Residential Combustion Venting Failure - A Systems Approach

Project 1, Phase 2

Canada-wide Survey Results

RESIDENTIAL COMBUSTION VENTING FAILURE

A SYSTEMS APPROACH

FINAL TECHNICAL REPORT

PROJECT 1, PHASE 2:

COUNTRY-WIDE SURVEY RESULTS

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STATEMENT OF PART V FUNDS

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

This 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.

Under Part V of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has a statutory responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

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SUMMARY

A Canada-wide survey was undertaken as part of a CMHC funded project on Residential Combustion Venting Failures - A Systems Approach. The objective of the survey was to identify specific houses across Canada that are currently experiencing significant spillage of combustion gases (spillage houses), and thereby make possible follow-up field studies to validate checklists, computer models, risk assessments, and remedial measures. It was also hoped that by monitoring spillage incidents in a large and representative housing sample, definite conclusions could be reached about the frequency of spillage occurrences.

Heat-sensitive dot detectors were used on gas- and oil-fired appliances, to provide permanent evidence of a prolonged or unusual spillage event. The dot detectors turned from white to black when exposed to hot spillage gases. Carbon monoxide and smoke detectors were mounted on the mantles above the fireplaces to record the frequency and duration of spillage from wood fires in houses.

In order to achieve a sample of houses and a range of climatic zones representative of all of Canada, the Canada-wide survey was conducted in five (5) regions: British Columbia, Manitoba, Southern Ontario, Eastern Ontario and Quebec, and Prince Edward Island. Detectors were installed in 937 houses by temporary employees knocking randomly on doors, or by contractors visiting houses for other purposes. After a two- to three-month monitoring period all householders were contacted by regional telephone interviewers. In this way questionnaires were successfully completed on 808 of the survey houses. Data was collected on the detector performance, and on house characteristics such as house style, age, appliance types, chimney types, maintenance history, and exhaust fan type.

Experts visited a portion of the survey houses to check on the accuracy of householder responses, and it was concluded that the householders' interpretation were reliable.

In total, 10 percent of the gas-heated houses had black dots on their detectors which indicated prolonged or unusual amounts of combustion gas spillage had occurred on at least one occasion over the monitoring period. Another 65 percent of the gas-heated survey houses had experienced short-term start-up spillage (or prolonged spillages of smaller quantities of combustion gas). Only a quarter (25 percent) of the houses surveyed had experienced no combustion gas spillage.

Of the 217 houses with oil furnace detectors, approximately one-half (55 percent) were found to experience significant combustion gas spillage. These spillage houses may be experiencing 10 or 15 seconds or more of hot start-up spillage, or prolonged and continuous spillage during appliance operation. Another one-third of the oil houses experienced very slight spillage. Only 15 percent of the oil-heated houses had experienced no spillage event over the monitoring period.

Specific features of the gas-heated houses which appeared to correlate with prolonged combustion gas spillage included the following:

- *Houses located in Winnipeg - the coldest region in the survey;*
- *Pre-1945 construction and post-1975 construction;*
- *One-storey houses;*
- *Chimneys on exterior walls, and masonry chimneys with metal liners;*
- *Houses with three (3) or more exhaust fans;*
- *Houses with two (2) open brick fireplaces; and*
- *Appliances that had not been serviced within the last year.*

Characteristics of oil-heated houses that appeared to correlate with combustion gas spillage were similar to the gas-heated houses, although the data was less conclusive. Only in the case of exterior chimneys, and masonry chimneys, was a strong trend apparent towards a higher proportion of spillage incidents.

Spillage incidents in wood-burning fireplaces were monitored over a shorter monitoring period. Spillage events recorded by the CO and smoke detectors ranged from 2 to 17. All houses experienced some spillage with an average of 1.25 spillage events per fire. Each event averaged 30 seconds in duration.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

The Canada Wide Survey involved the installation of spillage detectors in approximately 1,000 relatively randomly chosen houses in five regions of Canada. The detectors were designed to record the occurrence of combustion gas spillage from vented heating appliances.

The Detectors were developed for gas- and oil-fired furnaces and water heaters, using heat sensitive dots to indicate prolonged combustion gas spillage. The dots on these detectors would change permanently, from white to black, when their temperature is exceeded. More information on the detector design is available in a separate report on the Design and Evaluation of Spillage Monitoring Devices. (For an overview of other reports and research work completed as part of this research project, refer to Appendix E.

Detectors were also developed for use with fireplaces in the survey houses using carbon monoxide and smoke detectors connected to event counters and time totalizers. Due to the high material costs, only 5 houses were selected for fireplace spillage monitoring.

The detectors were installed in January and February of 1986, and remained in the houses throughout the remainder of the 1985-86 heating season. In May, 1986; householders were called and a detailed questionnaire was completed by means of a telephone interview. Householders were asked to inspect the spillage detectors and report on their performance. Information on the house and its operation was also collected. Data from these questionnaires has been summarized, and the results are presented in this report.

The primary objective of the Canada Wide Survey was to provide researchers and policy-makers with reliable information on the frequency and severity of combustion gas spillage events in Canada housing. It was also hoped, that by collecting detailed information on the characteristics of houses, a profile could be developed of those houses in Canada most likely to experience problems.

2.0 SURVEY PROCEDURES AND SUCCESS RATES

2.1 Selection of Houses:

In order to achieve a sample of houses and climatic zones representative of all of Canada, the Canada-wide survey was conducted on five (5) regions:

British Columbia	(Houses 1000 to 1200)
Winnipeg, Manitoba	(Houses 2000 to 2200)
Toronto, Ontario	(Houses 3000 to 3200)
Ottawa, Ontario and Hull, Quebec	(Houses 4000 to 4200)
Prince Edward Island	(Houses 5000 to 5200)

In each of the five regions, different approaches were used to locate householders and houses for participation in the study. In British Columbia a variety of different types of installers were employed including, temporary employees, an oil-furnace servicemen, two gas-furnace servicing companies, a plumbing contractor, a ventilation contractor (Terrace), and an insulation contractor (Invermere). The use of employees was found necessary in order to get detectors installed in the lower income, less well maintained houses that are hard to access in any other way. The use of contractors in the far north and in the Rockies was felt to be the only way to get detectors installed in the more remote and colder communities in B.C. The majority of B.C. Survey houses were gas-heated, although 40 oil-heated houses were also included in the sample.

In Manitoba the approach followed was to hire a number of temporary employees who then distributed detectors in eight different districts of Winnipeg with different house ages. In Ottawa and in Toronto the approach used was to work closely with heating contractors who installed the detectors as part of normal visits to houses. Reportedly these contractors found the guidelines easy to follow and the detectors easy to install. The only difficulty in using the heating contractors was delays encountered in return of the forms. All of the houses in these three regions were gas-heated, with the exception of five oil-heated houses in rural Quebec (near Ottawa).

In P.E.I. the approach was to use ex-energy auditors who canvassed houses in their neighborhoods and in communities near Charlottetown. All of these P.E.I. houses are oil-heated. In addition, fifteen (15) gas water heater detectors were installed by the local propane fuel distributor, on propane-fired water heaters.

In retrospect, it would appear that the most effective strategy for installing detectors was to hire temporary employees for this purpose. This can be done at less cost than using local contractors for visiting houses, and accomplishes the installation in a much shorter time period. It is also possible, when using temporary employees, to ensure more even distribution of installations and to obtain access into houses that are not normally visited by contractors - especially the lower income homes.

The installation efficiency of a temporary employee appears to range from a minimum of three detectors per hour, to a maximum of eight, depending on the neighborhood and the credibility of the installer.

Heating contractors, on the other hand, seem to lose interest in the detectors after several days, or worse still, lose the detectors. In some cases the contractors were difficult to reach for updates, and for picking up the forms. Contractors were paid a $10 stipend for each installation report. It is doubtful that an increase in the stipend would have improved contractor performance, since it was already generous.

The installation forms were designed to be as simple as possible, to expedite the installation procedure, and to avoid creating resistance from contractors who might wish to participate in the installation. While this was in general a good strategy, it overlooked the importance of determining whether some of the dots were changing immediately upon installation. A better approach may have been to ask all installers to operate the appliance immediately after installation, and then examine the detectors. This would have allowed researchers to differentiate between houses suffering from continuous spillage - due to a blocked flue, for example, - and houses where spillage is due to occasional interaction of chimneys with weather forces or house systems.

A variety of unusual circumstances and unusual appliances caused problems for installers during the installation period. Some old varieties of gas furnaces, for example, have a front cover which must be removed before the overflow vestibule can be accessed. Installing a detector behind the cover is difficult because of limited space, and is likely to cause further difficulties when it comes time for the householder to read the detector. For these reasons a decision was made to discourage installers from trying to apply detectors on non-standard appliances.

2.2 Installation Success and Information Retrieval

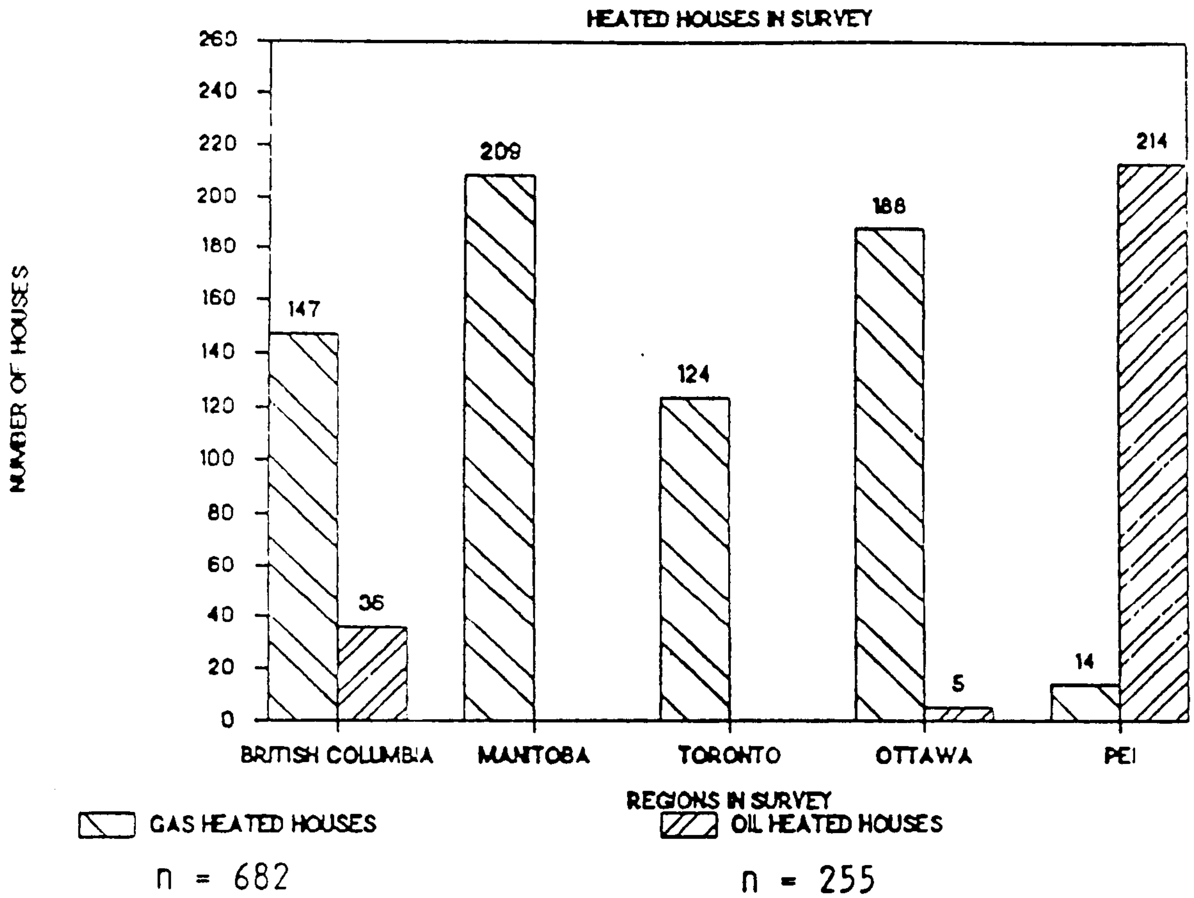
The number of houses with completed detector installation reports amounted to 937. The objective had been 1,050 houses. To compensate for loss of detectors, and improper installations, 1,150 detector sets had been fabricated and sent to regions for installation. This number assumed a success rate of at least 90%. The actual success rate was slightly less than expected, for a number of reasons, including:

- detectors lost by participating contractors;
- detectors destroy by installers (e.g. high heat on dashboard of vehicle);
- incorrectly completed installation report forms;
- poorly-motivated contractors who quickly lost interest in installing detectors;
- insufficient time remaining in the heating season for installing detectors returned by contractors.

An effort was made by each regional supervisor to telephone all houses in which detectors had been installed and on which a detector installation report had been completed. The regional supervisors and telephone interviewers were thoroughly briefed in the project design, and were provided with examples of detectors with white and black dots.

The telephone interviewers were successful in completing questionnaires on 808 of the 937 eligible houses, for a success rate of 86%. Failures to complete questionnaires on some houses were a result of:

- language problems;
- partially crippled householders unable to go to the basement;
- householders who denied that the detectors were installed;
- householders unwilling to take time away from T.V. watching;
- householders who had moved or who were travelling;
- householders unable to find the detectors;
- children removing the detector;
- detector melted or fell off (due to high heat);
- placement of the heating appliance;
- detector painted over.



GRAPH 1: Regional Distribution of Oil and Gas

The detector installation and telephone survey success rates in each region is presented in Table 1. The regional distribution of oil and gas (or propane) heated houses in the survey is presented in Graph 1.

Four separate questionnaires were developed, one for each of the following situations:

- houses with the detector on a natural gas furnace;
- houses with the detector on a natural gas furnace and hot water heater;
- houses with a detector on a natural gas water heater;
- houses with a detector on an oil-fired furnace or boiler.

The questionnaires were pretested in Vancouver, and were carefully worded to avoid ambiguity in response. A list of all possible responses from the questionnaire is presented in Table 2. A sample questionnaire is provided in Appendix A, including reference sheets used by interviewers to respond to questions about detectors.

The occupants of houses in which detectors indicated a significant combustion spillage event had occurred, were sent letters of explanation. Copies of these letters, and other correspondence with householders, are presented in Appendix B.

Telephone interviewers were requested to write comments on responses that did not fit the questionnaire format, or that required explanation. A survey of these comments is provided in Appendix C.

Time required to complete the telephone questionnaires averaged about 12 minutes per house, or about twice the time estimated for this task. Some of the factors which contributed to the survey taking longer than predicted were:

- a high percentage of long distance call with poor connections (especially in British Columbia and Prince Edward Island);
- a large number of call-backs required to find people home (in some cases four or five);
- a large number of elderly people involved in the survey, who naturally took their time in going downstairs (or outdoors and into the storm cellar);
- the detailed explanations given to householders to encourage accurate descriptions of detector for furnace;
- extra questions on house characteristics added to the questionnaire at the request of the project advisory committee;
- requests by householders for an explanation of why their detector showed black dots.

TABLE 1 - SURVEY SUCCESS RATE

Region	No. of Houses with Detectors (max.=230/region) (objective 210/region)	Installation Success Rate (%)	No. of Completed Questionnaires	Phone Success Rate (%)
B.C.	183	87	169	92
Winnipeg	209	100	187	89
Ottawa	193	92	184	95
P.E.I.	228	109	188	82
Toronto	124	59	80	65
Overall	937	89	808	86

2.3 Householder Reliability

The survey design required householder to examine the dot detectors and communicate their findings by telephone. This approach permitted the inclusion of a large sample size while minimizing labour costs. However, the involvement of householders in the survey increased the risk of inaccurate data, especially if householders experienced difficulty interpreting the dot detectors. To investigate the reliability of householder responses, two surveys were conducted by trained technicians. The technicians visited survey houses, shortly after the householder had telephoned, and examined the dot detectors to corroborate the householder's interpretation.

The first survey involved 21 Case Study houses, where householders had reported 4 or 5 black dots on at least one detector. In 2 of these 21 houses, householders had incorrectly reported 5 black dots when in fact the detectors had 5 white dots. This break down in communications could not be explained. In retrospect, it may have been worth including one black "reference" dot on each detector in addition to the white dots.

As a result of this first survey, a more expensive survey was undertaken to assess the reliability of householder interpretations. Twenty houses in each region were telephoned, and then re-visited in July, 1986. A comparison of householder and expert interpretations on all of these 100 houses is presented in Appendix C.

This second survey showed no major problem or inaccuracies with the householders' interpretations, and confirmed the accuracy of the data. Discrepancies occurred only in the interpretation of 38°C dots, which, unlike the higher-temperature dots, do not turn jet black, but rather turn a shade of gun-metal grey. Possibly because the questionnaire was worded cautiously, 3 of the 100 householders interpreted a 38°C dot as which when the expert called grey. No other problems were encountered with householder interpretations. Most importantly, all of the 54°C, 71°C, and 121°C dots were correctly identified, and the survey data is assumed to be reliable.

2.4 Fireplace Detector Installations

A survey of fireplace spillage incidence was intended to take place simultaneously with the survey of furnace and water heaters spillage. However, technical difficulties encountered with the development of fireplace spillage monitoring devices caused the installation of fireplace detectors in participating houses to be delayed. The fireplace spillage detectors consisted of a retrofitted ionization smoke alarm and a carbon monoxide detector, wired together, and fitted with an additional circuit board and two mechanical pulse counters. The counters record both the number of spillage incidents, and the total time of spillage. Mechanical counters were used since they do not lose count in the event of a power failure. The detector was turned off and on by the householder so as not to count spillage during loading and start-up.

Budget constraints allowed for only five fireplace detectors to be manufactured. Because the detectors required installation by a trained individual, it was decided to further reduce time delays and costs be installing the five entirely in the B.C. region. Installation forms collected from the 200 B.C. survey houses were reviewed, and a total of 25 were identified where the householder claimed to be operating their fireplaces three or more times per week. These houses were surveyed by phone, and agreement was obtained from five of the householders to allow for installation of a fireplace spillage detector on their mantle for a period of one month. The detectors were installed with the alarms turned off, so as not to affect the behaviour of the householders.

TABLE 2
LIST OF POSSIBLE ANSWERS TO THE HOUSEHOLDER QUESTIONNAIRE

Question 3 - Detector Performance

5 no black dots on furnace
6 38°C black dot on furnace
7 second 38°C black dot on furnace
8 54°C black dot on furnace
9 71°C black dot on furnace
10 121°C black dot on furnace
11 no black dots on hot water heater
12 38°C black dot on hot water heater
13 second 38°C black dot on hot water heater
14 54°C black dot on hot water heater
15 71°C black dot on hot water heater
16 121°C black dot on hot water heater

Question 4 - Detector Response Time

17 occupant noticed dots turn immediately
18 occupant noticed dots turn same day
19 occupant noticed dots turn within several days
20 occupant noticed dots turn within several weeks
21 occupant did not notice dots turn

Question 5 - Foundation Type

22 full basement
23 partial basement
24 crawlspace
25 slab-on-grade

Question 6 - House Style

26 one storey
27 one-and-a-half storey
28 two storey
29 two-and-a-half storey

Question 7 - Date of House Construction

30 pre-1900
31 1900-1945
32 1945-1960
33 1960-1975
34 post-1975

Question 8 - Furnace Location

35 furnace located in open basement
36 furnace located in furnace room in basement
37 furnace located on main floor
38 furnace located outdoors

Question 9 - Chimney Location

39 exterior chimney
40 interior chimney

Question 10 - DHW Heater Flue Connection

41 water heater shares the same chimney with furnace
42 water heater does not share the same chimney with furnace

Question 11 - Chimney Materials

43 outdoor portion of chimney made of brick
44 outdoor portion of chimney made of metal
45 outdoor portion of chimney made of brick and metal

Question 12 - Furnace Age

46 furnace is less than 5 years old
47 furnace is 5 to 10 years old
48 furnace is 10 to 20 years old
49 furnace is more than 20 years old

Question 13 - DHW Heater Age

50 hot water heater is less than 5 years old
51 hot water heater is 5 to 10 years old
52 hot water heater is 10 to 20 years old
53 hot water heater is more than 20 years old

Question 14 - Fuel Conversion

54 house has been converted from oil to gas
55 house has not been converted from oil to gas
56 occupant does not know if house has been converted from oil to gas

Question 15 - Maintenance History

57 furnace has been serviced within the last year
58 furnace has been serviced within the last 1 to 2 years
59 occupant does not know when furnace was last serviced
60 furnace has been serviced within last 2 to 3 years
61 it has been over 3 years since furnace was last serviced

Question 16 - Fireplace Type

62 open brick fireplace
63 second fireplace is open brick
64 brick fireplace with doors
65 second fireplace is brick with doors
66 open metal fireplace
67 metal fireplace with doors
68 wood stove
69 airtight insert

Question 17 - Fireplace Spillage History

70 mantle tends to stain when fireplace is used regularly
71 mantle sometimes stains when fireplace is used regularly
72 mantle does not stain when fireplace is used regularly
73 fireplace is seldom used

Question 18 - Exhaust Fan Type

74 no kitchen range hood fan
75 one kitchen range hood fan
76 two kitchen range hood fans
77 no bathroom fans
78 one bathroom fan
79 two bathroom fans
80 three bathroom fans
81 no stove-top barbecue fan
82 one stove-top barbecue fan
83 two stove-top barbecue fans
84 one clothes dryer vented to outdoors
85 clothes dryer is not vented outdoors
86 no other exhaust fans
87 one other fan
88 two other fans

NOTE:

Additional information had been collected on the survey houses during the installation of detectors, including types of appliances, flue dampers, and frequency of fireplace use.

3.0 RESULTS

3.1 Spillage Incidents Recorded by Detectors

3.1.1 Gas-Heated Houses

A summary of the spillage detector results for gas-heated houses is presented in Table 3. Interpretation of the detector results requires some familiarity with the spillage detector design and evaluation described in a companion report, titled Development and Evaluation of Spillage Monitoring Devices, (Ref. 1). For convenience, a brief guide has been presented in Figure 1 to assist in interpretation of the black dot spillage detectors for gas-fired appliances.

From Table 3, it is evident that 2.2% of the surveyed houses had dot temperatures exceeding 121°C, indicating a major failure from a hot appliance. Another 3.5% of the sample exceeded dot temperatures of 71°C, indicating a definite venting failure on at least one occasion from a hot appliance. Another 4.3% of the Survey houses exceeded the 54°C dot temperature, indicating an excessive amount of combustion gas spillage on at least one occasion, or continuous major spillage from cooler operating appliances. In total, 10% of the gas-heated housing had experienced excessive amounts of combustion gas spillage. These houses are referred to as spillage problem houses.

Fifty per cent of the surveyed houses experienced dot temperatures in excess of 38°C, but less than 54°C. The vast majority of these 38°C dot houses are probably experiencing start-up spillage in excess of 15 seconds on the furnace or water heater. This type of spillage is clearly a normal event for gas-fired appliances, and cannot be described as a spillage problem. Some portion of these houses are likely experiencing prolonged or continuous spillage of small quantities of combustion gas, and may be considered problem houses.

FIGURE 1: Interpretation of Black Dot Spillage Detectors for Gas-Fired Appliances

1. A 38°C DOT ON THE HOT SIDE, 13 mm BELOW TOP OF INLET

   This is the most sensitive dot available and is designed to detect SHORT TERM, START-UP SPILLS of about 15 seconds, or marginal spillage for prolonged periods. The dot is glued face down to the hot side of the detector so that the dot colour can be observed through the clear lexan plastic. The temperature buffer (i.e. insulating effect of air film and plastic) for this location is relatively insignificant, and results in dot temperatures about 98.7% of gas temperature (°K). The time delay is also insignificant. The detector is located so as to catch the slightest spills at the upper lip.

2. A 38°C DOT ON THE COLD SIDE, 30 mm BELOW TOP OF INLET

   This dot is designed to detect start-up spillage and/or possible failures. Cold weather backdrafting, or spills of approximately 15 to 60 seconds will be detected. The dots will typically have a temperature buffer that produces dot surface temperatures equivalent to two-thirds 95% of spillage gas temperatures (°K), and a time buffer of at least 15 seconds. An additional time delay of 20 or 30 seconds may exist if the furnace itself is still warming up. Colour change of this dot can indicate start-up against a temporary cold backdraft of one or two minutes duration, or prolonged start-up spillage.

3. A 54°C DOT ON THE COLD SIDE, 30 mm BELOW TOP OF INLET

   This dot is indicative of a PROBABLE FAILURE. A 54°C dot temperature translates to combustion gas temperature of 84°C, which occur after at least one minute of continuous backdraft or blockage, under most operating conditions.

4. A 71°C DOT ON THE COLD SIDE, 42 mm BELOW TOP OF INLET

   This dot indicates a DEFINITE FAILURE, in which the furnace has likely experienced a backdraft for at least one full cycle, or a major spillage incident due to blockage or other factors. Some cooler furnaces, however, may never cause a 71°C DOT to change, despite continuous spillage or long term backdrafting episodes.

5. A 121°C DOT ON THE COLD SIDE, 42 mm BELOW TOP OF INLET

   This "hot" dot translates to gas temperatures of approximately 190°C, which represent the upper range of temperatures recorded from spillage gases during field testing. A 121°C DOT, therefore, indicates furnaces with MAJOR FAILURES, due to large or frequent quantities of very hot spillage gases around the detector.

TABLE 3

SPILLAGE INCIDENTS IN GAS* HEATED HOUSES

Maximum Dot Temperature (°C) Exceeded on at Least One Detector	Number of Houses: Houses with DHW and Furnace Detectors	Houses with Only a Furnace Detector	Houses with Only a DHW Detector	Total	(%)
121	6	7	0	13	(2.2)
71	17	3	1	21	(3.5)
54	18	7	1	26	(4.3)
38 (cold side)	230	65	10	305	(50)
38 (hot side)	42	26	26	94	(15.5)
<38 (no black dots)	94	44	9	147	(24.3)
TOTAL	407	152	47	606	(100)

* GAS includes natural gas and propane fuels.

TABLE 4

RESULTS FOR GAS-HEATED HOUSES WITH BOTH A FURNACE AND DHW HEATER DETECTOR

Dot Temperature (°C) Exceeded on Each Appliance		Number of Houses in Each Category: Furnace Detector Dots (121)	(71)	(54)	(38)	(38)	No Dots Changed
DHW	(121)	2	1	0	1	1	0
DETECTOR	(71)	0	4	3	3	1	0
DOTS	(54)	0	1	3	2	1	2
	(38)	0	1	6	123	12	22
	(38)	0	2	0	32	16	9
No Dots Changed		1	2	4	41	17	94

NOTE: Houses in boxed area are considered problem houses because at least one appliance has a problem which caused a 54°C dot colour change.

At this point, however, no investigations have been conducted on houses with 38°C dot temperatures, and it is difficult to distinguish the start-up spillage phenomenon from more serious (continuous) spillage. A further 15.5% of the houses surveyed experienced very slight spillage, sufficient to exceed the 38°C dot temperature on the hot side of the detector. Since this dot temperature can be exceeded by even five seconds of spillage from a gas-fired appliance, these houses are almost certainly houses where chimneys are spilling slightly at start-up periods only.

Approximately 24% of the housing surveyed indicated dot temperatures less than 38°C, and it is likely that this portion of the housing surveyed is experiencing no combustion gas spillage through the dilution air inlets.

Table 4 presents results for gas-heated houses with both furnace and a DHW heater detector. This table makes possible a comparison of the furnace and water heater detector results in the same house. For example, the table indicates that in two houses both the furnace detector and the water heater experienced dot temperatures exceeding 121°C. The most common situation, is for both the furnace and water heater to have dot temperatures in the range of 38°C (123 of 407 houses - or 30% of the total houses). The table indicates a fairly even distribution of problem houses, with no strong tendency for houses with one problem appliance to experience problems with the other appliance.

3.1.2 Oil-Heated Houses

The spillage incidents in oil-heated houses are summarized in Table 5, which lists the number of houses falling in different ranges of dot detection temperatures. Of 217 oil furnace detectors, 11 (or 5.1%) of the Survey houses experienced dot temperatures in excess of 121°C. It is highly likely that this portion of the surveyed houses is experiencing some amount of spillage through leaks and other holes in the flue connector, since such high temperatures on a barometric damper are unlikely unless the flue is pressurized and spilling for relatively long periods. Another 49 houses, or 22.6% of the survey, experienced dot temperatures between 71°C and 121°C; and 50 houses experienced dot temperatures in the range of 54° to 71°C. These results indicate that approximately half (55%) of the oil-heated houses are experiencing combustion gas spillage. Because oil furnace detectors have a faster response time than the gas appliance detectors, some of these events may have involved start-up spillage of hot gases for durations of only 10 or 15 seconds. This is one reason why the survey results indicate such high frequency of spillage from oil-fired appliances, in comparison with gas. The detector used for gas appliances was designed to better differentiate between start-up spillage and prolonged spillage.

Another one-third (1/3) of the oil-heated houses experienced very slight spillage conditions - sufficient to exceed the 38°C dot temperature. Only 15% of the houses experienced *no* spillage events over the monitoring period.

Field investigations of survey houses with spillage problems, during the case study follow-up, have shown that, in some cases, the dots on the oil furnace detector may indicate high temperatures and turn black as a result of malfunctioning barometric dampers. Dampers that are stuck closed and in close contact with the flue pipe, may sometimes reach high temperatures despite the absence of spillage gases. Two out of seven oil-heated problem houses that were investigated during the survey follow-up phase were found to have malfunctioning dampers, and no apparent cause of spillage. The extent of this "stuck-damper" problem cannot be determined without more investigation, but it cannot in itself explain the high frequency of spillage events with oil furnaces.

It would have been preferable to ensure that barometric dampers were properly balanced and lubricated prior to installation of the spillage detector. The dot detectors could also have incorporated a more lengthy time delay, perhaps by mounting dots with a foam tape for insulation. Alternatively, the survey could have been conducted using superior technology, such as smoke detectors connected to counters, and hung above the barometric damper. [Use of smoke detectors was evaluated prior to execution of the survey, (Ref. 1), but rejected due to the higher cost components.]

TABLE 5

SPILLAGE INCIDENTS* IN OIL-HEATED HOUSES

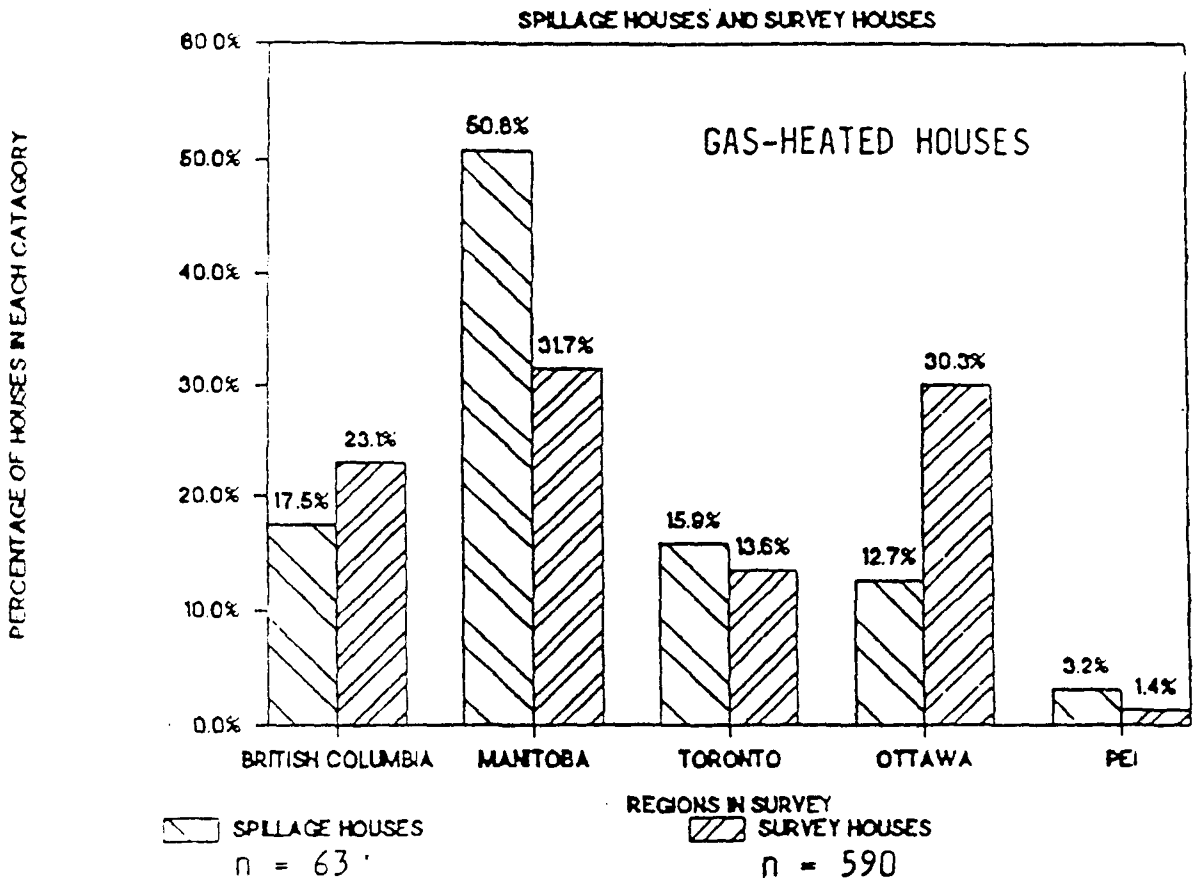
Maximum Dot Temperature (°C) Exceeded	Number of Houses	(%)
121	11	(5.1)
71	49	(22.6)
54	50	(23.0)
38	74	(34.0)
<38 (no black dots)	33	(15.2)
Total	217	(100)

* An unknown portion of these "spillage incidents' may involve malfunctioning barometric dampers, and NOT combustion gas spillage.

3.2 Characteristics of the Housing Sample in Comparison with the Spillage Problem Houses

The large number of factors that can influence combustion gas spillage in houses discriminates against strong correlations between particular house characteristics and spillage problems. Combinations of factors may produce stronger correlation in the data but require an even larger sample size than what was permitted in this survey.

Because of the large number of variables involved in spillage events, small changes in the proportion of spillage houses in any particular characteristics can be indicative of trends that are worth noting. To permit easy recognition of such trends, the data has been presented graphically, and spillage house distributions have been presented side-by-side with the total sample.



GRAPH 2: Distribution of Houses by Region

Householder responses were sometimes not obtained for particular questions during the telephone survey. For this reason, the total sample size under consideration for any particular house characteristics may vary slightly from graph to graph. The sample numbers (n) of survey houses and spillage houses included for each analysis have been noted in the legend on each graph.

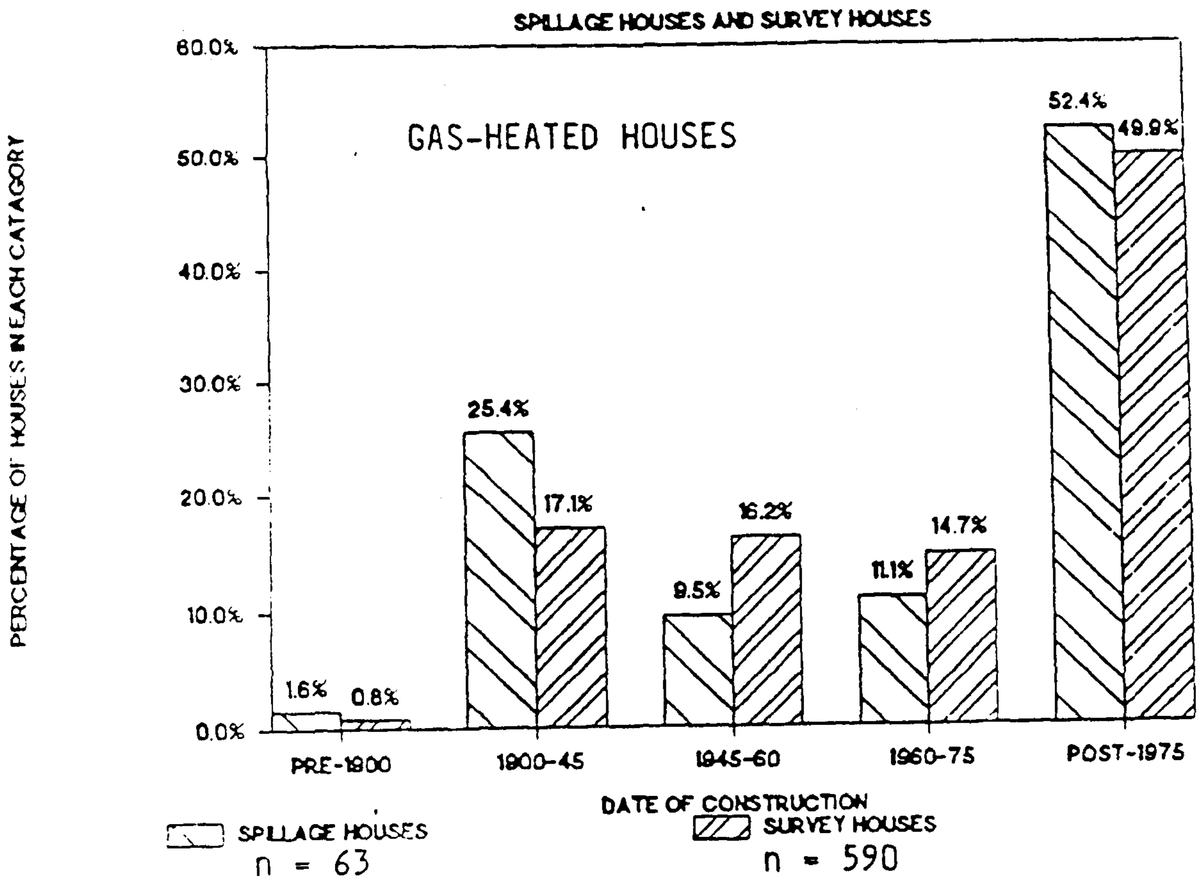
3.2.1 Gas-Heated House Characteristics

Variations Between Regions

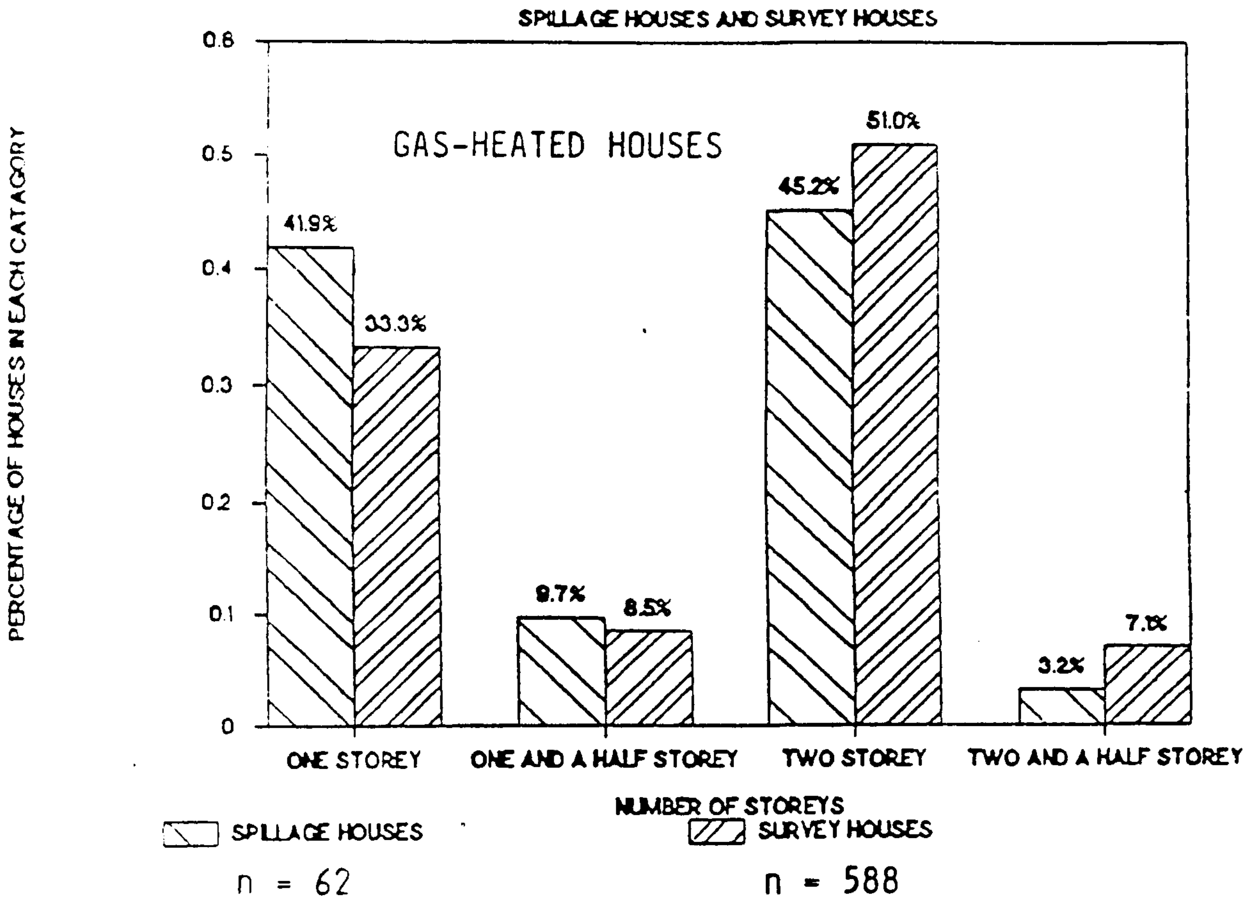
Graph 2 presents distribution of gas-heated house by region. A disproportionately large number of spillage houses are located in Manitoba, and a disproportionately low percentage of spillage houses are located in the Ottawa region. The higher incidence of spillage in Manitoba is most probably related to the tighter housing stock. The low incidence of spillage in the Ottawa region is not easily explained, although one factor which distinguishes the Ottawa region from others is the high percentage of gas-heated houses built post-1975. It is possible that the larger number of new houses in the Ottawa sample has biased the survey towards better maintained houses, and has eliminated spillage problems due to conversions or appliance breakdown.

Variations Due to Age of Houses

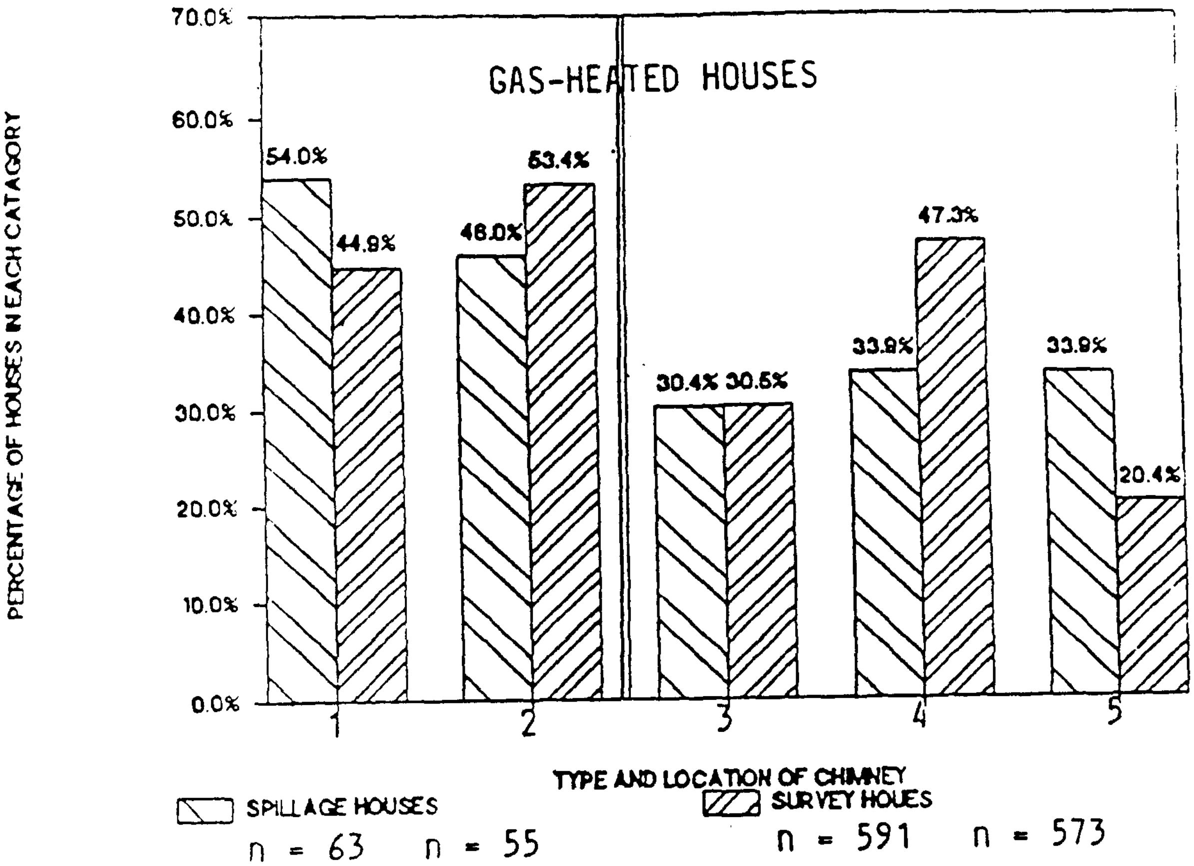
Graph 3 presents the distribution of spillage houses and survey houses by date of construction. Both the older and newer houses indicate higher than average spillage incidents. The strongest trend is towards increased problems in the pre-1945 houses, which may be related to chimney deterioration, liners, leaks, poor maintenance and fuel conversions. The higher incidence of spillage in the post-1975 houses is



GRAPH 3: Distribution by Date of Construction



GRAPH 4: Distribution by Number of Storeys



LOCATION OF CHIMNEY

1 Exterior chimney
2 Interior chimney

TYPE OF CHIMNEY

3 Masonry chimney
4 Metal chimney
5 Masonry chimney with metal liner

GRAPH 5: Distribution of Houses by Type and Location of Chimney likely related to house depressurization, since new houses tend to be much tighter than older houses.

Variations Related to Style of House

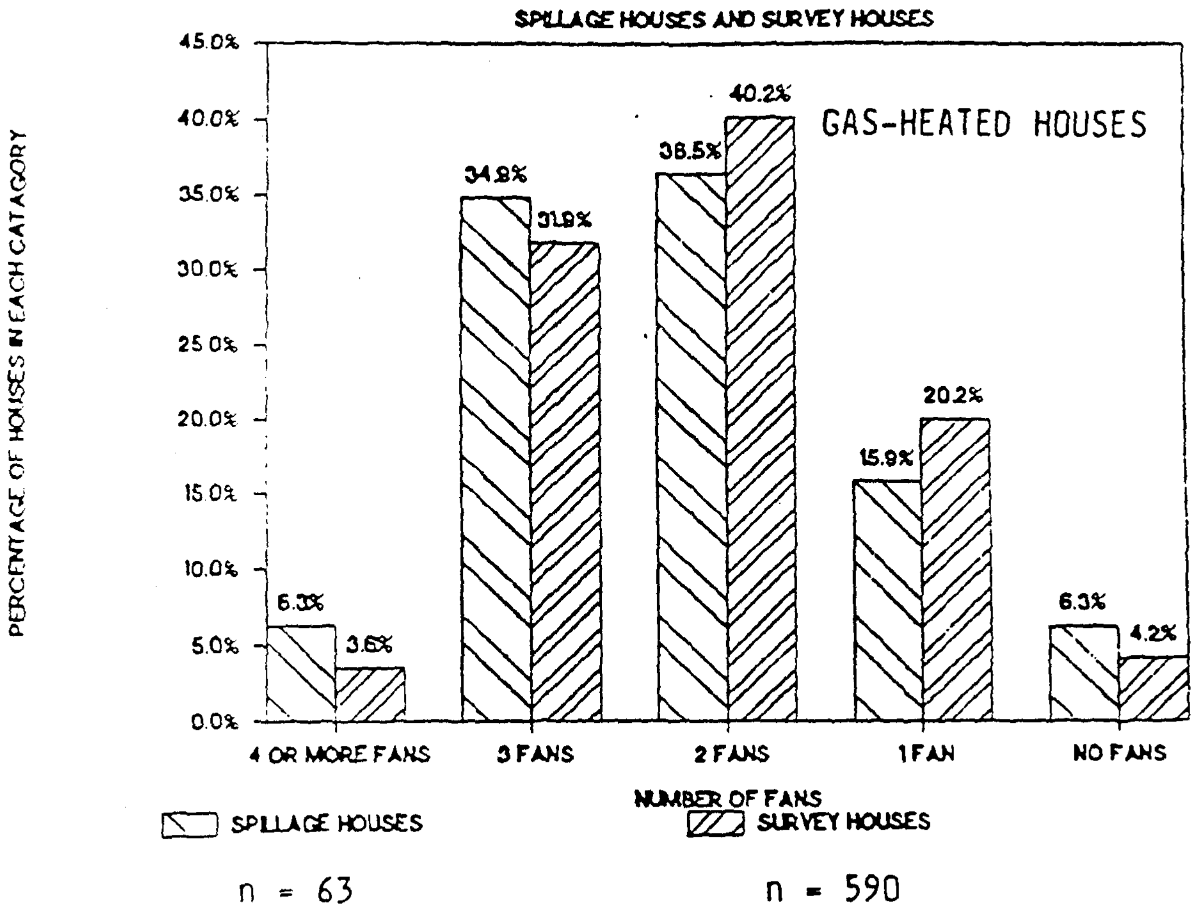
Graph 4 presents the distribution of spillage in survey houses by the number of storeys in the house. A strong trend is evident for increased spillage incidents in one and one-and-a-half storey houses, in comparison with two and two-and-a-half storeys.

Type and Location of Chimney

Graph 5 presents the distribution of survey spillage houses by the type and location of chimneys. There is a strong trend towards greater spillage problems with exterior chimneys, and with masonry chimneys with metal liners. Metal chimneys, on the other hand, have a much lower incidence of spillage problems in relation to the total number of houses. These trends are consistent with much of the field testing that had taken place prior to the survey, since exterior chimneys have been found to be cooler and less buoyant under some weather conditions, and to be in poorer repair due to blockages and leaks. The higher incidence of problems with lined masonry chimneys is surprising, but may be consistent with problems identified during the case study follow-up investigations, which found spillage occurring as a result of constrictions created by flexible liners, undersized liners, and rain caps.

Variations Due to Numbers of Exhaust Fans

Graph 6 presents the distribution of spillage in survey houses by the number of exhaust fans in the houses. As might be expected, houses with three, four or more fans showed a higher proportion of spillage problems. Presumably, these houses are suffering from house depressurization and backdrafting. Surprisingly, the "no fans" category also showed a higher



GRAPH 6: Distribution of Houses by Number of Fans

proportion of spillage houses. However, "no fans" is a feature which probably overlaps the older house characteristics, a category of houses which also showed a much higher proportion of spillage problems.

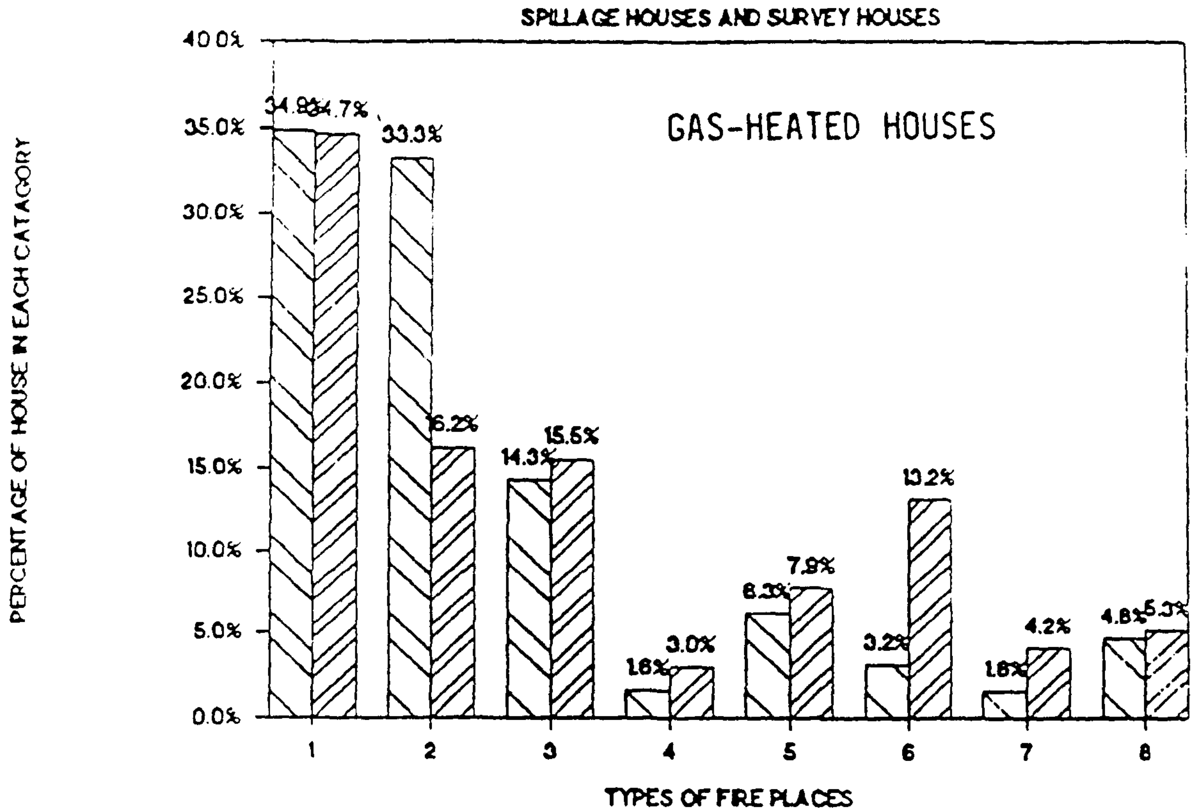
Variations Due to Numbers and Types of Fireplaces

Graph 7 shows the distribution of houses by type and number of fireplaces. Two categories show significant imbalances between spillage houses and survey houses. Category 2, representing houses with two open brick fireplaces, shows a much higher incidence of spillage occurrences. Category 6, representing houses with a metal-lined fireplace with doors, shows a much lower incidence of spillage problems. Categories 4 and 7 also indicate a lower proportion of spillage incidents in houses where fireplaces have doors, or where a wood stove is used instead of a fireplace.

Information was also collected from householders on the frequency of fireplace use. Unfortunately, this data was collected while detectors were installed in houses and has not been combined or correlated with data on types of fireplaces and spillage incidents.

Variations Due to Appliance Servicing

Graph 8 presents the distribution of spillage in survey houses by the date of the last service call. Houses where the appliance has been serviced within the last year show a significantly lower proportion of spillage houses when
compared to houses where the last service call was more than one year previous.



SPILLAGE HOUSES
n = 63

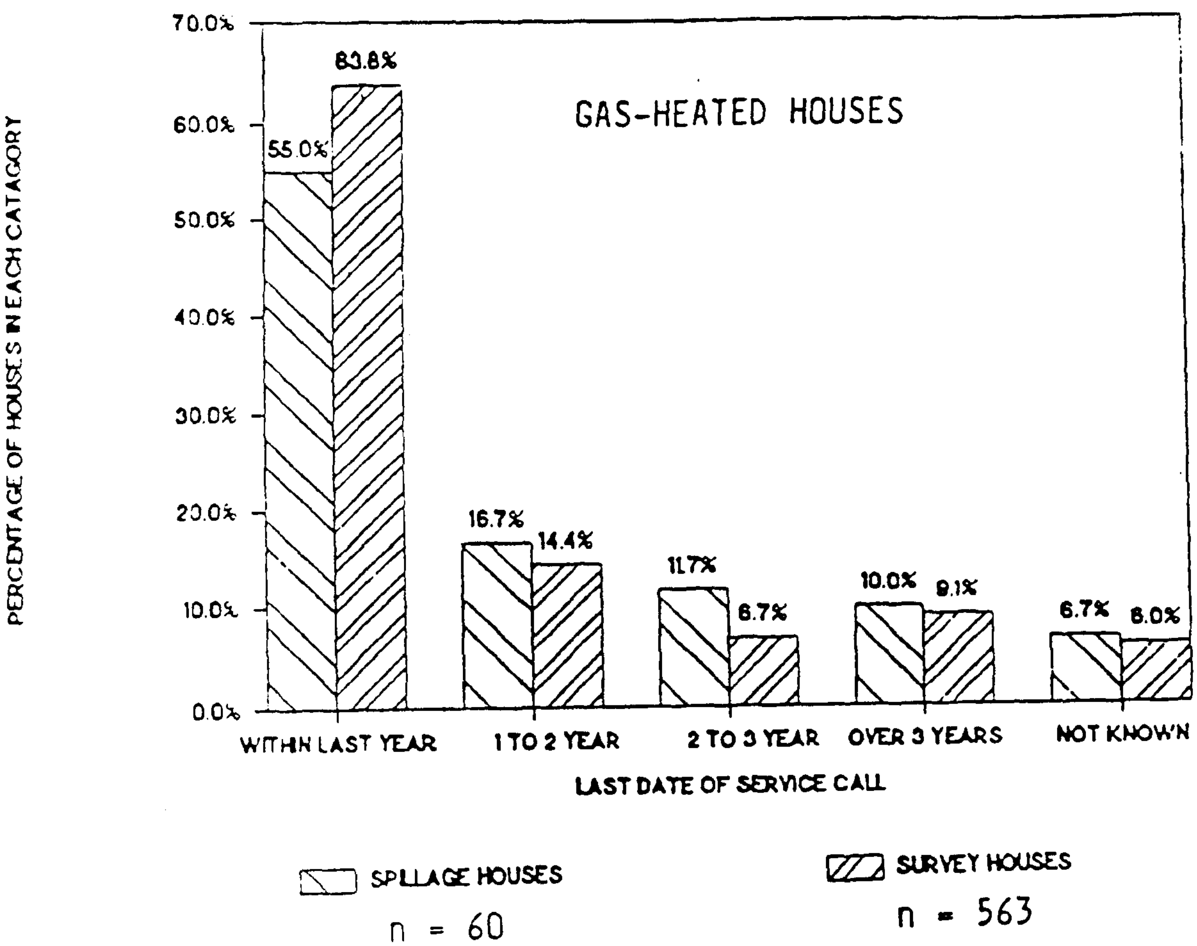
SURVEY HOUSES
n = 265

HOUSES WITH DIFFERENT TYPES OF FIREPLACES

TYPE:

1 Open brick fireplace
2 Second fireplace is open brick
3 Brick with doors fireplace
4 Second fireplace is brick with doors
5 Open metal fireplace
6 Metal with doors fireplace
7 Wood stove
8 Airtight insert

GRAPH 7: Distribution of Houses by Type of Fireplace



GRAPH 8: Distribution of Houses by Date of Last Service Call

3.2.2 Oil-Heated House Characteristics

Regional Variations in the Numbers of Spillage in Survey Houses

Graph 9 presents the distribution of spillage in survey houses by region. Prince Edward Island appears to have a large proportion of spillage houses than British Columbia or Ottawa. However, the small numbers of oil-fired appliances with detectors in British Columbia and Ottawa makes any regional trends difficult to identify.

Variations by Age of House

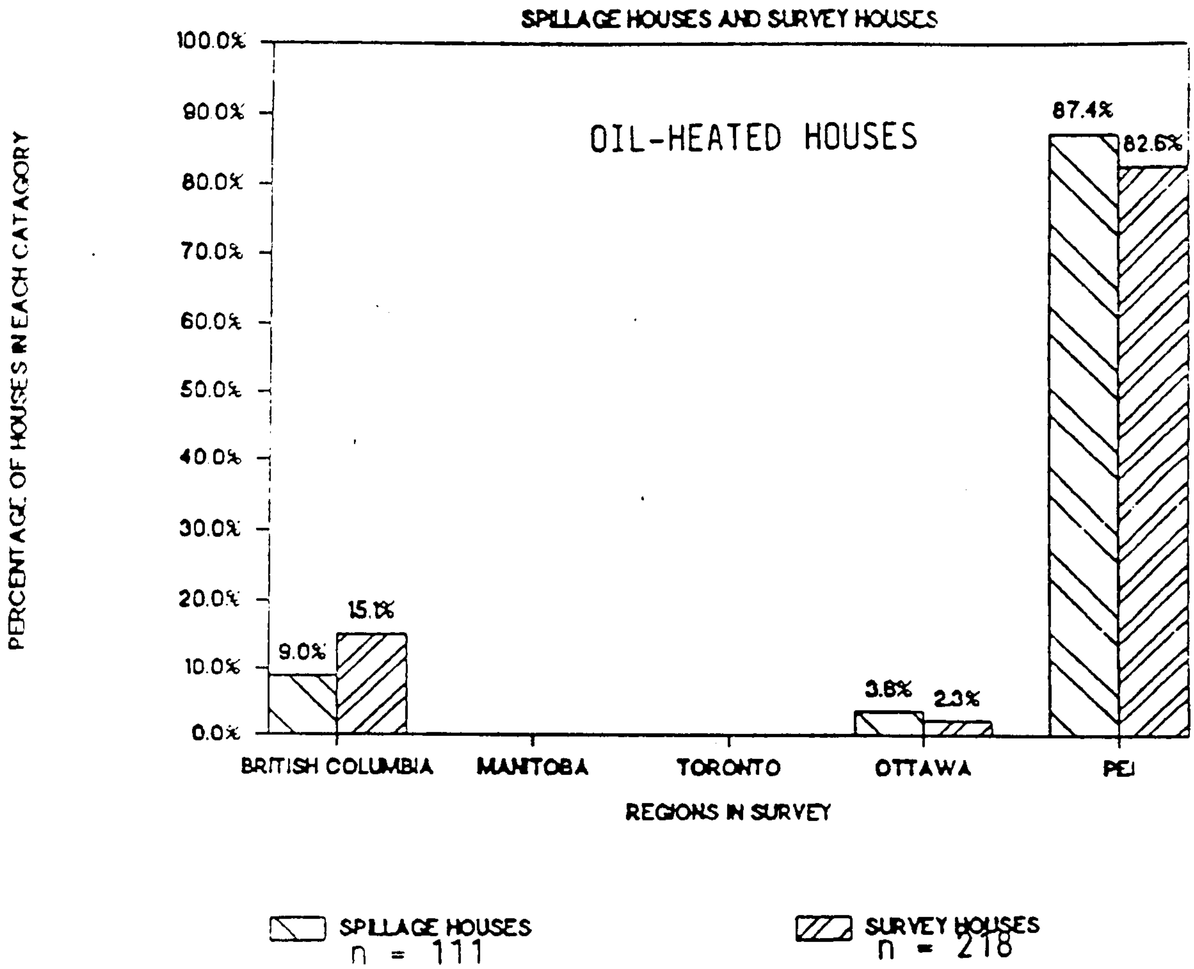
Graph 10 presents the distribution of oil-heated houses by date of construction. A slight trend is apparent towards increased spillage incidents in newer houses (post-1970) relative to the older houses (pre-1945). There is no obvious explanation for such a trend, although it may be related to increased envelope tightness in newer houses, or the operating characteristics of newer oil appliances.

Variations Related to House Style

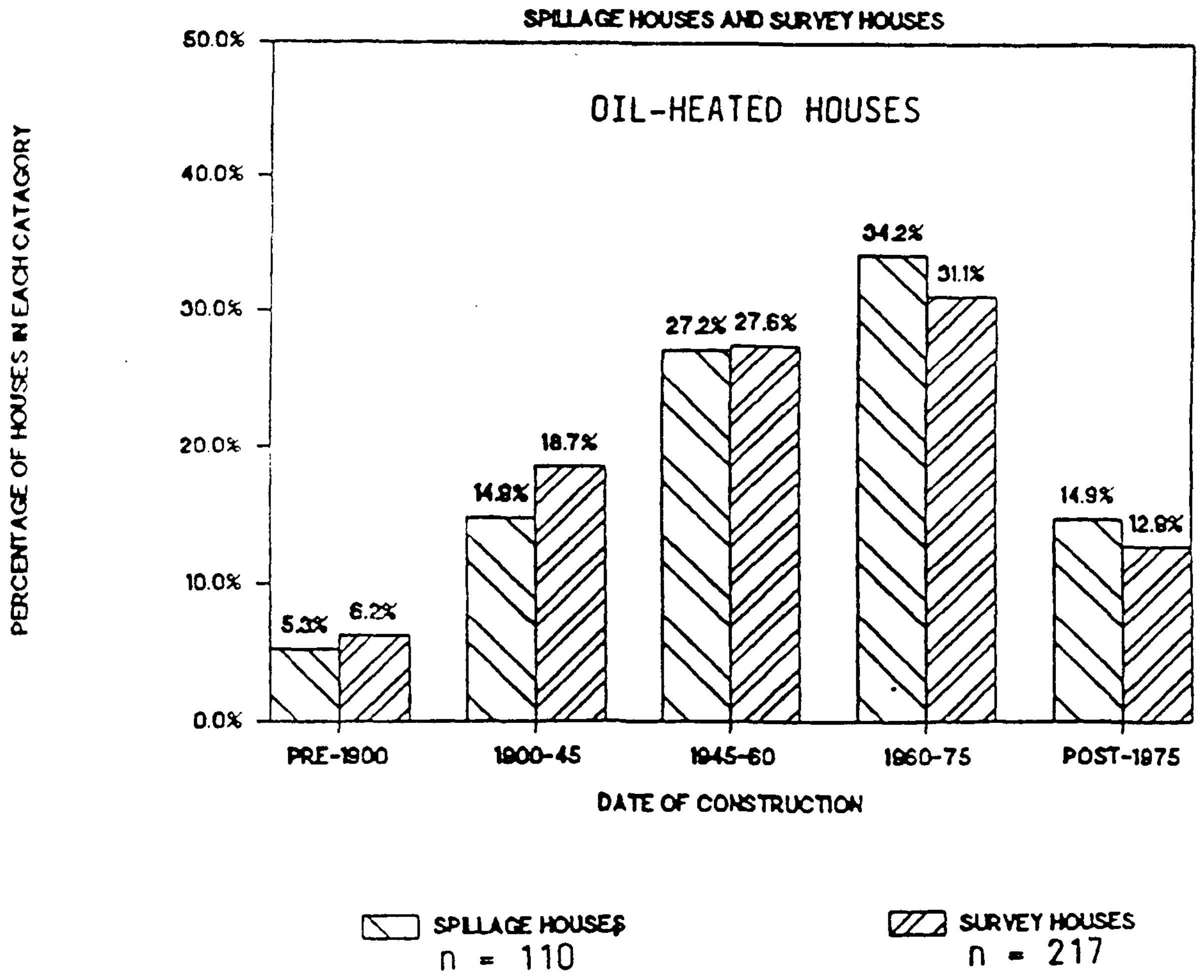
Graph 11 presents the distribution of oil-heated houses by number of storeys. Unlike gas-heated houses, there is no strong trend towards a higher proportion of spillage problems in the one and one-and-a-half storey houses.

Variations Related to the Type and Location of Chimney

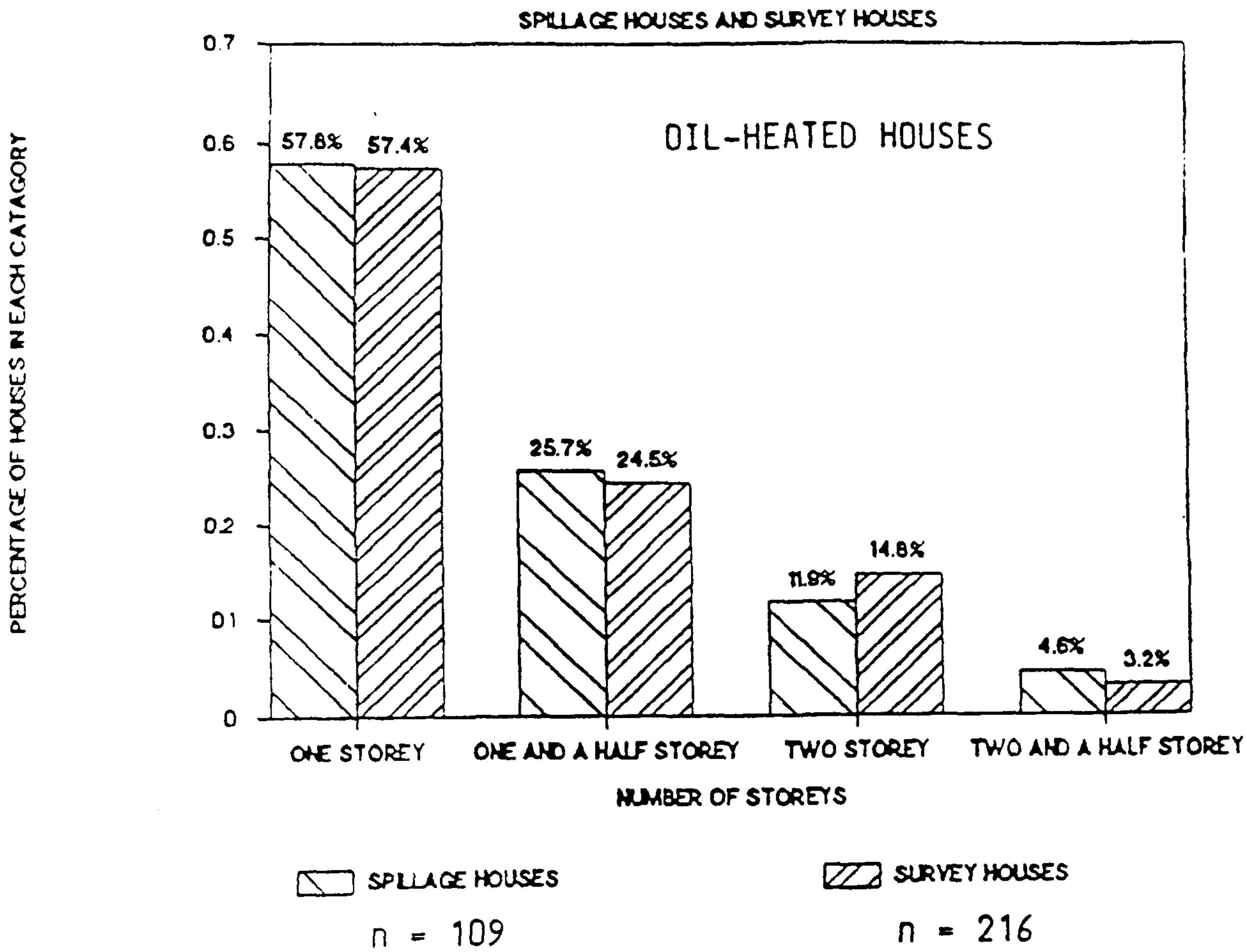
Graph 12 presents the distribution of oil-heated houses by type and location of chimney. Exterior chimneys appear more likely to experience spillage problems than interior chimneys. Masonry chimneys appear more likely to have problems than metal chimneys, although the variations are not great.



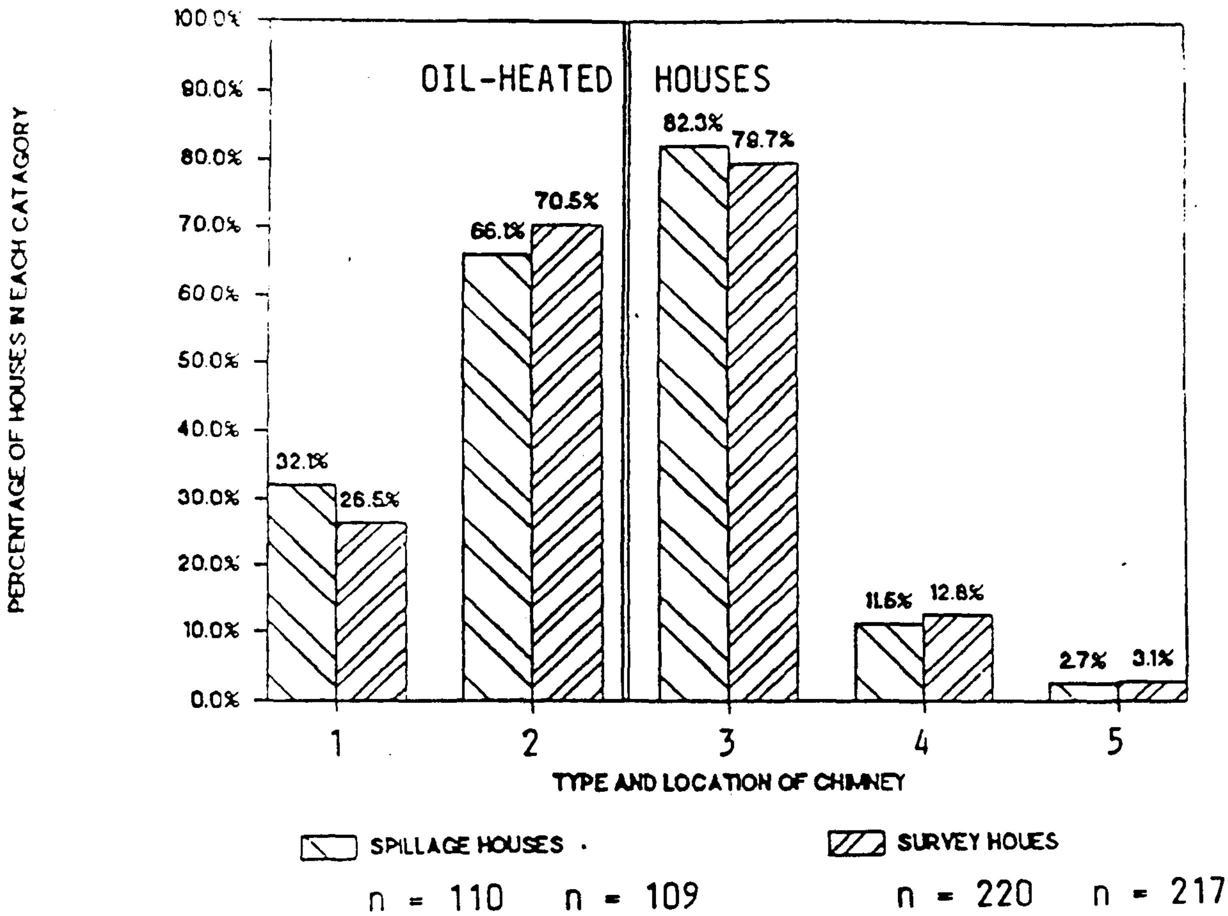
GRAPH 9: Distribution of Houses by Region



GRAPH 10: Distribution by Date of Construction



GRAPH 11: Distribution by Number of Storeys



LOCATION OF CHIMNEY

1 Exterior chimney
2 Interior chimney

TYPE OF CHIMNEY

3 Masonry chimney
4 Metal chimney
5 Masonry chimney
with metal liner

GRAPH 12: Distribution of Houses by Type and Location of Chimney

Variations Related to the Number of Fans

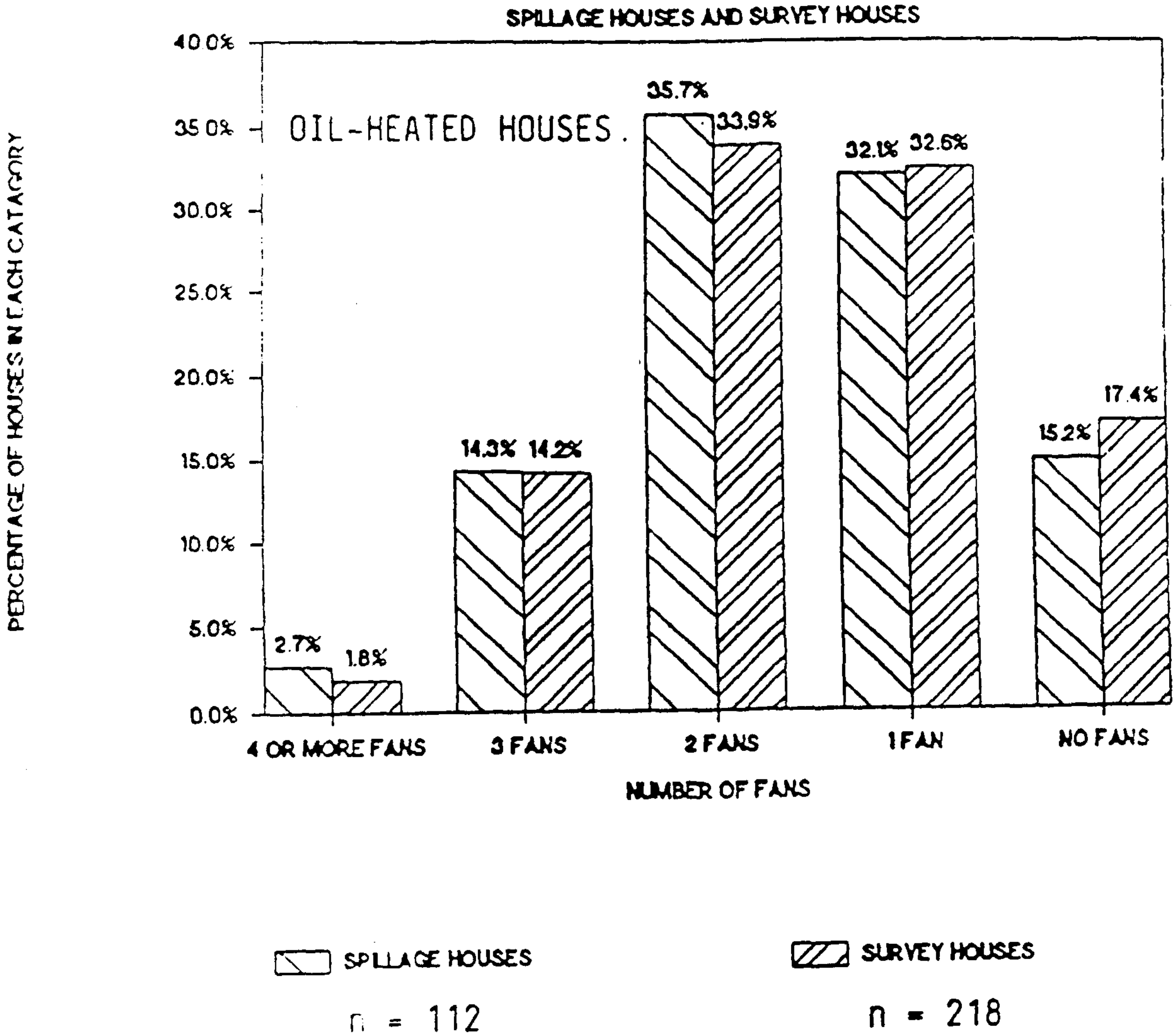
Graph 13 presents the distribution of oil-heated houses by the numbers of exhaust fans. Although a slightly greater tendency exists for houses with fans to experience problems, the trend is not strong. Approximately 17% of the oil-heated survey houses had no fans at all. This contrasts with the gas-heated homes, where only 4% of the houses had no fans at all.

Variations Related to Fireplaces

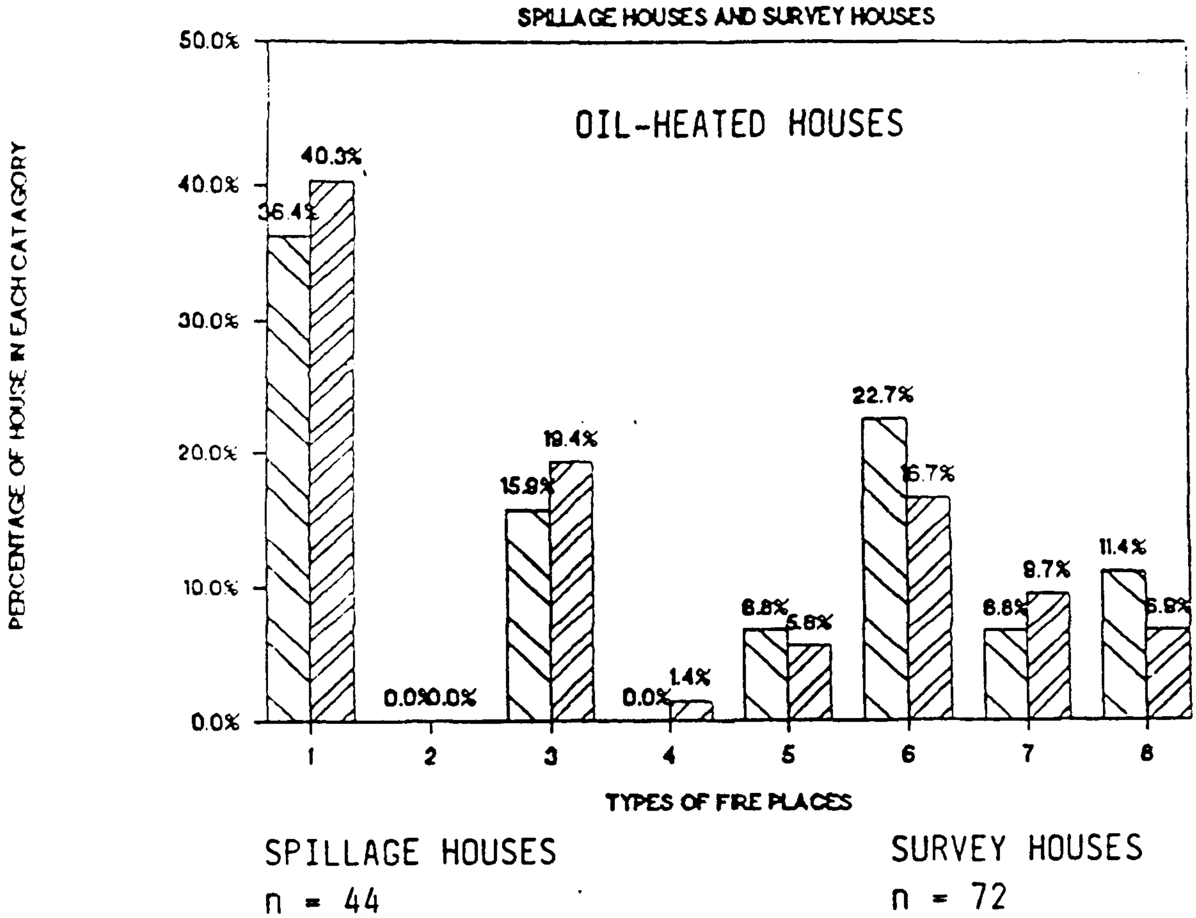
Graph 14 presents the distribution of oil-heated houses by the type and number of fireplaces. Due to a poor response by householders to this question, the sample size is considerably reduced relative to other characteristics. The large number of categories also makes it difficult to interpret trends. There would appear to be a lower incidence of spillage problems in houses with brick fireplaces, and a higher incidence in houses with closed metal fireplaces with airtight inserts. However, the researchers in Prince Edward Island have emphasized that the open fireplaces are rarely if ever used, due to the high energy loss and associated heating costs. It may be that the airtight inserts and metal doors with fireplaces correlate with increased use of wood to heat the house, and those conclusions are not possible without more information on frequency of fireplace use.

Variations Related to Servicing and Maintenance

Graph 15 presents the distribution of oil-heated houses by date of last service call. Houses that have had their furnace serviced in the last year appear to have a lower proportion of spillage incidents. The distribution of houses in these categories is almost identical to the gas-heated houses.



GRAPH 13: Distribution of Houses by Number of Fans

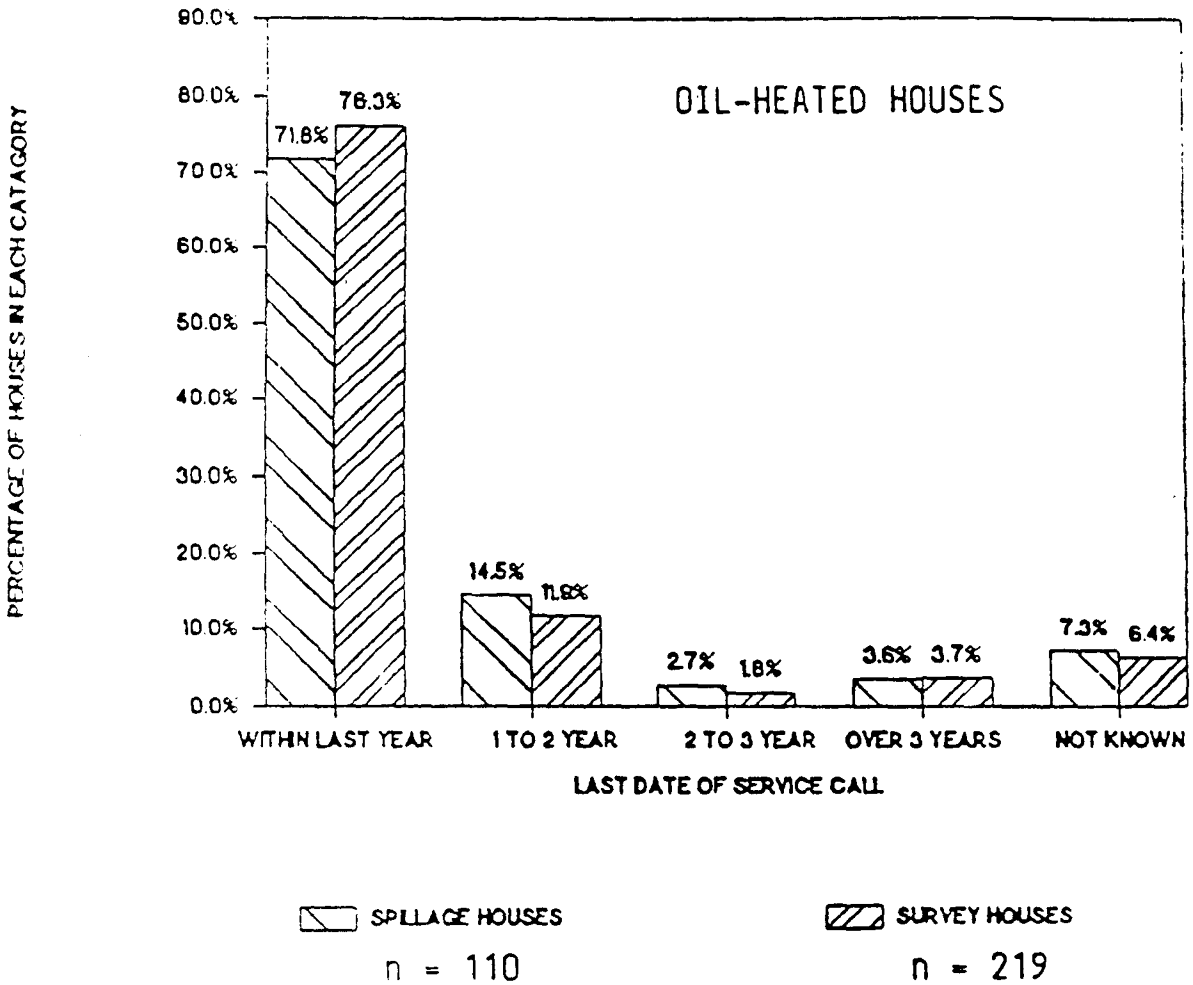


HOUSES WITH DIFFERENT TYPES OF FIREPLACES

TYPE

1 Open brick fireplace
2 Second fireplace is open brick
3 Brick with doors fireplace
4 Second fireplace is brick with doors
5 Open metal fireplace
6 Metal with doors fireplace
7 Wood stove
8 Airtight insert

GRAPH 14: Distribution of Houses by Type of Fireplace



GRAPH 15: Distribution of Houses by Date of Last Service Call

3.3 Spillage Incidents Recorded by Fireplace Detectors

TABLE 6

FIREPLACE SPILLAGE INCIDENTS

House	No. of Fires	Number of Spillage Events	Duration of Spillage (seconds)	Events Per Fire
1	9	2	44	0.2
2	8	3	81	0.4
3	7	6	42	0.9
4	5	13	841	2.6
5	4	17	194	4.3

The results of the fireplace survey are presented in Table 6. On average, householders burned wood on 6.6 occasions over the monitoring period. The low number of fires in the survey houses is a result of installing the detectors late in the season. Spillage events recorded by the CO and smoke detectors ranged from 2 to 17 events, or from 0.2 to 4.3 events per fire. Spillage was most significant in House No. 4 and House No. 5.

Except for a slight clicking noise when counting, the detectors appeared to work well. (In House No. 4, the occupant reported that on one occasion he could hear the clicking from the mechanical counters, and out of curiosity, he opened the door separating the living room from the hallway to improve draft and the counter stopped.) Information on each detector installed can be found in Appendix D, including photographic illustrations of each fireplace, and dimensions of the firebox and chimney. No correlation exists between the fireplace design and the number of spillage events.

In general, the fireplace survey was too brief, and the sample too limited, to provide a clear indication of typical fireplace spillage frequency. However, the results suggest that spillage may be a normal aspect of fireplace operation, even when householders are unaware of any problems. None of the occupants in these five survey houses had noticed any spillage, or any wood aroma from their fireplace.

This survey has laid a foundation for more research on fireplace spillage frequency. More extensive monitoring of fireplaces is planned to take place, as an extension to this project, over the 1986/87 heating season.

4.0 CONCLUSIONS

The installation of combustion gas spillage detectors on vented heating appliances in 606 gas-heated houses in five regions across Canada has indicated that in 10% of these houses prolonged combustion gas spillage occurred on at least one occasion during the period of January 1986 to May 1986. These spillage events are all in excess of the start-up spillage that is a normal event for gas-fired appliances.

An examination of the characteristics of gas-heated houses in the survey shows a wide variety of housing styles and venting systems. Specific features of the gas-heated houses appeared to correlate with prolonged combustion gas spillage, including the following:

- Houses located in the Winnipeg Region;
- Pre-1945 construction and post-1975 construction;
- One storey houses;
- Exterior chimneys;
- Masonry chimneys and chimney liners;
- Houses with three or more exhaust fans;
- Houses with two open brick fireplaces; and
- Appliances that had not been serviced within the last year.

Installation of combustion gas spillage detectors on the barometric dampers of flue pipes of oil furnaces and oil boilers for the period of January 1986 to May 1986 indicated that 55% of the survey houses had experienced prolonged combustion gas spillage.

In 5% of the oil-heated houses, the dot detection temperature exceeded 121°C, and excess combustion gas spillage almost certainly occurred for periods of 60 seconds or more. The remainder of houses where spillage occurred may have experienced shorter-term spills (15 to 60 seconds) or may have been houses where the furnace or flue design causes lower temperature combustion gas. Because of the high frequency of spillage incidents in oil-heated houses, and the many variables that influence spillage quantity, a more sophisticated detector is worthwhile for surveying spillage events.

An analysis of the characteristics of oil-heated survey and spillage houses did not reveal strong trends towards combustion gas spillage in particular categories of oil-heated houses. Although trends were in a similar direction to the gas-heated houses, the variations were not as noticeable. Only in the case of exterior chimneys, and masonry chimneys, was a strong trend apparent towards a higher proportion of spillage incidents.

RESIDENTIAL COMBUSTION VENTING FAILURES

A SYSTEMS APPROACH

PROJECT 1, PHASE 2:

CANADA-WIDE SURVEY RESULTS

APPENDIX A

SAMPLE QUESTIONNAIRE

Prepared for:
The Research Division
Policy Development and Research Sector
Canada Mortgage and Housing Corporation

Prepared by:
Scanada Sheltair Consortium

January, 1987

HOUSEHOLDER QUESTIONAIRE NO. 1

2 DETECTORS INSTALLED - NATURAL GAS FURNACE
- NATURAL GAS WATER HEATER

PREAMBLE:

Hello! My name is ______________________________ and I work for ____.

We are the people who are conducting research on chimney safety in Canadian houses.

Our records show that a chimney spillage detector was installed on your furnace and your water heater on _________ ____ of this year.

QUESTION 1:

Have you seen the detector on your furnace or the detector on your water heater?

Both ___ (1)   Furnace ___ (2)   Water Heater ___ (3)   No ___ (4)

IF NO - the detectors are thin plastic strips about the size of two fingers, on which we have glued five white or grey dots. The furnace detector is usually hung on the front of your furnace, close to where the chimney pipe leaves the furnace. On some older types of furnaces the detector is occasionally hung behind the front cover grill on the furnace.

The water heater detector is located right on top of the water heater propped against the chimney pipe.

IF YES - Good.

QUESTION 2:

Is now a good time to ask you a few questions?

If Yes - Great, we should be finished in about 5 minutes.
If No - Is there someone else we can talk with, or is there a better time to call?

QUESTION 3:

Most importantly, we need to know how our detectors have performed.

Each detector has five dots. When the detectors were installed, the colour of the dots varied from white to grey. By now, some of these dots may have turned to solid black. I need to know how many dots have changed to black. I also need to know the temperature listed above each dot that has turned to black.

It is sometimes hard to distinguish grey dots from black dots. Grey dots have a cloudy or grainy appearance. A black dot, however, will look like it has been coloured with a black felt pen.

Do you have any questions?

Yes - Note: repeat explanation as required.
No - Good.

Could you please go now, to the furnace and water heater, and count the black dots on each detector and record the temperature listed above each black dot. If you can take a pen and some paper, it may help you to accurately record the number of black dots and their temperatures.

		38°C	2nd 38°C	54°C	71°C	121°C
Furnace:	none ___ (5)	one ___ (6)	two ___ (7)	three ___ (8)	four ___ (9)	five ___ (10)

		38°C	2nd 38°C	54°C	71°C	12°C
Water Heater:	none ___ (11)	one ___ (12)	two ___ (13)	three ___ (14)	four ___ (15)	five ___ (16)

(If householder requests explanation of black dots, refer to reference sheet No. 1.)

QUESTION 4:

(Only to be asked if black dots are present, and if householder had seen detectors prior to telephone call.)

By any chance, do you recall noticing how long after installation the dots turned black?

Immediately: ___ (17) Same day: ___ (18) Several days: ___ (19)

Several weeks ___ (20) Don't know ___ (21)

QUESTION 5:

To complete our research and analysis, we need to know a few details about your house.

Does your house have a basement or a crawl space?

Full basement: ___ (22) Partial basement: ___ (23)

Crawl space: ___ (24) Slab-on-grade: ___ (25)

QUESTION 6:

How many storeys does your house have, excluding the basement?

one ___ (26) one and a half ___ (27) two ___ (28) two and a half ___ (29)

QUESTION 7:

Approximately when do you think your house was built?

Pre-1900 ___ (30) 1900-1945 ___ (31) 1945-1960 ___ (32)

1960-1975 ___ (33) post-1975 ___ (34)

QUESTION 8:

Where is the furnace located in your house?

Open basement ___ (35) Furnace room in basement ___ (36)

Main floor ___ (37) Outdoors ___ (38)

QUESTION 9:

Is the chimney for the furnace located on an outside wall?

yes ___ (39)   no ___ (40)

QUESTION 10:

Does the water heater share the same chimney as the furnace?

yes ___ (41)   no ___ (42)

QUESTION 11:

Is the outdoor portion of the chimney made of brick or metal or both brick with a metal liner?

brick ____ (43) (or masonry)   metal ____ (44)   brick & metal ___ (45)

QUESTION 12:

Approximately how old do you think the furnace is?

Less than 5 years _____ (46)   5 to 10 years _____ (47)

10 to 20 years _____ (48)   More than 20 years ____ (49)

QUESTION 13:

Approximately how old do you think the water heater is?

Less than 5 years _____ (50)   5 to 10 years _____ (51)

10 to 20 years _____ (52)   More than 20 years ____ (53)

QUESTION 14:

Have you or previous owners converted from oil heating to gas?

yes ____ (54)   no ____ (55)   don't know ____ (56)

QUESTION 15:

How long has it been since the furnace was last serviced?

Less than a year ____ (57)   1 to 2 years ____ (58)   don't know ___ (59)

2 to 3 years ____ (60)   More than 3 years ____ (61)

QUESTION 16:

(Only for houses with fireplaces)

Could you please describe the types of fireplaces in your house in terms of whether they are made of brick or metal and whether they have doors that close.

Open brick	1____ (62)	2____ (63)	Brick with doors	1____ (64) 2____ (65)
Open metal	____ (66)		Metal with doors	---- (67)
Wood stove	____ (68)		Airtight insert	---- (69)

QUESTION 17:

Does the mantle or masonry above the fireplace tend to get stained when the fireplace is used regularly?

Yes ____ (70)   Sometimes ____ (71)   No ____ (72)   Seldom used ____ (73)

QUESTION 18:

Finally, I need to know how many exhaust fans are in your house.

By exhaust fan, I mean a fan that blows air out of the house, or into the attic.

Could you please tell me how many fans you have of the following types:

Kitchen range hood fans	0 ___ (74)	1 ___ (75)	2 ___ (76)	
Bathroom exhaust fans	0 ___ (77)	1 ___ (78)	2 ___ (79)	3 ___ (80)
Stove-top barbeque fans	0 ___ (81)	1 ___ (82)	2 ___ (83)	
Clothes dryer vented to outdoors?	yes ___ (84)	no ___ (85)		
Other exhaust fans?	0 ___ (86)	1 ___ (87)	2 ___ (88)	

QUESTION 19:

Would you mind if we called you once more in June, just to see if any more dots have turned black?
Yes - Great. Thanks for taking part in our research project. Goodbye.
(No - If they'll be away, note dates on comment sheet and thank them.)

REFERENCE SHEET NO 1

EXPLANATION OF BLACK DOTS

PREAMBLE:

Our spillage detectors were developed for this research project, and there was not time to thoroughly test them on every type of appliance. Consequently, we can't be positive about what a particular number of black dots means in terms of chimney performance. However, based on our limited research I can say that -

0 DOTS:

- 0 black dots means that there has been little or no combustion gas spillage from your chimney and that the system is probably working well.

1 OR 2 DOTS:

- 1 or 2 black dots indicate that a minor amount of combustion gas has spilled from your chimney.

- Small amounts of spillage will occur from gas furnaces and gas water heaters during the start-up period.

- This is a normal occurrence and it is probably not something that you should be concerned about.

3 DOTS:

- 3 black dots on a single detector indicate that there has been some amount of gas spillage from your chimney on at least one occasion, and possibly on more occasions.

- The spillage probably occurred for a period of longer than a minute.

- This is an abnormal amount of spillage for a chimney, but the quantities are probably not great.

- You may want to have the chimney system inspected by a furnace serviceman.

- In any case, we will be sending you a letter with a more complete explanation and with recommendations for improving your chimney performance.

4 OR 5 DOTS:

- 4 or 5 black dots on a single detector indicates excessive amounts of combustion gas spillage from your chimney.

- Spillage has occurred for a period of several minutes on at least one occasion and possibly more occasions.

- You may want to have your chimney system inspected by a furnace serviceman.

- In any case, we will be sending you a letter with an explanation and some recommendations.

- We may also offer to send out a team of researchers to investigate the problem in your house at no charge to you.
- You can expect a letter in the mail within the next few days.

CANADA WIDE SURVEY
REFERENCE SHEET #2

IMPORTANT:

PROCEDURES FOR GAS, OIL & PROPANE PROBLEM HOUSES IDENTIFIED DURING TELEPHONE INTERVIEWS

Procedure for the first 4 houses that have 4 or 5 black dots on a single detector.

1. Explain that this is not normal and that we would like to install, at no cost to them, a CO alarm and a new detector.

2. If the householder is agreeable, make arrangements to visit the home within the next day or two to install the CO alarm and the new detector.

   (The new detector will actually consist of a small metal box that mounts beside the existing dot detector. It will count the total time of spillage occurrences. These "spillage counters" will be provided to you, with the CO alarms by April 25.)

Procedure for additional houses with 4 or 5 black dots (if they exist), and, for houses with 3 black dots on a single detector.

1. Immediately mail out Householder Letter Number 4 (Gas & Propane Detectors) or Letter Number 5 (for Oil Detectors).

   (These letters offer them CO alarms at no cost if their serviceman can't identify a problem. The letters also suggest that we may visit their house - if they are agreeable - and conduct our own safety check).

   Keep in mind, however, that a visit would only occur if: (1) one or more of the first 4 houses didn't work out; and, (2) the house was of particular interest to our study.

   Time may also be available during the problem house testing to conduct some brief safety checks on problem houses. This would be done in addition to extensive testing of four of the 4 dot or 5 dot houses.

****

IMPORTANT:

PROCEDURES FOR GAS, OIL & PROPANE PROBLEM HOUSES IDENTIFIED DURING TELEPHONE INTERVIEWS

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   Keep in mind, however, that a visit would only occur if: (1) one or more of the first 4 houses didn't work out; and, (2) the house was of particular interest to our study.

   Time may also be available during the problem house testing to conduct some brief safety checks on problem houses. This would be done in addition to extensive testing of four of the 4 dot or 5 dot houses.

****

WHAT TO DO DURING YOUR PRELIMINARY VISIT TO THE 4 PROBLEM HOUSES

1. Check the dots and confirm householders count.

2. Use a smoke pencil and check for spillage when the appliance is operating. Record your observations.

3. Install the box counter according to the instructions supplied.

4. Whether or not spillage is major and continuous, install a CO alarm. The alarm should be installed close to an AC outlet, on a wall at approximately head height (2 m), in a central location in the house on the first floor (e.g., next to house thermostat).

5. Confirm other responses from the householders phone interview (number of fans, type of chimney, etc.).

6. Make personal judgments on the suitability of the house for testing. (e.g. are their bedridden or sick people confined indoors?)

7. If no major obstacles are identified, make arrangements for a visit to the house during the 4 days identified in the Problem House Testing Calendar.

8. If the house is not suitable for testing by ourselves, advise the householder to have the appliance and chimney inspected by a licensed furnace technician.

****

RESIDENTIAL COMBUSTION VENTING FAILURES

A SYSTEMS APPROACH

PROJECT 1, PHASE 2:

CANADA-WIDE SURVEY RESULTS

APPENDIX B

LETTERS TO HOUSEHOLDERS

Prepared for:
The Research Division
Policy Development and Research Sector
Canada Mortgage and Housing Corporation

Prepared by:
Scanada Sheltair Consortium

January, 1987

Scanada-Sheltair-Consortium Inc.

PROJECT OFFICE:
436 MacLaren St., Ottawa, Ont. K2P 0M8

Tel. (613) 236-717
TELEX 053-447

LETTER TO HOUSEHOLDER #1

SUBJECT: CHIMNEY PERFORMANCE RESEARCH

Dear Householder:

We would like to include your house as part of a 1000 house Canada-wide survey into chimney performance. The survey is part of an important research study funded by the Federal Government. We are attempting to determine how frequently chimneys spill their combustion gases indoors, and what can be done to improve chimney performance.

The survey involves the installation of a very simple detector on your furnace and hot water heater. The detector will not affect the performance of the furnace or water heater. A number of tradesmen in the community are helping us by installing these detectors in randomly selected houses.

Your participation in this survey will not entail any costs or inconvenience. All that is required is for you to answer a few questions on the telephone, some time in April, and once again in June. During these phone calls, you'll be asked to look at the detectors installed on your furnace and water heater and tell us how many dots have turned dark black. (This will be easy for you to see.) The number of white and black dots on each detector relates to the temperature of combustion gases at that location. The detector is a research tool, and should not be used as an indication of whether or not your chimney is performing correctly. If the results in your house are out of the ordinary, you will receive advice from our research supervisor in April.

We hope you are willing to co-operate in this important research study. If you have any questions or concerns, please feel free to contact our regional research supervisor. Request the "Combustion Hot Line" at the nearest office listed below.

SHELTAIR	G.K. YUILL	SCANADA	SCANADA	SOLSEARCH
3661 W. 4th Ave.	1441 Pembina Hwy.	436 MacLaren St.	446 Reynolds St.	34 Queen St.-3rd F
Vancouver, B. C.	Winnipeg, Man.	Ottawa, Ont.	Oakville, Ont.	Charlottetown, PEI
V6R 1P1	R3T 2C4	K2P 0M8	L6J 3M4	C1A 7N5
Tel: 732-9106	Tel: 474-2461	Tel: 236-7179	Tel: 842-3633	Tel: 892-9898

Scanada Sheltair Consortium Inc.
PROJECT OFFICE:
436 MacLaren St., Ottawa, Ont. K2P 0M8
Tel. (613) 236-7179
TELEX 053-4472

#2

Dear Householder:

As you know, our company is conducting research into the frequency of chimney spillage problems in Canadian houses. The research includes a Canada-wide survey of chimney performance in over 1000 houses. Your house is part of this sample, and we really do appreciate your cooperation. We would now like to propose one additional chimney detector for your house.

On 10 of the 1000 houses in our survey, we are planning to install a fireplace chimney detector. We would like to include your house as one of the 10 houses, because you indicated to us on the installation form that you frequently use your fireplace. The purpose of the fireplace chimney detector is to determine how often the fireplace spills accidentally into your house.

The fireplace detector it is similar to the detectors on your furnace and water heater in that it is designed to detect gas spillage. It resembles a conventional smoke alarm, but has been significantly altered. We are proposing to hang the detector above your fireplace for a one-month period, after which we will return and remove the detector.

This additional research we are conducting on fireplace spillage events will greatly improve the quality of our research findings, and should lead to recommendations on how to improve the operation and safety of typical fireplaces.

You will find some brief operating guidelines on the attached page.

Once again, we thank you for your participation.

Sincerely,

Sebastian Moffatt

SM/lt

Scanada Sheltair Consortium Inc.

PROJECT OFFICE:
436 MacLaren St., Ottawa, Ont. K2P 0M8

Tel. (613) 236-7179
TELEX 053-4472

HOUSEHOLDER LETTER NO. 3

Dear Householder:

As you know, our company recently installed special detectors on your furnace and water heater as part of our survey of chimney performance in 1000 Canadian houses. The detectors are designed to tell us whether combustion gases are being fully vented out your chimney or whether, on certain occasions, some of the gases are "spilling" into your house instead of going up the chimney.

I am writing to you because preliminary results from our work indicate that some spillage of combustion gases has occurred in your home. While some amount of combustion gas spillage is common in Canadian houses, it is fairly certain your house is experiencing abnormal spillage.

It is not clear yet how much of a hazard combustion gas spillage represents, but it can constitute a health hazard under some circumstances. If the spillage is prolonged, for example, the air quality in your house may deteriorate and lead to increased respiratory complaints, or other ailments. If the spillage gases contain large quantities of carbon monoxide (CO), the result can be CO poisoning. (Fortunately CO is not usually a by-product from natural gas appliances.) The detectors installed in your home only indicate that hot gases spilled on at least one occasion. We don't know how frequent the problem is, or whether CO might be present.

Although our research is not yet complete, we know that combustion gas spillage can be caused by the following factors:

- wind downdrafts;
- blocked, damaged or poorly designed chimneys;
- a very leaky heat exchanger inside the furnace;
- back pressure caused by operating household exhaust fans or fireplaces.

Although, again, research is still in progress, possible remedial measures to avoid this problem include the following:

- heightening the chimney or installing an improved cap or an insulated liner;
- repair and adjustments to the furnace or water heater and its flue pipe;
- additional air supply into your house, especially when fans or fireplaces are operating.

We recommend that you pay to have your furnace and chimney checked by a qualified service technician. We have enclosed a letter of explanation for your service technician which you can show him prior to his inspection.

If you or the technician have any questions regarding this letter or the choice of a course of action, you can call the representative of the Scanada-Sheltair Consortium at the office nearest to you (see below).

It is quite possible that your service technician will be unable to determine the cause of the spillage. Weather conditions or house operation can effect chimney performance in ways that are difficult to predict. If no obvious explanation exists for the spillage, we recommend that you install a CO detector for greater peace of mind. CO detectors are easily installed devices that provide a warning when the carbon monoxide concentration reaches a level that constitutes an immediate health hazard. They do not, however, provide any warning regarding lower concentrations that may constitute a long term health hazard.

We will send you a CO detector at no charge, if your service technician is unable to explain the spillage that has occurred. Contact our representative, at the address below, to receive your CO detector.

Even if you or the service technician feel that no immediate corrective action is required, we expect to be contacting you within the next month to propose a visit to your house to further investigate the causes of your spillage problem.

In the meantime, we encourage you to take whatever precautions you feel are necessary.

Sincerely,

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3661 W. 4th Ave.
Vancouver, B. C.
V6R 1P1
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34 Queen St. -3rd Fl
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Scanada-Sheltair-Consortium Inc.

PROJECT OFFICE:
436 MacLaren St., Ottawa, Ont. K2P 0M8

Tel. (613) 236-7179
TELEX 053-4472

BACKGROUND INFORMATION FOR FURNACE TECHNICIAN

The Scanada-Sheltair Consortium is a consulting firm that is currently undertaking field research work on combustion spillage problems in housing on behalf of the Canada Mortgage and Housing Corporation. As part of the ongoing research in which we are involved, we have received information which leads us to believe that the chimney in this house is not performing properly. Consequently, we have recommended to the occupants of this house that they request an inspection by a certified furnace technician. This letter is intended to provide you with background information on the research we have conducted and on what we recommend for your inspections.

One of the objectives of our research is to establish the frequency and severity of chimney spillage into houses. To throw some light on this issue we have organized a cross-Canada survey of chimney spillage incidents. Simple, low cost detectors were developed for this purpose and installed in over 1000 random houses. The detectors are made from temperature resistant plastic on which are glued five temperature sensitive dots. When a specific temperature is exceeded, these dots turn from light grey to dark black.

Each dot on the detector has a different turning temperature. The detectors are mounted on furnaces and water heaters in such a way as to catch the combustion gases that might spill from the dilution air inlet. Spillage of hot combustion gases therefore causes these dots to turn dark black. As the spillage duration and quantities increase, so does the temperature, which causes more dots to turn dark black.

As you know, some amount of combustion gas spillage at start-up is quite common, and is generally considered acceptable for gas furnaces and water heaters. Start-up spillage will usually cause one or two of the dots on the detectors to turn dark black.

If spillage occurs for longer than a minute, our research indicates that it is likely that three dots on the detector will have turned black. In order to turn four dots black, we have found that it probably requires combustion gas spillage for a duration of several minutes, and quite possibly longer. Five black dots on a single detector would indicate major spillage for one or more cycles.

Scanada Sheltair

Once the dots have turned dark black, they remain in that condition. Consequently, all we know at this time is that on at least one occasion excess spillage has occurred in this house, for reasons unknown. It may have been a single event caused by wind downdrafts, or caused by back pressures in the house due to the operation of exhaust appliances like powerful kitchen fans, or an open fireplace. On the other hand, the spillage may be continuous and severe in this house due to a damaged or blocked chimney.

Although we intend to make our own field investigations of problem houses some time in May, we anxious in the meantime that the occupants of this house not be exposed to continuous or severe spillage. It is for this reason that we have requested the householder to ask you to undertake an inspection of the chimney and appliances to ensure that the systems appear to be venting properly.

We leave it up to your experienced judgement to determine what is the most appropriate inspection procedure to use. To begin with you might want to use a lighter or match or smoke pencil to determine if spillage is occurring, under operating conditions, in the vicinity of the detector.

It may well be that your inspection will not expose any problems. in this case, we may provide the householder with a carbon monoxide alarm to ensure their safety in the event of further combustion gas spillage. We may also undertake further investigations some time in May, if the householder is agreeable.

Whether or not you uncover the source of spillage problems in this house, we will want to contact you briefly sometime within the next two months so we can prepare a brief report on what you have observed. We would very much appreciate it if you could make notes at this time, so that you will have something to refresh your memory when we contact you.

If you have further questions about our research work, or if you have comments that you feel we should hear immediately, please feel free to telephone our representative at the office nearest to you (see below).

Sincerely,

SHELTAIR
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RESIDENTIAL COMBUSTION VENTING FAILURES

A SYSTEMS APPROACH

PROJECT 1, PHASE 2:

CANADA-WIDE SURVEY RESULTS

APPENDIX C

CORROBORATION OF DOT DETECTOR RESULTS
IN 100 HOUSES

Prepared for:
The Research Division
Policy Development and Research Sector
Canada Mortgage and Housing Corporation

Prepared by:
Scanada Sheltair Consortium

January, 1987

JULY 1986, SURVEY OF DOT DETECTORS IN 100 HOUSES

RECORDED DOT DETECTOR TEMPERATURES (MAX)

PRINCE EDWARD ISLAND

	April Results		July Results				
			Furnace		DHW		
House Numbers	Furnace	DHW	Householder	Expert	Householder	Expert	Deviation In Readings
5048	54	-	54	54	-	-	
5049	38	-	38	38	-	-	
5050	71	-	71	71	-	-	
5051	38	-	38	38	-	-	
5052	71	-	71	71	-	-	
5055	0	-	0	0	-	-	
5056	38	-	38	38	-	-	
5057	54	-	54	?*	-	-	X
5058	?*	-	71	71	-	-	
5060	0	-	38	38	-	-	
5062	38	-	38	38	-	-	
5063	71	-	71	71	-	-	
5064	0	-	54	54	-	-	
5065	54	-	54	54	-	-	
5066	121	-	121	121	-	-	
5067	38	-	38	38	-	-	
5068	0	-	38	38	-	-	
5170	?*	?*	38	38	54	?*	X
5171	71	-	71	71	-	-	
5178	54	-	54	54	-	-	

* Information not available

RECORDED DOT DETECTOR TEMPERATURES (MAX)

OTTAWA

	April Results		July Results				
			Furnace		DHW		
House Numbers	Furnace	DHW	Householder	Expert	Householder	Expert	Deviation In Reading
4003	2-38	2-38	2-38	2-38	2-38	2-38	
4022	0	0	2-38	2-38	2-38	2-38	
4036	2-38	2-38	2-38	2-38	2-38	2-38	
4046	0	2-38	2-38	2-38	2-38	2-38	
4056	0	0	2-38	2-38	2-38	2-38	
4059	2-38	2-38	2-38	2-38	2-38	2-38	
4096	38	38	38	38	2-38	2-38	
4103	0	38	2-38	2-38	2-38	2-38	
4104	38	38	2-38	2-38	2-38	2-38	
4112	2-38	2-38	2-38	2-38	2-38	2-38	
4141	0	0	0	0	2-38	2-38	
4146	2-38	2-38	2-38	2-38	2-38	2-38	
4151	0	0	2-38	2-38	2-38	2-38	
4153	38	2-38	?*	?*	2-38	2-38	
4154	0	0	2-38	2-38	2-38	2-38	
4155	38	0	2-38	2-38	2-38	2-38	
4158	0	0	2-38	2-38	2-38	2-38	
4161	38	2-38	2-38	2-38	2-38	2-38	
4172	0	0	2-38	2-38	2-38	2-38	
4192	2-38	2-38	2-38	2-38	2-38	2-38	

* After the first survey the detector was left on top of the furnace's dilution device and was spoiled.

RECORDED DOT DETECTOR TEMPERATURES (MAX)

TORONTO

House Numbers	April Results Furnace	April Results DHW	July Results Furnace Householder	July Results Furnace Expert	July Results DHW Householder	July Results DHW Expert	Deviation In Readings
3005	38	38	2-38	2-38	2-38	2-38	
3007	2-38	2-38	2-38	2-38	2-38	2-38	
3010	0	0	0	0	0	2-38	X
3029	71	71	2-38	2-38	2-38	2-38	
3031	121		2-38	2-38	2-38	2-38	
3032	38	2-38	2-38	2-38	2-38	2-38	
3051	-	38	-	-	2-38	2-38	
3052	38	-	2-38	2-38	-	-	X
3057	0	0	2-38	2-38	2-38	2-38	
3065	2-38		2-38	2-38	2-38	2-38	
3072	2-38	38	2-38	2-38	2-38	2-38	
3090	38	38	2-38	2-38	2-38	2-38	
3096	-	2-38	-	-	2-38	2-38	
3098		2-38	2-38	2-38	2-38	2-38	
3100		0	0	0	0	0	
3104	2-38	-	2-38	2-38	-	-	
3114	38	2-38	2-38	2-38	2-38	2-38	
3115	0	0	0	0	2-38	2-38	
3116	0	2-38	0	0	-	-	
3121	2-38	0	2-38	2-38	2-38	2-38	

RECORDED DOT DETECTOR TEMPERATURES (MAX)
WINNIPEG

House Numbers	April Results Furnace	April Results DHW	July Results Furnace Householder	July Results Furnace Expert	July Results DHW Householder	July Results DHW Expert	Deviation In Reading
2139	0	0	2-38	2-38	2-38	2-38	
2140	38	-	38	2-38	-	-	X
2141	2-38	2-38	2-38	2-38	2-38	2-38	
2147	0	-	0	0	-	-	
2148	2-38	54	0	2-38	2-38	2-38	X
2149	2-38	-	2-38	2-38	-	-	
2150	?*	?*	2-38	2-38	2-38	2-38	
2151	1	-	2-38	2-38	-	-	
2153	0	-	0	0	-	-	
2154	2-38	-	2-38	2-38	-	-	
2160	0	0	0	2-38	2-38	2-38	X
2161	0	2-38	0	2-38	2-38	2-38	X
2166	2-38	38	2-38	2-38	2-38	2-38	
2169	2-38	2-38	2-38	2-38	2-38	2-38	
2170	0	0	38	2-38	38	2-38	X
2172	0	0	2-38	2-38	2-38	2-38	
2173	2-38	38	2-38	?**	2-38	2-38	
2175	2-38	2-38	2-38	2-38	2-38	2-38	
2176	2-38	2-38	2-38	2-38	2-38	2-38	
2178	2-38	0	2-38	2-38	2-38	2-38	

* The first telephone survey questionnaire was filled out wrong for this house (one and t black dots were marked for the furnace; nothing was marked for the hot water heater).

** We are not sure whether this detector has "2" or "3" black dots. The 54°C dot partially blackened at the upper edge.

RECORDED DOT DETECTOR TEMPERATURES (...

VANCOUVER

House Number	April Results: Furnace	April Results: DHW	July Results: Furnace Householder	July Results: Furnace Expert	July Results: DHW Householder	July Results: DHW Expert	Deviation In Reading
1010	0	0	0	0	2-38	2-38	
1013	2-38	38	0	2-38	38	38	
1018	0	2-38	2-38	2-38	2-38	2-38	
1019	0	0	0	0	0	0	
1024	2-38	2-38	2-38	0	2-38	2-38	
1025	0	0	0	0	0	0	
1027	0	0	0	0	38	38	
1039	2-38	2-38	2-38	2-38	2-38	2-38	
1044	0	0	38	2-38	38	38	
1050	2-38	0	2-38	2-38	2-38	38	X
1051	0	0	2-38	2-38	0	0	
1052	2-38	2-38	2-38	2-38	2-38	2-38	
1056	38	0	38	38	0	0	
1058	2-38	2-38	2-38	2-38	2-38	2-38	
1059	0	0	2-38	2-38	2-38	2-38	
1060	2-38	2-38	2-38	2-38	2-38	2-38	
1061	2-38	2-38	2-38	2-38	2-38	2-38	
1063	2-38	-	2-38	2-38	-	-	
1082	0	-	0	0	-	-	
1146	2-38	2-38	0	0	2-38	2-38	

RESIDENTIAL COMBUSTION VENTING FAILURES

A SYSTEMS APPROACH

PROJECT 1, PHASE 2:

CANADA-WIDE SURVEY RESULTS

APPENDIX D

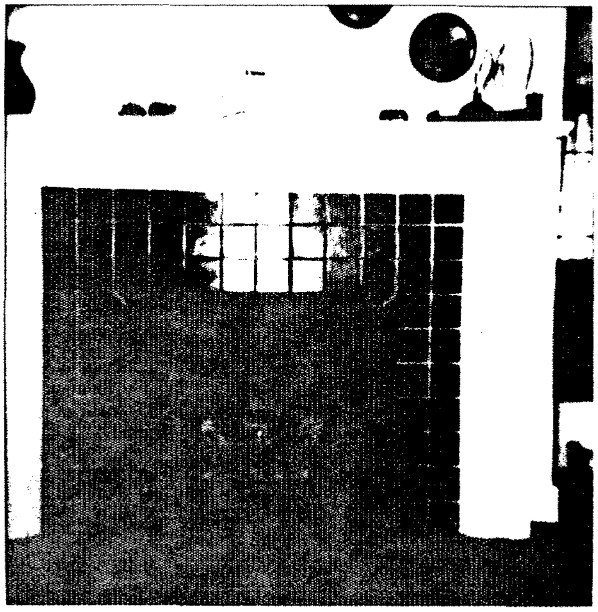
FIREPLACE SPILLAGE SURVEY INSTALLATIONS

Prepared for:
The Research Division
Policy Development and Research Sector
Canada Mortgage and Housing Corporation

Prepared by:
Scanada Sheltair Consortium

January, 1987

FIREPLACE SPILLAGE SURVEY INSTALLATIONS



HOUSE NO. 1

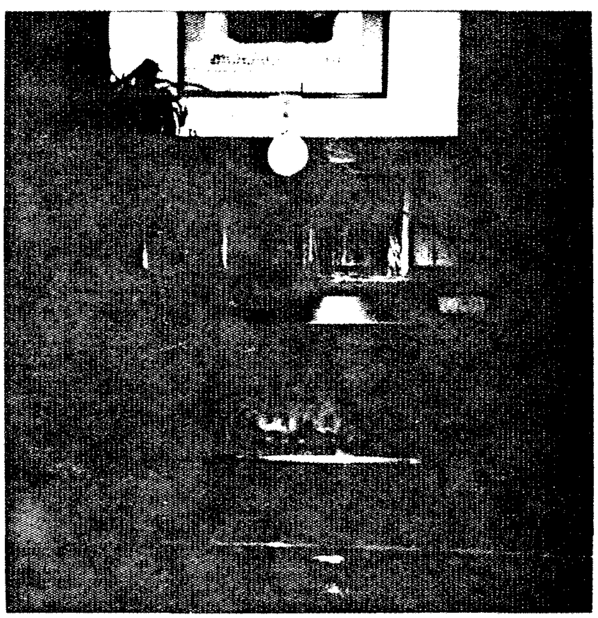
Chimney Height: 4 m

Fireplace Dimensions:
Height: 737 mm
Width: 875 mm
Depth: 485 mm

Number of fires: 9

Number of spillage events: 2

Duration of spillage: 44 seconds



HOUSE NO. 2

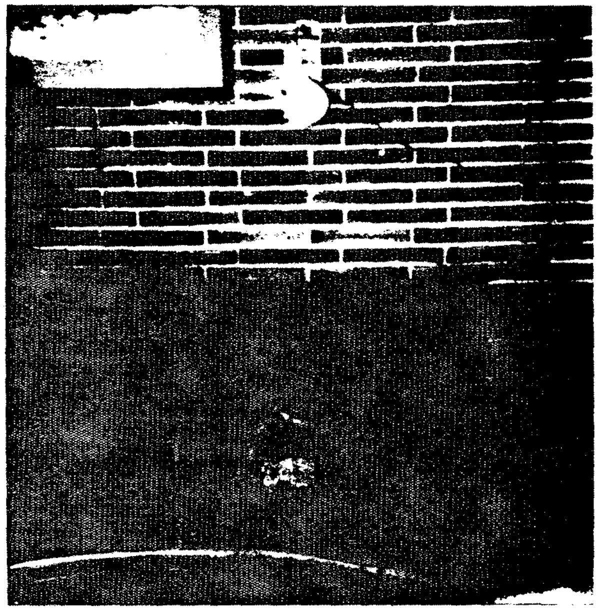
Chimney Height: 4 m

Fireplace Dimensions:
Height: 578 mm
Width: 732 mm
Depth: 521 mm

Number of fires: 8

Number of spillage events: 3

Duration of spillage: 81 seconds



HOUSE NO. 3

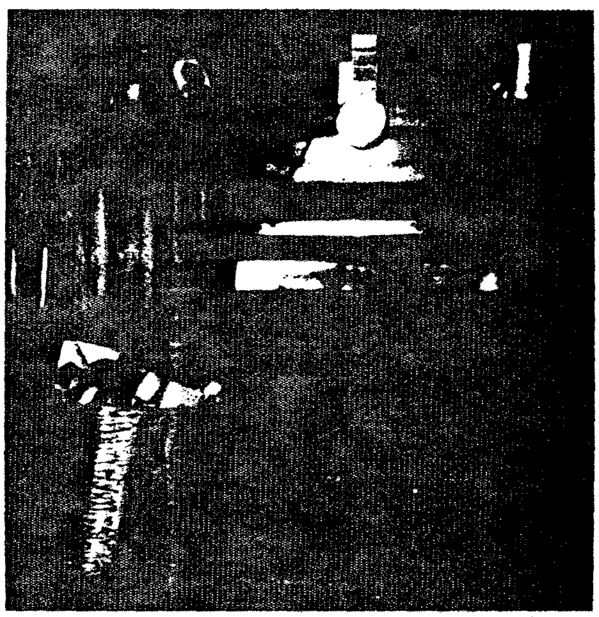
Chimney Height: 6 m

Fireplace Dimensions:
Height: 700 mm
Width: 1060 mm
Depth: 550 mm

Number of fires: 7

Number of spillage events: 6

Duration of spillage: 42 seconds



HOUSE NO. 4

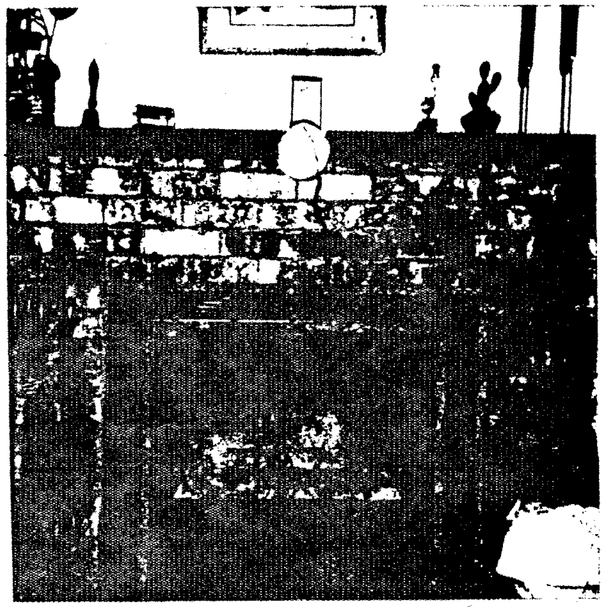
Chimney Height: 3 m

Fireplace Dimensions:
Height: 690 mm
Width: 765 mm
Depth: 550 mm

Number of fires: 5

Number of spillage events: 13

Duration of spillage: 841 seconds



HOUSE NO. 5

Chimney Height: 7 m

Fireplace Dimensions:
Height: 422 mm
Width: 737 mm
Depth: 356 mm

Number of fires: 4

Number of spillage events: 17

Duration of spillage: 194 seconds

RESIDENTIAL COMBUSTION VENTING FAILURE

A SYSTEMS APPROACH

PROJECT 1, PHASE 2:

COUNTRY-WIDE SURVEY RESULTS

APPENDIX E

OVERALL PROJECT SUMMARY

Prepared for:
The Research Division
Policy Development and Research Sector
Canada Mortgage and Housing Corporation

Prepared by:
Scanada Sheltair Consortium

June 26, 1987

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 -

- refinements to algorithms
- more efficient operation of the program
- modelling additional features and system types
- 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 "WOODSIM", 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 checklist.

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.