INDOOR AIR QUALITY DEVICE

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INDOOR AIR QUALITY DEVICE - IAQD

Final Report

Phase III, HTIP file no. 6521-15/89

Submitted To:

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1.0 PROJECT OVERVIEW

The purpose of this project was to design, construct and test prototypes of a device that would improve residential indoor air quality by providing increased ventilation automatically in such a manner so as to prevent unacceptable levels of house depressurization that could otherwise cause pollutants to enter the building envelope from combutsion appliances and soil gases. In addition, offer a manually activated means of providing increased ventilation at times of acceptable levels of depressurization but when inborne levels of pollutants from household sources such as cooking odours, smoke, paint, new furniture or building materials etc. become unacceptable to the occupant. It was a mandate of the design and construction criteria to minimize the finished product cost while incorporating minimum performance parameters.

At the start of this project the author had already developed a device such as described but with known deficiencies. The first step of this project was to design a new prototype incorporating the various features and components that would make the necessary improvements. The most difficult and time consuming improvement was obtaining a differential air pressure switch (the activating control for the device) that would reliably function at set pressures of 5 pascals or less and be suitably priced. Components for other improvements concerning such details as fan air flow capacity, heat output, overheat protection etc. are readily available. However, since the goal of this project was not just to get the system working but to get it into a manageable size cabinet at a minimal cost, the selection of the best componnets for the application must consider part cost, performance, size, method of installation and positioning in the cabinet and the resulting cost for same. This amounts to considerable more work than appears and perhaps it is the most important consideration in making this a viable product. It is also a subject requiring further consideration in this projects final prototype.

The other area of design requiring work was the conceptional development of the control logic of the device for its various functional components once the system was activated by the air pressure switch. Such things as the heat source and when should it come on and for how long, what temperature should the outlet air be, should there be staged heating etc. And when the fan comes on how long should it operate or until what level of depressurization is reached - should the fan have more than one speed?

Much of the input used in the various system design and selection of components came from technical representatives of manufacturers and distributors of products that might be used in the device and from consultants, in particular a residential products division of Honeywell Inc. Honeywell were responsible for some of the system logic and did the electrical component wiring design. Dean Ross of Kilborn Engineering, a senior mechanical consultant technology advisor for the National Resaerch Council of Canada was a source of information and witnessed testing of a prototype successfully reacting to a set pressure differential of less than 5 pascals.

It was the nature of this project that during the course of the design, construction and testing of the prototypes many problems surfaced and ultimately remedied and retested and then subsequently incorporated into the final prototype. There were many components, features and opertaing concepts investigated and then discarded as a result of this work. Most noticeably is the abandoning of the round duct enclosure cabinet designed to house all of the device components that was used in the original prototype and two of this projects prototypes. While this was the most economical way of making the enclosure cabinet it proved to be an undesireable design when considering all aspects in particular the installation of the various components which added extra cost and an undesireable overal length to accomodate same.

2.0 FINAL PROTOTYPE DESIGN

After much consideration and testing and with a view to minimize product and operating costs while providing the desired performance, the preferred system and the major components incorporated into the final prototype are as follows. The final prototype is designed specifically to be installed in an unoccupied room, typically the furnace room. This minimizes the required supply air temperature. While this prevents universal use of the product, it is suitable for the vast majority of new and existing Canadian housing stock. There is simply too much additional cost to include the necessary components to make the device siutable for occupied rooms, when it is required for only a minority of applications. A separate model with the additional components should be offered for use in occupied rooms.

The final prototype uses a centrifugal blower fan powered by a one speed shaded ploe motor (tolerant to short cycling)and operates at a relatively low noise level. It prvides a device flow rate of approximately 110 L/S.

Two 2Kw corrosion resistant finned tubular elements formed in a spiral shape provide 4Kw of single stage heating (2Kw is clearly inadequate). The nature of the operation of the heater at times when 4Kw would be more than required makes little difference to operating costs but rather to cycling time of the element. The heater provides approximately 60 degrees F of temperature rise at the device air flow of 110 L/S. The heater is controlled by a remote wall thermostat.

The damper is a barometric type and is positioned at the air intake end of the device and is set well above the desired set point of the pressure switch to prevent movement due to wind. The damper was selected for its freedom of movement and not to act passively to variance in inside/outside air pressure. The damper opens fully when the fan is activated and is maintained in a stable position. The damper housing is gasketed to provide a good seal when in the closed position.

The air pressure switch is designed in such a manner that the activation pressure is greater than the deactivation pressure. This variable is adjustable at the time of manufacture within limits. This is advantageous because it minimizes the potential for short cycling that would otherwise be common with a one speed fan. With the air pressure switch set at 5 pa depressurization, once activated the fan would remain on until the house depressurization level was brought down to 2.5 to 3 pa. The switch has a screw adjustment to field set the activation pressure if desired. It is expected the cost to manufacture said switch is less than $25.00 without any hard tooling costs.

The pressure averaging chamber has a volume of 2 litres. Testing with a 1 litre container had revealed this to be too small as it was susceptable to certain wind conditions that would momentarily activate the device. It is equipped with 6 pressure taps; 4 for wall taps, 1 for the pressure switch and the other for a measuring device for servicing or field adjustment.

3.0 PROTOTYPE OPERATION

When the house is depressurized to the level as set at the pressure switch (eg. 5 pascals), the pressure switch activates the fan and the damper opens supplying outside air in sufficient quantity to equal or surpass the combined exhaust flow rate of the various exhaust devices in the house. Once activated the device will operate until the house depressurization is brought down to a level built into the switch (eg. 3 pascals) preventing the possibilty of pressurizing the house. When the fan circuit is energised it enables the heater via the thermostat. If the room temperature is above that set on the device thermostat the heater will not be activated. If sufficient in-house flow is maintained so that the unheated device air flow lowers the room temperature in which the device is installed (typically the furnace room) to below that set on the device thermostat then the heater is activated until room temperature is brought up to the thermostat setting. It was the purpose of this method of heater operation to take advantage of the surplus heat that often exists in furnace rooms during the heating season - the prime operating time for this device. For example, one of the houses tested had furnace room temperatures consistantly in the 80 degree F range when the furnace was operating and for a considerable time thereafter. This is a result of leaky ducts and sheet metal patches from air conditioner coil installations and duct cleaning access holes. This provides a sizeable temperature differential between what would be acceptable for an unoccupied room and consequently reduces the required operating time of the heater. Since the majority of the operating costs of the device are due to heater operation, significant savings can be gained. The recommended location of the device thermostat is at the entrance into the enclosed room in which the device is located so as to have control over the air temperature exiting the room that may affect a neighbouring occupied room.

When house depressurization levels exceed the pre-set level, the on/off cycling will vary depending on the combined exhaust flow rate of any combination of exhaust devices operating. For example, a large steady flow from several exhaust devices may activate the device and it may remain on until one or more of the exhaust devices are turned off. On the other hand, an exhaust flow rate that is just enough to activate the device will result in the shortest on/off cycles and this also depends on house volume and air tightness. "on" times of only 15 seconds with "off" times of 30 seconds have been recorded in this situation. This is acceptable for the safe operation of the components used but may result in shorter component life if this was common place.

4.0 PROTOTYPE TESTING

4.1 Shop Testing

Testing was done at both the company's premises as well as field testing at 4 different houses in the Toronto area. The company's test structure consisted of an effectively air tight room in which the air pressure could be accurately controlled and this was used to simulate any desired pressure differential for the device to react to. The room volume was too small to allow the device to discharge into to bring the pressure to the desired level and was only used to determine the reaction sensitivity of the air switch. In fact for convenience of conducting other tests on the device while the device was operating, the airtight room was pressurized to simulate the outdoor environment to which the pressure averaging chamber was connected. This allowed me freedom to work in the rest of the building which was representative of the indoor environment. Test room pressurization was increased /decreased by the dampering of a fan blowing air into the test structure. Slowly adjusting the damper to increase airflow into the room until the device is activated and then waiting until the gage fluid in the inclined micromanometer peaked, as the air pressure switch reacts faster to air pressure change than does the gage fluid, allowed for accurate determination of the air pressure sensitivity. Reversing this procedure allows one to determine the pressure at which the switch deactivates. This proved to be very effective in providing consistant, repeatable results. With graduations marking the amount of damper closure of the fan one can reset room pressure so that there is no discernable difference in the displacement of the gage fluid from one time to the next indicating that almost identical room pressures are being recreated. Other tests were performed to determine the unit airflow, rise in air temperature resulting from the heater element, element temperature, enclosure cabinet temperature, and motor core temperature.

4.2 Field Testing

Field testing was concentrated on the device performance. The test houses characteristics such as airtightness and exhaust device air flow, while desireable to know were of secondary importance in this project. This is because these individual characteristics are irrelevant to the operation of the device and only the resulting pressure differential is important in determining if the device is operating properly. Assuming the device has sufficient flow capacity to meet or exceed total house exhaust airflow, it is expected that variations in house tightness and exhaust capacity will only affect the frequency and duration of operation of the device. House data was limited to a house description, listing of exhaust devices and recording the house depressurization. The majority of the test time was spent observing the device in operation and its affect on room temperature, drafts, noise level etc. Monitoring of the activation/deactivation pressure levels, cycling time, indoor/outdoor temperatures, temperature rise when heater on was also carried out.

4.3 Field Test Sheets

INDOOR AIR QUALITY DEVICE - FIELD TEST SHEET

Test House A

House Description

- a 30 year old, all brick construction, s storey house
- it has approximately 12,000 cu.ft. volume
- no insulation in the walls and minimal in the ceiling
- no significant sealing up efforts
- basement windows replaced with reasonably well sealing ones

Existing Exhaust Devices	
Kitchen fan / range hood	X
Bathroom fan: main floor	
second floor	X
Auxilary fan	
Dryer	X
Fireplace	
Existing make up air inlet/device	none
House Depressurization Level	
No exhaust devices on	4.5 pa
All exhaust devices on	10 pa
IAQD Operation	
Activation pressure	4 - 5 pa
Deactivation pressure	2.5 - 3 pa
Outside air temp.	- 6 C
Inlet air temp. w/heater on	25 C

Observations.

- strong winds with occasional stronger gusts
- IAQD was installed in an enclosed room which is also the utility room, approximately 20' x 9' in size
- wind caused higher than normal depressurization levels (typically 2.5 pa w/exhaust fans off, 8 pa w/exhaust fans on)
- IAQD would not deactivate unless one or more of the exhaust devices were turned off
- IAQD was operating much more than on milder days
- the only sound discernable from the adjoining family room from the device operation was the single "click" from the relay magnetic contacts making and breaking the activation circuit
- no objectionable drafts

4.3 Field Test Sheets

INDOOR AIR QUALITY DEVICE - FIELD TEST SHEET

Test House B

House Description

- a 6 year old, brick veneered, wood framed, 2 storey house
- standard wall and ceiling insulation with poly vapour barrier
- it has a volume of approximately 18,000 cu.ft.

Existing Exhaust Devices	
Kitchen fan / range hood	X
Bathroom fan: main floor	X
second floor	X
Auxilary fan	
Dryer	X
Fireplace	X
Existing make up air inlet/device	none
House Depressurization Level	
No exhaust devices on	2 pa
All exhaust devices on	7.5 pa
IAQD Operation	
Activation pressure	4.5 - 5 pa
Deactivation pressure	3 pa
Outside air temp.	- 2 C
Inlet air temp. w/heater on	33 C

Observations.

- light winds today
- the IAQD was installed in an open basement in the vacinity of the furnace
- with all the exhaust devices on, the house would depressurize to the 5 pa level within 1 - 2 minutes and activate the device
- the device would cycle with "on" times varying between 5 - 10 minutes and "off" times of approximately 1 minute.
- suspect the fireplace chimney flow varying in size contributing to larger than normal "on" time differential - usually within one minute of each other if exhaust flow is from mechanical means only
- inlet air well distributed - no objectionable drafts
- fan noise could be heard from all parts of the basement if operating by itself, it would be completely drowned out by the sound of either furnace fan or dryer

4.3 Field Test Sheets

INDOOR AIR QUALITY DEVICE - FIELD TEST SHEET

Test House C

House Description

- a 30 yearold, brick veneered, wood framed bungalow
- it has a vloume of approximately 16,000 cu.ft.
- no wall insulation, 4" of fiberglass insulation
- minimal sealing of doors and windows etc.
- all doors and windows original (except storm doors)

Existing Exhaust Devices	
Kitchen fan / range hood	inoperative
Bathroom fan: main floor	
second floor	
Auxilary fan	X
Dryer	X
Fireplace	X
Existing make up air inlet/device	none
House Depressurization Level	
No exhaust devices on	1.5 pa
All exhaust devices on	7.5 pa
IAQD Operation	
Activation pressure	5 pa
Deactivation pressure	3 pa
Outside air temp.	1 C
Inlet air temp. w/heater on	31 C

Observations.

- mild, no wind
- IAQD installed in enclosed furnace room, approximately 9' x 15' room also used for storage and laundry
- without the fireplace burning this house would not depressurize beyond 5 pa (this might change if the kitchen fan is made operable)
- with fireplace on and other exhaust fans on the IAQD would cycle on and off - "on" times of 3 - 4 minutes with "off" times of approximately 1 minute
- no noticeable drafts or noise directed to adjoining rooms

4.3 Field Test Sheets

INDOOR AIR QUALITY DEVICE - FIELD TEST SHEET

Test House D

House Description

- a 25 year old, brick and wood framed, L-shaped bungalow
- basement level is at ground level at rear of house
- it has a volume of approximately 20,000 cu.ft.
- a large number of windows including 2 sets of sliding doors

Existing Exhaust Devices	
Kitchen fan / range hood	X
Bathroom fan: main floor	X
second floor	
Auxilary fan	
Dryer	X
Fireplace	X has 2 above average size masonry fireplaces, only one used during these tests
Existing make up air inlet/device	none
House Depressurization Level	
No exhaust devices on	1.5 pa
All exhaust devices on	8.5 pa
IAQD Operation	
Activation pressure	4.5 - 5 pa
Deactivation pressure	2.5 - 3 pa
Outside air temp.	0 C
Inlet air temp. w/heater on	32 C

Observations.

- slight wind, occasional gusts
- the IAQD was installed in an enclosed room (no door) approx. size 8' x 6' with adjoining storage room that opens to a hallway - not near occupied areas
- exhaust devices seemed more powerful than average but there is potential for greater infiltration
- with medium size fire, exhaust fans on, the IAQD would remain on until the kitchen range hood was turned off
- absolutely no problems with discomfort or noise
- IAQD thermostat could be kept very low

4.4 Furnace Spillage Tests

All houses tested had conventional gas furnaces. A brief test was performed to check for the spillage of products of combustion after a cold start of each furnace. Each furnace was turned of for 30 minutes. Weather conditions were similar for all tests with the outside air temperature varying between 0 to -6 degrees C (21F - 32F) and minimal wind. Spillage was determined by temperature measurements taken directly above the dilution air intake of the furnace. All in house exhaust devices were turned on several minutes before the furnace was turned on depressurizing the houses to a minimum of 7.5 pascals. In three of the four houses only momentary spillage was observed (less than 15 seconds). One house did have a spillage problem.

Temperatures above this furnaces dilution air intake exceeded 110 degrees C (230 F). These temperatures while fluctuating were maintained for over 5 minutes with no sign of letting up. At this time, power was supplied to the device which immediately activated. It took several minutes for the spillage to stop even though after one minute the device had reduced the house depressurization level to below 5 pascals. Shortly after the device was allowed to come on,air temperatures started to decline slowly until spillage stopped.

The furnace was shut off for another 30 minutes and another test performed. Exhaust devices were turned on, the device was allowed to opertae and then the furnace was turned on. Again spillage was noticed with air temperatures above the dilution air intake measured at 70 degrees C (158F). The temperature almost immediately started to decline but it took a couple of minutes before spillage had stopped.

The furnace was shut-off for another 30 minutes and another test performed. This time only one exhaust device was turned on and the house was depressurized to 2.5 pascals. The device was inactive and the furnace turned on. Only momentary spillage was noticed before it corrected itself. This last test seems to indicate the spillage problem is related to house depressurization and not some other factor.

Furnace spillage testing was not planned as part of the original test format and only included as a last minute after thought. This was because certain basic assumptions were made concerning design and operating parameters for this device based on other major research work. One of these assumptions was that the maximum house depressurization limit to prevent the above described spillage problem was 5 pascals.

So my testing was concerned with ensuring the device would satisfy this requirement and not with checking the validity of that assumption. In retrospect, it seems that the majority of this test project should have revolved around this one test house that has this spillage problem which is a main function of the device to prevent. The spillage tests described are all that have been done in time to include in this already delayed final report.

5.0 OBSERVATIONS

5.1 Spillage Susceptability

Of particular interest was the fact that these test houses would have to be described as average houses with average exhaust devices and yet all were subject to sufficiently high house depressurization levels to potentially cause gas furnaces to spill products of combustion in quantity and duration that is a definite hazard as seen in one of the test houses. My exposure to the spillage during the outlined testing was sufficient to cause me dizziness and a slight headache. Also worth noting,this cold start spillage problem in this test house does not have such a remote possibility of occurence as one might associate with this venting problem.

As mentioned in the test results, the furnace had been operating all day and was shut-off for only 30 minutes before restarted with the spillage occurring immediately. In this household, it is not uncommon for the homeowners to return home from work to find the baby sitter had turned the heat up to 72F-75F. It is then turned down to approximately 68F and this can often take more than 30 minutes before the thermostat calls for heat again. This is also the time when the kitchen range hood and other exhaust devices are used potentially duplicating the spillage conditions depending on outside air temperature and wind conditions. This is not such an uncommon scenario and there are many other situations that could duplicate these spillage conditions.

5.2 House Depressurization Levels

All test houses were capable of depressurization levels that exceeded 7.5 pascals when all existing in house devices were on. On windy days, house depressurization levels could reach 5 pascals without any mechnaical exhaust device on. With exhaust devices on and strong winds a house depressurization level of over 10 pascals was recorded. There is some question in my mind that the pressure levels on windy days are accurate or whether some error is being introduced into the pressure averaging apparatus due to certain wind conditions.

5.3 Heater Operation

It was encouraging to see the device supplying unheated air at times when outside air temperatures were below freezing and for a reasonable length of time without adversely affecting adjoining rooms with respect to discomfort. This is particularily effective in furnace rooms and could be maximized if the furnace room door was fitted with a large grill (with specified minimum opening area) at the top of the door and the door was kept closed. The device also performed well in an open basement in minimizing discomfort and I attribute this to the air outlet diffuser which did a very good job of directing air flow along the ceiling providing better mixing with heated room air.

5.4 Pressure Switch

The pressure switch performed well but it was difficult in field testing to determine the exact activation pressure because the device would come on before the gage fluid in the inclined micromanometer stopped and it would then be brought down by the incoming air. The activation pressure would seemingly become lower with increased exhaust flow - a result of the air pressure switch reacting faster than a fluid. However, the activation pressure was consistant time and time again at a given exhaust flow and time frame. This highlights potential inaccuracies with field set point adjustments with this type of instrumentation. With the pressure switch factory set point of 5 pascals, the field tests showed that the switch would activate the device before the manometer reading of 5 pascals, indicating it was operating as it should. In shop testing the pressure switch was consistantly well within $\pm$ .5 pascals.

5.5 Test House Spillage Problem

While there is insufficient testing of this spillage problem to determine this furnace installations house depressurization limit or the effectiveness of the device to prevent it, it does provide some insight. It suggests that these spillage problems can occur at depressurization levels of less than 5 pascals. In additon, it is perhaps unreasonable to expect the operation of such a device to be black and white so as to prevent any spillage whatsoever. There are bound to be some grey areas such as temporary or minimal spillage when the house depressurization limit as set on the device (eg. 5 pascals) is close or equal to the limits that can cause some furnace installations to spill products of combustion under certain conditions. Generally, one would provide a reasonable margin of safetey of at least 2 pascals in setting a maximum HDL. But since this limit is so close to the bottom this may not be possible. In most cases this 5 pascal limit does probably provide ample margin of safety; however, it is potentially too high to prevent this spillage occurence in the more sensitive furnace installations. It is very likely, if the HDL that this furnace spilled at was 7 pascals which is still within the range of the exhaust devices, the air supply device probably would have prevented all but momentary start up spillage.

6.0 CONCLUSIONS

The device operates as designed and will supply the house with air to prevent house depressurization beyond a set point (eg. 5 pascals) as determined with 4 exterior wall taps and a pressure averaging chamber. However, I believe additonal testing is required of the pressure averaging apparatus to develop a standardized system and method of installation to provide consistant low pressure determination. Such things as the effect on air flow from wall tap to the pressure averaging chamber, if any, due to differences in wall tap tube length, number of bends, bend radius, tube connectors that reduce internal cross sectional area if used to join lengths of tubing instead of one continuous length that may introduce inaccuracy in the pressure determination. Certainly a cover must be designed for wall taps not only to prevent blockage from rain, snow,ice and other debris but to protect the wall tap from being subjected to a velocity pressure due to certain wind conditions. Unfortunately, the Canadian General Standards Board standard on building airtightness testing (CAN/CGSB-149.10) does not address any of these issues. Since this standard deals with air flow measurements at varying pressure settings upto 50 pascals, perhaps these potential inaccuracies are insignificant. But when the critical pressure is only 5 pascals it may be a source of inaccuracy of significance. My "feel" for this matter from the testing I've done is that it is capable of introducing error at the pressure averaging chamber of 1 - 2 pascals. This is enough error to allow depressurization levels high enough to potentially cause a cold start spillage problem depending on other conditions or on the other hand have the device operating much more often than required adding to operating cost and product life.

In addition, comparison testing of an improved wall tap pressure averaging system versus a chimney top (furnace chimney) pressure tap should be carried out. The latter may provide for more appropriate differential pressure measurement as it seems the furnace spillage problem has the more critical set point for house depressurization than for soil gas entry.

While it seems that more consideration of a "safe" house depressurization limit may be warranted, it is not a problem with setting the device to operate at a lower HDL. The pressure switch is capable of operating at levels of 2-3 pascals, it is more a matter of the resulting higher operating costs and component life as a result of significantly greater frequency of operation of the device.

The pressure switch developed and incorporated into the device has an advantage in checking and/or stopping these very sensitive spillage prone installations. This is because when the set point is 5 pascals and house depressurization reaches this, the device activates and will operate until the house depressurization level is brought down to 2.5 to 3 pascals. If a furnace was spilling below the 5 pasacl level, it could be reduced or stopped as the house depressurization was brought down to the 2.5 to 3 pascal limit as it actually did with the test house. If the device was operating before the furnace came on and had already lowered the depressurization level the spillage could be potentially prevented.

Conversely, a pressure switch that is designed to keep the limit of depressurization at a set level (eg. 5 pascals) and has an activation and deactivation point at almost the same pressure. Spillage may not be stopped at all during the furnace cycle, if conditions were such to cause spillage to occur in the first place. I believe the pressure switch developed and incorporated into this prototype operates in a fashion that is very desireable for this type of device.

7.0 Figure 1

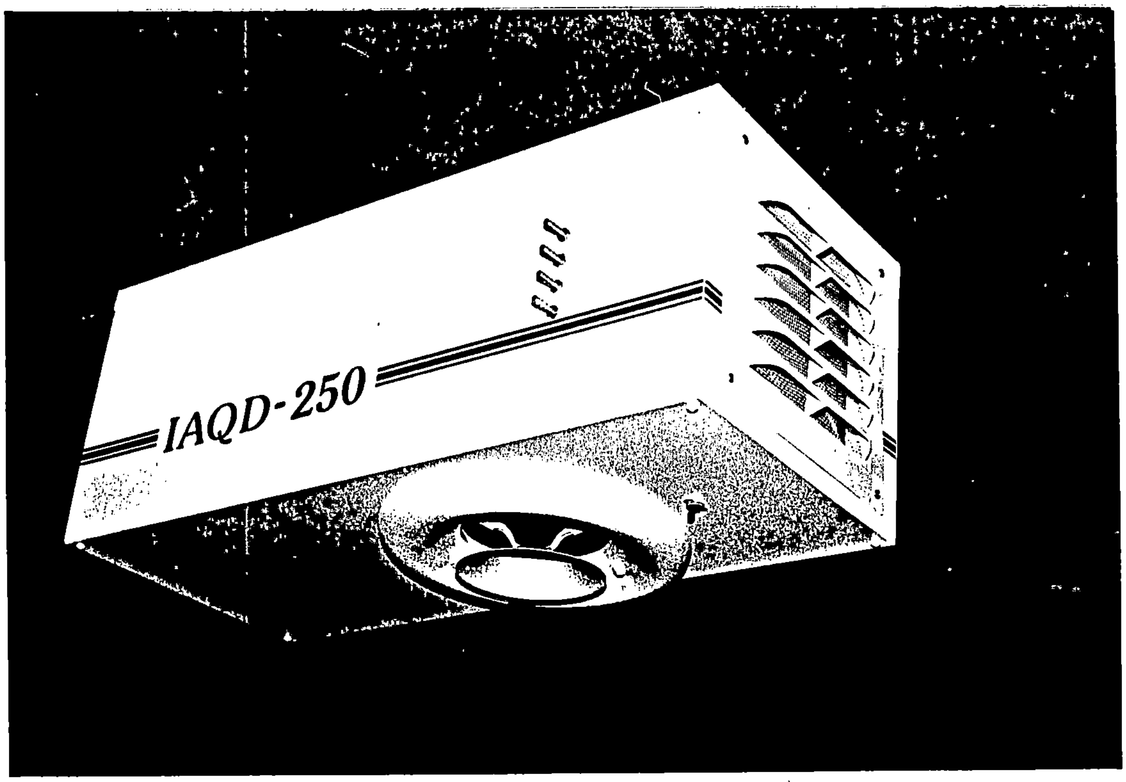

Figure 1 : Final Prototype