CMHC SCHL
Helping to house Canadians

8028

Canada

DESIGN AND DEVELOPMENT
OF AIR VENT CLOSURE
SYSTEMS

DESIGN AND DEVELOPMENT OF AIR VENT CLOSURE SYSTEMS

A Final Report: Phase III

Submitted to:

Housing Technology Incentive Program
Canada Mortgage and Housing Corporation
National Office
700 Montreal Road
Ottawa, Ontario
K1A 0P6

Submitted by:

Buchan, Lawton, Parent Ltd
5370 Canotek Road
Ottawa, Ontario
K1J 9E6

January, 1994
BLP File No. 2715

This project was carried out with the assistance of a grant from Canada Mortgage and Housing Corporation under the terms of the Housing Technology Incentives Program. The views expressed are those of the author and do not represent the views of the Corporation.

DISCLAIMER

This study was conducted for Canada Mortgage and Housing Corporation under Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

Abstract

The following report documents the design and development of an automatic vent closure system for residential exhaust systems. The report discusses the rationale behind the perceived need for such a system and defines the objectives of the design and development work with respect to these needs.

A detailed account of the development of the design and construction of successive prototypes will be given along with a thorough description of the testing procedures employed to evaluate the operational characteristics of each prototype as their design was further refined and developed.

The operational characteristics of the vent closure systems developed will be presented to demonstrate their capabilities and limitations with respect to airflow and pressure requirements for operation, battery life, and acceptable outdoor ambient temperature ranges. The installation requirements of the systems will also be demonstrated.

Given the capabilities and limitations of the air vent closure systems developed, the report will conclude by listing the successes and failures of the design. Based on this analysis, the potential for such a device to ultimately be accepted in the marketplace will be postulated. Additionally, recommendations for any further refinements will be submitted.

Table of Contents

1.0 EXECUTIVE SUMMARY

Under the terms of an agreement between Canada Mortgage and Housing Corporation and Mr. Hubert Gervais (Reference File No. 6521-13/92), Mr. Gervais received funding under the Housing Technology Incentives Program (HTIP) to carry out the design and development of an automated air vent closure system. The proposed system—in essence, an outdoor hood with a self-contained motorized damper and air flow sensing system—was to be self-actuated, airtight, and insulated unlike the conventional outdoor exhaust hood and damper assemblies currently available for residential applications.

The initial design and development efforts led to the fabrication of prototypes of the air vent closure system which were suitable for installation at the outdoor termination points of 150 mm round and 87 mm x 254 mm rectangular exhaust ducts. Each device contained a single, 9 V battery, which powered the hood damper open upon the commencement of air flow within the exhaust duct and shut upon the termination of the exhaust air flow. The operation of the motor was controlled by an integral air flow pressure sensing device and electronic circuitry. The devices were entirely self-contained and easily installed by untrained personnel.

An evaluation of the performance of the devices in actual field tests demonstrated the viability of the concept of an inexpensive, self-contained, relatively airtight and well insulated closure for residential exhaust vents. The major complications experienced concerned the effects of frozen condensate on the operation of the air flow pressure sensor and the closure mechanism's damper. Additionally, the use of a DC battery to power the device placed limitations on the operation time, cold weather performance, and associated control options.

All but one of the aforementioned limitations of the design were resolved by changing the power source from a 9 V battery to a common 9 V DC/120 V AC adapter. This single change allowed for a significant improvement to the control hardware which, in turn, improved the reliability of the device and the ease with which it could be controlled. The problem of the damper mechanism freezing shut still remained, but it was envisioned that the use of alternative materials for the damper (such as polyethylene) and gasket materials would prevent such occurrences in the future.

The shop and field testing of the devices led to design refinements that ultimately improved the viability of the concept from the standpoints of practicality and marketability of the vent closure system device.

The final prototype will be used to demonstrate the concept to potentially interested manufacturers of ventilation related equipment for inclusion in their product lines.

1.0 RÉSUMÉ

Aux termes d'un accord conclu entre M. Hubert Gervais et la Société canadienne d'hypothèques et de logement (n° de référence 6521-13/92), M. Gervais a reçu une subvention dans le cadre du Programme d'encouragement à la technologie du bâtiment résidentiel (PETBR) en vue de concevoir et de mettre au point une bouche d'évacuation à fermeture automatique. L'appareil proposé, composé essentiellement d'un capuchon extérieur, d'un clapet motorisé intégré et d'un capteur de mouvement d'air, devait être isolé, automatique et étanche à l'air pour ainsi pallier aux lacunes des bouches d'évacuation classiques actuellement sur le marché pour les applications résidentielles.

Les premiers travaux de conception et de mise au point ont mené à la fabrication de prototypes pouvant être posés à l'extrémité extérieure de conduits d'évacuation ronds (150 mm) et rectangulaires (87 mm x 254 mm). Chaque appareil est doté d'une seule pile de 9 V servant à alimenter le moteur commandant l'ouverture du clapet dès l'arrivée de l'air par le conduit et sa fermeture lorsque cesse le mouvement d'air. Le fonctionnement du moteur est réglé par un circuit électronique et un capteur de pression d'air d'une seule pièce. Les deux bouches d'évacuation sont entièrement autonomes et peuvent très bien être installées par un non-spécialiste.

L'évaluation de la performance des appareils, à l'occasion d'essais en service, a démontré la viabilité du concept. En effet, il s'est avéré que les appareils pourraient être peu coûteux, autonomes et relativement étanches à l'air tout en constituant une fermeture bien isolée pour les bouches d'évacuation résidentielles. Les principales complications ont trait aux effets du gel du condensat sur le fonctionnement du capteur de mouvement d'air et sur le mécanisme de fermeture du clapet. De plus, l'utilisation d'une pile c.c. pour alimenter l'appareil nuit à la vitesse d'exécution, au fonctionnement par temps froid et aux options de commande connexes.

Tous ces inconvénients, sauf un, ont pu être résolus en remplaçant la pile 9 V par une pile ordinaire 9 V à c.c. associée à un adaptateur 120 V c.a. Ce seul changement a permis d'améliorer considérablement le matériel de commande et, de ce fait, la fiabilité de l'appareil et la facilité avec laquelle il peut être commandé. Le problème touchant le gel du clapet est demeuré, mais on croit que l'emploi de matériaux différents pour le clapet (comme le polyéthylène) et pour le joint d'étanchéité pourrait le régler.

Les études en service et en atelier des bouches d'évacuation à fermeture automatique ont permis de mettre au point des détails qui ont finalement contribué à améliorer la viabilité du concept quant à sa commodité et à sa valeur marchande.

Le prototype final servira à faire la démonstration du concept à des fabricants d'équipement de ventilation qui pourraient être intéressés à ajouter ce produit à leur propre gamme.

CMHC SCHL

Helping to house Canadians
Question habitation, comptez sur nous

National Office
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Bureau national
700 chemin de Montréal
Ottawa (Ontario)
K1A 0P7

Puisqu'on prévoit une demande restreinte pour ce document de recherche, seul le sommaire a été traduit.

La SCHL fera traduire le document si la demande le justifie.

Pour nous aider à déterminer si la demande justifie que ce rapport soit traduit en français, veuillez remplir la partie ci-dessous et la retourner à l'adresse suivante :

Le Centre canadien de documentation sur l'habitation
La Société canadienne d'hypothèques et de logement
700, chemin de Montréal, bureau C1-200
Ottawa (Ontario)
K1A 0P7

TITRE DU RAPPORT : ______________________________

____

Je préférerais que ce rapport soit disponible en français.

NOM ______________________________

ADRESSE ______________________________
rue app.

____
ville province code postal

No de télephone ( ) ____________

2.0 BACKGROUND

The project to develop the vent closure device was undertaken to respond to the need for an airtight and reliable means of closing off residential exhaust ducts when the associated exhaust fans were not operating. Existing exhaust hood and damper assemblies are poorly made and, as such, do not close in an airtight manner (if at all). This, combined with the absence of any insulative value in most conventional exhaust hood and damper assemblies, results in a waste of home heating energy over the course of a typical winter. Additionally, unsealed exhaust ducts can cause uncomfortable drafts for the dwelling's occupants.

A review of the "state-of-the-art" vent closure systems revealed there were a number of motorized damper assemblies available that could be used to seal off ducts. However, none of the dampers were insulated, and all were powered by a standard 120 V or 24 V AC service. Additionally, none of the dampers reviewed had an integrated control system for initiating the "open" and "close" sequences of the damper's operation. Consequently, the homeowner or contractor who wanted to incorporate a vent closure system into an exhaust air duct system would have to design and install an air flow sensing device, wiring, and associated controls to allow the operation of the vent closure system. The complexity of such installation requirements would tend to discourage the typical homeowner from attempting such an effort.

The proposed vent closure system was designed to offer a reliable, low-cost, airtight, automatically actuating alternative to conventional exhaust dampers. The system would be easily retrofitted in place of the existing hood or could be included in new home construction. The device, as originally conceived, would be able to operate independently of the host dwelling electrical system (i.e., battery powered) and, as such, would not require an electrician for installation.

The development of such a device would benefit homeowners who were performing energy upgrade retrofits in their homes. The device would decrease air leakage through the exhaust ducts when their respective exhaust fans were not in use. Additionally, the device would offer a low-cost, relatively simple alternative to existing damper systems for contractors to install in the homes of discerning clients.

3.0 OBJECTIVES

The specific objectives of the project were to design and develop a prototype vent closure device. The device had to be low cost, easily installed, automatically actuating, airtight, insulated, and powered by a common 9 V battery. It also had to be available in the common exhaust duct sizes to be compatible with standard residential exhaust ducts.

The system had to be entirely self-contained in terms of power source and air flow sensing capability so that it could be easily retrofitted into existing exterior exhaust port locations; and it had to be capable of operating reliably under extreme winter conditions

4.0 PROTOTYPE DESCRIPTION

4.1 General

Two versions of the air vent closure system prototype were originally developed. One version was compatible with 150 mm round vent systems (e.g., cooktop range fans, HRV ducts, dryers, etc.); while the other version was compatible with 89 mm x 254 mm ducts (e.g., rangehoods). Photos No. 1 through 3 show the 89 mm x 254 mm version. Photo No. 4 shows the 150 mm diameter version. Figures 1 and 2 detail the physical dimensions of both units.

Despite the nominal dimensional differences, both devices had essentially the same configuration and assembly. They were constructed of galvanized sheet metal. Each device consisted of a housing and internal frame for the air static and dynamic pressure sensing device, vent closure motor, and drive. A weather hood and screen was attached to the exterior side of the housing. An adapter duct, complete with an internal compartment for the battery and control circuit hardware, was attached to the interior side of the housing.

It was envisioned that the vent closure device would be used to replace existing exhaust vents. To this end, the unit was designed to be installed easily. The original vent would be removed, and the vent closure device would be installed in its place by inserting the duct adapter into the exterior termination point of the exhaust duct and then screwing the closure housing into the exterior wall (See Photos No. 11 and 12).

A 100 mm diameter version of the prototype, which incorporates several improvements to the design and operation of the unit, has since been developed. The refinements were made in response to the results and observations of the laboratory and field testing of the original two prototypes, as documented in the Phase II report. The motor/enclosure assembly was fabricated completely of molded fibreglass; although the exterior housing was made of steel. The layout of the control circuitry was altered to allow for its storage in the exterior housing as opposed to the duct compartment of the original prototypes. The air flow sensing device and switches were also altered as described in subsequent sections. The 100 mm version of the vent closure device is shown in Photos No. 7 through 9. Detailed drawings of the device are depicted in Figures 3 through 5.

4.2 Air Flow Sensing Device

The most critical component of the air vent closure system was determined to be the air flow sensing component and associated switches. In the original versions of the prototype, an "L" shaped sensing vane (shown in Figure 1) was designed to respond to either static or dynamic air pressures created in the exhaust duct by the operation of the exhaust fan. Based on these capabilities, the sensor was used to initiate the vent closure opening and closing sequences in the following manner:

1. The exhaust fan begins operation, while the vent closure damper is shut.

2. Static pressure within the exhaust duct acting on the horizontal leg of the sensor forces it to swing up to make contact with the open sequence starter contact.

3. The open sequence starter contact signals the motor to open the closure damper.

4. Opening of the vent closure damper causes the static pressure within the duct to diminish, while the dynamic pressure resulting from the air flow from the exhaust fan increases and acts on the vertical leg of the sensor. This continuous action maintains the contact between the horizontal leg of the sensor and the "open" contact. The continued contact maintains the vent closure damper in an open position.

5. Upon deactivation of the exhaust fan, the static and dynamic air pressures within the duct fall to zero; the air pressure sensor breaks contact with the "open" contact and falls back to its original position, thereby making contact with the "close" contact.

6. The "close" contact signals the motor to return the vent closure damper to the closed position.

The sensitivity of the pressure sensor was dependent upon the dimensions of the vertical and horizontal legs. The dimensions of the vertical and horizontal legs were established to allow them to respond to both dynamic and static pressures that would be developed within the duct by the operation of an exhaust fan with an air flow capacity typical for that size of duct.

In an effort to improve the performance of the vent closure system, the pressure sensing device and controlling switches were revised. The pressure sensing device was improved through the alteration of the static pressure sensing horizontal arm to a static pressure sensing polyethylene slack diaphragm (shown in Figure 5).

The use of a slack diaphragm prevented air leakage from the exhaust duct into the vent closure housing, thereby protecting the internal circuitry and motor/drive assembly. The slack diaphragm eliminated the installation related problems associated with having to install the device perfectly horizontal to achieve the required positioning of the horizontal static pressure sensing arm. Additionally, the slack diaphragm proved to be far superior at reacting to lower static pressures in the duct, thereby allowing the device to operate over an increased range of exhaust fan capacities.

4.3 Motor and Drive

The motor selected to operate the vent closure was originally chosen in keeping with the notion that the system be battery operated and of low voltage. The motor is a 9 volt DC unit with a two-way, reversible clutch. The motor drive shaft rotates at 2 rpm. The motor and drive shaft rotate the vent closure through an arc of approximately 30° from the open to closed positions. The manufacturer's recommended ambient operating temperatures of the motor range from -20° C to 60° C; although the unit was capable of operating at lower temperatures.

The motor drives the vent closure open and shut by way of a shaft to which the closure is attached. The shaft is supported by the motor at one end and a bearing sleeve at the other.

The motor and drive assembly are mounted on the frame contained in the vent closure housing. Both are accessible by removing the frame from the housing.

Ultimately, the redesign of the prototype included the removal of the battery from the design of the unit. The final prototype is powered by a 9 V to 120 V adapter, which is connected to the host house electrical system. This change was necessary for many reasons. The operating life of the 9 V battery during the winter months was unacceptably short, and frequent replacements were necessary. Additionally, a battery powered system was not conducive to the use of the photo-electrical contact and switching circuitry which was designed into the final prototype (as discussed in the next section).

4.4 Control Circuitry

The operation of the vent closure system is dependent upon the control circuit, which responds to flow/no flow conditions as detected by the pressure sensing vane and slack diaphragm. Figure 6 depicts the original control circuit diagram, while Figure 7 depicts the final circuit that employs the optical switches.

The control circuit was originally mounted on a circuit board along with the battery (Photo No. 10). The assembly was attached to the motor and contacts by way of a detachable wiring harness. The circuit and battery assembly was contained in an internal housing in the exhaust duct adapter section. This configuration not only minimized the size of the exterior housing, but also placed the circuitry and battery in a relatively warm location within the wall assembly when the vent closure device was installed.

Since the change from the battery powered system to the 9 V DC/120 V AC adapter powered system, the operation of the control circuitry is no longer as susceptible to outdoor temperatures as it once was. Therefore, the control circuitry is now located in the exterior housing of the device as is shown in Figure 3.

The basic logic of the original control circuitry was as follows. Upon start-up of the exhaust fan, the vent closure damper was closed. The static pressure resulting from the closed condition and the operation of the fan caused the horizontal leg of the pressure sensing device to push up, making contact with the circuit contact and starting the "open" sequence. The motor then powered the vent closure damper to an open position. The operation of the motor was halted when the vent closure damper made contact with another circuit contact which stopped the motor. The vent closure damper was maintained in an open position as the pressure sensing vane was held in position by the dynamic pressure exerted on the vertical leg by the exhaust air flow. When the exhaust fan was shut off, the air flow ceased; and subsequently, the dynamic and static air pressure within the duct fell to zero—allowing the pressure sensing vane to drop back to its original position. Upon returning to its original position, the vane made contact with another circuit contact that signaled the motor to reverse and close the vent damper. When the vent damper returned to a closed position, the damper made contact with another circuit contact that stopped the motor from operating. The vent closure device then remained closed until the next time the exhaust fan started to operate.

As noted during the field testing, there were contact related problems experienced that sometimes caused the device to operate erratically. Additionally, it was suspected that the contacts were susceptible to icing, which limited their capability to sense the location of the vent closure. There was also a problem relating to the positioning of the contacts, which sometimes resulted in the motor running on in an attempt to either close or open the damper whenever a positive contact was not established as a result of the location of the contacts.

The original contacts have been replaced with inexpensive photo-optical switches, which rely on the interruption of an integral beam of light to signal a contact. There are three optical switches in the device. One switch is located above the slack diaphragm static pressure sensor. When the static pressure in the duct increases, the slack diaphragm pushes a shaft up through the optical switch which interrupts its integrated light signal. This interruption initiates the "open" sequence of the device. The damper is held in the open position by the action of the dynamic pressure vane which maintains the position of the shaft in the optical switch. The damper is moved to the open position where a cam, located on the drive shaft, interrupts another optical switch to signal the motor to stop the damper in the open position. The damper remains open until the exhaust air flow is stopped, and the slack diaphragm and dynamic pressure vane falls back into resting position, thereby allowing the shaft to break contact with the optical switch above. This action initiates the "close" sequence, which continues until the damper is shut and the cam located on the drive shaft makes "contact" with the third optical switch to signal the damper to stop in the closed position.

5.0 PERFORMANCE CHARACTERISTICS

The vent closure devices were subjected to both laboratory and field testing in order to determine performance characteristics and any needs for further design development. The following sections iterate the observations made during the two phases of testing.

5.1 Phase I: Laboratory Testing

Tests were performed on the two original vent closure damper systems to establish the following parameters:

- the minimum amount of air flow necessary to initiate the "open" sequence and to maintain the damper in an open position, and
- the range of negative house pressures that could be developed by the operation of other exhaust appliances (e.g., clothes dryers, furnaces, domestic hot water heaters, central vacuum systems, etc.) under which the vent closure device would continue to operate effectively.

Figure 8 depicts the apparatus used to determine the aforementioned performance characteristics.

The first test performed determined the minimum amount of air flow required to open each of the vent closure devices. Typically, 150 mm exhaust ducts are sized and installed for exhaust fans having a capacity greater than 50 L/s; while 89 mm x 254 mm ducts are most commonly used for rangehoods, which have exhaust capacities ranging from 40 to 100 L/s. Experience has proven that rangehoods typically operate at 50 to 75 L/s.

The 'initiation' flow rate required to open the devices was heavily dependent upon the size and orientation of the pressure sensing vanes. Based on the size of vane finally used in the closure systems, the 150 mm device could be made to operate at air flow rates in the order of 45 L/s. The 89 mm x 254 mm device opened at an air flow rate of 30 L/s. It is important to note that both these air flow rates are within the acceptable range of air flow that would actually be found in ducts of these sizes.

The second test conducted was performed to establish the performance tolerance of the vent closure systems under different "house" pressure regimes. This type of information was considered necessary, as the ability of the pressure sensing vane to effectively initiate the "open" sequence was likely to be affected by negative house pressures produced through the operation of other air consuming appliances typically found in houses.

Through the use of the apparatus depicted in Figure 8, the prototype air vent closure systems were connected to a variable speed exhaust fan, which was connected to the pressure chamber. The pressure chamber was used to simulate the "house". By varying the pressure between the inside and outside of the chamber to simulate different levels of negative house pressures, the amount of exhaust duct air flow necessary to initiate the "open" sequence of each device was determined.

The 89 mm x 254 mm device would operate effectively with the following exhaust fan flow rates up to the level of the negative house pressures indicated.

Fan Flow rate	Maximum House Depressurization
44 L/s	12 Pa
51 L/s	22 Pa
57 L/s	30 Pa

It is generally accepted that "naturally" occurring negative house pressures usually do not exceed 10 Pa. Mechanically induced negative house pressures typically do not exceed 20 Pa. This being the case, it can be concluded that the 89 mm x 254 mm vent closure device will operate effectively within these pressure regimes as long as the air flow rate through the device is not less than 50 L/s. As mentioned earlier, this level of flow rate is in keeping with the type of exhaust appliance that would require a 89 mm x 254 mm exhaust duct; therefore, it can be concluded that the 89 mm x 254 mm vent closure device will perform satisfactorily in these applications.

The 150 mm vent closure system was also evaluated in this manner with the following results:

Fan Flow Rate	Maximum House Depressurization
44 L/s	5 pa
48 L/s	8 pa
55 L/s	20 pa

Again, this test revealed that the 150 mm vent closure system could operate within the range of negative pressures typically found in houses as long as the air flow rate through it was in the order of 55 L/s. As exhaust systems requiring 150 mm ducts usually operate with air flows exceeding 55 L/s, it is expected that the 150 mm vent closure system will also operate satisfactorily in all applications.

5.2 Phase II: Field Testing

5.2.1 Kitchen Rangehood Installation

The following table documents observations concerning the operation of the air vent closure system installed in the vent hood of a standard kitchen rangehood exhaust system. The rangehood was located over the kitchen stove on an outside wall. The rangehood was vented directly outdoors through a four-inch, deep framed wall. Air flow measuring tests performed on the rangehood indicated that the exhaust fan was capable of exhausting air at a rate of 30 to 35 L/s on low speed and 80 L/s on high speed operation.

Table 1.0 documents the notes made over the course of the field testing of the vent closure device. It should be noted that the vent closure was routinely cycled open and shut regardless of whether or not the rangehood was actually required by cooking activity.

Table 1.0 Rangehood Observation Log

Date	Outdoor Temperature	No. of Cycles	Time/Cycle	Comments
February 20, 1993	-22° C	3	5 sec.	• OK-new battery installed.
February 24, 1993	-20° C	3	10 sec.	• OK
February 24, 1993	-20° C	1	10 sec.	• Closure damper frozen shut. High-speed fan operation required to open damper.
February 25, 1993	-18° C	2	10 sec.	• Closure frozen shut - had to be manually opened. Frozen condensation visible inside duct.
February 25, 1993	-18° C	5	10 sec.	• OK - all speeds opened closure device.
February 25, 1993	-20° C	1	10 sec.	• OK
February 26, 1993	-10° C	1	10 sec.	• Ice formed between vent damper gasket and housing freezing the unit shut. Clutch slipped during operation.
February 27, 1993	-10° C	1	15 min.	• Ice on vent damper prevented closure device from opening for 15 to 20 seconds from start. • Ice held dynamic pressure sensing valve in "open" position - temporarily. Unit closed two minutes after rangehood fan operation was ceased.
March 1, 1993	-4° C	2	10 sec.	• OK
March 2, 1993	-6° C	2	10 sec.	• OK
March 3, 1993	-3° C	2	10 sec.	• OK
March 4, 1993	-4° C	2	10 sec.	• OK
March 5, 1993	-14° C	1	5 min.	• OK
March 7, 1993	-16° C	2	30 sec.	• Dynamic pressure sensing vane frozen in "closed" position and would not allow device to open for the one minute of fan operation required to defrost the unit.
March 7, 1993	-15° C	0	0	• Dead battery
March 7, 1993	0° C	2	30 sec.	• OK
March 8, 1993	-2° C	5	30 sec.	• OK
March 8, 1993	-2° C	1	15 min.	• OK
March 9, 1993	0° C	3	30 sec.	• OK
March 10, 1993	-7° C	3	30 sec.	• OK
March 11, 1993	-17° C	1	10 min.	• OK
March 11, 1993	-17° C	1	15 min.	• Closure iced shut. 2 minutes of continuous fan operation required to defrost unit.
March 12, 1993	-	0	0	• Dead battery
March 17, 1993	-13° C	4	10 sec.	• Duct air temperature 4° C/room temperature 16° C • Operation OK
March 18, 1993	-19° C	3	10 sec.	• Duct air temperature -5° C/room temperature 16° C • Operation OK
March 19, 1993	-11° C	4	15 sec.	• OK
March 20, 1993	-2° C	4	10 sec.	• OK
March 21, 1993	-2° C	3	10 sec.	• OK
March 21, 1993	-5° C	1	15 min.	• OK
March 22, 1993	0° C	2	10 sec.	• OK
March 24, 1993	0° C	3	10 sec.	• OK
March 26, 1993	0° C	1	10 min.	• OK
March 27, 1993	10° C	3	10 sec.	• OK
March 29, 1993	0° C	1	12 min.	• OK
March 30, 1993		0	0	• Dead battery

Table 1.0 documents the observations noted regarding the operation of the air vent closure system over the life span of three batteries. The first battery device operated over a period of 16 days, during which time it powered the vent closure device through 19 cycles.

The outdoor temperatures during the first half of the first battery's life were quite cold, ranging from daytime highs of -15° C to nighttime lows of -30° C. It was during the cold periods that the vent closure device had the most difficulty with either the vent damper freezing shut (i.e., the damper gasket would freeze to the vent closure housing), or the air pressure sensing vane freezing in the "damper shut" position.

When the vent damper was frozen shut and the air pressure sensing vane was operative, operation of the rangehood fan caused the vent closure device to attempt to open. Air pressure in the duct was generally sufficient to initiate the "open" sequence by engaging the "open" contact located above the vane in the housing of the device and disengaging the "end closure" contact located on the vent damper itself. This series of actions would cause the motor to continue its attempts to open the closure damper (despite the damper being iced shut). Subsequently, the motor drive clutch would slip until the rangehood fan was deactivated. Unfortunately, the failure of the vent closure device to open could not be detected from inside the house for this particular installation. An outdoor visual inspection would be required to confirm the vent damper status.

In several instances, operation of the rangehood fan was sufficient to warm the interior of the outer housing of the vent closure device to the point where frozen condensate melted and the vent damper opened freely. Generally, except under severe icing conditions, the vent damper opened after one or two minutes of rangehood fan operation. During the "warming" period, the vent closure device motor continuously attempted to open the device resulting in high battery power consumption and clutch wear.

Freezing of condensate within the vent closure device intermittently caused problems with the pressure sensing vane and, possibly, the related circuit contacts. The vane was found frozen in the "shut" position on several occasions. This required rangehood operation or manual intervention to correct. In one instance, the pressure sensing vane froze in the vent "open" position, which prevented the vent closure from shutting when the rangehood fan was deactivated. This occurrence was somewhat unexpected, as there was a continuous flow of warm exhaust air over the vane which should have prevented any condensate deposited on the vane from freezing. The situation corrected itself when the vane dropped back to the vent "close" position one or two minutes after the rangehood fan was deactivated.

The second battery operated the vent closure device over a disappointing period of 6 days, during which time it cycled the device open and shut 16 times. The outdoor temperature during this period was relatively mild; and, subsequently, there were no operational problems. After the premature expiry of the battery, the vent closure device was removed from the field for evaluation. A short circuit in the control wiring was presumably responsible for the short battery life. The short circuit most likely occurred where the control circuit wiring leaves the circuit board. At this location, the exposed areas of the wires could contact one another if the wiring harness was twisted or sharply folded (which was sometimes required to make the circuit board fit into the compartment within the vent closure housing when the device was assembled or the battery was changed). Efforts were undertaken prior to replacing the unit's battery to prevent such short circuiting from occurring by providing more clearance between the wires leaving the circuit board.

The third battery was able to cycle the vent closure device 29 times over 14 days. The outdoor temperature ranged from -19° C to 0° C throughout the testing, with a high temperature of 10° C being recorded. During this time period, the vent closure device operated effectively with no problems noted. The relatively short battery life was again likely attributable to a wiring short, as the wiring from the control circuit board was again folded in such a manner as to allow some of the wires to contact one another. This problem has since led to reconsideration of the manner in which the control circuit, contact switches, and vent motor are connected.

Temperature measurements taken just inside the vent damper itself revealed that, given an indoor air temperature of 16° C and an outdoor temperature of -13° C, the air temperature within the duct could be maintained at 4° C. It should be noted that the prototype did not yet have any insulation incorporated into the design. When the outdoor temperature dropped to -19° C, the temperature just inside the vent closure damper was found to be -5° C.

The battery failed unexpectedly early, leading to suspicions that circuit related problems were again at fault despite the attempts made to isolate the wiring.

When the vent closure device operated without interference from ice, the unit quickly opened upon rangehood fan activation and closed immediately upon fan shutdown. The device held the vent damper securely shut and prevented cold drafts from developing around the area of the stove.

5.2.2 Range Cooktop Exhaust System Installation

The second vent closure device, the 150 mm ø model, was installed at the vent termination of a cooktop ventilation system (similar to a Jennaire installation—see Photo 11). The vent closure device was fitted with an independent counter circuit and vent damper position indicator circuit. This device was installed to allow the operator to quickly record the number of cycles obtained per battery and to confirm the correct operation of the vent closure device.

Table 2.0 documents the basic time frame of battery life versus the number of open/close cycles recorded.

Table 2.0

Date	Number of Cycles
January 18, 1993 to February 28, 1993	78
March 1, 1993 to March 31, 1993	43
April 1, 1993 to April 23, 1993	22

The following points represent the comments the homeowner made concerning the air vent closure device's operation.

- The unit experienced a decreasing battery lifespan despite the general overall warming of the weather.
- A few problems were experienced where the vent closure device was not only frozen shut, but also tended to freeze open due to ice forming on the pressure sensing vane during continuous operation.
- During cold weather operation, the vent closure device experienced instances where the unit would not open immediately. This was either due to the pressure vane failing to activate the controlling circuit because of ice forming on the vane or to the vent closure damper being frozen to the housing of the unit.

6.0 PERFORMANCE AND TESTING ANALYSIS

The testing of the two air vent closure devices could be considered a success, as the information gathered regarding the actual physical and operational characteristics of the devices was extremely useful in the development of further refinements to the design of the devices. Additionally, the basic concept and feasibility of a workable, remotely activated, residential vent closure device was adequately demonstrated.

The following points represent a summary of the observations noted to date regarding the physical and operational characteristics of the 89 mm x 254 mm and the 150 mm diameter versions of the air vent closure systems:

1. The battery life was relatively limited given 3 to 4 weeks' winter operation.

2. The actual vent damper experienced regular icing related problems during cold weather.

3. The static/dynamic air pressure sensing vane experienced icing and contact problems during cold weather. It was suspected that the "end" contacts located on the closure device housing also experienced contact problems, which may have caused premature failure of the battery.

4. The vent closure status was not readily apparent to the fan operator. Outdoor inspection was required to verify operation and position of the damper.

5. The vent closure devices were capable of responding appropriately and reliably to the operation of the exhaust fans concerned, notwithstanding the aforementioned problems.

Given these observations, the following conclusions were made.

1. It was determined that the disadvantages of a battery operated vent closure device far outweighed the advantages. Battery life in cold conditions, battery changing procedures, battery status, and the limitations imposed on the control circuitry and contacts through the use of a battery effectively ruled out a battery powered option for the vent closure device. Therefore, further research and design was then conducted on the version of vent closure

device using a 120 V AC household supply via a common 9 V DC/120 V AC adapter.

The change of power source allowed the development of a device that would not be temperature dependent; would require little attention on the part of the end user; and would allow for the use of optical switches to control the various sequences of the device. To this end, all design and development efforts were then centered around the use of the 9 V DC/120 V AC adapter power supply.

2. The freezing of the actual vent closure damper to the housing is a problem that has not yet been completely solved. It was found that the foam air sealing gasket adhered to the perimeter of the vent damper would freeze to the housing when the damper was closed. The indoor moisture in the air was able to condense and freeze at this point, thereby causing the problem noted. The refined prototype of the vent damper and housing is constructed of fibreglass; and it is hoped that frozen condensate will not adhere to the surfaces of the device. Insulative material has been incorporated into the design of the vent closure device in an effort to prevent duct temperatures and surfaces from falling below the freezing point. Additional field testing will be required to confirm this approach.

3. The problems associated with the current integrated static and dynamic air pressure sensing vane led to the development of a more refined design. Since the current design would allow the vane to freeze to the duct or the contacts to be covered by ice or moisture, a new design has been developed that will prevent this from happening. Although the concept involves the continued use of a vertical vane in the air stream to detect dynamic pressure, the static pressure sensor has been modified to use a polyethylene "slack diaphragm" to sense the static air pressure in the duct. This approach allows the vane to operate in such a manner that it never comes in contact with the duct except at its hinge (which has not been a problem point). The use of a slack diaphragm has an added advantage; i.e., the air flow from the duct through the housing of the air vent closure device will no longer be required. The confinement of the exhaust air stream to the duct will prevent moisture, grease, or dust buildup on the control circuitry and control contacts located within the device's housing.

The "end" contacts of the controlling circuit were replaced with optical switches. This change was possible due to the change of power source from the 9 V DC battery to the 9 V DC/120 V AC power adapter. The use of optical switches offers many advantages over the original direct contact approach to switching. The direct contacts were suspected to have been prone to ice buildup, which reduced their ability to make an effective contact. Additionally, the adjustment required to locate the individual contacts relative to one another will no longer represent a serious problem. The optical switches were located within the vent closure housing and, as such, will be protected from the outdoor elements and indoor exhaust air. Optical switches will be used to detect the static pressure rise in the duct due to exhaust fan activation and to stop the drive motor when the vent damper has either completely opened or closed.

4. Although the change of power source will undoubtedly make the vent closure device much more reliable than the original device, it would be advantageous to include a "status" indicator for the vent position. This will provide feedback to the homeowner as to whether or not the vent closure device has opened or closed at the appropriate times.

7.0 ADDITIONAL RESEARCH AND DEVELOPMENT REQUIREMENTS

Given the performance and physical characteristics of the various prototype vent closure devices fabricated to date, several different aspects of the device requiring more research and development efforts to further refine the concept have been identified.

7.1 Vent Closure Materials

During the testing of the prototypes, the actual closure damper became frozen to the vent closure housing due to the freezing of condensate on the inside of the damper. The problem probably occurred as a result of the freezing and adhesion of the gasket material used to provide the seal between the damper and housing.

At this time, the problem has not been fully resolved. The types of materials available for gaskets all appear to be susceptible to this type of problem. Notwithstanding the development of a "non-stick" gasket material, it is envisioned that the gasket will be dropped from the design. The seal between the vent closure damper and housing will rely instead upon the direct connection of the two surfaces. Adhesion of the two surfaces due to freezing condensate may be alleviated by the use of polyethylene or other similar non-stick material for the vent closure damper and housing. This concept will have to be further developed by producing the appropriate sections for cold weather testing.

7.2 Power Adapter Installation Particulars

Given the change of the design from a fully independent, battery powered device to a device that relies upon a connection to the host house electrical system; its installation will not be as straightforward. A route for the electrical connection between the device and a 120 V outlet will be required. Additional work will have to be performed to determine how the connection can be facilitated by the design of the device.

Design modifications to accommodate a power cord path will be required. It is likely that the low voltage wire from the device will be fed back from the device through the duct. The wire could then be run from the duct to a convenient 120 V outlet. For installations in exposed header areas or for new construction installations, the power connection will not represent that much of an obstacle for the average homeowner/installer. Installations in such locations, where the exhaust duct is contained within a finished cavity (such as a joist space), will be slightly more difficult both in terms of feeding the power wire and utilizing a convenient 120 V outlet.

7.3 Field Testing of Final Design

Although the final design of the vent closure damper system has been "shop" tested to confirm the operational performance of the new circuit and switching systems, the refined device has not been field tested because this was beyond the scope of the original project.

The performance of the optical switching system, the static pressure diaphragm, and the fibreglass housing—particularly under cold weather conditions—must be determined to confirm the success of the final design. The field test will also allow for an assessment of the installation related difficulties that may be encountered.

7.4 Potential for Battery Operation

Although the refined design of the vent closure damper system utilizes power from the host house, the potential opportunity to return to the use of a DC battery cell within the new circuitry should be determined.

As originally contested, the use of a battery to power the device has many advantages in terms of ease of installation, compactness of design, and the independence of the device from the host house electrical system. Unfortunately, the cold weather testing of the original prototypes suggested that the expected life of a battery operated system would be unfavourably short. Additionally, the use of power consuming optical switches in the refined control circuitry would consume battery power at all times. It is proposed that additional research may be worthwhile to resolve these problems so that a battery could be used to power the system.

Insulating the entire closure device (particularly the battery compartment), while still allowing relatively warmer duct air into the battery compartment may prevent the battery from becoming sufficiently cold enough to impair the device's performance.

The issue of the continuous power draw of the optical switches will take more effort to resolve. It may be possible to develop an "initiation" sequence that would allow the optical switches to be unpowered during periods of inactivity. Upon the activation of the exhaust fan, a switching circuit would sense the static pressure rise in the closed duct and, in turn, activate the battery powered circuit and the optical switches. The vent closure device would then operate normally until the exhaust fan was deactivated and a decrease in the exhaust duct of the static and dynamic pressures initiated a "power down" sequence to deactivate the optical switches. Further electrical engineering will be required to determine the feasibility of this concept, but is the opinion of the design team that it would be well worth performing due to its implications on the vent closure system's design, operation, and installation considerations.

7.5 Extended Applications of the Vent Closure Device

Over the course of the research and development of the vent closure device prototypes, other potential applications for the technology were realized. Modified versions of the device may eventually prove to be useful in combustion air delivery systems for fuel fired equipment. Additionally, the technology employed in the device may have direct applications in the control of building pressures through its integration into make-up air systems.

It should be noted that, while the technology developed for the vent closure device may prove useful in such applications, no effort has yet been made to examine the true potentials. For instance, the need for damper systems in such applications to be "fail safe" would have to considered. Presently, there is no such consideration in the damper for the vent closure device, as the failure of the device would only represent an inconvenience as opposed to a threat to the health of the building's occupants. In order for the device to be adapted to make-up air systems, the sensitivity of the device would have to be improved to be operable in the 5 to 20 pascals range. Again, the device would also have to be "fail safe". The measuring point(s) for the static pressure differential between indoor and outdoor pressures would have to be optimized; as a simple, duct mounted sensor would be susceptible to wind and other location related pressures that may not be indicative of the true, average indoor-to-outdoor pressure differentials.

Although much work would remain to adapt the technology to such applications, the potential benefits in terms of increased occupant comfort and system control would tend to make the endeavour worthwhile.

8.0 COMPARISON OF VENT CLOSURE OPTIONS

Table 3 provides a qualitative comparison of the vent closure device and two of the more conventional approaches to vent closing devices.

Table 3: Evaluation of Closure Devices

	Vent Closure Device	**Barometric Dampers**	**Electric Dampers (Hood Mount Type)**
PHYSICAL			
Material	Fibreglass Polyethylene	Plastic Sheet Metal	Sheet Metal
Power	9 V DC from 120 V A/C Source	None	24 V AC and 120 V AC
Available Size (Non-Custom)	$100^{\varnothing}$, $150^{\varnothing}$, 89 x 254	$100^{\varnothing}$, $150^{\varnothing}$ 175,200, 89 x 254	125, 150, 200
OPERATIONAL			
Operation	Power Open/Power Shut	Barometrically Opened/Closed	Power Open/Spring Return
Controls	Self-Contained Static/Dynamic Pressure Sensing	None	Wired to Control Circuit of Exhaust Fan
Airtightness	Good	Poor-Good	Good
Reliability	Good	Poor	Excellent
INSTALLATION	Easy with Minor Difficulties for Power Wiring	Easy	More Difficult as Control Wiring is Complicated
COST (Installed)	$ 100	Less than $ 25	$ 150 to $ 200

It is apparent from Table 3 that the vent closure device effectively fills the niche between barometric dampers and a typical example of conventional motorized damper assemblies. Although the barometric dampers have a low initial cost and are easily installed, their performance in terms of consistency of airtightness is universally poor. Typical problems include: poorly fabricated components that do not fit closely together when the damper is shut allowing air leakage; inconsistent performance from damper to damper with respect to the ability of the damper to open and close effectively; static pressure drop across dampers that do not completely open; failure to prevent air leakage when shut; and susceptibility to pressures caused by stack effect, wind operation, and other air consuming devices.

The conventional, motorized damper assembly represents a significant improvement over the barometric damper. These devices are most often powered open by a 24 V AC motor and held open by the motor operating in a permanent stall condition (i.e., the motor continues to try to open the damper even though the damper has reached its maximum open position). The properties of AC motors allow them to operate in such a fashion without damaging the motor. When the damper shuts, power is cut to the motor, and a spring returns the damper to a closed position. The dampers can be wired in such a manner to allow the motor to operate in the permanent stall mode to keep the damper shut. When power is cut to the motor, the spring moves the damper to an open position. Such configurations are used when a "fail safe" condition is required.

The cost, availability, and installation considerations have prevented the conventional motorized dampers from gaining universal acceptance. The installed costs of such systems are typically in the range of $150 to $250, which proves to be prohibitive when compared to barometric dampers. Additionally, the installation usually requires the talents of an electrician to wire the transformer to power the damper and the controls to the exhaust fan. Furthermore, as most exhaust equipment is CSA approved, field modifications cannot be performed to the exhaust fan circuitry to allow for the connection of control wiring from the exhaust fan to the vent closure. Independent flow switches or voltage detectors must be installed to detect the operation of the exhaust fan to signal the vent damper to open. Such requirements further complicate the installation.

Given the issues that affect conventional motorized dampers, the vent closure device offers some distinct advantages. The projected cost of the device is expected to be reasonable at $100. The self-contained exhaust fan operation sensing system greatly simplifies the installation procedures to merely finding (or providing) a convenient location to "plug" the device into the 120 V supply of the host house. It is expected that the device will be readily available in all the conventional exhaust hood sizes, as there are no obstructions within the duct that would seriously affect exhaust air flow. (It should be noted that the conventional motorized dampers are only available down to a 125 mm diameter leaving the 100 mm bathroom exhaust ducts without motorized alternatives).

9.0 CONCLUSIONS

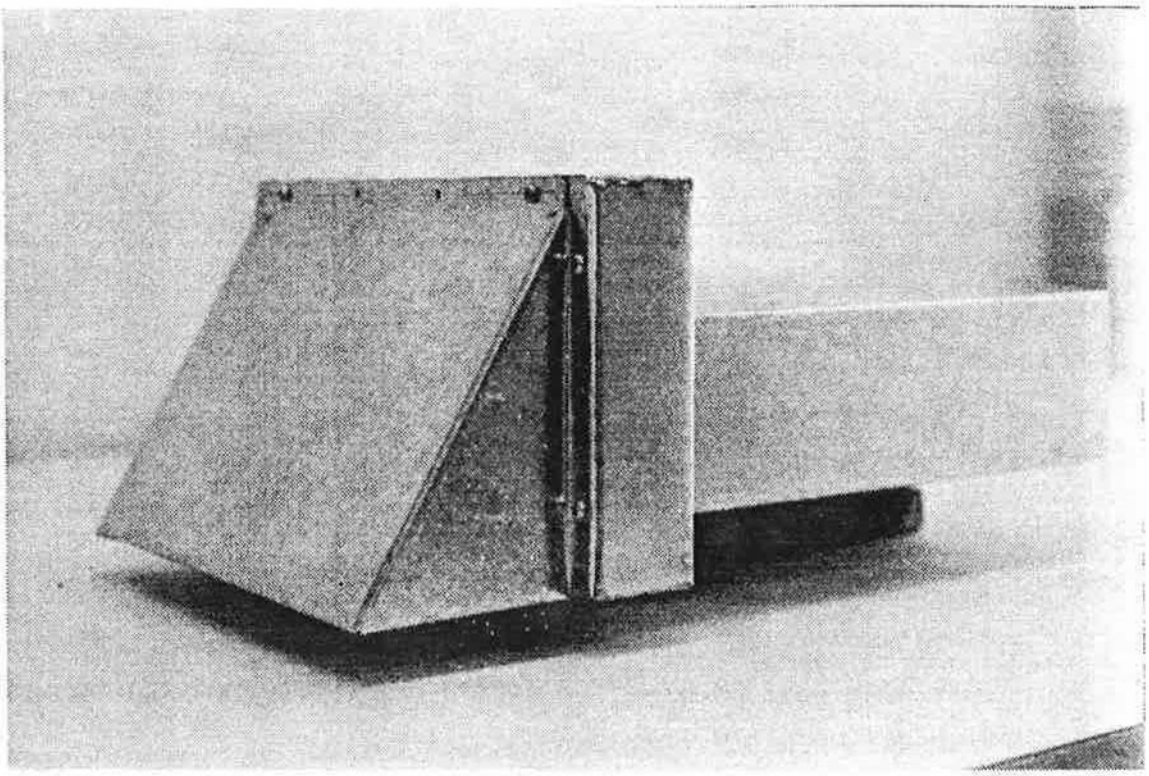
Overall, the project to develop an innovative vent closure device can be considered a success. The two, initial prototypes developed demonstrated the feasibility of a self-actuated, independent (notwithstanding the power supply) vent closure device that is not only inexpensive, but also is easily installed. Upon further refinement of the design, the device will potentially represent a viable alternative to conventional barometric and motorized dampers.

One of the most important successes of the project concerned the design of a reliable control and switching strategy. Over the course of the project and the development of the controls, the emphasis evolved from that of a mechanical design (which was demonstrated in the first vent closure device) to a sophisticated, yet simple and relatively inexpensive electronic circuit. The first electronic circuit, which relied upon physical contact switches, performed reasonably well but proved to have several faults both physical and operational in nature. These faults, realized during the field testing, led to the development of the circuitry that now controls the most recent 100 mm diameter prototype. The controlling circuit is not sensitive to operational irregularities as was the original control circuit. The refined design is capable of determining what position the damper should be in based on the status of the exhaust air flow in the duct only, thereby making the controls and entire vent closure system relatively insusceptible to irregularities in the exhaust fan operation.

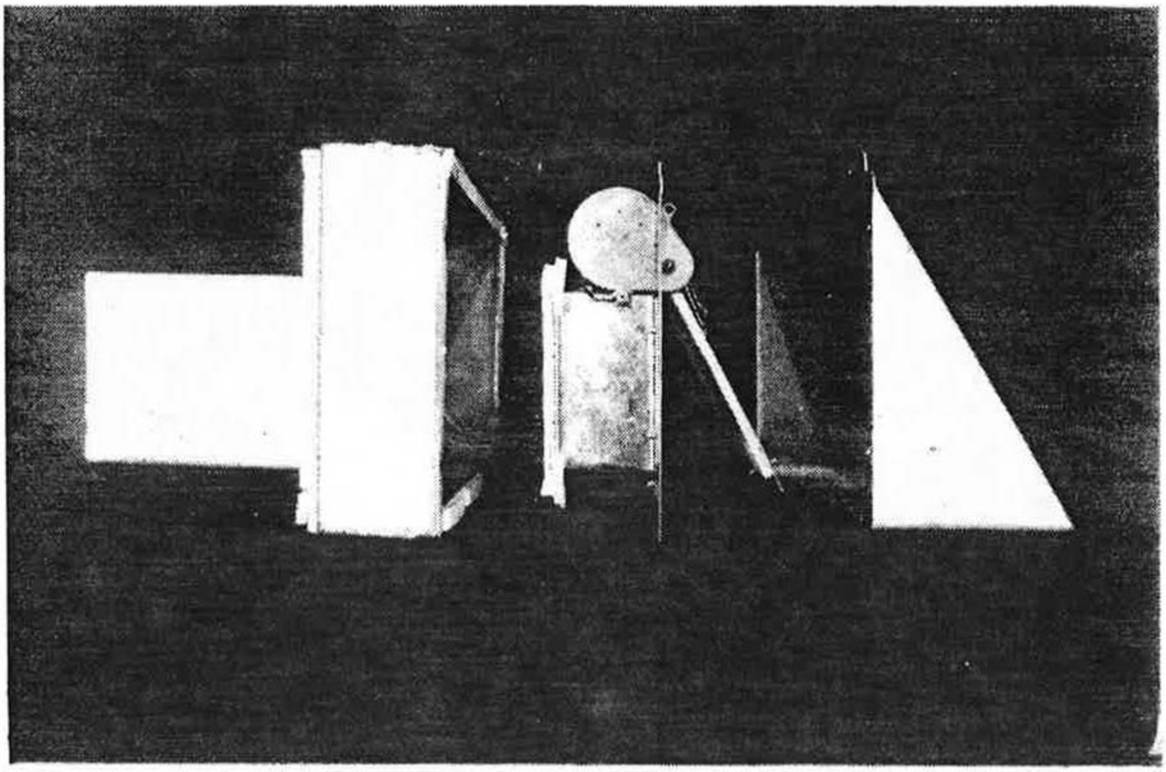
The rugged, solid-state design of the control circuit has no moving parts, thereby eliminating the circuitry from maintenance considerations. The circuitry and dynamic and static flow sensors have proven to be sufficiently sensitive to the range of air flow expected from typical exhaust fan operation to allow them to be universally applied to all sizes of vent closure dampers, thereby optimizing the entire system in terms of product costs and assembly efficiency.

Further refinements to the design of the device will be required to optimize performance and cost considerations. The success of such efforts will have a direct impact on the future acceptance of the device as a realistic approach to sealing off exhaust duct vent termination points.

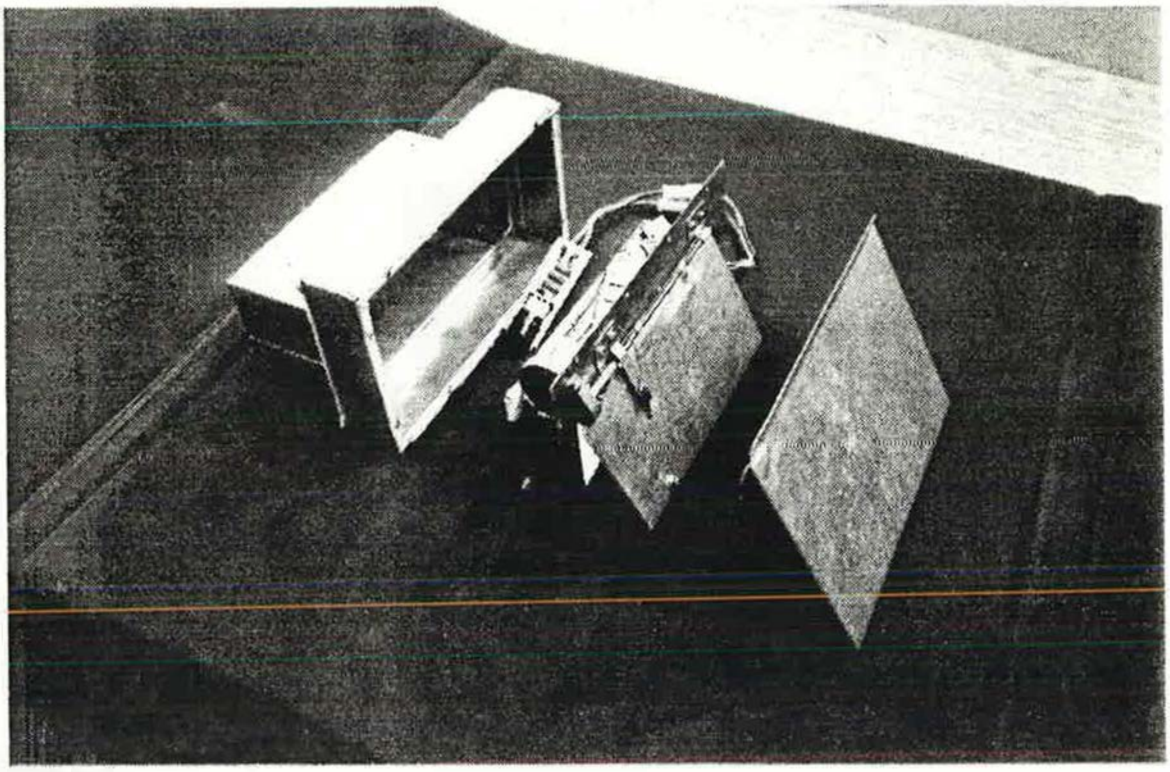
APPENDIX A - Photographic Record



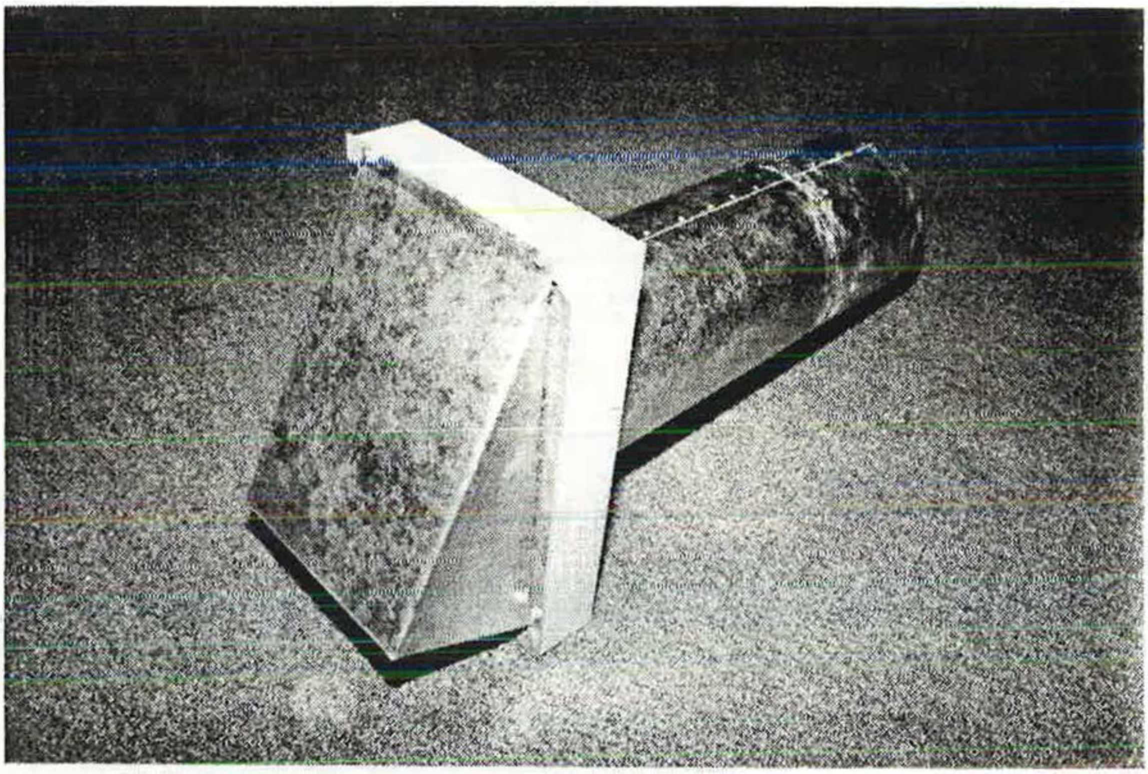
1. 89 mm x 254 mm Vent Closure Device



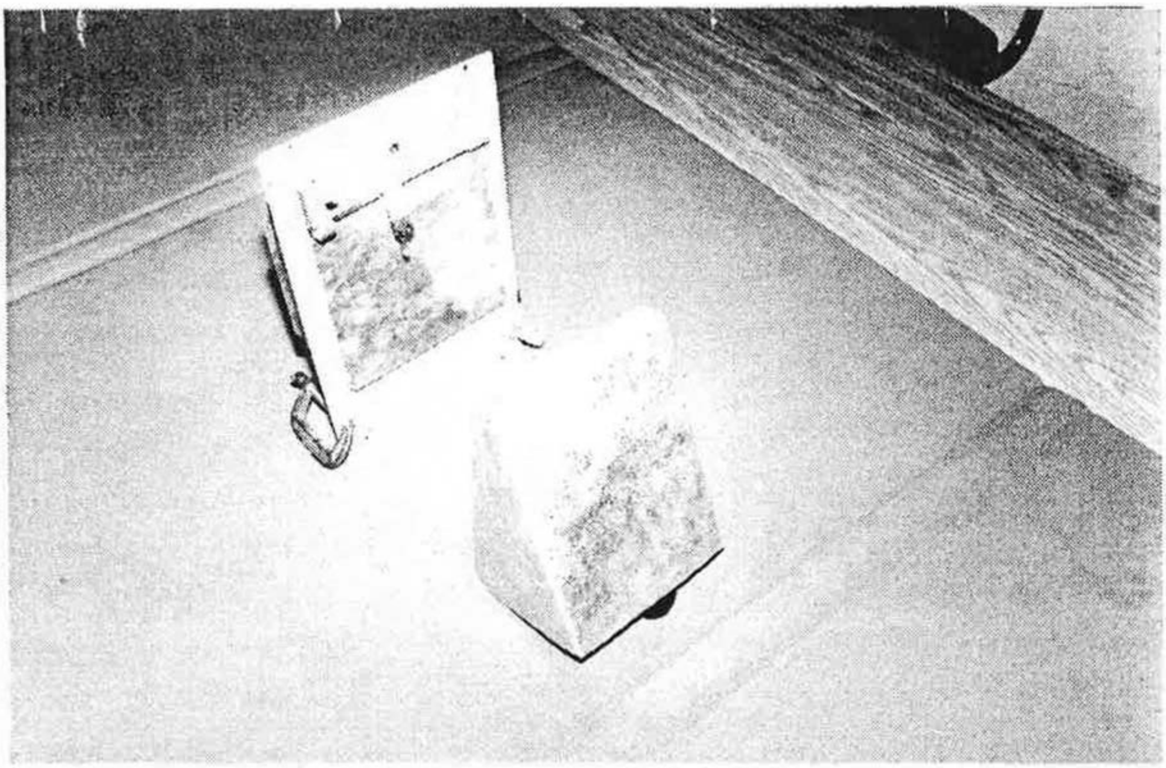
2. Exploded View: 89 mm x 254 mm Vent Closure Device



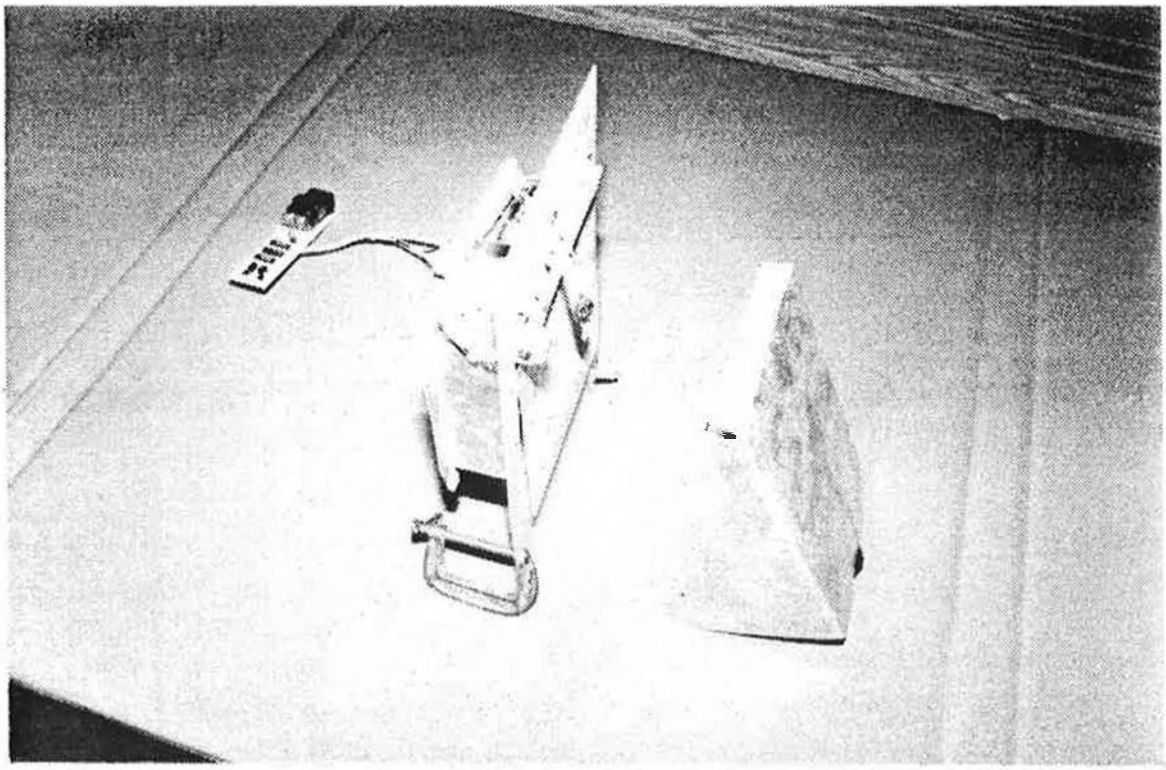
3. Exploded View: 89 mm x 254 mm Device



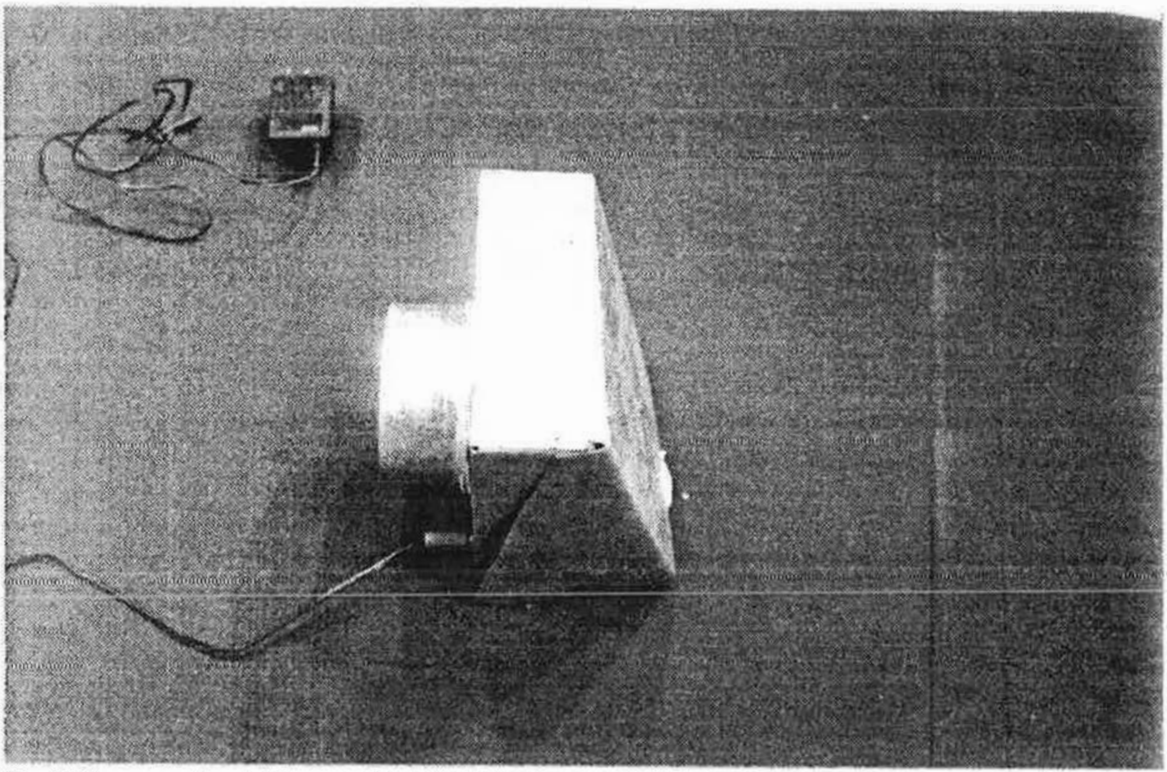
4. 150 mm ø Vent Closure Device



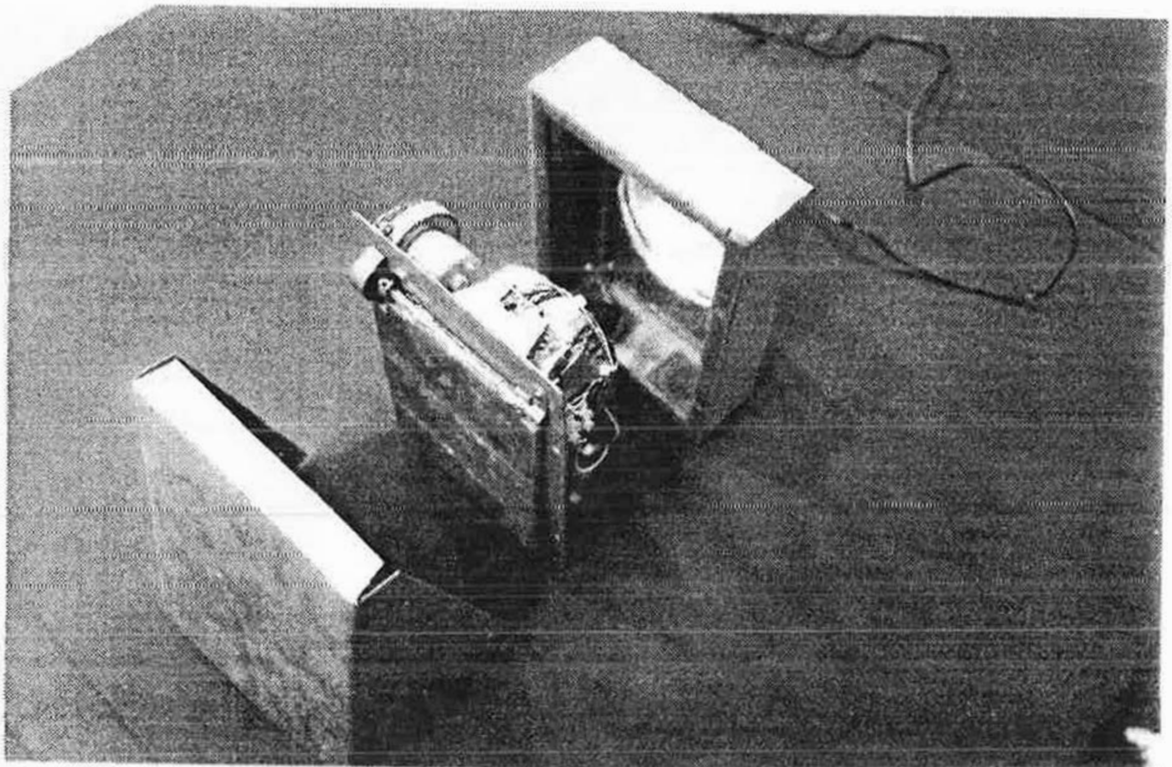
5. Exploded View: 150 mm ø Device



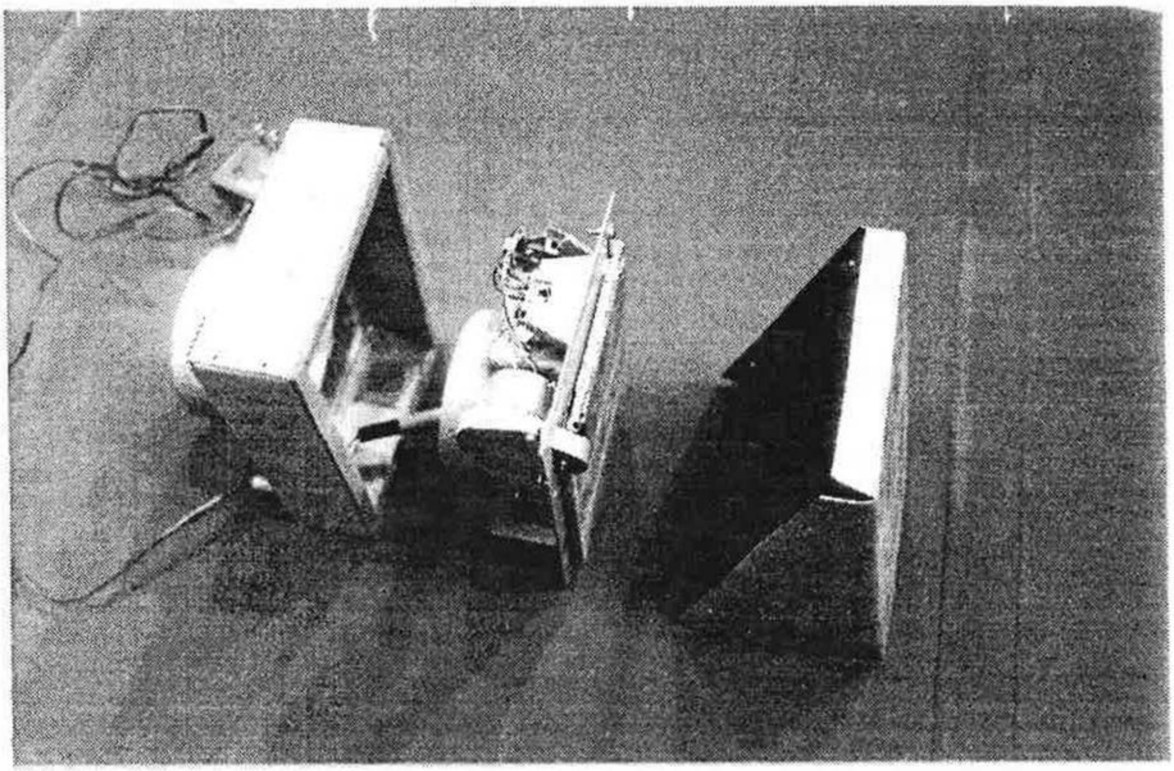
6. Exploded View: 150 mm ø Device



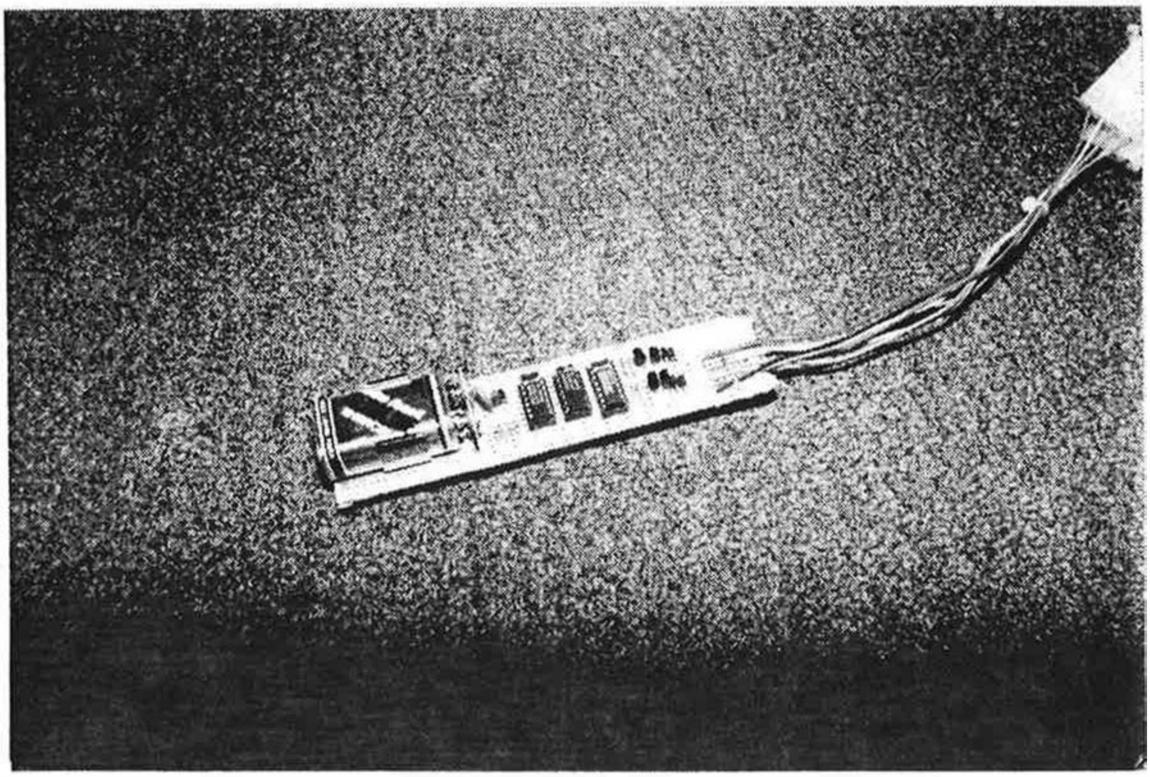
7. 100 mm ø Vent Closure Device



8. Front View: Exploded 100 ø Device

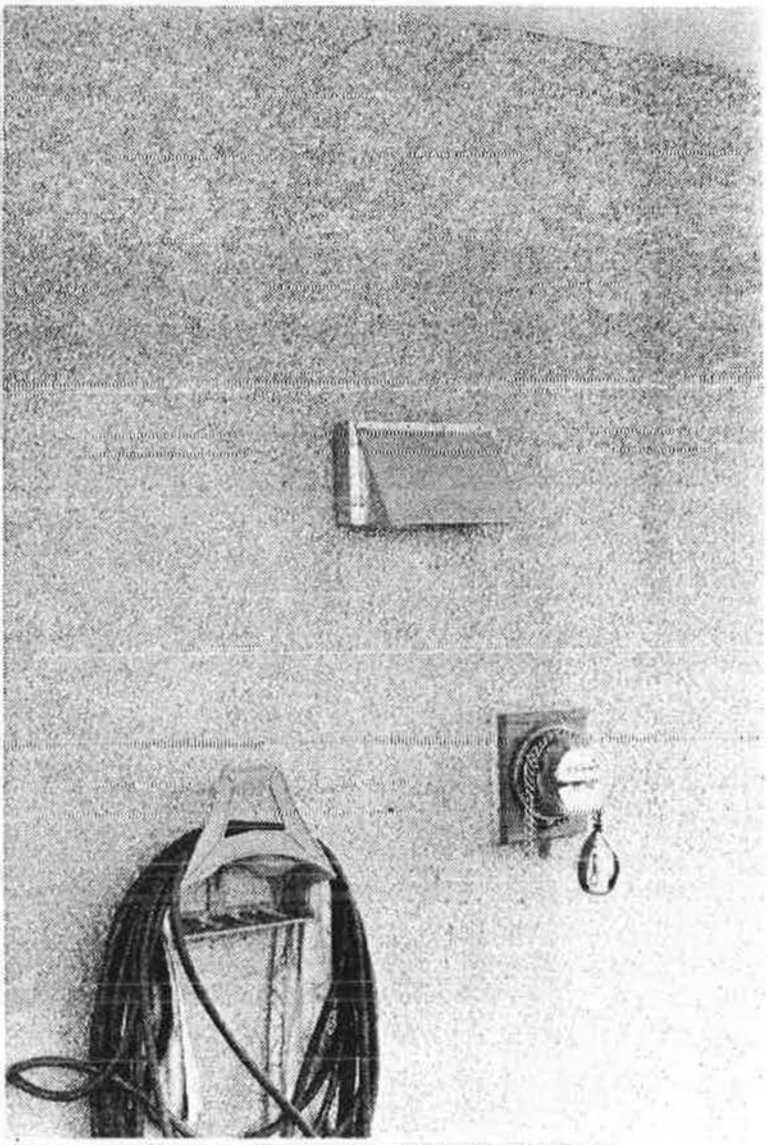


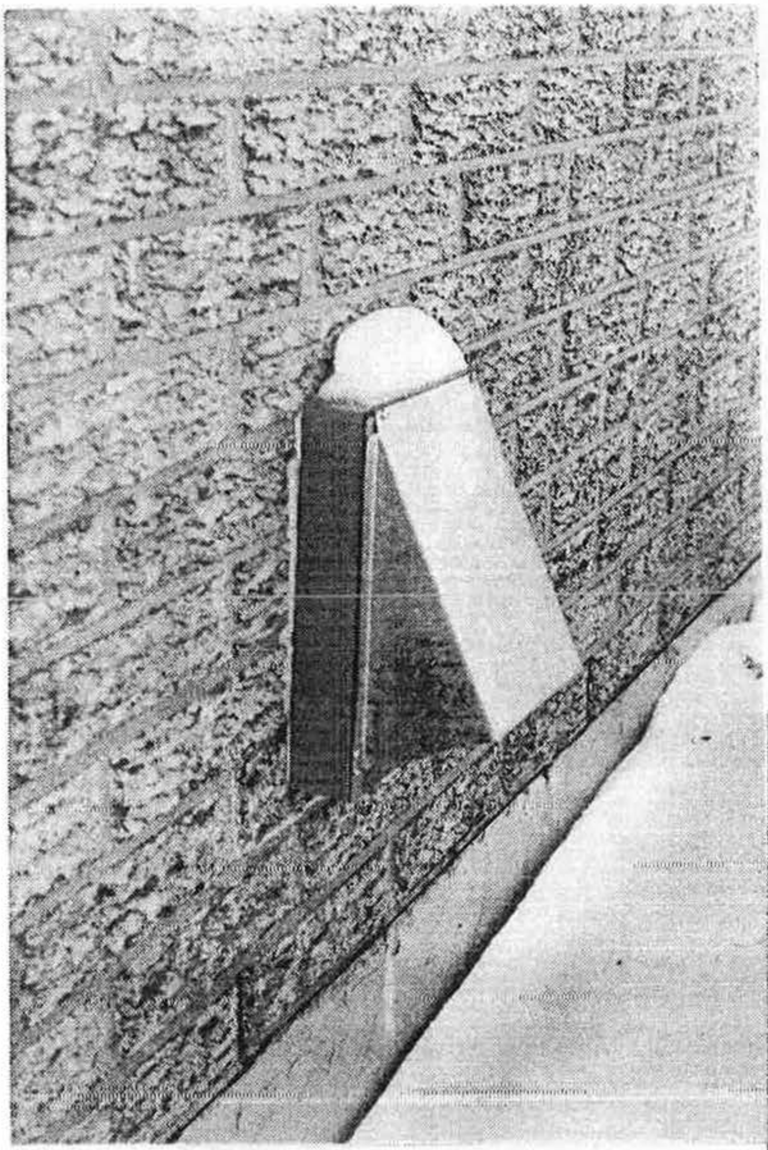
9. Exploded View: 100 mm ø Device



10. Original Control Circuit with 9 V Battery

11. 150 mm ø Installation on Jennaire Outlet





12. 89 mm x 254 mm Installation at Rangehood

APPENDIX B - Figures

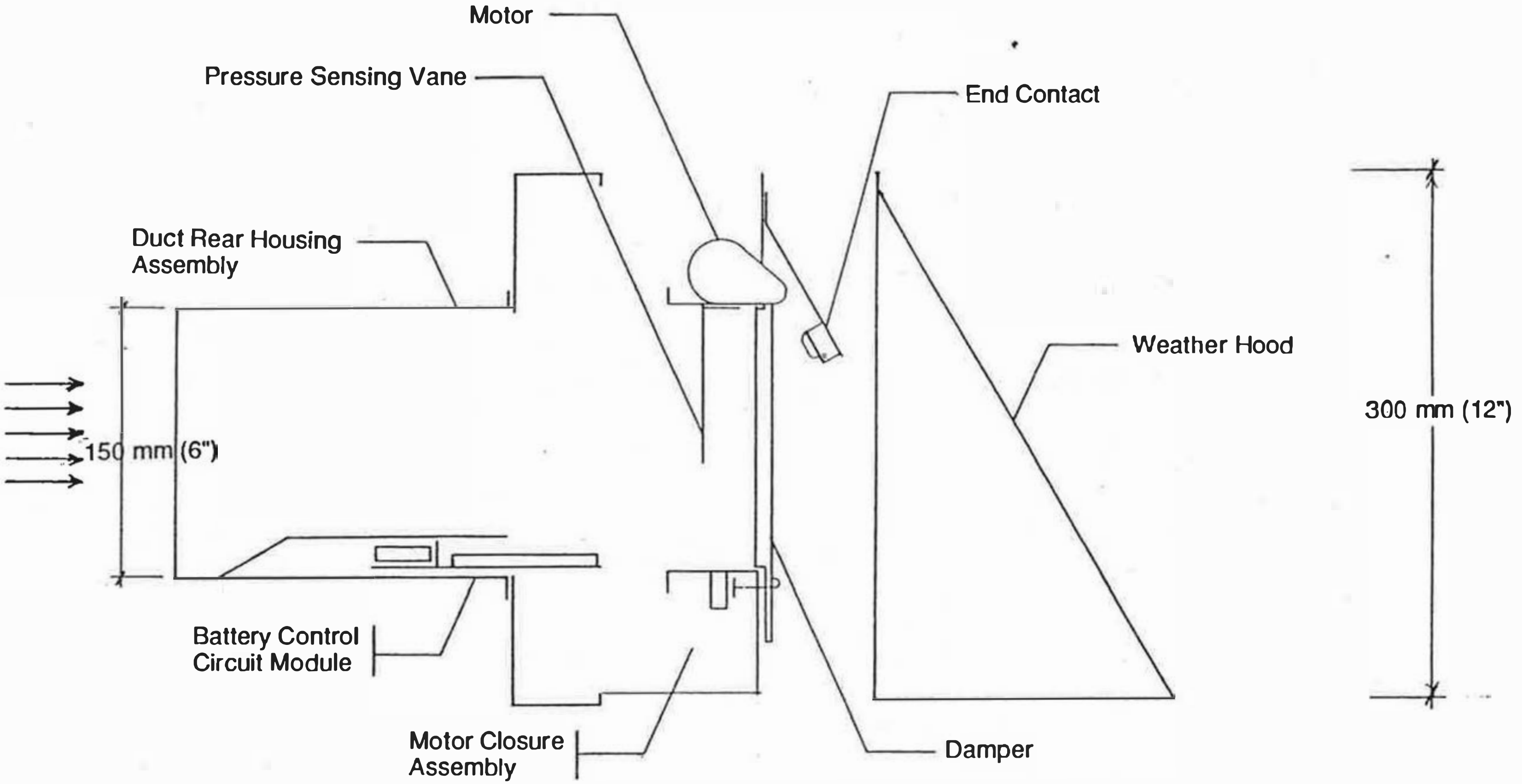


Figure 1: 150 mm ø Vent Closure Device

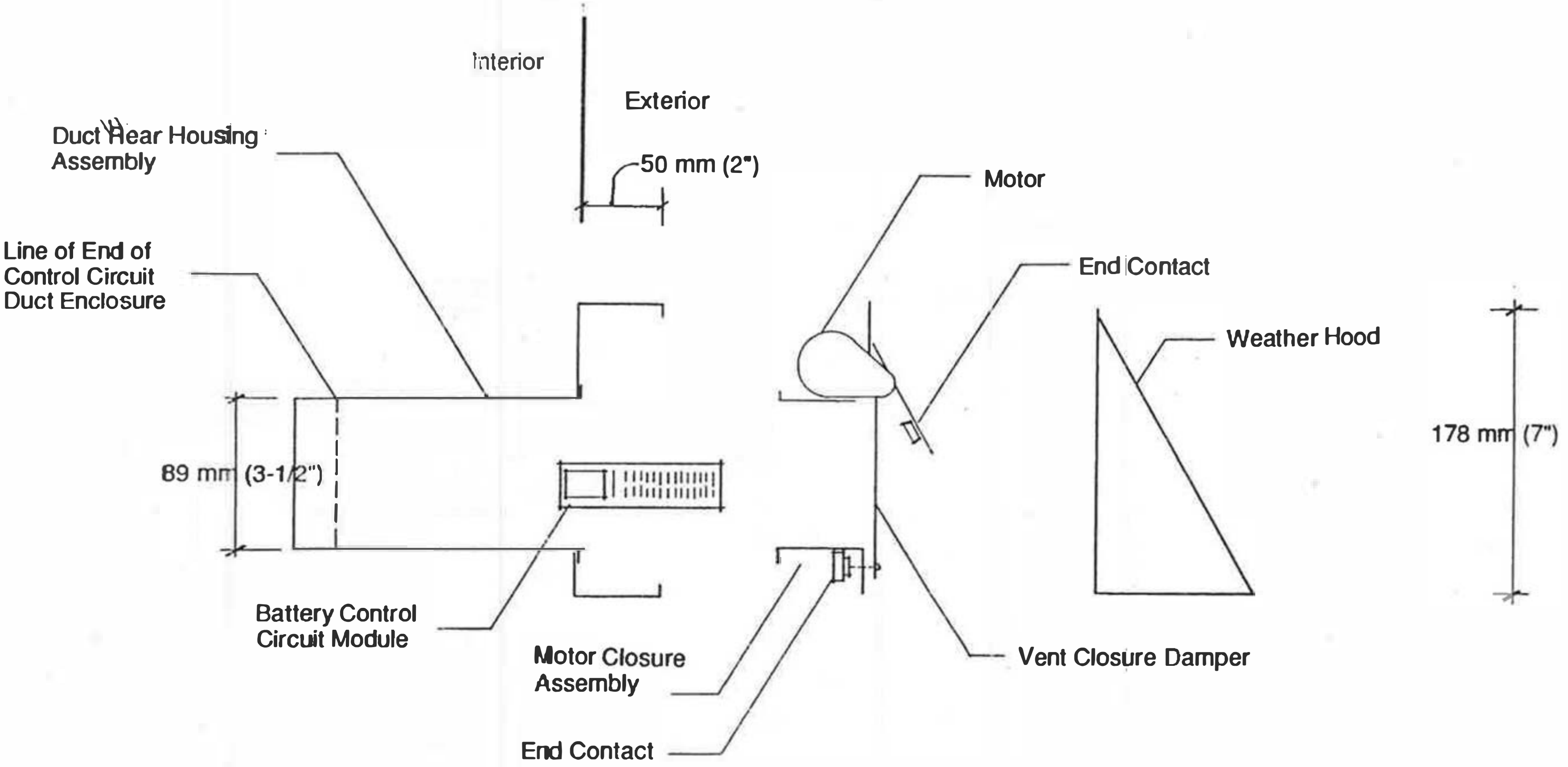


Figure 2: 89 mm x 254 mm Vent Closure Device

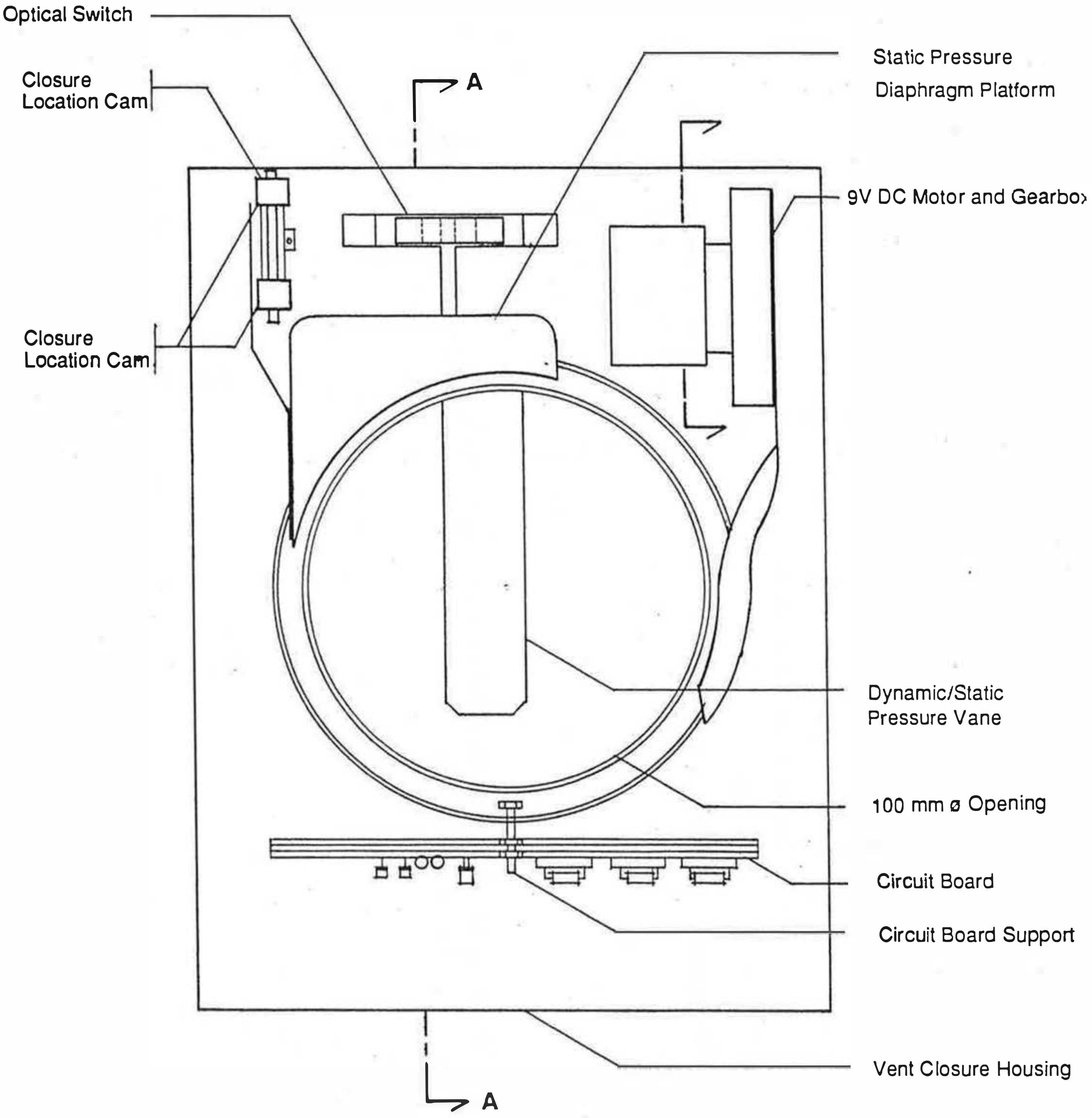


Figure 3: Interior Rear View—100 mm ø Device

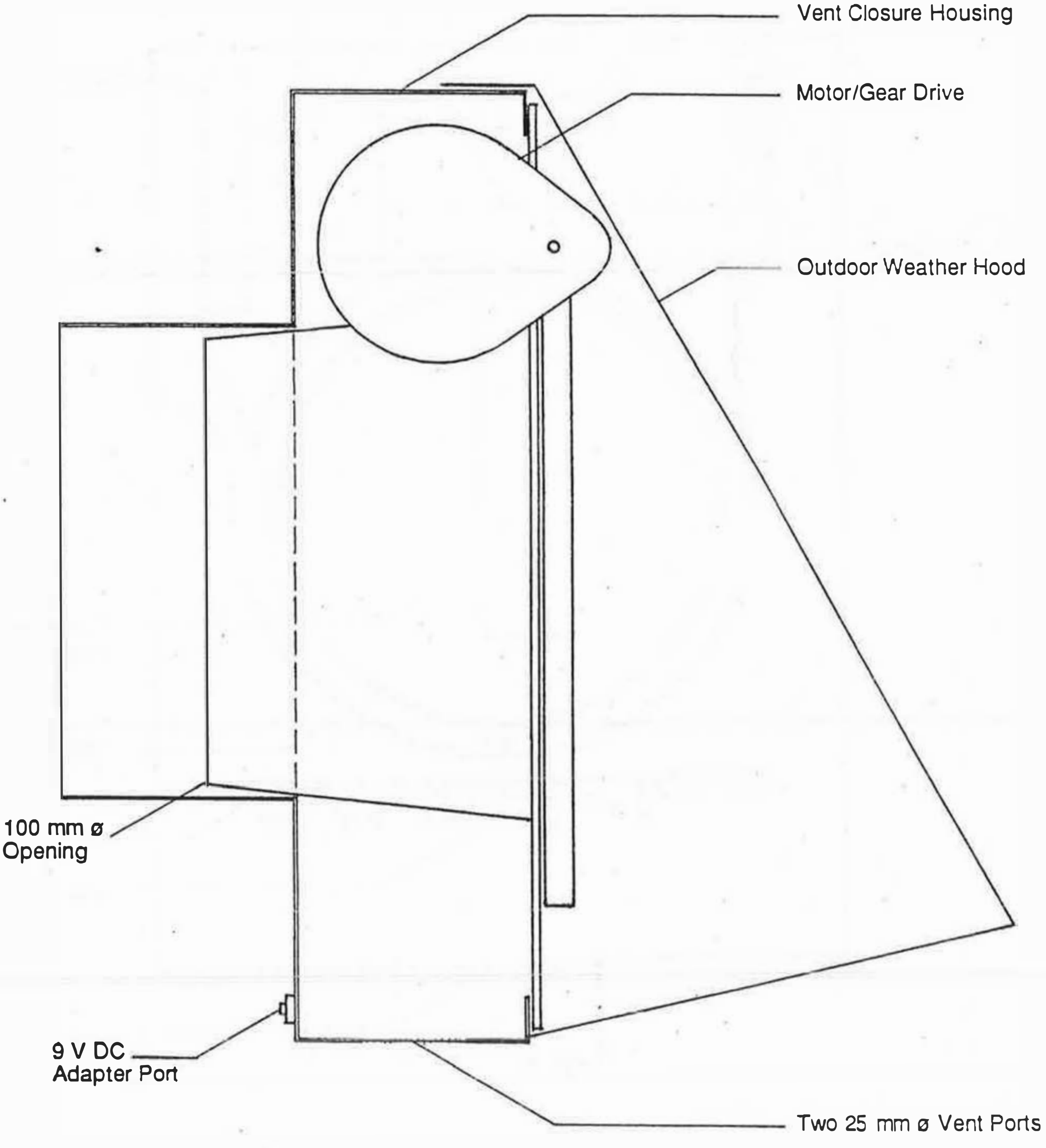
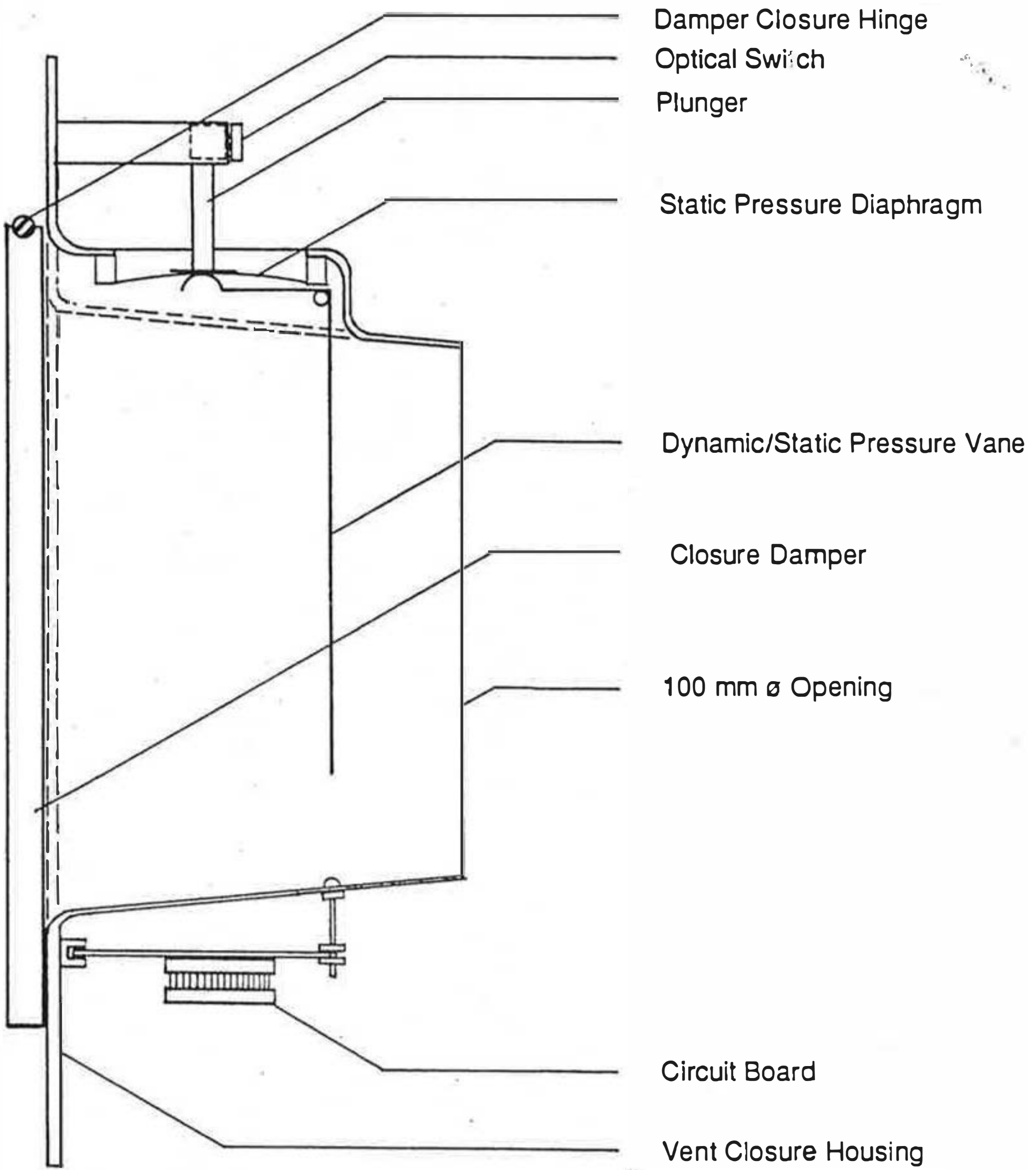
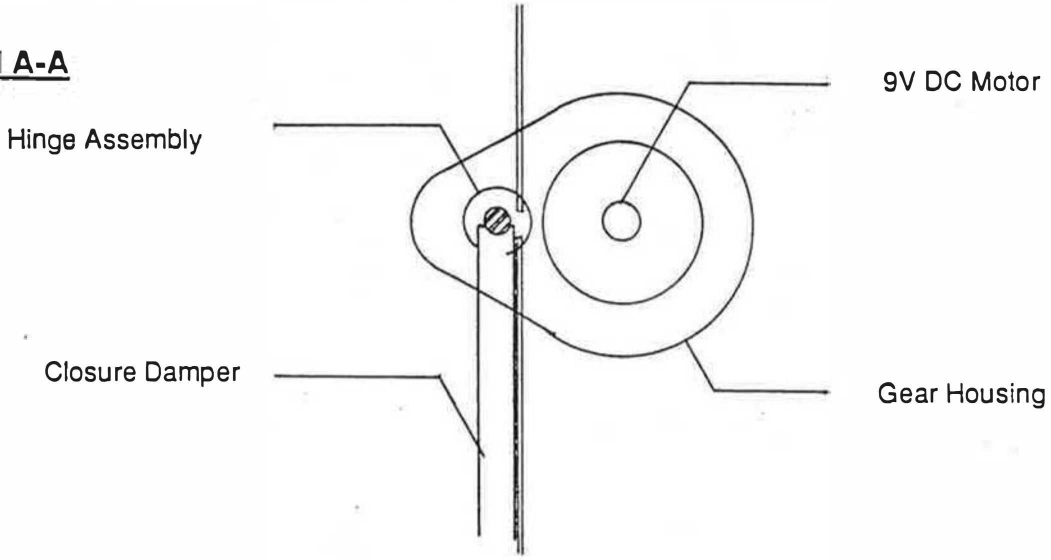


Figure 4: Interior Side View—100 mm ø Device

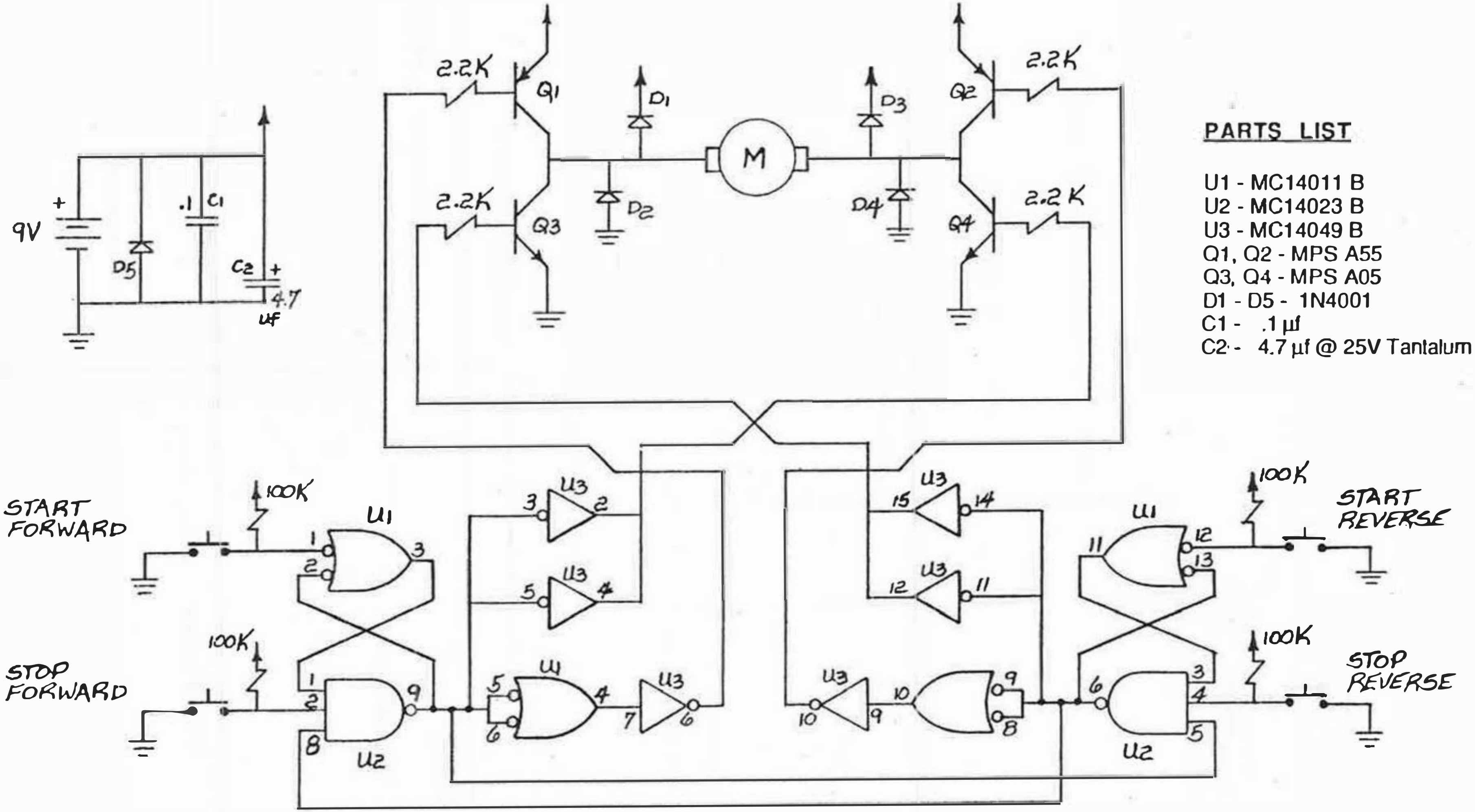


SECTION A-A



SECTION B-B

Figure 5: Sections—100 mm ø Device



PARTS LIST

U1 - MC14011 B
U2 - MC14023 B
U3 - MC14049 B
Q1, Q2 - MPS A55
Q3, Q4 - MPS A05
D1 - D5 - 1N4001
C1 - .1 µf
C2 - 4.7 µf @ 25V Tantalum

Figure 6: Control Circuit

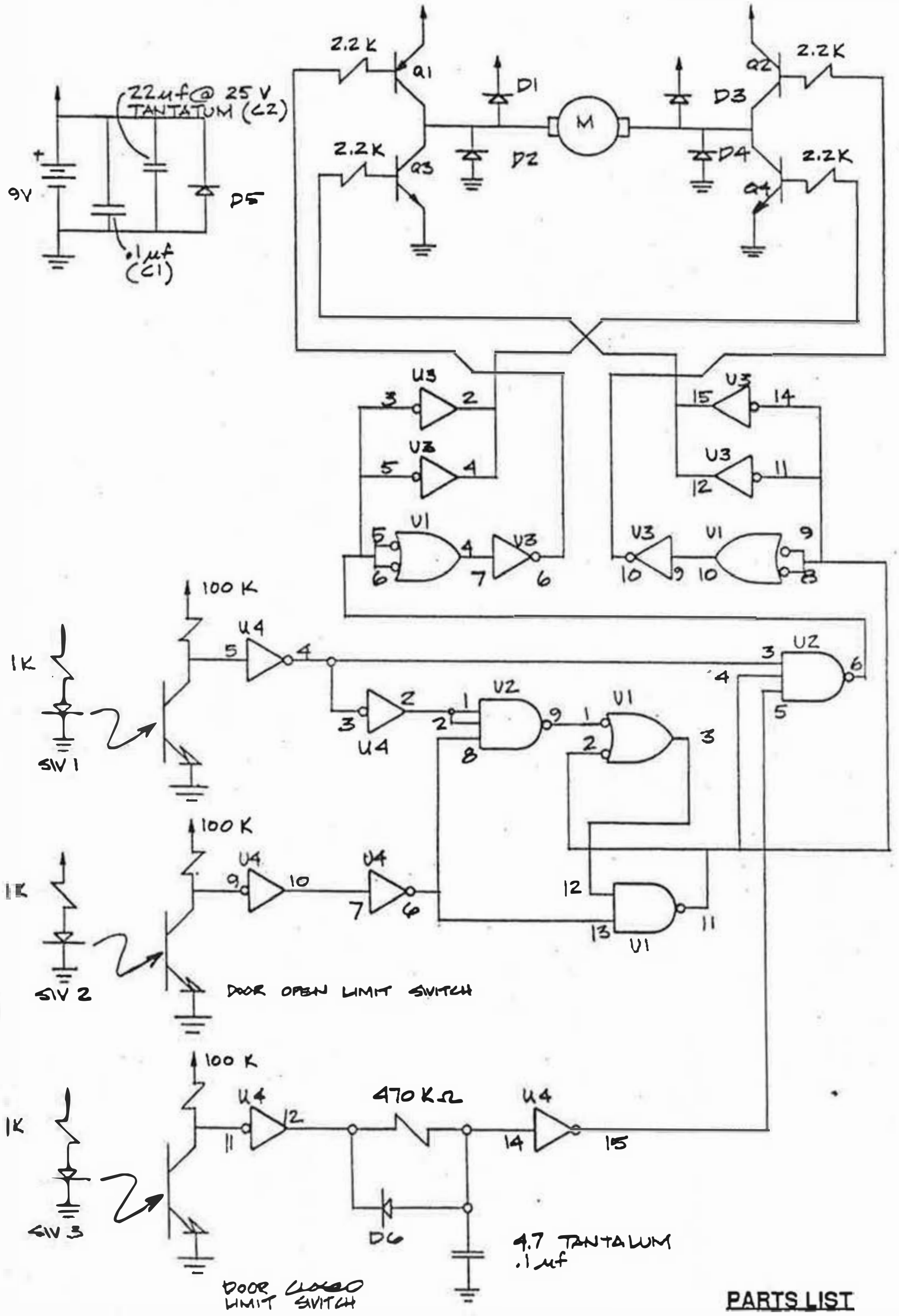


Figure 7: Final Control Circuit Diagram

PARTS LIST

U1-MC-14011B
U2-MC-14023B
U3-MC-14049B
U4-MC-14049B
D1-D6-1N4001
Q1-Q6-MPSA55
Q3-Q4-MPSA56
C1-.1µf
C2-22µf @ 25V Tantalum

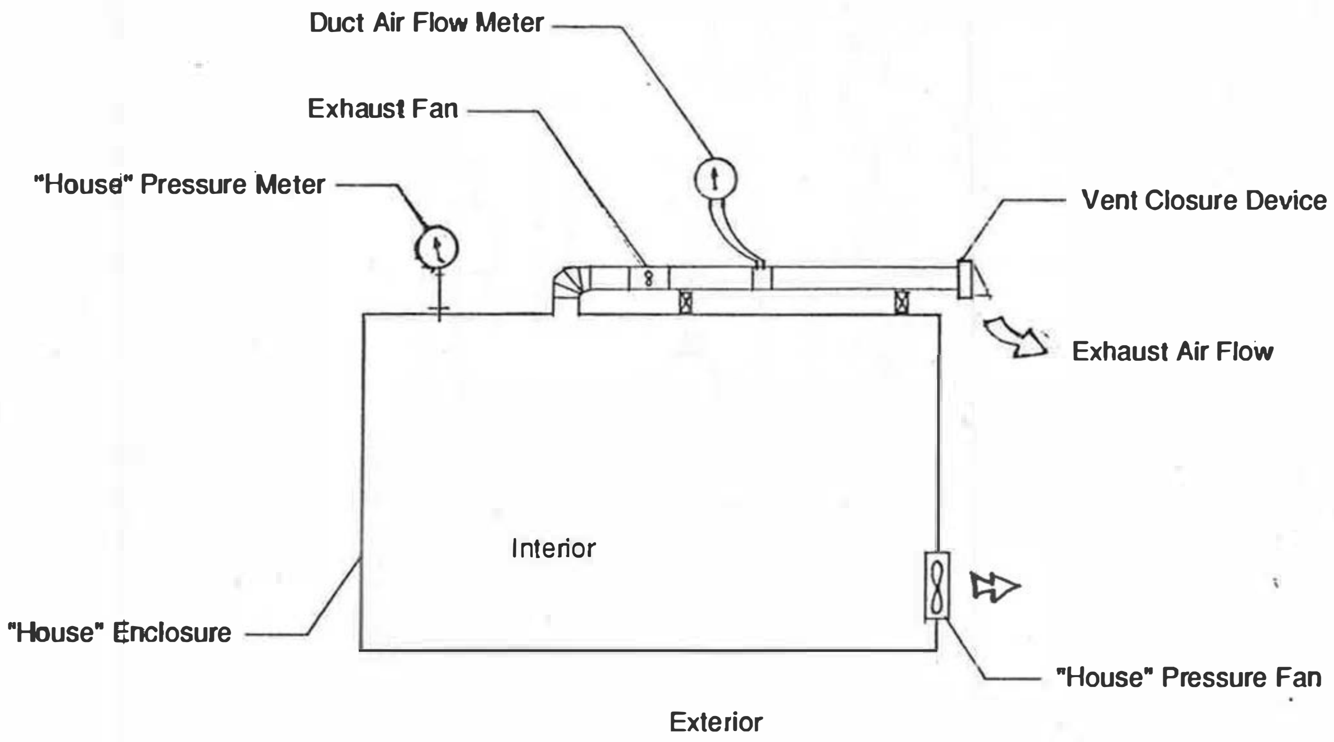


Figure 8: Test Apparatus