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# MONITORING COMBUSTION GAS SPILLAGE FREQUENCY AND DURATION IN 20 PROBLEM PRONE HOUSES

FINAL REPORT

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*SUMMARY*

*A research project was carried out for the purpose of determining the number of combustion gas spillage events, and the total duration of spillage, in 20 houses where pressure-induced spillage was thought to be occurring. The project was a follow-up to an earlier CMHC research project (1985/86), which included a Country-wide Survey of Residential Combustion Venting Failures carried out by the Scanada-Sheltair Consortium.*

*Houses were selected in 4 regions of the country, and included 15 gas heated houses and 5 oil heated. The counters mounted on gas-fired appliances relied on a thermistor to detect hot gas spillage from the dilution air inlets. The number of events, and total event duration, were recorded on battery-operated mechanical counters. Oil-fired detectors were similarly designed, but used conventional smoke alarms mounted above the barometric damper, instead of thermistors, for sensing spillage.*

*Spillage events were monitored over an 80-day period of the 1986/87 heating season.*

*Loss of data in one house reduced the sample to 19.*

*The frequency and duration of spillage showed a great deal of variation, from house to house. Thirteen of the houses (68 percent) recorded at least one spillage event over the monitoring period. Three of these 13 experienced one event only. Another three houses experienced frequent long-term backdrafting episodes, with 5 to 23 minute average spill durations. It is highly likely that the longer-term spills occurred as a result of chimney backdrafting.*

*Oil-fired appliances experienced short-term spillage of 15 to 36 seconds, typical of start-up problems.*

*Flue dampers on 4 of the houses interfered with placement of the monitors and hampered data collection and interpretation. In two of these houses spillage was seen to be occurring on a continuous basis by the technicians installing the monitors, and yet no data on spillage was recorded. More sophisticated monitors could solve this problem and give a better record of the spillage patterns.*

*In general, this survey has confirmed the presence of significant spillage incidents amongst houses identified as "spillage" houses during the country-wide survey. If flue dampers had not prevented proper monitoring on two houses where spillage was observed to be a problem, fully 79 percent of the sample would have recorded problem spillage incidents.*

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## 1. INTRODUCTION

This research project was designed to determine the number of spillage events, and the total duration of spillage, in 20 houses where pressure-induced spillage was thought to be occurring. This project was a follow-up to an earlier survey conducted as part of a multi-part research project carried out by the Scanada-Sheltair Consortium for the Canada Mortgage and Housing Corporation (CMHC), entitled Residential Combustion Venting Failures - A Systems Approach (Ref.1). As part of a 900 house survey of combustion gas spillage, 20 houses with spillage evidence were to be fitted with monitors. The monitors would total the number of spillage events, and the total spillage duration. Project implementation delays, and the arrival of spring, prevented the collection of any significant data.

This progress report describes the selection of 20 houses for a second survey during the 1986/87 heating season, and the re-design and re-installation of the monitoring devices.

## 2. PROCEDURE

### 2.1 Selection of Houses

Houses were chosen for monitoring in the four regions where the 1985/86 survey identified spillage houses. Monitors were installed on 20 houses, as follows:

| | |
|---|---|
| Vancouver, British Columbia | 4 gas-heated, 1 oil-heated houses |
| Winnipeg, Manitoba | 7 gas-heated houses |
| Ottawa, Ontario | 4 gas-heated houses |
| Prince Edward Island | 4 oil-heated houses |

The distribution of houses reflected both a desire to have a regional balance, and a desire to conduct more monitoring in Winnipeg and B.C. Winnipeg houses are of interest because a much higher percentage of gas-heated houses in that region have been shown to experience problems with pressure-induced spillage.

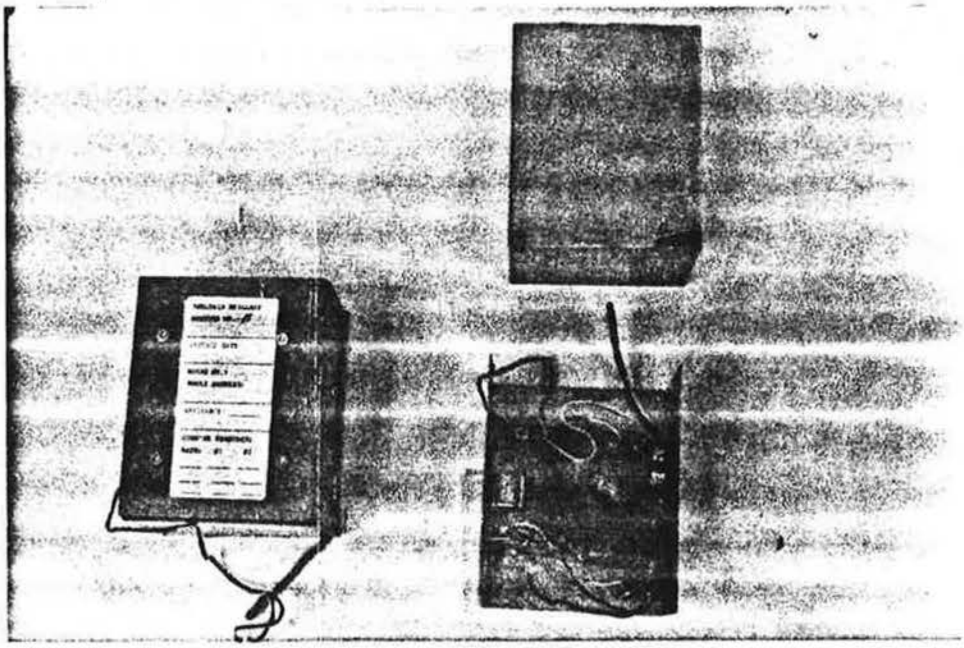
Each region was provided with a list of recommended houses, from which they selected a final sample. (See Appendix 1 for house lists.) The recommended houses included houses that had been visited as part of the Case Study investigations during the previous winter, specifically those houses where the investigations had revealed a propensity for pressure-induced spillage. Other houses were included from the data base on 3-, 4-, and 5-dot "spillage" houses. Each spillage house was described by summarizing the many characteristics of the house that are known from the data base (location of chimney, number of exhaust fans, age of furnace, etc.). On this basis, the spillage houses in each region were given priority classifications, with highest priority given to houses with features correlating with house depressurization or poor chimney draft. These summaries were reviewed by regional installers, and the final house sample was composed of a portion of these houses. (Appendix 1 lists the number of the monitors installed in the houses, and cross references these numbers with the house numbers from the 1986/87 Country-wide Survey.)

## 2.2 Re-design and Fabrication of the Counters

The original furnace spillage detectors contained a single counter for recording the number of spillage events. Upon further thought and discussion, it was decided that the duration of the spillage events was also a very important issue, and warranted a second counter. Only by means of two counters - one recording events and the other duration - was it possible to characterize the type of spillage problems, and differentiate, for example, between minor start-up spillage and occasional prolonged spillage.

Consequently, the counters were re-designed to include a second counter. (Appendix 2 shows the wiring schematic for new counter.) The poor physical condition of some of the returned counters suggested the need for a more durable monitoring system, and in some cases the entire assembly and box was replaced. A majority of the thermistors were replaced with

**Figure 1:** Two Completed Spillage Counters
(one closed and one with back removed)



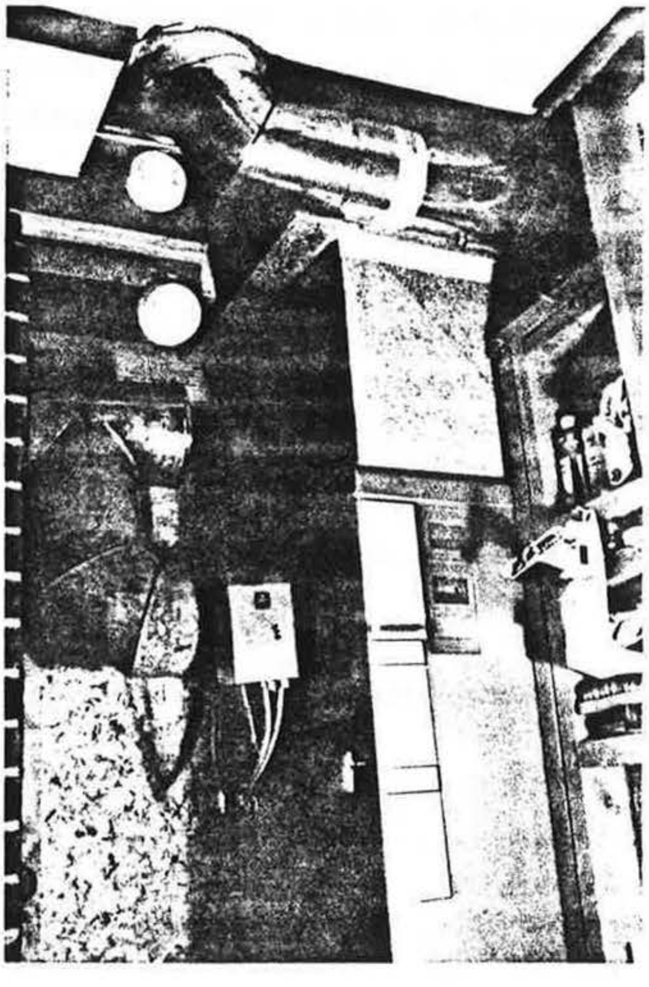


**Figure 2:** Testing Smoke Alarms at varying locations above and Barometric Damper

stiffer, more responsive, glass thermistors, and sheathed in plastic. Resistors were added to the circuits to minimize the power draw on the thermistors and extend the battery life. Tests were conducted on the batteries, and the manufacturers consulted, to determine the minimum life span of the detectors. Final calculations showed approximately 30 days of life per battery. To avoid re-visiting houses simply to replace batteries, the counters were re-designed to permit three (3) batteries to be connected in series, and thus to allow for approximately three (3) months of continuous monitoring. A photograph of the spillage counter developed for gas appliances is presented in Figure 1, which shows the completed counters - one open for inspection and one closed and ready for installation.

### Trigger Temperatures and Response Times

Four different models of thermistors were used during fabrication, since supplies were limited on short notice. All thermistors were set to respond at 45°C. The accuracy and response times varied slightly, depending on the model of thermistor. Most thermistors were highly responsive models (Fenwal GA511 or Dale 9M1002.1) and had time constants of 10 seconds or less (see Appendix 2), with an accuracy of $\pm$ 4°C or better.

The 45°C trigger temperature was selected to provide maximum sensitivity to spillage occurrences, without risk of interference from warmer air temperatures (summery days, hot basements), warm weather, or radiant heat transfers from a hot appliance.

After fabrication, the counters were lab tested using a toaster oven to generate a controllable high heat source. Trigger temperatures and response times conformed with specifications.

### A New Detector for Oil-Fired Appliances

The use of thermistors on the spillage counters for oil furnaces was re-evaluated and a decision was made to convert the five (5) oil-furnace counters to smoke detectors, using conventional smoke alarms wired to the counters in place of the thermistor. Previous research into detection devices for the Country-wide Survey, had shown great potential for smoke alarms as spillage detection devices, when mounted directly above the barometric damper of an oil furnace. In three (3) houses visited by Sheltair, smoke alarms had alerted householders to spillage from oil furnaces. It was felt that a smoke alarm, hung above the barometric damper and with the siren removed, would provide a reliable and rapid indication of spillage events for purposes of this research project.

The responsiveness of smoke detectors to combustion gas from oil furnaces had not previously been documented. It was felt that some documentation was necessary before re-designing the detectors. In particular, investigation was needed into such issues as the optimum location of the detector, and the responsiveness of the detector to gas with varying soot concentrations (or smoke numbers). To resolve these issues, a brief field test was conducted on a Vancouver test house. Smoke detectors were mounted in varying locations and the oil furnace was repeatedly caused to spill in varying quantities, while the combustion air intake on the burner was opened and closed to vary the soot concentrations. The test set-up is illustrated in Figure 2. The results of this testing have been incorporated into the Final Technical Report on the Development and Testing of Detection Devices for the Country-wide Survey (Ref. 1). When mounted approximately 150 mm above the damper, the smoke detectors were found to respond rapidly to all quantities and types of spillage. Consequently, the spillage counters for oil furnaces were re-designed to replace thermistors with smoke detectors.

Fabrication of the new counters was delayed due to difficulties encountered in retrieving counters that had been sent to the regions. Two counters in both P.E.I. and Toronto seem to have been permanently misplaced, and were thus never returned. Further delays were encountered in obtaining the extra mechanical counters for recording spillage duration, and in producing new circuit boards. The extra parts and the extensive re-design of the counters resulted in a significantly more responsive, durable, and intelligent spillage counter.

Final fabrication of the spillage counters included re-labeling of all the boxes to permit a record of both counter numbers, and the application of new attachment hardware.

## 2.3 Installation of Counters

Instructions for correctly installing the spillage counters were prepared and sent to each region. (Examples of the instructions are presented in Appendix 1.)

In addition to the installation of the counter, an effort was made to conduct a Venting Systems Test on those houses that had not been visited previously. If all the monitored houses has been Case Study Houses as originally planned, Venting System test results would have been available. (Unfortunately some of the non-Case Study Houses were not tested, and data is incomplete.)

Installation of the counters in the 20 spillage houses was conducted primarily during the week of December 12 to 19, 1986, although several of the selected houses could not be visited until after Christmas due to holiday trips by householders. A counter was lost in Winnipeg, and not recovered until the end of the research project. Another counter was partially damaged in Ottawa when the installer tried to bend the glass encased thermistor. Despite delays and difficulties, all of the counters were installed in the selected houses. (A list of the houses, installation dates, and counter numbers is provided in Appendix 1.) The spillage counters were removed from the houses in the middle of March, 1987. Consequently the monitoring period for houses averaged 80 days, although some houses were monitored for as few as 68 days, and others for any many as 90 days).

## 3. RESULTS

A description of the 20 houses is presented in Table 1, including the number stories, date of construction, and numbers of exhaust fans and fireplaces. Additional data on the maximum house depressurization (with all exhaust devices operating) and the air leakage rating (ELA) is also provided (where available).

Table 2 is a description of the appliance and venting systems. The sample includes 4 oil-fired boilers, one oil-fired furnace, 9 gas-fired furnaces and 7 gas-fired water heaters (DHW).

The results of the spillage monitoring on gas-fired appliances are presented in Table 3.

Of the sample of 15 gas-heated houses, 1 had data destroyed[1] (monitor No. 3). The results are also suspect on two houses with flue dampers (monitor No. 6 and 7) due to the possibility of the detectors being triggered, at least in part, by heat spillage caused by automatic flue dampers. This is not necessarily combustion gas spillage. On the 12 gas heated houses where the data is considered trustworthy, 7 had no significant spillage during the monitoring period (i.e. one event or no events). Five of the 12 had spillage of varying amounts.

Good data was not obtained on another two houses with flue dampers, because the dampers prevented proper placement of the thermistors. Monitor No. 1 and 4 both recorded no spillage despite the fact that results of a Venting Systems Test, conducted during installation of the monitors, showed

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[1] One of the gas fired water heaters (Monitor 3) recorded spills for a long duration, but reports were received from Ottawa that this water heater had been forced to spill when the house was being tested for air quality problems by other consultants working on behalf of CMHC. These consultants were also conducting follow-up research into the Country-wide Survey, but failed to realize that on-going monitoring was in progress. Hence data for Monitor No. 2 (House Survey No. 4002) is unreliable and has been removed from the statistics.

continuous spillage from the inlet whenever the appliance operated. In both houses, spillage was occurring because of restrictions, and a poorly sloped flue connector. Testing of similar "spillage" houses has indicated that continuous spillage of this type can be aggravated by house depressurization.

Results for oil-fired appliances are presented in Table 4. One of the oil-fired boilers also had no spillage. Two of oil-fired boilers also had a single spillage event, one lasting half a minute and the other lasting an unknown time period. The remaining two oil-fired appliances experienced significant amounts of spillage.

In total, 7 appliances out of 17 experienced repeated and significant amounts of combustion gas spillage, or 41 percent of the sample. The number of events for each house, and the average event duration, vary greatly. Each home and appliance is best analyzed on an individual basis.

TABLE 1
DESCRIPTION OF THE HOUSING SAMPLE

| House/ Counter Number | Location | Number of Stories | Construction Date | Exhaust Fans | Fireplace | Maximum House Depressurization (Pa) | ELA ($cm^2$) |
|---|---|---|---|---|---|---|---|
| 1 | Ottawa | 1 | 1960-1975 | 1 | Yes | 2.5 | NT |
| 2 | Ottawa | 1 | Post 1975 | 3 | Yes | 8.5 | 587 |
| 3 | Ottawa | 1 | Post 1975 | 2 | Yes | 7 | 857 |
| 4 | Ottawa | 2 | Post 1975 | 2 | Yes | 5 | NT |
| 5 | Winnipeg | 2 | Post 1975 | 5 | Yes | 8 | NT |
| 6 | Winnipeg | 1 | Post 1975 | 5 | Yes | 11 | 415 |
| 7 | Winnipeg | 1-1/2 | Post 1975 | 6 | Yes | 10.5 | NT |
| 8 | Winnipeg | 2 | Post 1975 | 5 | Yes | 15 | NT |
| 9 | Winnipeg | 2 | 1900-1945 | 3 | No | 0.5 | NT |
| 10 | Winnipeg | 2 | 1900-1945 | 1 | Yes | 6 | 472 |
| 11 | Winnipeg | 1 | Post 1975 | 5 | Yes | 12 | 250 |
| 12 | Vancouver | 2 | Post 1975 | 1 | Yes (2) | NT | NT |
| 13 | Vancouver | 3 | Post 1975 | 2** | Yes (2) | NT | NT |
| 14 | Vancouver | 2 | Post 1975 | 2** | Yes (2) | 6.9 | NT |
| 15 | Vancouver | 3 | Post 1975 | 3 | Yes | 6.0 | 1668 |
| 16 | P.E.I. | 1 | 1960-1975 | 2 | Woodstove | NT | NT |
| 17 | P.E.I. | 1 | 1960-1975 | 5 | Yes | NT | NT |
| 18 | P.E.I. | 1 | Post 1975 | 3 | Yes | NT | NT |
| 19 | P.E.I. | 1-1/2 | 1900-1945 | 3 | No | NT | NT |
| 20 | Vancouver | 1 | 1960-1975 | 2 | Yes (2) | NT | NT |

** House also has a Heat Recovery Ventilator

NT No test completed on these houses, since they were not among the original Case Study Houses

## TABLE 2
## DESCRIPTION OF THE APPLIANCE AND VENTING SYSTEM

| House/ Counter Number | Location | Fuel | Appliance Type | Appliance Location | Chimney Location | Shared Flue | Chimney Type | Appliance Age | Chimney Height (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ottawa | G | Furnace | Furnace Room Basement | Exterior | Yes | Brick & Metal | <5 yrs. | 6** |
| 2 | Ottawa | G | DHW | Open Basement | Exterior | Yes | Metal | <5 yrs. | 7 |
| 3 | Ottawa | G | DHW | Furnace Room Basement | Exterior | Yes | Metal | <5 yrs. | 5 |
| 4 | Ottawa | G | Furnace | Furnace Room Basement | Exterior | Yes | Brick | >5 yrs. | 9** |
| 5 | Winnipeg | G | Furnace | Open Basement | Interior | Yes | Brick & Metal | <5 yrs. | 7 |
| 6 | Winnipeg | G | DHW | Open Basement | Exterior | Yes | Brick (masonry) | <5 yrs. | 6 |
| 7 | Winnipeg | G | Furnace | Furnace Room Basement | Exterior | Yes | Brick & Metal | <5 yrs. | 10 |
| 8 | Winnipeg | G | Furnace | Furnace Room Basement | Exterior | Yes | Metal | <5 yrs. | 10 |
| 9 | Winnipeg | G | Furnace | Furnace Room Basement | Interior | Yes | Brick | >20 yrs. | 11 |
| 10 | Winnipeg | G | Furnace | Furnace Room Basement | Exterior | No | Brick & Metal | >20 yrs. | 10 |
| 11 | Winnipeg | G | DHW | Furnace Room Basement | Interior | Yes | Metal | <5 yrs. | 5.5 |
| 12 | Vancouver | G | DHW | Furnace Room Basement | Interior | Yes | Metal | <5 yrs. | 7 |
| 13 | Vancouver | G | DHW | Open Basement | N/A | No | Metal | N/A | 10 |
| 14 | Vancouver | G | DHW | Crawl Space | Interior | Yes | Metal | <5 yrs. | 7 |
| 15 | Vancouver | G | Furnace | Furnace Room Basement | Interior | Yes | Metal | <5 yrs. | 10 |
| 16 | P.E.I. | Oil | Boiler | Basement | Exterior | Yes with Fireplace | Brick | 5-10 yrs. | 7** |
| 17 | P.E.I. | Oil | Boiler | Open Basement | Exterior | N/A | Brick | 10-20 yrs. | 7** |
| 18 | P.E.I. | Oil | Boiler | Furnace Room Basement | Exterior | N/A | Brick | 5-10 yrs. | 7** |
| 19 | P.E.I. | Oil | Boiler | Furnace Room Basement | Interior | N/A | Brick | 10-20 yrs. | 8** |
| 20 | Vancouver | Oil | Furnace | Open Basement | Interior | No | Brick (masonry) | 10-20 yrs. | 6 |

** Approximated data

TABLE 3
SPILLAGE MONITORING DATA FOR
GAS-FIRED APPLIANCES IN ONTARIO, WINNIPEG, AND VANCOUVER

| House/ Counter Number | Monitoring Period (days) | Spillage Monitoring Data: Spillage Event Duration (hr:min:sec) | Spillage Event Frequency (No.) | Average Duration of Spillage Event (min:sec) |
|---|---|---|---|---|
| 1 | 68 | 00:0:00 | 0 | 0 |
| 2 | 89 | 1:10:08 | 3 | 23.36 |
| 3 | 89 | Data Lost* | Data Lost* | Data Lost* |
| 4 | 68 | 0:00:00 | 0 | 0 |
| 5 | 86 | 0:00:20 | 1 | 00:20 |
| 6 | 79 | 14:49:08 | 2358 | 00:22 |
| 7 | 79 | 265:04:12 | 1628 | 09:48 |
| 8 | 79 | 57:45:00 | 654 | 05:28 |
| 9 | 86 | 0:00:00 | 0 | 0 |
| 10 | 81 | 0:00:00 | 0 | 0 |
| 11 | 81 | 1:20:00 | 10 | 08:00 |
| 12 | 80 | 0:00:00 | 0 | 0 |
| 13 | 84 | 0:00:00 | 0 | 0 |
| 14 | 81 | 0:34:20 | 35 | 00:59 |
| 15 | 56 | 0:19:30 | 16 | 00:47 |

* Data was lost when house was tested by other consultants working for CMHC.

TABLE 4
SPILLAGE MONITORING DATA FOR
OIL-FIRED FURNACES IN P.E.I. AND VANCOUVER

| Survey House No. | House/ Counter Number | Period (days) | Spillage Monitoring Data: Spillage Event Duration (hr:min:sec) | Spillage Event Frequency (No.) | Average Duration of Spillage Event (min/event) |
|---|---|---|---|---|---|
| 5005 | 16 | 90 | 0:00:00 | 0 | 0 |
| 5173 | 17 | 90 | 0:00:36 | 1 | 00:36 |
| 5047 | 18 | 90 | 0:11:24 | 21 | 00:32 |
| 5171 | 19 | 84 | * | 1 | * |
| 1123 | 20 | 90 | 0:00:15 | 3 | 00:15 |

* This box contained only an event counter, hence spillage duration is unkown

**A Review of the Monitoring Data for Houses with Spillage Events:**

Monitor No. 2 recorded 3 spillage events with an average duration of 23 and a half minutes. The monitor was mounted on a gas-fired DHW heater connected to a 7 m exterior B-vent in a post 1975 Ottawa bungalow. New dot detectors showed 71°C black dots on both appliances, and a Venting Systems Test recorded a maximum house depressurization of 8.5 Pascals. Occupants reported that their smoke detectors in the furnace room went off once when using the Jacuzzi and fireplace. The three events appear to have been full cycle backdrafts. This problem was accurately predicted during the case study evaluation on their house (Survey No. 4002).

Monitor No. 6 recorded 2358 events, with an average duration of 22 seconds. Not surprisingly, the batteries were almost dead when this monitor was moved. More spillage may have occurred, but not registered.

Monitor 6 was installed in Survey House No. 2053, a case study house that is well documented in the Final Technical Report on Project 6 of the Residential Combustion Venting Failures. This is a tight house (ELA = 415 $cm^2$) with 5 exhaust fans and a fireplace. It has a very high depressurization (11 Pa), with all exhaust fans operating. The monitor was installed on a gas-fired furnace which shares a 6 meter B-vent with a DHW heater. Both furnace and DHW had created black dots during the survey, and the follow-up case study investigations had shown the venting systems to be susceptible to backdrafting. The case study revealed that the kitchen range hood operating alone is capable of exceeding the HDL, and investigators concluded that combustion gas spillage with the house is probably a daily event.

However, the high frequency of spillage events suggests the possibility that the monitor was not working as intended in this house. The number of events is in the order of the total number of furnace cycles that would have occurred over the monitoring period, (i.e., an average of 30 events per day). Since the furnace has a motorized flue damper, it is probable that spillage of simple hot air, rather than combustion gas, at the end of each cycle was triggering the counters. This type of interference had been avoided when using dot detectors, by locating the detectors at the bottom of the inlet. Apparently the great sensitivity of the thermistors required added precautions.

Monitor No. 7 was monitoring a gas-fired furnace, and, similar to Monitor 6, was located in a post 1975, Winnipeg house with a high level of depressurization (10.5 Pascals). The monitor recorded 1628 spillage events with an average spillage duration of 9 minutes, 48 seconds. The furnace was fitted with a automatic damper, and once again it is possible that the damper has interfered with the spillage monitoring.

A duration of over 9 minutes per event in this house suggests, however, that the damper is not the problem. The appliance is almost certainly experiencing partial spillage on a continuous basis.

Monitor No. 8 was installed on another gas-fired furnace in Winnipeg, in this case without a flue damper. The house depressurization is 15 Pascals under worst cast conditions (fans and fireplaces), and 9 Pascals (fans only). The chimney is a 10 meter exterior B-vent. The monitor recorded 654 spillage events with an average duration of 5 minutes, 28 seconds. Once again the high frequency and long duration of the spillage events suggests a major problem. Either the chimney is experiencing full-cycle backdrafting several times per day, or some kind of continuous spillage event is occurring. During the Venting Systems Test on this home the chimney was observed to backdraft continuously (at a outdoor temperature of -24°C), under worst case conditions, but vent normally when the house is not depressurized. Hence backdrafting appears to be the only explanation for the long periods of combustion gas spillage.

Monitor No. 11 recorded 10 events for a average of 8 minutes each. This monitor was mounted on a gas-fired DHW heater on a very tight (ELA = 250 $cm^2$) Winnipeg house. Maximum house depressurization was recorded at 12 Pascals (fans and fireplace) and 9 Pascals (fans only). The Case Study investigation had concluded that the house suffered from chimney backdrafting, exacerbated by a long, twisted flue pipe and a short, metal insulated exterior chimney. The data suggests that the DHW flue backdrafted for most (or all) of it operating cycle on 10 occasions over the 81 days of monitoring. It is also possible that the furnace could have spilled through the DHW vent connection, but the long duration of spill makes this scenario very unlikely.

Monitor 14 recorded 35 spillage events for an average duration of one minute. This monitor was mounted on the DHW heater of a R2000 house with a worst case depressurization of 6.9 Pascals. The water heater vent connector was fitted with a thermally activated Ameritherm vent damper. The DHW flue backdrafted continuously if operated under worst case conditions, during a Venting Systems Test. The thermally activated damper is slow to open, and typically causes spillage to occur at start-up. One minute of spillage is excessive however, and it is probable that some of the spillage events were short term (e.g., 15 to 30 seconds) and at other times the water heater flue was backdrafting through its cycle. The occupants of the house took an extended winter vacation, which explains the small number of events.

Monitor No. 15 recorded 16 events with an average of 48 seconds per event. This home is identical to one of the Case Study houses (next door), and was selected for monitoring because occupants would be unaware of previous research, and because this house, along with all other houses in its sub-divisions, appeared to have the same features which made the Case Study house prone to backdrafting problems. The home is a recent, 3 storey Vancouver home with a maximum depressurization of 6 Pascals.

Monitor 18 was mounted on a oil-fired heater, which experienced 21 spillage events, with an average duration of 32 seconds. This monitor (using a smoke detector) appears to have recorded the half minute of spillage that was witnessed on frequent occasions during the Case Study investigations of oil heated homes. The short-term spillage is very likely caused by start-up of the appliances against a cold, backdrafting chimney.

Monitor 20, with 3 events of 15 seconds each, was another monitor mounted above an oil furnace. It also seems to be experiencing start-up spillage.

**Difficulties with Monitoring Appliances with Flue Dampers:**

In a number of cases, flue dampers have interfered with the monitoring work for this study. Motorized dampers close immediately at the end of the cycle, causing warm air to spill out the inlets and creating an 'apparent' spillage event. Thermally activated dampers are slow to open, and cause start-up spillage so often that it becomes impossible to distinguish occasional prolonged spillage events from start-up spillage, using the recording equipment of this project.

In retrospect, installations of monitors require careful on-site calibration. It would also have been useful to obtain more detailed data and photographs from each region on the types of appliances, and the precise location of thermistors, especially in the houses where case studies had not been conducted.

An effort was made during this study to avoid spillage induced by operation of flue dampers, by mounting the thermistors at the lower part of the dilution air inlet. This was not a total solution. In at least one case, the spillage was recorded anyway. In two other cases, spillage occurring for other reasons was missed by mounting the thermistor in a lower location. More sophisticated monitoring technology is required before these types of problems can be analyzed. Electronic data logging devices are needed to record the duration of each spill as opposed to a cumulative record, and a detection method is needed that can gauge the quantity of spillage.

## 4. CONCLUSIONS

Twenty spillage-prone houses were monitored for approximately 80 days on the 1986/87 heating season. Data from one of the houses was destroyed, and the final sample numbers 19.

Twelve of these 19 houses recorded at least one spillage event. Three of the houses appear to have experienced frequent long-term backdrafting episodes.

The frequency and duration of spillage events showed considerable variation from house to house. In several cases, the spillage data proved difficult to interpret because the possibility existed of interference by flue dampers, which in some cases prevented proper placement and operation of the spillage detectors (thermistors). For this reason, two houses, where spillage was observed to occur during testing and installation were among the seven houses where no spillage incidents were recorded.

Appliances that experienced spillage events included four gas DHW heaters, five gas furnaces, three oil boilers and one oil furnace. The varying duration of spillage events for these appliances is consistent with previous research into the nature of venting failures.

Oil-fired appliances experienced short-term (15 to 36 seconds) spills, typical of start-up problems.

At least one gas-fired furnace, and two gas-fired water heaters appear to have experienced a high number of continuous backdrafting episodes. These apparent backdrafting events ranged in duration for the different appliances, from 5 minutes per event for the furnace, to 23 minutes per event for DHW heaters.

Since a majority of these houses were selected from the spillage-prone houses identified using dot detectors during the Country-wide Survey (1985/86), a high incidence of spillage is not surprising. If consideration is given to the difference in sensing abilities between dot detectors and thermistors - which in at least two cases prevented the recording of spillage events during this survey - the results of this study confirm the extent of spillage, as well as the variety of failure mechanisms, identified during the Country-wide survey.

## 5. REFERENCES

1. RESIDENTIAL COMBUSTION VENTING FAILURE: A SYSTEMS APPROACH, SUMMARY REPORT AND FINAL TECHNICAL REPORT FOR PROJECT 1: COUNTRY-WIDE SURVEY, Prepared for CMHC by Scanada Sheltair Consortium Ltd., January, 1987.

**MONITORING COMBUSTION GAS SPILLAGE**
**FREQUENCY AND DURATION IN**
**20 PROBLEM HOUSES**

## APPENDIX 1

## INSTALLATION INSTRUCTIONS AND FORMS

# GAS FIRED FURNACE AND WATER HEATER
# SPILLAGE SURVEY

## TASK DESCRIPTION

The purpose of this project is to re-install our grey-box spillage counters on furnaces or water heaters in survey houses where spillage problems are known to have occurred.

For this second attempt at monitoring combustion gas spillage frequency and duration, the grey-box spillage counters have been retrofitted. An additional two (2) batteries have been installed, so that counters should be capable of lasting for longer periods without running out of power. An additional counter has also been installed, so that the grey-box spillage counters will now record the frequency, as well as the duration of spillage events. The counters are designed to be stuck onto the furnace or water heater (as before), and the thermistors will be located in a similar location to the dot detectors used for the Canada-wide survey.

It is very important that the box is installed securely onto the appliance, so that it will not slip or fall off, and that the thermistor is located in the best spot for identifying spillage. If the box is being hung from a vertical surface, the two-sided tape may be inadequate to hold it in place. If so, use the sheet metal screws supplied to attach it securely to the front of the furnace. (Holes must be drilled for this purpose.) It may be a good idea, if the chimney can easily be plugged, to cause the appliance to spill after installing the counters to ensure that the counters are working properly. This is an optional procedure left up to your best judgement. However, remember that these counters have already been used during the previous research during our last heating season, but in many cases they were installed in the houses too late, or were not installed at all, and hence the research results were useless. This time it must be done right.

The work breaks down into six (6) tasks:

1. Select appropriate houses.

   You will find attached, print outs and installation report forms describing a sample of houses from your region where black dots indicated spillage problems. In some cases these houses may have been visited as part of our case study work in the spring of last year, and in other cases householders will have only have received a letter in regards to their spillage problem. In any case, we want to restrict the houses participating in this project only to those houses where no significant changes have been made to the heating system since last winter. You can explain to the householders, that their participation in this additional phase of research will provide us and them with much more information on the extent of the spillage hazards. In fact, through this spillage counter box, we will be able to recommend to them definitely whether or not they have a potential health hazard due to spillage from their furnace or water heater.

   The householder must be prepared to have you visit the house on two (2) occasions: the first time to conduct a Venting Systems Test (if one has not already been conducted during case study work), and to install the spillage counter on the appliance; the second visit will be to remove the spillage counter.

   Based on your knowledge of these houses, and on discussions with householders, it will be up to you to select the houses most suitable for participation in this project. Try to choose houses where the potential exists for more spillage events.

2. Phone the householders and arrange visits.

3. Visit each house, and conduct a Venting Systems Test and install the box.

Your time in the house is expected to be less than an hour. Immediately after arriving in the house you should conduct a Venting Systems Test using the checklist and report forms provided. After conducting this test, install two (2) alkaline batteries in the spillage counter box, attach leads to the third battery (already in place), and then affix the box to the furnace or water heater (whichever appliance had the greatest number of black dots).

Installation and removal of batteries from these boxes must be done very gently so as not to disturb the circuit board!

There are two (2) counters in each box. Both counters are activated whenever the temperature thermistor exceeds approximately 40°C. The counter on the side of the box will count a single digit every time such an event occurs, and the counter on the circuit board will continue counting for as long as the event takes place.

After installing the counter on the furnace and making any tests, you <u>must</u> record the starting counts for both counters on the face plate of the counter.

4. Send results to Sheltair.

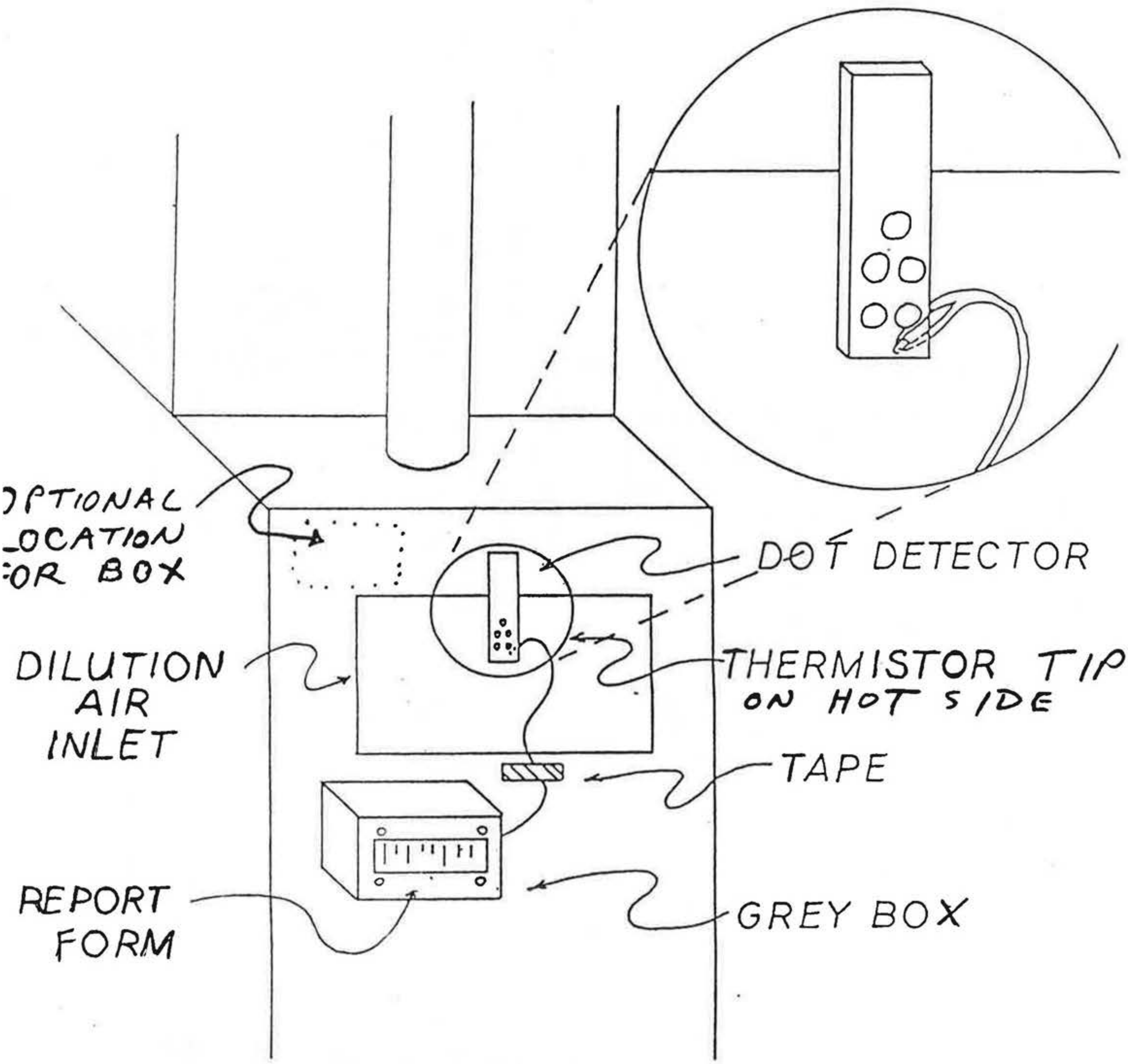
For billing purposes we need to know as quickly as possible:
- Which houses you have installed the spillage counters.
- The results of any Venting Systems Tests conducted on these houses.
- The starting counts on the counters that have been installed, and the installation date.

## A CROSS REFERENCE LISTING FOR MONITORED HOUSES

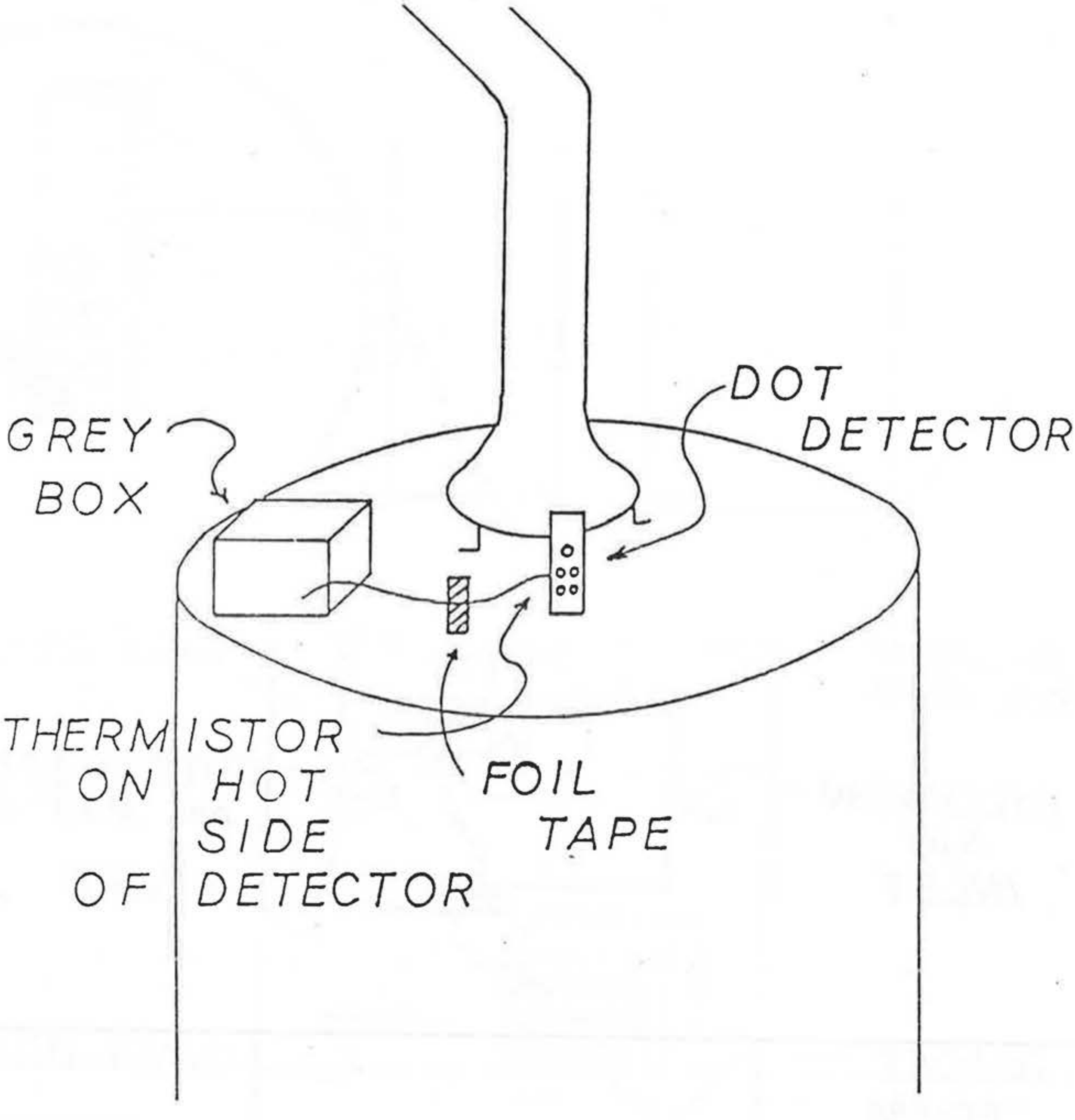
For the monitored houses that were part of the 1986/87 Country-Wide Survey.

| Monitor No. | House Survey No. from previous Country-Wide Survey |
|---|---|
| 1 | 4193 |
| 2 | 4002 |
| 3 | 4184 |
| 4 | 4187 |
| 6 | 2053 |
| 7 | 2066 |
| 8 | 2051 |
| 9 | 2013 |
| 10 | 2022 |
| 11 | 2122 |
| 16 | 5005 |
| 17 | 5173 |
| 18 | 5047 |
| 19 | 5171 |
| 20 | 1123 |

WHERE TO MOUNT COUNTER ON GAS FURNACE

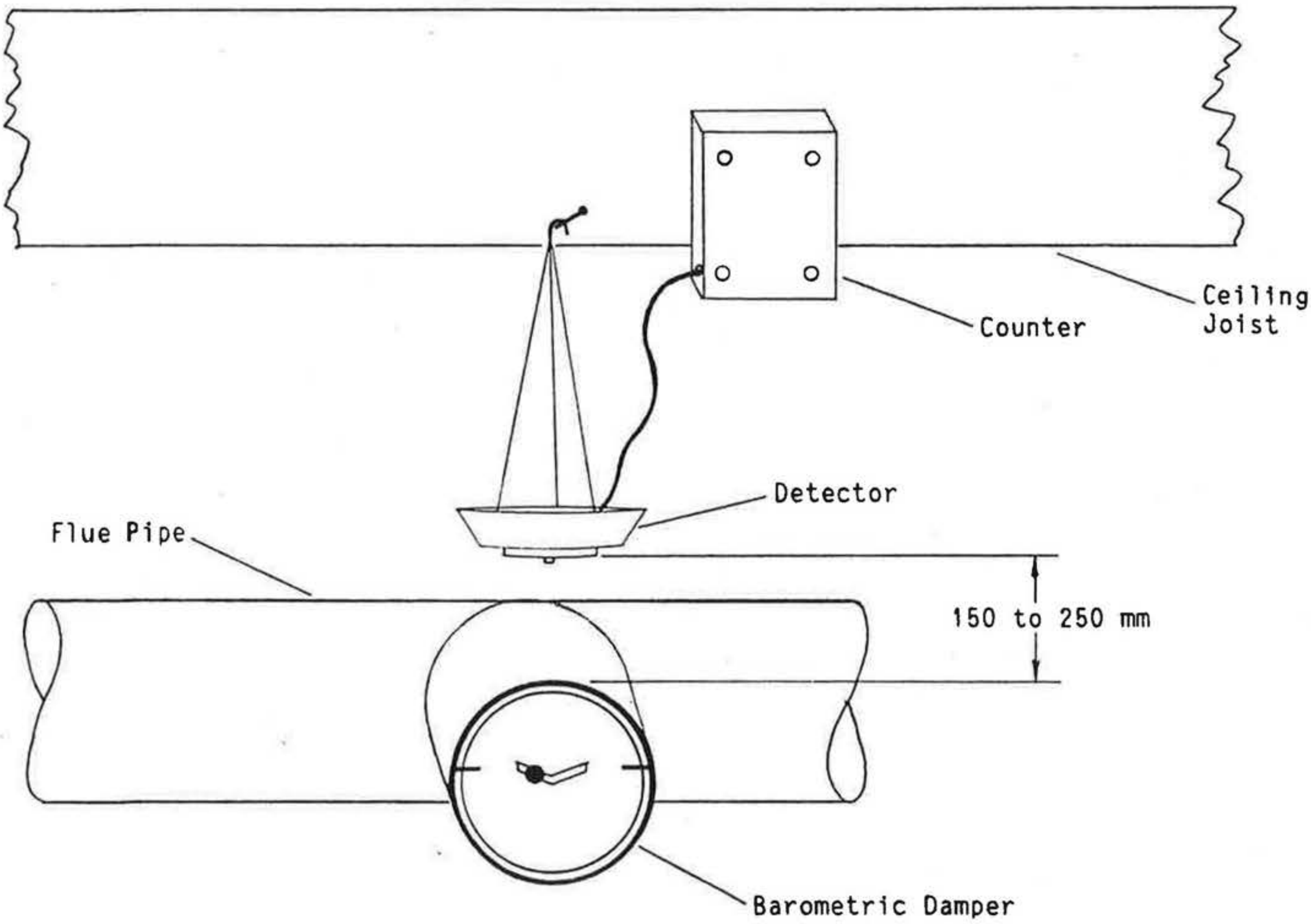


WHERE TO MOUNT THE GREY BOX COUNTER
ON A WATER HEATER




(NOTE: THERMISTOR TIP SHOULD BE MIDWAY BETWEEN TOP OF TANK AND LOWER RIM OF DRAFT HOOD.)

WHERE TO MOUNT THE COUNTER AND DETECTOR FOR AN OIL FURNACE



MONITORING COMBUSTION GAS SPILLAGE
FREQUENCY AND DURATION IN
20 PROBLEM HOUSES

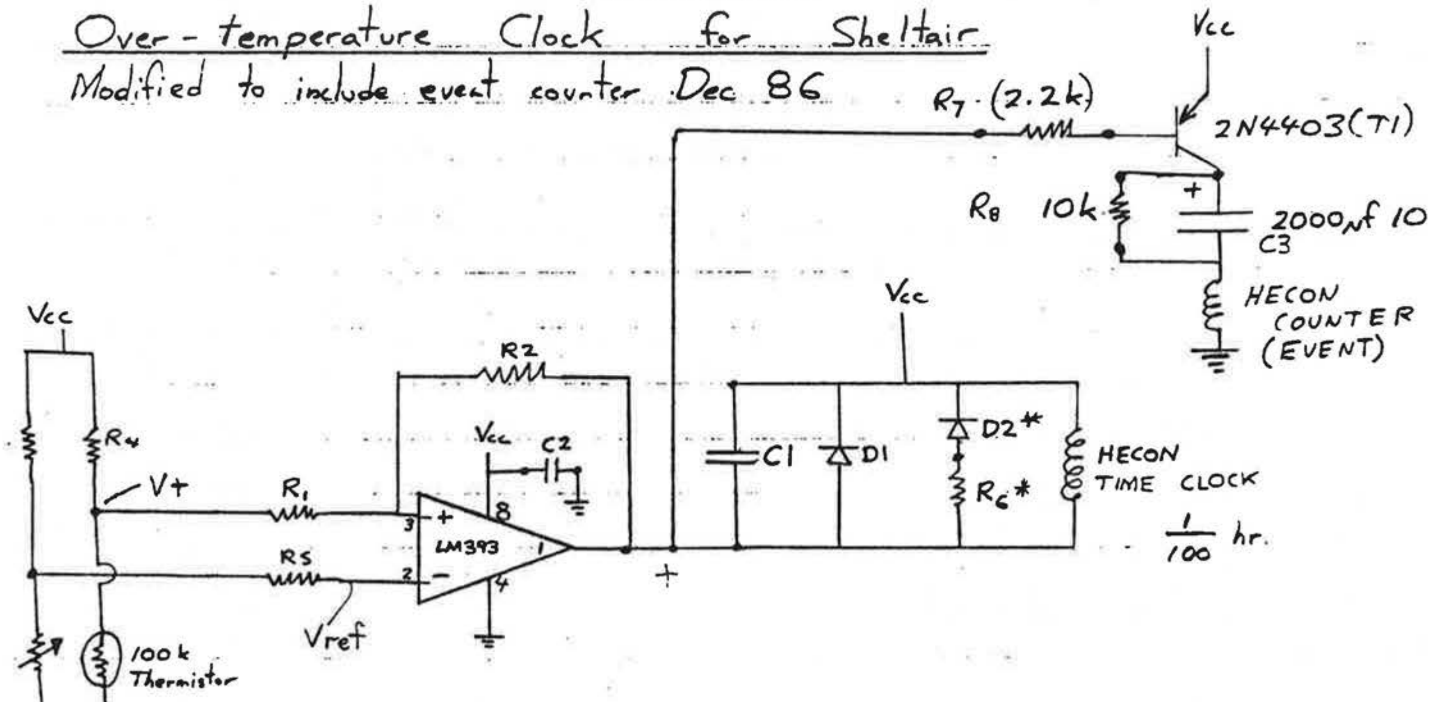
APPENDIX 2

COUNTER DESIGN

**Wiring Schematic**

<u>Over - temperature Clock for Sheltair</u>

Modified to include event counter Dec 86




* Optional LED - consumes about 2 ma. when on. (OMIT)

Output is on when $V_+ < V_{ref}$ (i.e. pin 3 is grounded)

<u>Component Values</u>

- $R_T$ — 100k - 15 turn trimmer
- $R_s$ - 10k , $R_8$ = 10k
- $R_1$ - 10k
- $R_2$ - 10 M
- $R_4$ - 200 k
- $R_5$ - 200 k
- ~~$R_6$ - 1k (optional)~~ ; $R_7$ = 2.2k
- Thermistor - 100k Fenwal (minimum 2k at 25°C but 100k is better)
- $D_1$ - 1N4001
- ~~$D_2$ - LED (optional)~~
- C1 - 2000µf - 10 volt
- C2 - 0.1µf ceramic ; C3 = 2000µf 10v
- Comparator - LM 393
- T1 — 2N4403

**Furnace Spillage Clock**

**Thermistor Values** FENWAL

| Item | | Thermistor Type GB32P8 | JA41J1 | GA51 |
|---|---|---|---|---|
| 1 | Resistance at 25°C | 2,000 Ω | 10,000 Ω | 100,00 |
| 2 | R-T Curve | 11 | 16 | 15 |
| 3 | Tolerance at 25°C | 20% | 10% | 20% |
| 4 | Time Constant | 22 secs. | 10 secs. | 5 sec |
| 5 | Resistance at 40°C | 1146 Ω ±22% | 5330Ω ±11% | 51.0k ± |
| 6 | 50°C | 810 Ω ±22.5% | 3600 Ω ±11.5% | 33.6k ± |
| 7 | Resistance setting on circuit board | 1000 to 1050Ω | 4900 to 5000Ω | 45kΩ |

| | DALE |
|---|---|
| Part # | 9M1002-1 |
| R at 25°C | 10,000 Ω |
| RT curve | 9 |
| Tolerance | 1% |
| R 40°C | 5592Ω |
| R 50°C | 3893Ω |
| SET AT | 4.8 k |