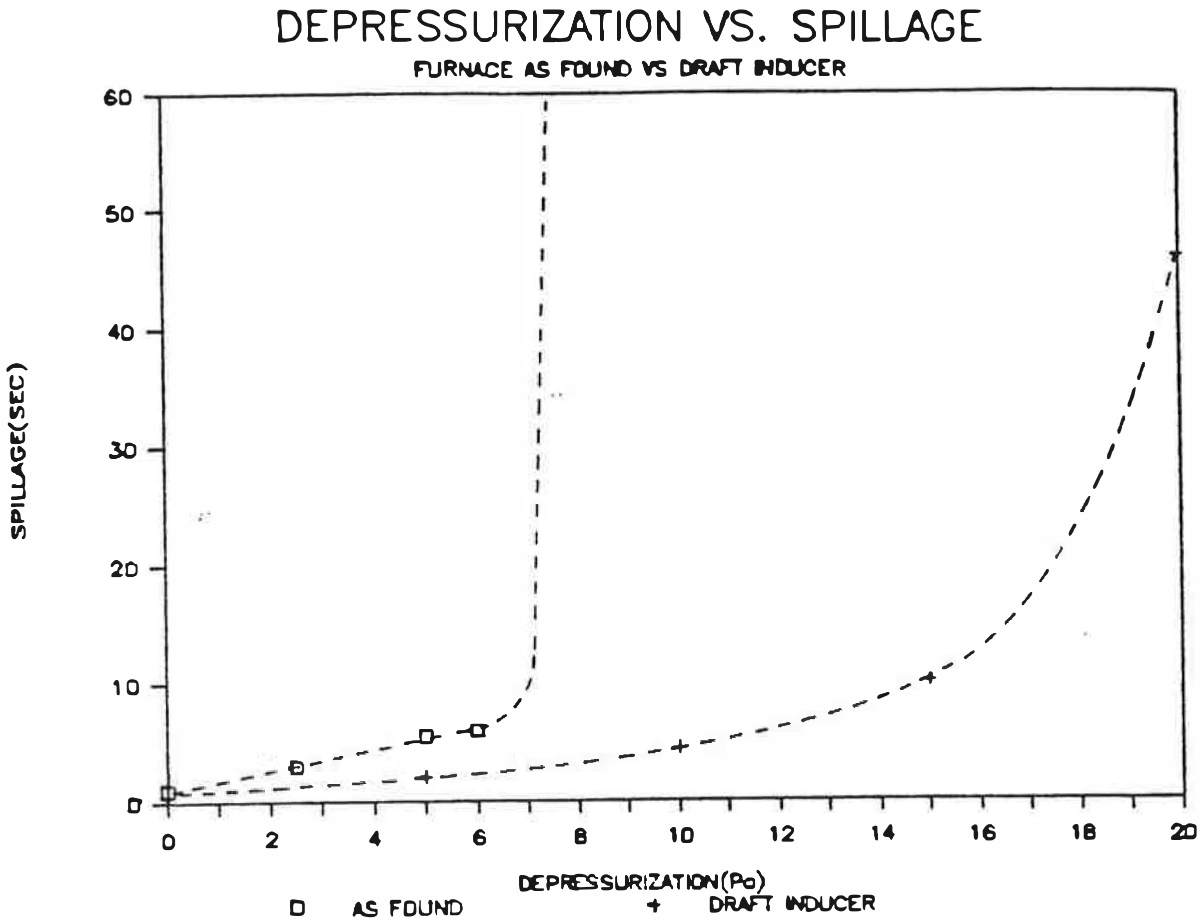


FIGURE 10: Depressurization vs. spillage - furnace as found vs. furnace with draft inducer

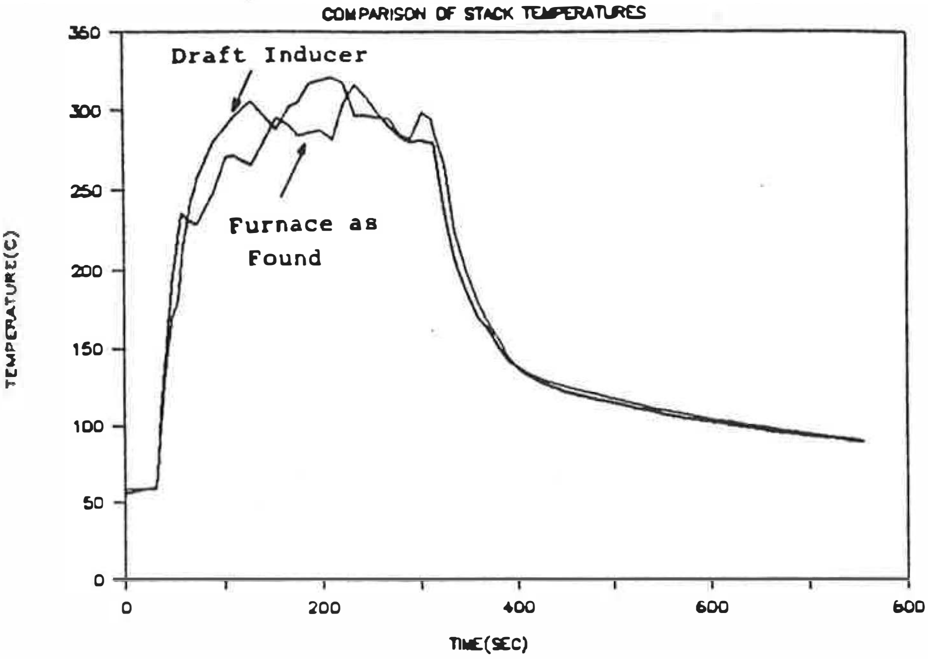


FIGURE 11A: Heat-up/cool-down test: stack temperatures - furnace as found vs. furnace with draft inducer

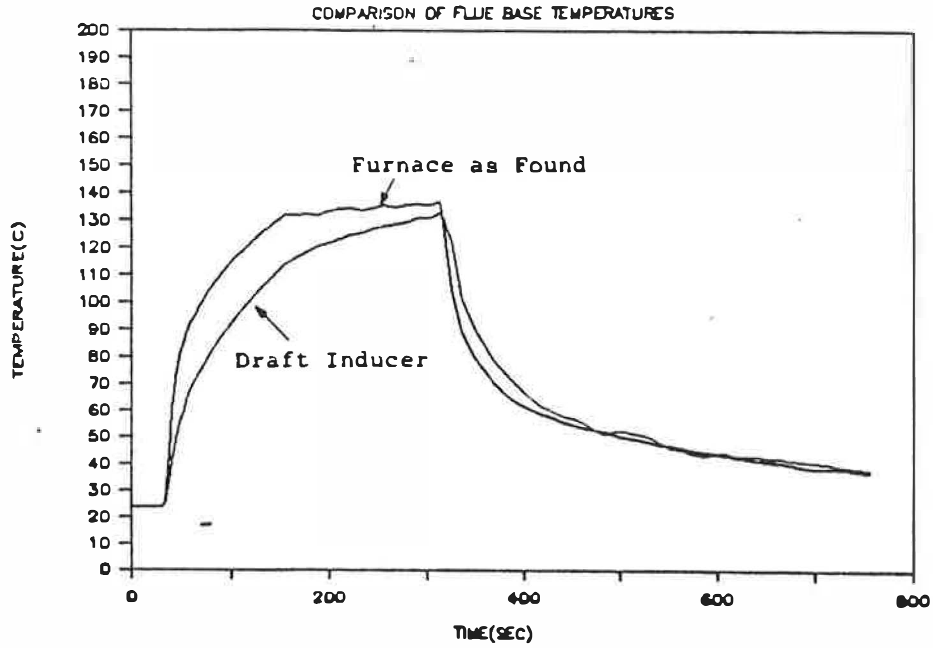


FIGURE 11B: Heat-up/cool-down test: temperatures at chimney bottom - furnace as found vs. furnace with draft inducer

Spill Switches

The performance of the spill switches was evaluated in two separate series of tests. The first series of tests was designed to determine what conditions were necessary to activate the switches. The data provided a baseline upon which more exhaustive testing could be performed. These results are summarized in Table 1A.

The table shows the time from furnace start-up until each of the spillage switches was activated as a function of level of depressurization. Also shown is the temperatures along each of the capillary tubes at the moment the switch was activated. (Note that the 73.3°C switch extended across only one half of the dilution opening and as a result only two temperature readings are used to determine the average temperature along the tube. The 80.5°C switch extended across the full width of the opening and three temperature readings are used to determine the average activation temperature for the tube.)

As indicated earlier, the transition from apparently reversible spillage to apparently irreversible spillage is very sudden. In all cases of reversible spillage, the reversal occurred with 20 seconds of furnace start-up. Neither of the spill switches were triggered in these cases.

The switches only tripped on those test cases where spillage occurred for three minutes or more; i.e. in those conditions where the House Depressurization Limit was exceeded.

In the first series of tests, the switches appeared to perform as expected, the 73.3°C switch triggering first followed by the 80.5°C. Under identical levels of depressurization, the switches tripped consistently (within ± 10 seconds) although the 80.5°C switch showed the most variability in activation time. These results are shown in Table 1A. It was also noted that as the level of depressurization increased it took longer for the switches to be activated. A closer examination of the temperatures in the dilution opening showed that the maximum temperature in the dilution opening changes as the level of depressurization increases. In general, as the level of depressurization increases, the maximum temperature moves from the top of the dilution opening down towards the middle and middle edges of the opening. Similar findings were documented by Sheltair in their mapping efforts of the dilution opening. (Reference 2)

The change in the location of maximum temperatures and activation time of the switches as the depressurization level increased observed in the first series of tests prompted a more detailed second series of tests. In this series of tests, an additional variable, vertical location of the spill switch was added to the test protocol. These results are shown in Tables 1B to 1D.

The data shown in Tables 1B to 1D is also plotted in Figure 12 and 13 for each of the spill switches. The curves show activation time as a function of level of depressurization for each of the three locations in which the spill switches were installed. These were again:

A) 12 mm from the top lip, recessed 6 mm into the dilution opening.

B) Halfway between the top and bottom of the dilution opening, recessed 6 mm into the opening.

C) 12 mm from the bottom of the dilution opening, recessed 6 mm into the opening.

The results can be summarized as follows:

1) For each vertical location, a curve of time to activate the switch vs. level of depressurization can be generated. At each vertical location, the curve generated for the 80.5°C switch is similar to the curve generated for the 73.3°C switch. For each level of depressurization the activation time for the 73.3°C switch is shorter than the 80.5°C switch.

2) Each vertical location has its own unique curve of switch activation time vs. level of depressurization.

3) At about 15 Pa depressurization, the temperature distribution in the dilution port is quite uniform and the activation time for either switch is essentially independent of its location.

4) For the switches located at the top of the dilution opening, the activation time at 10 Pa is greater than at 7.5 Pa. This is identical to results observed in the first series of tests. At 10 Pa the effect of recessing the capillary tubes 6 mm into the dilution opening

reduced the activation time of the 80.5°C switch from 90 seconds to 70 seconds. A similar 20 second reduction was also observed at 7.5 Pa.

The effect of recessing the shorter 73.3°C switch into the dilution opening reduced the activation time at 7.5 Pa from 36 to 28 seconds, a reduction of only eight seconds. An increase of six seconds was observed at 10 Pa. Thus it appears that the shorter 73.3°C switch is less sensitive to location in the opening than the longer 80.5°C switch.

For levels of depressurization greater than 10 Pa, the activation time for the 80.5°C switch drops from 70 seconds at 10 Pa to 65 seconds at 15 Pa. The activation time for the 73.3°C switch drops from 67 at 10 Pa to 47 seconds at 15 Pa.

5) For the switches located halfway between the top and bottom of the dilution opening, activation time of both of the spill switches is linearly proportional to level of depressurization. As level of depressurization increases, so too does the activation time of the switches. At 7.5 Pa, both switches were observed to trip about 26 seconds after furnace start-up. At 15 Pa, activation time for the 80.5°C switch was 61 seconds, and activation time for the 73.3°C switch was 49 seconds.

6) For switches located at the bottom of the dilution opening, activation time of the switches was greatest at 7.5 Pa. It took over 100 seconds before the 80.5°C

switch was activated and 87 seconds before the 73.3°C switch was activated. At 10 Pa the time to activate both switches decreased dramatically to 61 seconds for the 80.5°C switch and 52 seconds for the 73.3°C switch. At 15 Pa the activation time for both switch was almost identical to that observed at 10 Pa.

To summarize, locating the spill switches halfway between the top and bottom of the dilution opening resulted in the fastest response to spillage. However, this activation time increased as level of depressurization increased. Despite this fact, the activation time was still less than that when the switches were located at the top or bottom of the dilution opening at any level of depressurization.

At levels of depressurization of 10 Pa or greater, there was only a small difference between moving the switches closer to the top of the opening than to the bottom of the opening. For a given distance from the centerline, a slightly greater delay was caused by moving the switches closer to the top of the opening rather than the bottom of the opening. However, the maximum variation (i.e. locating the switch at the top instead of the bottom) was less than 10 seconds for the 80.5°C switch and less than 15 seconds for the 73.3°C switch.

At the house depressurization limit, i.e. 7.5 Pa, locating the switches at the top of the dilution opening and the vertical centerline made no difference to the activation time. Delays were only caused by moving the switches toward the bottom of the dilution opening.

Based on these test results, it appears there may be a location somewhere between the vertical centerline and the bottom of the dilution opening where activation time is independent of the level of depressurization. If one could determine this location, the activation time of the switch would depend on only one variable - the temperature limit of the switch - rather than the three variables of location, depressurization, and temperature limit.

Although detailed examination of the temperature profiles in the dilution opening was beyond the scope of this project, a preliminary review of the data reveals that as the level of depressurization increases, the temperature distribution in the dilution opening changed from being symmetric about the horizontal centerline to a pattern with the hottest temperatures shifting gradually towards the left side of the dilution opening. This is significant since the shorter 73.3°C switch covered only the right half of the dilution opening. This makes it difficult to compare the relative performance of the two switches since the shorter, lower limit spill switch was probably located in a cooler temperature zone. This might also explain why the activation times for both switches were remarkably similar despite the 7.2°C difference in the temperature limits between the two switches.

TABLE 1: Summary of results for spill switches

TABLE 1A: ACTIVATION TIME OF SPILL SWITCHES:SERIES 1 TESTS:SWITCHES IN PLANE OF DILUTION OPENING

LOCATION A

SWITCH 1:OPEN @ 80.5C						SWITCH 2:OPEN @ 73.3C					
PRESSURE	TIME	TEMPERATURES(C)			AVG TEMP	PRESSURE	TIME	TEMPERATURES(C)			AVG TEMP
(Pa)	(sec)	1	2	3	(C)	(Pa)	(sec)	1	2	3	(C)
7.5	34	65.8	66.5	63.2	66.2	7.5	49	78.6	75.2	56.2	70.0
7.5	33	58.4	65.1	48.8	61.8	7.5	38	61.9	68.3	46.9	59.0
10	89	85.8	65.9	74.1	75.9	10	69	57.3	67.8	92.2	72.4

TABLE 18: ACTIVATION TIME OF SPILL SWITCHES:SERIES 2 TESTS:SWITCHES RECESSED 6mm INTO DILUTION OPENING

LOCATION A

SWITCH 1:OPEN @ 80.5C						SWITCH 2:OPEN @ 73.3C					
PRESSURE	TIME	TEMPERATURES(C)			AVG TEMP	PRESSURE	TIME	TEMPERATURES(C)			AVG TEMP
(Pa)	(sec)	1	2	3	(C)	(Pa)	(sec)	1	2	3	(C)
7.5	26	87	102	39	94.5	7.5	28	89	108	74	90.3
10	70	108	88	108	98.0	10	67	106	83	95	94.7
12.5	71	111	88	87	99.5	12.5	61	105	81	82	89.3
15	65	101	81	89	91.0	15	47	92	82	82	85.3

TABLE 1C: ACTIVATION TIME OF SPILL SWITCHES:SERIES 2 TESTS:SWITCHES RECESSED 6mm INTO DILUTION OPENING

LOCATION B

SWITCH 1:OPEN @ 80.5C						SWITCH 2:OPEN @ 73.3C					
PRESSURE	TIME	TEMPERATURES(C)			AVG TEMP	PRESSURE	TIME	TEMPERATURES(C)			AVG TEMP
(Pa)	(sec)	4	5	6	(C)	(Pa)	(sec)	1	2	3	(C)
7.5	26	60	90	23	75.0	7.5	26	60	90	23	57.7
10	39	81	85	67	83.0	10	36	78	82	66	75.3
12.5	49	86	78	79	82.0	12.5	46	84	76	77	79.0
15	61	87	75	83	81.0	15	49	82	73	76	77.0

TABLE 1D: ACTIVATION TIME OF SPILL SWITCHES:SERIES 2 TESTS:SWITCHES RECESSED 6mm INTO DILUTION OPENING

LOCATION C

SWITCH 1:OPEN @ 80.5C						SWITCH 2:OPEN @ 73.3C					
PRESSURE	TIME	TEMPERATURES(C)			AVG TEMP	PRESSURE	TIME	TEMPERATURES(C)			AVG TEMP
(Pa)	(sec)	1	2	3	(C)	(Pa)	(sec)	1	2	3	(C)
7.5	102	69	83	29	84.7	7.5	87	66	75	30	57.0
10	61	87	83	84	77.0	10	52	83	78	86	82.3
12.5	n/a	n/a	n/a	n/a		12.5	n/a	n/a	n/a	n/a	
15	59	86	79	87	74.7	15	56	85	78	85	82.7

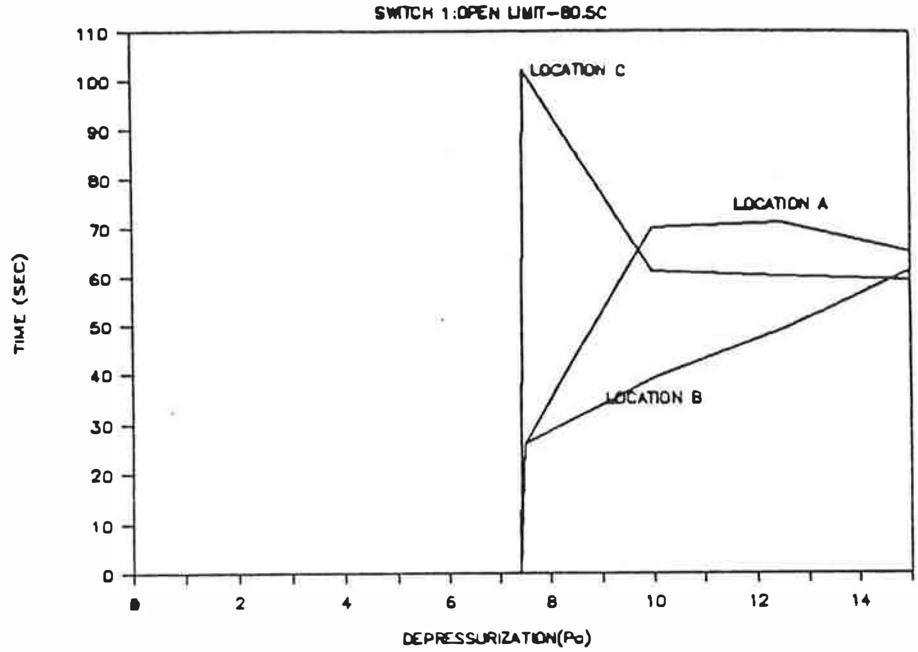


FIGURE 12: Time to activate spill switch vs. depressurization: spill switch open limit - 80.5°C

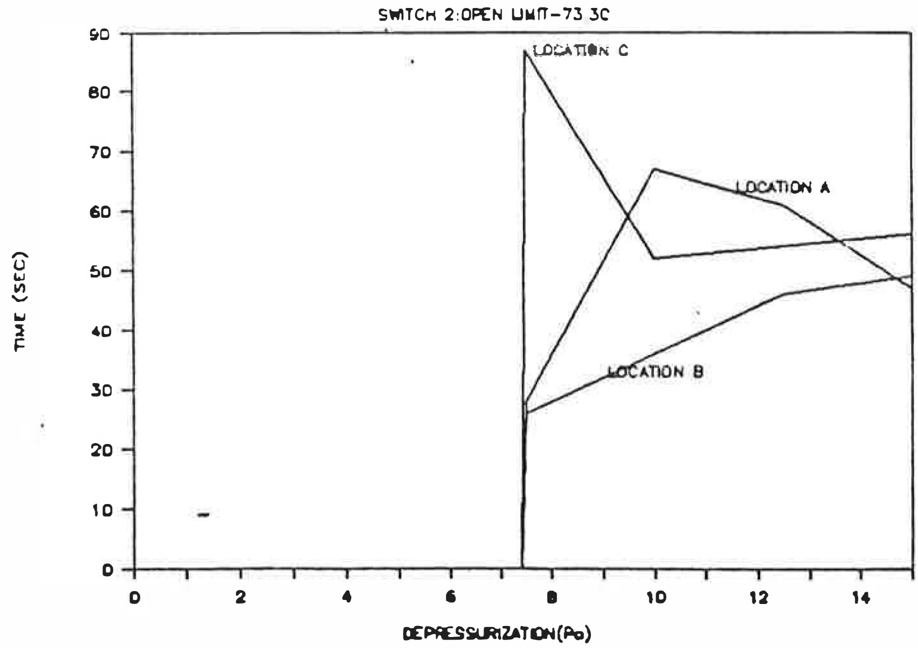


FIGURE 13: Time to activate spill switch vs. level of depressurization: spill switch open limit - 73.3°C

CONCLUSIONS

Warning Devices (Spill Switches)

The results of these tests indicate that it should be possible to develop a number of different devices to warn of the occurrence of abnormal combustion products spillage from a naturally aspirating gas furnace or to somehow alter the operation of the furnace (e.g. turn it off or activate a draft inducer) when such spillage occurs. These devices could all be triggered by a temperature sensitive switch (spill switch) of the Thermodisc type, which has been shown to react consistently to spillage incidents.

However, these tests were not exhaustive; e.g. the effect of cold backdrafts was not assessed.

Draft-Assisting Chamber

The prototype "draft-assisting chamber" evaluated in this present testing has been shown to be an effective remedial measure for containing spillage of combustion products from the dilution opening of naturally aspirating gas furnaces in houses where combustion venting is a minor problem. Unfortunately, the prototype tests does not appear to improve the House Depressurization Limit significantly.

The reasons for this lack of significant improvement are not clear at this stage, since theoretical modelling showed a potential improvement in system driving pressures of the order of 3 Pa. One explanation can be postulated at this stage: The particular prototype chosen may have allowed the hot portions of the gases to stratify out of the way of the main backdrafting stream, thus losing potential buoyancy in that stream. Another factor may have been the fact that the test house had a rather high depressurization limit (7.5 Pa). The chamber would be expected to have a more pronounced effect in raising the depressurization limit of a house which started at a lower level.

This research has not addressed the issues of code and regulation amendments or waivers which might be required to permit the widespread use of the draft-assisting chamber. However, the results of the before and after heat-up/cool-down tests indicate that the draft-assisting chamber does not affect the normal operation of the furnace/flue system.

Draft Inducer

The draft inducer, too, appears to be an effective remedial measure. It improves the House Depressurization Limit by at least 20 Pa which is sufficient to overcome all but the most severe combinations of naturally aspirating gas furnaces with tight building envelopes and large capacity exhaust equipment.

REFERENCES

1. Development and Testing of a Thermal Spill Switch for Conventional Gas Fired Furnaces and Water Heaters, Consumers Gas Company Ltd., Research and Special Departments, February 1985.

2. Development and Evaluation of Survey Technology: A Progress Report Concerning Venting Failures - A Systems Approach, Scanada-Sheltair Consortium, January 1986.

A P P E N D I X " A "

OVERALL PROJECT SUMMARY

OVERALL PROJECT SUMMARY

The project reported on here was designed to expand on previous studies of the problem of incomplete venting of combustion products from heating appliances in order to approach a more nearly comprehensive understanding of the extent and nature of the problem in the Canadian housing stock. This project, which was carried out for Canada Mortgage and Housing Corporation by the Scanada Sheltair Consortium Inc., consisted of the seven sub-projects described below.

PROJECT 1 COUNTRY-WIDE SURVEY

Spillage detectors were installed on the draft hoods or barometric dampers of gas and oil furnaces and water heaters in 937 houses spread throughout the Vancouver, Winnipeg, Toronto, Ottawa and Charlottetown regions. The detectors were left in place for approximately 2 months in late winter.

Of the gas heated houses surveyed, 10% had experienced prolonged and unusual amounts of combustion gas spillage and 65% had experienced either short duration start-up spillage or prolonged spillage of small amounts of combustion gas. Of the oil heated houses, 55% had experienced significant spillage of high temperature combustion gas, but some of these spillage events may have been of only short duration.

Preliminary analysis indicates that spillage problems seem to be related to the following house or heating system characteristics:

- Winnipeg houses (believed to be more nearly airtight due to extensive use of stucco)
- pre-1945 houses
- post-1975 houses
- one storey houses
- exterior chimneys
- masonry chimneys with under-sized metal liners
- houses with three or more exhaust fans
- houses with two open masonry fireplaces
- poorly maintained heating appliances

PROJECT 2 MODIFICATIONS AND REFINEMENTS TO THE FLUE SIMULATOR MODEL

FLUE SIMULATOR, a detailed theoretical computer-based model of the combustion venting process had been developed for CMHC prior to this project. It is intended for use as an aid in understanding the mechanisms of combustion venting failure and the circumstances that give rise to them. The modifications undertaken in this project were intended to make the program easier to use and to allow it to model a wider variety of furnace/flue/house systems. The modifications included -

- o refinements to algorithms
- o more efficient operation of the program
- o modelling additional features and system types
- o user-friendly input and output

The modified model was validated against field test data and used to investigate a number of issues.

A separate developmental version of the program, called WOOD BURNING SIMULATOR, was successfully developed to model the combustion and combustion venting process in wood stoves and fireplaces.

PROJECT 3 REFINEMENT OF THE CHECKLISTS

A procedure for identifying and diagnosing combustion venting failures had previously been developed for CMHC - the Residential Combustion Safety Checklist. This project provided an opportunity to refine the checklist and develop variations of it suitable for a variety of possible users such as furnace service personnel, air sealing contractors, homeowners, etc. Early in the project, it was decided to separate the identification procedures from the diagnostic procedures. This allowed the process of identifying houses with potential for combustion venting problems to remain relative simple and allowed the diagnostic process to become more complex since it would only be used on houses where the extra effort would likely be worthwhile. Thus the original backdraft checklist has grown into five separate tests/procedures -

Venting Systems Pre-test
- a quick, visual inspection procedure which identifies a house as either unlikely to experience pressure-induced spillage or requiring further investigation

Venting Systems Test
- a detailed test procedure for determining to what extent the combustion venting system of a house is affected by the envelope airtightness and operation of exhaust equipment, perhaps the clearest descendent of the old backdraft check-list.

Chimney Performance Test
- a simple method of determining whether a chimney is capable of providing adequate draft

Heat Exchanger Leakage Test
- a quick method of determining if the heat exchanger of a furnace has a major leak

Chimney Safety Inspection
- a visual check for maintenance problems in the chimney system

These tests/procedures are all presented in a manual entitled "Chimney Safety Tests". Full trials of the procedures were carried out on the case study houses investigated in Project 6.

PROJECT 4 HAZARD ASSESSMENT

Although little was known at the outset of this project about the frequency of combustion spillage, even less was known about how much of a health hazard such spillage represents. Therefore this sub-project was included to investigate the real nature of the health and safety risk associated with venting failures. The work was divided into five tasks -

1. Review of current knowledge on pollutant generation due to improper venting of combustion appliances (literature review).
2. Development of a computer program to predict levels of various pollutants under various combustion venting failure scenarios.
3. Acquisition and calibration of a set of instruments required to measure the various pollutants at the levels predicted by the computer model.
4. Monitoring pollutant levels in problem houses identified in the Country-wide Survey (Project 1) using the instruments acquired in Task 3.
5. Analysis of the results of Task 4 to arrive at an overall assessment of the health hazard represented by combustion venting failures in Canadian houses.

The results indicate that, in most houses, one would rarely encounter acute, immediately life-threatening concentrations of pollutants as a result of combustion spillage from furnaces or water heaters. However, chronic health risk due to low level, long term exposure to pollutants , particularly NO_2, may be a more significant problem which requires further investigation. High levels of CO do not seem to be caused by the problems which cause spillage and thus occur in spillage events only as a result of coincidence.

PROJECT 5 REMEDIAL MEASURES

Remedial measures for pressure-induced combustion venting problems were identified and researched for a number of different types of combustion appliances.

The remedial measures identified for FIREPLACES were:

Spillage Advisor

- This is an adjustable volume alarm triggered by a combination of particulate and CO detectors and intended to be mounted on the front of the mantle or on the wall just above the fireplace.

Airtight Glass Doors Combined With An Exterior Combustion Air Supply Duct

- The research indicated that conventional glass doors are not nearly airtight and do little to separate the fireplace from the house's pressure regime. Prototype doors using special glass, heavier than normal steel frames and special sealing techniques were fabricated and installed and tested. It was found that these doors increased the level of house depressurization required to cause prolonged spillage from the fireplace from 3 Pa to 22 Pa. It is estimated that the installed cost would be $600. Further research on the effect of airtight doors on temperatures within the fireplace and flue and the possible hazard to surrounding combustible materials is required.

The remedial measures identified for GAS-FIRED APPLIANCES were:

Spillage Advisor

- This could be similar to the fireplace spillage advisor but would be triggered by a heat probe mounted in the dilution port of the appliance. The heat probes investigated could also be used to trigger other remedial measures discussed below.

Draft-inducing Fan

- A paddle-wheel-type fan mounted in the vent connector was found to increase the level of house depressurization required to cause irreversible spillage from a naturally aspirating gas furnace from 7 Pa to more than 20 Pa.

Draft-assisting Chamber

- A chamber surrounding the appliance's dilution port and extending downwards contains combustion products flowing out of the dilution port and prolongs the period before they are actually spilled into the room. It was expected that the chamber would also use the buoyancy of the contained combustion products to assist the flue in developing upward flow and thus would increase its resistance to house depressurization; however, the results obtained with the prototype tested did not live up to expectations. It is expected that modification of the design and testing with a furnace/flue/house combination more prone to pressure-induced spillage will improve this aspect of the chamber's performance.

The research on remedial measures for OIL-FIRED APPLIANCES indicated that stable backdrafting is unlikely to be a problem with oil-fired appliances since the pressure generated by the burner blowers is able to rapidly overcome backdrafting due to house depressurization and initiate upward flue flow. However, this pressurization of the flue system is what accounts for the start-up spillage associated with oil appliances and it is the duration of this spillage that remedial measures must address. The measures identified were:

Solenoid Valve

- By delaying the start of combustion until the burner has had a chance to overcome backdrafting and initiate upward flue flow, the solenoid valve reduces the duration of spillage but does not eliminate it altogether.

Draft-inducing Fan

- A fan, similar to that described above under gas appliances, mounted in the flue pipe downstream of the barometric damper is not needed to overcome backdrafting since the burner blower can do this. However, it does relieve pressurization of that portion of the flue pipe upstream of itself and hence reduces spillage from that portion. There can still be spillage from the downstream portion; but, since that portion does not include the barometric damper, it is easier to seal.

Elimination of the Barometric Damper

- Provision of a well-sealed flue pipe without a barometric damper is one obvious way to reduce spillage. However, elimination of the barometric damper exposes the burner to the full chimney draft and disturbs the combustion process of conventional burners. Therefore this procedure must include replacement of the conventional burner with a high pressure burner which is less influenced by flue pressure. Provision of an insulated flue liner is often included as part of this measure.

The work on MAKE-UP AIR SUPPLY remedial measures was less directed towards specific measures but served to clarify a number of general air supply issues. It indicated that the provision of additional supply air is not likely to be effective as a remedy for pressure-induced spillage of combustion products if the supply air is introduced unaided through an envelope opening of any size likely to considered practical. It is only likely to be effective if a supply air fan is used and if that fan has a capacity at least equal to the total capacity of all exhaust equipment it is attempting to counteract. The discharge from such a supply air fan can be introduced essentially anywhere in the house, but is likely to create fewer thermal comfort problems if introduced in a normally unoccupied area such as the furnace room.

The knowledge generated in the remedial measures research and already available to Consortium members was synthesized into the draft Remedial Measures Guide, a manual intended to be a decision-making guide for tradesmen and contractors who have identified pressure-induced spillage problems in houses with vented fuel-fired appliances and want to know how best to remedy these problems. It is designed to accompany the Venting Systems Test. Although the draft Guide is not yet comprehensive and in some cases describes procedures which have not been thoroughly field tested and/or approved by regulatory authorities, it is hoped it will stimulate thought and discussion and improve current trade practices.

PROJECT 6 PROBLEM HOUSE FOLLOW-UP

Twenty of the houses identified in the country-wide survey as experiencing the worst combustion spillage problems were visited with the following objectives:

- to categorize and quantify the nature of venting failures
- to isolate contributing factors
- to collect field data on venting failures for use in the flue simulator model validation
- to measure the frequency and quantity of spillage in problem houses
- to measure the approximate impact on air quality of venting failures in houses
- to evaluate the effectiveness of the chimney safety tests in diagnosis of failures and identification of remedial measures
- to evaluate communications techniques
- to evaluate remedial measures under field conditions

In most of the houses, there were several factors that were assessed as contributing causes of the combustion spillage problem - thus confirming the "systems" nature of the problem. It is also worth noting that, in many houses, although the spillage observed was indeed pressure-induced, it occurred at quite low levels of house depressurization because the chimneys were only able to generate very weak draft due to some problem such as a blocked or leaky flue. The main problem in these cases, therefore, was not depressurization but weak chimneys.

PROJECT 7 COMMUNICATIONS STRATEGY

As the survey revealed that the problem, while substantial, is not epidemic in proportion, there is no need to create widespread alarm in the general public. A communication strategy has been drafted with this in mind. It places emphasis on motivating the heating and housing industries to be aware of the combustion venting problem and its causes and to make effective use of the diagnostic tools and preventive and remedial measures developed in this project.

OVERALL PROJECT SUMMARY AND CONCLUSIONS

The project has gone a long way towards meeting its original objectives and has significantly advanced the state-of-the-art in this field.

It has led to improved understanding of the combustion venting process and confirmed the "systems" nature of the failures that lead to combustion venting problems.

It appears that a significant portion of the Canadian housing stock has potential for combustion venting failure to occur on a regular basis. In most cases, this is unlikely to lead to immediate life-threatening pollution levels, but long term chronic health hazards could be a problem; however this latter concern requires further investigation before any definite conclusion can be reached.

A number of techniques are available for identifying houses prone to combustion venting failure and for diagnosing the causes of such failure. There are also available a number of measures for preventing combustion venting failure in new houses and for remedying it in existing houses. A communication strategy has been drafted for conveying these techniques and measures to relevant people in the housing and heating industries and for encouraging them to make use these tools.

A P P E N D I X " B "

RESEARCH PLAN FOR GAS FIRED APPLIANCES

Progress Report
Originally Submitted

January 21, 1986

PROJECT 5.2: RESEARCH PLAN FOR GAS FIRED APPLIANCES

1.0 INTRODUCTION

The purpose of this research plan is to identify the most promising remedial measures for correcting or avoiding venting failures in gas fired appliances and to lay out a course of action for preliminary investigation of these measures.

The detailed terms of reference (issued Dec. 17, 1985) outlined four areas which deserve priority attention. These are:

1) Induced Draft Kits
2) Failsafe and Alarm Systems
3) Wind Diverting Caps
4) A Draft-Assisting Chamber

Further investigations into remedial measures revealed an additional category:

5) Optimization of the Size of the Dilution Device Opening

(Also identified was the "combustion air supply systems" category for gas appliances, which will be handled for all fuel types by SRC.)

This research plan is based on existing devices and/or techniques that, if selected, would have a high probability of correcting or avoiding venting failures. In addition, the chosen remedial measures are to be applicable to a majority of houses experiencing significant problems.

In order to ensure that the chosen remedial measures have a high probability of being ready for immediate or near term use by the public, the survey is limited to those devices or techniques that are well developed or will be in the near future. The selection process identified measures that should be practical, common sense solutions that are also reasonably priced.

2.0 LITERATURE SEARCH

The first task in this research plan was to review the most recent surveys and studies in the field of remedial measures for gas fired appliances for residential applications. Based on this review, three of the most promising measures were chosen for detailed field evaluation. The survey included recent studies conducted by CGRI, CCRL, Sheltair Scientific and Scanada Consultants.

Draft Inducers

Survey/Assessment of Draft Inducers, Energy Systems Centre, ORF, March 1985.

Fail Safe and Alarm Systems

Development and Testing of a Thermal Spill Switch for Conventional Gas Fired Furnaces and Water Heaters, Consumers' Gas Company, February 1986.

Testing of Warning and Safety Switches, CGRI, October 1985.

Monitoring Chimney Performance in Four Ottawa Houses, Sheltair Scientific, April 1985.

Residential Combustion Safety Checklist, Sheltair Scientific, December 1984.

Personal Communications with Michael D. Monette, Aptech Detectors Inc.

Communications between NEWTEC INDUSTRIES ALARM and Sheltair.

Wind Diverting Caps

Chimney Cowl Laboratory Tests, Polytechnic Innovation and Resource Centre, Lab Test Report.

The Testing of Full Scale Ventilator Cap Types to Determine Their Effect on Natural Ventilation, Polytechnic Innovation and Resource Center.

Draft-Assisting Chamber

Concept Description, January 1985. Patent Application, August 1985, Scanada Consultants Limited.

The above reports were selected on the basis of recommendations of researchers familiar with the problems of spillage and backdrafting of gas fired appliances. These include Don Fugler of CMHC, John Rinella of Consumers' Gas and Michael Tremayne of EMR. Follow-up conversations with each of these individuals ensured that the information and status of each of the measures examined in this research plan was as current as possible. Most of the legwork has been performed by these individuals and only those measures that showed the most promise have been brought forward. Further systematic searching might yield other measures that are promising and still require further testing or refinement. The remedial measures described herein can thus be labelled "the most promising technology identified to date". This label will undoubtedly change for some measures over the course of this project.

2.1 Review of Remedial Measures

The following section summarizes the findings of several studies on various remedial measures. Based on this review the most promising remedial measures will be highlighted.

Draft Inducers

Based on the survey performed by ORF on Draft Inducers, four types of inducers were found suitable for retrofit to residential gas appliances. These were:

1) An In-Line Power Venter
2) A Side Wall Venter
3) A Megasave Supermate Condensing Package
4) A Heat Extractor

The last two products pertain to the conversion of conventional gas fired appliances to condensing gas furnaces. Although a viable remedial measure (the vertical chimney is eliminated as is most or all of the spillage and backdraft problems), the cost of this retrofit ($1200-$1500) and the much broader objective met by this device (i.e. energy conservation) precludes its application in this research plan.

The Side Wall Venter resolves the backdrafting problem in the same way as does the condensing gas furnace retrofits by exhausting combustion gases horizontally to the side of the house (i.e. powered exhausting). This may represent a mid-cost solution in the context of resolving conventional backdrafting and spillage problems. However, in the event of blocked or damaged chimneys this may be the most cost effective alternative to rebuilding the chimney. Estimated costs, installed, was quoted at about $600.

The In-Line Power Venter is comprised of either a propeller or centrifugal type exhauster designed to provide positive venting for gas fired appliances. Like the Side Wall Venter, this device appears to be a practical mid-cost solution to backdrafting and spillage. The advantage of the In-Line Power Venter over the Side Wall Venter is the Power Venter retains the use of the existing chimney. Clearly an In-Line Power Venter that mechanically assists draft would eliminate spillage and backdrafting problems. Presumably the controls of this system could be integrated with the thermostat to provide induced draft in response to furnace demand.

One concern is the potential backdrafting of fireplaces if the Power Venter contributes significantly to the depressurization of the house. This could be resolved by coupling the Power Venter to a motorized damper on a combustion air supply opening. The cost of this In-Line Power Venter ranges between $400 to $600. Additional costs of the combustion supply duct, motorized damper and control systems to integrate this whole system would probably add another $200. Further development as well as volume production of this system might help to bring down costs in the future.

Fail Safe and Warning Devices

Although these measures might not be considered as remedial measures in the sense that they do not promote positive draft, they are designed to signal the existence of the problem which in itself is a very important part of the solution.
A recent survey by CGRI reviewed current research and development of warning and safety devices. According to that study, warning devices were considered devices that detected the presence of combustible gases. These devices were fitted with an audible alarm only. Safety devices were considered switches which shut down equipment if combustion gases were not venting properly.

The study showed that most warning devices that relied on the detection of combustibles or Carbon Monoxide (CO) were susceptible either to false alarms or were simply unreliable. To date, only one CO sensor manufactured by Co-Sensor International is currently on the market. Discussions with Don Fugler of CMHC suggest that, based on a 40 house survey, CO levels in the stack gas rarely exceed 50 ppm with most being well below. Current information suggests that the minimum detection level for the CO sensor manufactured by Co-Sensor is in the range of 10 to 50 ppm, however, product literature is still unavailable from the manufacturer. If such sensitivity can be confirmed, this might prove to be a suitable warning device for evaluation. Another concern is the "guesstimated" life span of the sensor of about 3 years, whereupon the sensor must be re-calibrated back at the factory. Costs of this sensor were quoted at about $100. Newtec Industries Alarms is also working on CO detector technology in combination with a semi-conductor sensor. This allows the detector to recognize carbon monoxide at lower limits. According to the manufacturer, laboratory results are encouraging but at present the information is proprietary. Costs are expected to be about $60.00. Finally, although the spillage of CO is the most serious problem, especially for malfunctioning furnaces, it is not the only one. It may be a better strategy to identify all spillage episodes, thereby addressing other concerns (e.g. air quality, moisture generation) and introducing a safety factor in the detection system.

CGRI also reviewed safety devices and found no existing retrofit options for conventional gas fired furnaces although various safety devices are incorporated in new, higher efficiency furnaces. All these devices are designed to shut down the equipment if insufficient venting exists. These sensors are based on pressure sensing. CGRI has been working on a temperature based spill switch that can be retrofitted to conventional gas furnaces and the results appear promising. The device is a temperature sensitive liquid which when heated expands within a sealed tube until sufficient pressure builds up to trigger a switch. Both manual and automatic resets are available. The device is also failsafe, i.e. in the event the sealed tube breaks the switch will automatically be triggered, shutting down the appliance. A follow up conversation with John Rinella of Consumers' Gas indicates that no further work has been done on this spill switch since October 1985. According to Rinella, the cost of this switch would be only a few dollars.

If the tube did fail and the furnace was shut down, (and there is no information on the lifespan of these tubes), there is concern about the freezing of the house in the event the occupants were not home. One possibility would be to integrate an over-ride switch that would turn the furnace back on at some low temperature that would, nevertheless, be above freezing. Appropriate indicators would be incorporated to alert homeowners of a spillage or backdraft occurrence while they were away. Again, as the level of sophistication increases, so does the cost.

Similar warning and safety devices have been under development by Sheltair Scientific for the past two years. These devices are also based on temperature sensing. One of these is a SNAP THERMODISC, made of a heat sensitive switch, which when is exposed to a temperature that exceeded the factory set limit would set off an audible alarm. Experience has indicated that the effectiveness of these devices is very sensitive to their placement on or near the dilution device. Work both by Sheltair and Monette of Aptech has resulted in extensive mapping of the temperature profiles in and around the dilution port. The results have produced specific locations indicating areas for optimum placement of the device to sense either a backdraft or spillage. Monette has also extrapolated this work to various furnace types and found that significant variations in placement are needed from one furnace type to another. The application of this remedial measure would require that all possible furnace types and configurations be completely documented if it is to be applied successfully by the industry.

The possibility of extending the capability of this warning device to also include a spill switch or failsafe that would shut off the furnace was investigated by Sheltair but abandoned because of the increased complexity associated with combining an alarm with a failsafe mechanism. Additional complexities of providing a low temperature over-ride would also add to the cost of this device. Failsafe devices for the DHW have also been developed. The limitations of these devices is that they have a manual reset and they also extinguish the pilot light of the DHW.

Wind Diverting Chimney Caps

Some aerodynamic testing of various chimney ventilator caps were found in literature. These tests are recorded in the two references cited previously. Reported in these two sources are test results for:

- an air foil
- a delta wing
- an air shield
- a turbine
- a chimney cowl
- open stack (no device)

The first four devices showed varying degrees of draft improvement over a chimney at higher wind speeds (10-30 mph) (4.5 - 13 m/s) with the air foil showing the largest and the turbine the smallest effect. However, their effect on down drafting wind was not tested. The chimney cowl on the other hand, was shown to effectively prevent backdrafting due to down drafting wind when it was properly sized for the flue. Cowls that were too small did not prevent downdrafting and carried spillage in calm conditions. As this device addresses specifically the problem of downdrafting winds, it should be tested in this study if the appropriate case is found.

Draft-Assisting Chamber

The draft-assisting chamber is positioned between the combustion chamber and the flue pipe of a heating appliance. The system was conceived by Michael Swinton of Scanada Consultants in December 1984, and a patent application was made in August 1985. The concept has been rigorously modelled using the "FLUESIM" computer simulation and the results are very encouraging. Exploratory field testing has been undertaken, also yielding encouraging results. This measure has been included in this review for several reasons:

1) The concept is a practical and common sense measures.

2) The chamber should be inexpensive and easy to manufacture.

3) The concept is totally passive (i.e. no moving parts).

4) The chamber can easily be adapted to existing gas appliances, including hot water heaters.

5) It has been conceived to minimize interference with the normal operation of atmospheric burners.

The objective of the testing would be to evaluate the worth of this device in preventing and/or containing and reversing spillage and backdrafting under conditions that produce these phenomena.

Optimization of the Size of the Dilution Port

Preliminary investigations through the modelling work and analysis of a limited number of field tests have suggested that decreasing the size of the dilution port may have a positive effect on the draft by allowing more of the furnace buoyancy to be diverted to the flue, thus energizing the flue instead of directly spilling the combustion products into the room. The implication is a potential reduction of the occurrence of spillage and backdrafting. The ease in modifying the size of the dilution port makes this concept a relatively simple measure to investigate.

NOTE: Preliminary testing of both the draft-assisting chamber and of the Dilution Port Reduction Option has shown that present built-in dilution devices do not have continuous walls (there are openings that lead down to the control area, and up the side of the device) so that inherent in these latter two concepts is the elimination of uncontrolled leakage sites.

3.0 SELECTION OF THE REMEDIAL MEASURES FOR DETAILED FIELD EVALUATION

The remedial measures survey discussed above identified several alternative measures which may help prevent or avoid spillage or backdrafting. Based on this survey, the following remedial measures are recommended for detailed field evaluation. In order of priority these are:

1) Warning and safety devices
2) Draft-assisting chamber and dilution port size modification
3) An in-line power venter

Although wind diverting caps do have the potential for reducing or eliminating downdrafting, this measure has not been included in this research plan because it was considered that the incidences of backdrafting or spillage directly attributable to wind effects is a minority of the cases. However, if a problem house is found in the survey that appears to be a clear cut case of downdrafting wind action, the opportunity will be seized upon and a chimney cowl will be installed.

Each of the measures selected for field evaluation has been chosen because it is anticipated that there is a high probability that sufficient data can be gathered with the limited field testing permitted in this project, to reach conclusions on its likely effectiveness and practicability. Each of the measures will be discussed in the context of the following:

a) Rationale for the measure
b) Objective of the field testing
c) Proposed field testing
d) Format for presentation of results

Warning and Safety Devices

We propose that the first priority in developing appropriate remedial measures for gas fired appliances is to fully evaluate the most promising warning and safety devices that have been developed to date. These are the THERMODISC developed by Sheltair and the spillage switch developed by CGRI. Since both sensors are relatively inexpensive, the incremental cost to evaluate two sensors in the field under identical operating conditions would be small. The results will provide comparative performance evaluations of each device.

Objectives

The device evaluation field testing will have two objectives. The first objective is to examine qualitative criteria such as cost, ease of fabrication and installation, reliability in manufacturing (quality control), and acceptability of the measure by homeowners. The last evaluation criterion will address homeowners response to a fail safe device (one that shuts off the appliance) vs. an audible alarm.

The second objective will be to assess quantitatively the technical performance of these two devices in the field. The information that will be sought in this part of the field testing will include, but not be limited to, the following:

1) Ability of sensor to consistently detect incidences of backdrafting and/or spillage.

2) The duration of spillage before sensor detection.

3) Duration of the failsafe or warning process (automatic re-set devices are assumed).
4) Verification of manufacturers' specifications (i.e. does the sensor trip appropriate switches at the temperature specified by the manufacturer).

Method

The procedure to evaluate these warning and safety devices is outlined below.

1) Select three case study houses that have been documented as having the potential to spill or backdraft.

2) Procure three thermodiscs and three spill switches.

3) Verify the thermal mapping of dilution ports documented by Aptech and Sheltair on these actual case furnaces.

4) Install one thermodisc and one spill switch at the appropriate locations.

5) Repeat the procedure several times.

For each test, temperature profiles at the location of each sensor will be monitored. (The temperature sensors used to map the profiles in the dilution port will be left in place.)

Presentation of Results

It is proposed that the results be presented in a matrix form that summarizes the comparative performance of each of the sensors in terms of the qualitative and quantitative criteria outlined in the objectives.

Summary

It is recognized that these devices will not promote positive draft, but, if successful, they will at least help determine where more expensive solutions are required. The focus of the development of warning and safety devices is based on the premise that there is a fundamental need to alert occupants to conditions that pose a potential health hazard. The option should be as inexpensive and nuisance-free as possible in order to be readily accepted by the public at large. In the event of a potential health hazard (spillage or backdrafting), the device should provide adequate warning so that homeowners can take precautionary measures. It is possible that, in the same manner that the smoke alarm is not commonplace in homes, so too will spillage alarms, patterned on these prototypes, be commonplace on gas fired appliances. The first step towards that end might be this field evaluation process.

The intent of developing reliable warning or safety sensors is to provide an appropriate safety mechanism for houses that are marginally susceptible to spillage and backdrafting but do not warrant more sophisticated remedial measures. If the sensors are installed in houses with more significant spillage and backdrafting problems, other measures will also be required but at least,

safety will have been assured. This will provide the catalyst to develop more sophisticated remedial measures.
It should also be pointed out that the development of failsafe and warning devices for gas furnaces parallels the research plan for fireplaces. It has been proposed that a family of alarms might be developed using a common housing and circuitry. Different sensors could then be installed depending on the application, for example, thermodiscs for gas furnaces or smoke based sensors for fireplaces. This seems to be a logical course upon which to follow. As a result, we plan to co-ordinate the efforts on the development of warning devices for gas furnaces with those for fireplaces.

Draft-assisting Chamber and Optimization of the Size of the Dilution Device

These measures have been given a high priority because, like the warning devices, these measures are likely inexpensive, easy to fabricate and easy to install. Modelling efforts have indicated good potential for these measures.

Objectives

The evaluation of these remedial measures has three objectives. The first is to determine whether decreases in the size of the dilution port can reduce or eliminate incidences of spillage or backdrafting.

The second objective is to assess the potential of draft-assisting chamber as a device that prevents incidences of spillage or backdrafting by containing spills and assisting the draft initiating process.

Third, since the computer modelling is the primary reference for recommending these measures, it is appropriate that these theoretical concepts be investigated in the field.

Method

These remedial measures will be evaluated on only one house that has been documented to be very susceptible to spillage or backdrafting.

The field testing will be designed to evaluate the effect of each remedial measure in reducing or eliminating spillage and/or backdrafting problems.

A test procedure is outlined below.

Dilution Port Opening

1) Monitor the temperatures in the furnace and chimney, as found, for various levels of house depressurization up to complete backdrafting for 1 minute or more. Depressurization will be achieved by a blower door to permit the measurement of exact levels of exhaust flow rate.

2) For each level of depressurization record the duration of spillage.

3) Reduce the width of the dilution port by various amounts and repeat depressurization tests, recording the temperature profiles and spillage times.

4) Repeat the tests for several incrementally larger dilution port widths.

5) Repeat the steps 1 to 4 except vary the height of the dilution port.

Draft-Assisting Chamber

A similar procedure will be adopted for the draft-assisting chamber, except in this case only one spillage chamber will be mounted and the temperature profiles and duration of spillage will be recorded for varying levels of exhaust fan flow rate. In addition we also propose to investigate the effects of optimizing the size of the dilution port opening with the draft assisting chamber.

The chamber will be instrumented with temperature sensors. In each case, sufficient data will be collected to input into the FLUESIM model for comparison with field results.

Typical data that would be collected includes:

1) Initial heat exchanger temperature.
2) Dilution air temperature.
3) Stack temperature.
4) Flue gas temperature at the end of the vent connector.
5) Flue gas temperature at the top of the chimney.

In addition it is also proposed the for both the restricted dilution port and the draft-assisting chamber, signs of adverse impact on the combustion process will be monitored. It is recommended that the house selected for this remedial measure also be included in the field evaluation of warning devices. This will reduce instrumentation installation efforts on the chimney and dilution port.

Presentation of Results

Duration of spillage vs. exhaust fan flow rate will be plotted for each dilution port size. Quantities of combustion products spilled into the room will be estimated. Temperatures will be plotted against exhaust fan flow rate for each dilution port size.

Similar results will be presented for tests performed with and without the draft-assisting chamber.

Summary

The evaluation of these two remedial measures is important for several reasons. The measures are totally passive, relying on no moving parts or electronic systems, and they should not interfere with the operation of the existing combustion process. If the results are encouraging, it will be recommended that a separate study be initiated to fully evaluate these measures in detail.

In-Line Power Venter

This measure has been chosen to address those houses that are currently experiencing recurring severe backdraft or spillage problems. Although more expensive, this measure may represent a near-failsafe solution for systems with known and severe spillage or backdrafting problems.

Objective

The objective is to evaluate the effectiveness of an In-Line power venter as a method of eliminating combustion gas spillage and backdrafting for houses that have been clearly identified as problematic.

Method

Field testing will involve the selection of a house that is experiencing frequent incidents of spillage or backdrafting. The severity of the spillage and backdraft problems will be documented using the Residential Combustion Checklist procedures.

Temperature profiles in the chimney and furnace will be plotted before and after installation of the power venter. Various levels of exhaust fan flow rate will be employed using existing house fans and fireplaces and/or blower door to verify the success of the power venter.

Presentation of Results

Results will be presented in terms of cost, ease of installation, noise and degree of success of the power venter in eliminating spillage and backdrafting problems.

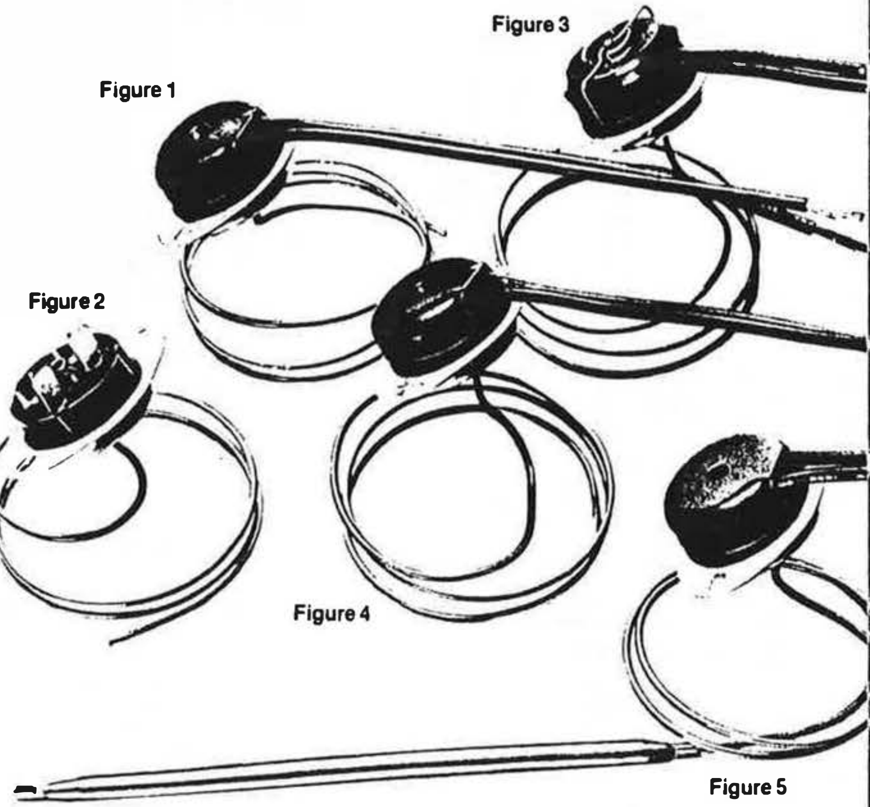
In the event of spillage, duration of spillage vs. level of depressurization will be plotted.

Temperature profiles for the furnace and flue will also be presented before and after installation.

Degree of occupancy acceptance will also be addressed.

A P P E N D I X " C "

PRODUCT LITERATURE ON THERMODISC SWITCHES



Therm-O-Disc

General Bulletin

10H SERIES CONTROLS

The 10H is a SPST linear limit thermostat that provides continuous thermal sensing along a capillary tube. Available in both automatic and manual reset construction. It employs a snap action diaphragm and is rated to carry electrical loads up to 15 amperes (resistive) at 120/277 VAC.

THERM-O-DISC, INCORPORATED
Plants in Mansfield, Ohio; Aiken, South Carolina; London, Kentucky and St. Thomas, Ontario.
A SUBSIDIARY OF EMERSON ELECTRIC CO.
EMERSON
1320 SOUTH MAIN STREET
MANSFIELD, OHIO 44907
TELEPHONE (419) 756-5911
TELEX 987455 • CABLE TODMFL

The 10H Series control was first developed for the electric baseboard heating industry to sense hot spots that may develop along the length of the heating unit. It has been used in other applications where it is necessary to sense temperatures along a continuous length.

The capillary is charged with selected fluids to give specific calibrations. These fluids expand on temperature rise causing the diaphragm to snap through at the calibration temperature and operate the electrical contacts.

Features

Impact Action: The electrical switch of the 10H is powered by a welded diaphragm which rapidly snaps through and imparts its kinetic energy to the bumper which opens the contacts. The resulting high speed contact separation ensures long contact life and a minimum of radio and television interference.

Switch Actions: Two different switch actions are available:

Automatic Reset — The standard 10H11 is built with SPST contacts which will open (cut-out) on temperature rise, and automatically reset on temperature fall.

Manual Reset — In the manual reset design (10H14) the SPST contacts will open on temperature rise. The reset function operates only when the control has cooled to a lower temperature and the reset button has been depressed.

Sensitivity: Since the entire capillary tube is charged, the 10H will respond to the hottest spot along the capillary tube or the diaphragm cup. In typical applications the capillary tube is mounted on the surface being sensed.

Flexibility: The automatic reset 10H11 is available with attached lead wires (Figure 1), or with 1/4" quick-connect terminals (Figure 2). This control — with lead wires — can be supplied with or without the terminal insulating cover which snaps over the top of the control. The manual reset 10H14 is supplied only with lead wires and the terminal cover (Figure 3).

The standard mounting bracket includes two slots .170 inches wide. An alternate "push on" bracket is available (Figure 4). For applications where the switch ambient temperature may exceed the desired calibration temperature, Cross Ambient bulbs are available (Figure 5).

Quality: In the manufacturing processes, the controls are 100% checked to the opening calibration temperatures. In addition, a statistical quality control audit of the calibration temperature and other critical variables is made prior to shipment.

The 10H Series is designed with a subatmospheric vacuum charged capillary. This means that the contacts will automatically open on loss of the fluid in the capillary.

Calibration Temperature, Differential and Tolerances:

The 10H Series can be calibrated to open (cut-out) on temperature rise between 150°F and 350°F. The standard manufacturing tolerance on the open calibration is ±15°F. The 10H11 will automatically reset approximately 40°F below its opening temperature.

Please consult the factory for special temperatures, manufacturing tolerances, differentials and electrical ratings.

Typical Electrical ratings

10H11: 100,000 cycles, 350°F Max. Temp.
10H14: 6,000 cycles, 350°F Max. Temp.

TYPE	RESISTIVE AMPERES	INDUCTIVE AMPERES FLA	INDUCTIVE AMPERES LRA	VOLTS AC	RECOGNIZED BY*
10H11	15	10	60	120	UL & CSA
	15	5	30	240	UL & CSA
	15	4.8	28.8	277	UL & CSA
	10	—	—	600	CSA ONLY
10H14	25	5	30	240	UL & CSA
	25	4.8	28.8	277	UL & CSA
	10	—	—	600	CSA ONLY

*UL File MH-5304, Guide No. MBPRZ.
CSA File LR-37242 and LR-19988.

Samples and Quotations

Here is a check list of the facts we need to supply samples and quotations. After you have indicated your requirements, please mail this form, or a copy, to Therm-O-Disc, Inc., P.O. Box 3538, Mansfield, Ohio 44907. Or, if you wish, you may telephone the information to us at 419/756-5911.

1. *Electrical Load:*
   a. Resistive ☐ Inductive ☐.
   b. Amperes _____ Voltage _____ VAC.
2. *Calibration:*
   a. Open ______________ °F.
   b. ☐ Standard differential (approximately 40°F).
   c. ☐ Manual Reset (Supplied only with attached lead wires and terminal insulator cover).
3. *Capillary Length:*
   a. ☐ Standard - 24″ measured from mounting flange.
   b. ☐ Other - Specify length ________″.
4. *Terminations:*
   a. ☐ Standard - Two 6-1/2″ leads, #14 AWG, 105°C, 1/32″ - thick black PVC insulation stripped 1/2″.
   b. ☐ Non-standard lead wire - specify
   ____
   ____
   c. ☐ .032 x .250 brass terminals (Not available on Manual Reset).
   d. ☐ Snap-on terminal insulator cover. (Available only when control is furnished with attached lead wires.)
5. *Mounting Bracket:*
   a. ☐ Standard - .170″ slots per Drawing 1.
   b. ☐ "Push on" mounting bracket per Drawing 3.
6. *Life Requirement:*
   a. ______________ cycles.
7. *Maximum Temperature Exposure:*
   a. Capillary tube ____________ °F.
   b. Switch body ____________ °F.
8. *Estimated Annual Quantity Requirements:*
   a. ____________ per year.
   b. ____________ ordered at one time.
9. *Appliance or Application:*
   Please describe the function of the control in your application and the type of units you manufacture.
   ____
   ____
   ____
   ____
   ____

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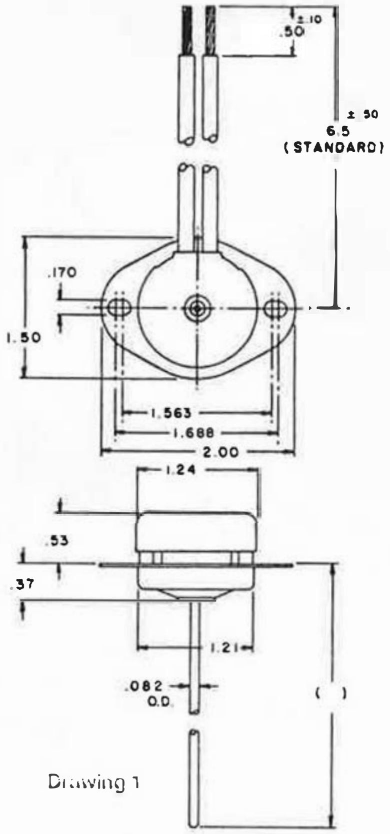
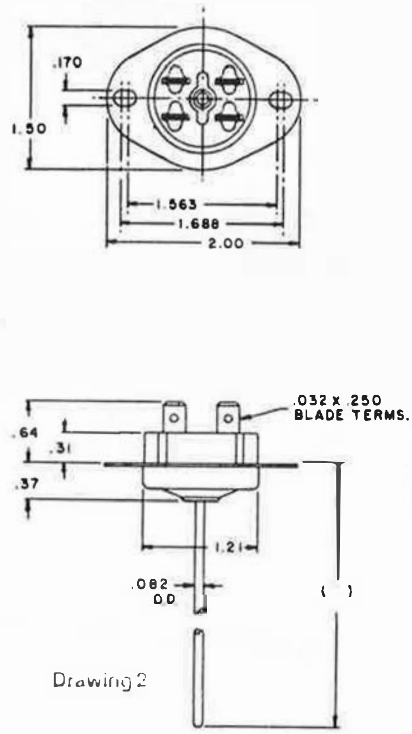
Printed in U.S.A.

10H11
WITH WIRE LEADS AND TERMINAL COVER



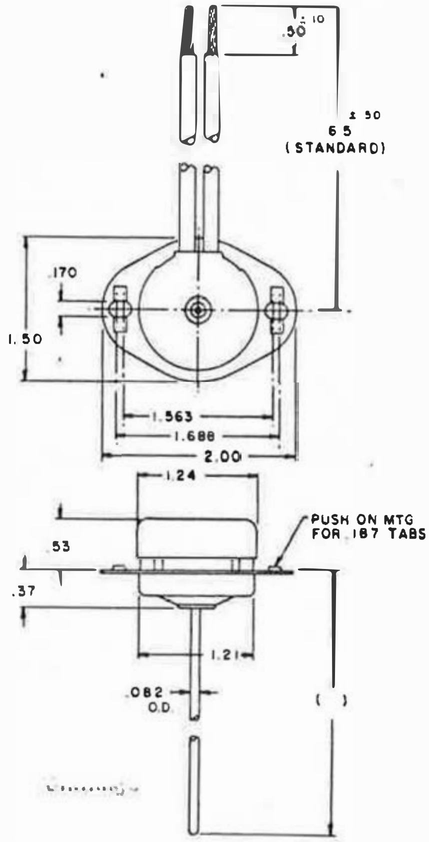
Drawing 1

10H11
WITH 90° BLD. TERMINALS

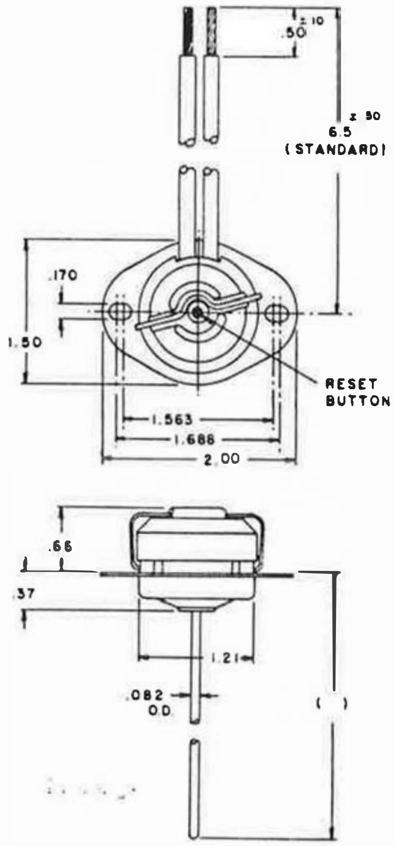


Drawing 2

10H11
WITH WIRE LEADS, TERMINAL COVER, AND PUSH ON MTG. BKT.



10H14
WITH WIRE LEADS AND TERMINAL COVER



APPENDIX "D"

PRODUCT LITERATURE ON FIELD CONTROLS POWER VENTERS

A P P E N D I X " E "

DURATION OF SPILLAGE AND DEPRESSURIZATION DATA

TABLE C.1: SUMMARY OF SPILLAGE RESULTS:REMEDIAL MEASURES:SERIES 1 TEST:MARCH 27/28, 1986

	AS FOUND						DRAFT ASSISTING CHAMBER								DRAFT INDUCER		
	TEST 1			TEST 2			TEST 1				TEST 2				TEST 1		
DEPRESSURIZATION Pa	CHIMNEY BOTTOM SEC	DILUTION OPENING SEC	VISUAL SEC	CHIMNEY BOTTOM SEC	DILUTION OPENING SEC	VISUAL SEC	CHIMNEY BOTTOM SEC	DILUTION OPENING SEC	D.A.C OPENING SEC	VISUAL SEC	CHIMNEY BOTTOM SEC	DILUTION OPENING SEC	D.A.C OPENING SEC	VISUAL SEC	CHIMNEY BOTTOM SEC	DILUTION OPENING SEC	VISUAL SEC
0	2	2	1	0	0	1									0	2	1
2.5	0	2	2	2	4	4											
5	0	6	4	2	5	4.4	2	6	0	2							
6				2	6	7.7	0	8	0	5.5	0	6	0	5.4	0	2	2
7.5	6	12	8.5	NR	NR	NR	4	10	0	6	2	9	0	8			
9.5							NR	NR	NR	NR	NR	NR	NR	NR			
10	NR	NR	NR												0	5	4.4
15															0	10	10
20															0	46	46

*NR-NO RECOVERY AFTER 3 MINUTES OF BACKDRAFTING

TABLE C.2: SUMMARY OF SPILLAGE RESULTS:REMEDIAL MEASURES:SERIES 2 TEST:APRIL 14/15, 1986

	AS FOUND			DRAFT ASSISTING CHAMBER			
	TEST 1			TEST 1			
DEPRESSURIZATION Pa	CHIMNEY BOTTOM SEC	DILUTION OPENING SEC	VISUAL SEC	CHIMNEY BOTTOM SEC	DILUTION OPENING SEC	D.A.C OPENING SEC	VISUAL SEC
0	2	8	9				
5				2	10	0	10
6.5	2	11	15	2	6	0	14
7.5	NR	NR	NR	9	19	0	13
8				23	36	0	34
8.5				NR	NR	NR	NR

*NR-NO RECOVERY AFTER 3 MINUTES OF BACKDRAFTING