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PROJECT TO CONTINUOUSLY MONITOR THE PERFORMANCE OF THE LAMINAR AIR FLOW SUPER WINDOW-HUMIDITY CONTROLLED AIR INLET - BASEBOARD HEATER VENTILATION AND HEATING SYSTEM

REPORT FOR

CANADA MORTGAGE AND HOUSING CORPORATION

Project to Continuously Monitor the Performance of the Laminar Air Flow Super Window - Humidity Controlled Air Inlet - Baseboard Heater Ventilation and Heating System

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November 28, 1989

Mr. Frank C. Pelley
Project Implementation Division
CANADA MORTGAGE AND HOUSING CORPORATION
682 Montreal Road
Ottawa, Ontario
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Dear Mr. Pelley:

Attached is our final report for Willmar Window Industries Ltd. on our project to continuously monitor the performance of the Laminar Air Flow Super Window - Humidity Controlled Air Inlet - Baseboard Heat System in a house under occupied conditions.

It was a pleasure to have the opportunity to carry out this interesting project.

Sincerely,

G. K. YUILL AND ASSOCIATES LTD.

Gordon M. Comeau, P.Eng.

GMC:lde

Enclosure

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EXECUTIVE SUMMARY

The Laminar Air Flow Super Window - Humidity Controlled Air Inlet - Baseboard heat (LAFSW/HCAI/BH) system is a means of supplying preheated ventilation air to individual rooms in a house. The system consists of three elements:

1. The Laminar Air Flow Super Window is a triple glazed window which draws outdoor air into the house between its panes and pre-warms this outdoor air with the heat which would normally be lost through the window by conduction. From computer simulations, nighttime RSI values as high as RSI 2.5 have been predicted for this window.

2. The Humidity Controlled Air Inlet system consists of two parts, a central exhaust fan and humidity controlled air inlets in each room. The exhaust fan operates continuously, drawing air from the kitchen and bathrooms and maintaining a negative pressure in the house. The HCAIs in the other rooms open depending on the humidity level in each room. The negative pressure draws intake air into the house through the HCAIs which are located at the outlets of the LAFSWs.

3. The baseboard heaters supply the fluctuating heat demands of the rooms, and avoid the loss of ventilation efficiency which can be caused by the air mixing action of a central furnace. The HCAI system relies on diluting the indoor pollutants in the house with fresh air rather than air from other areas of the house.

This project summarizes the work on a project to demonstrate and monitor the performance of the LAFSW/HCAI/BH system installed in a newly constructed house in Winnipeg, Manitoba. The objective of the project was to identify both the benefits and deficiencies of employing the LAFSW/HCAI/BH system in new energy efficient housing by conducting one time/pre-occupancy measurements of airtightness and air infiltration and carrying out continuous monitoring under normal occupancy conditions of various temperatures, relative humidities and exhaust fan flow rates.

The project commenced in January, 1989. At that time construction of the demonstration house was approximately 60 percent complete with the windows already installed and ducting for the central exhaust ventilation system in place. By Mid-February, 1989, construction of the demonstration house was complete. Fine tuning of system components and, airtightness and air infiltration measurements followed thereafter. By mid-April, the house was occupied by two people and continuous monitoring began. Testing and continuous monitoring was completed in July.

The LAFSW/HCAI/BH system was found to perform reasonably well in heating and ventilating the house. However, some difficulties were encountered and further development of the controlled air inlets will be required. The HCAIs that were used did not restrict air flow sufficiently in the closed position. It was also determined that relative humidity is not a good indicator of occupancy. It was also realized that back draft dampers at the air inlets are necessary to avoid backdrafting problems and temporary frosting of windows in the winter (backdrafting sometimes occurred in windows on the leeward side of the house on very windy days).

Radon levels in the basement were measured to be above the United States Environmental Protection Agency's (U.S.E.P.A.) action level of 4 pCi/L, although they did remain below Health and Welfare Canada's long-term exposure guideline of 20 pCi/L. Incorporating subslab ventilation into the central exhaust system should reduce the radon levels to below the U.S.E.P.A. action level.

1.0 INTRODUCTION

In recent years, a move toward energy efficiency in residential housing has resulted in tighter house construction and a need to provide controlled ventilation to maintain acceptable indoor air quality. Subsequently, a draft set of guidelines for ventilating houses has been developed. These guidelines are contained in CSA Standard F326.1, Residential Ventilation Requirements.

In the CSA Standard, there are strict ventilation requirements which specify the amount of outdoor air to be supplied to each room. At present, a heat recovery ventilator (HRV) with a forced air furnace is the only common means of satisfying the requirements. (Another means which is less common is an HRV with appropriate ducting and baseboard heating.) However, the cost of a heating system and HRV is relatively high. There is therefore, a need to identify alternate means of meeting the F326.1 ventilation requirements. This initiated the development of the Laminar Air Flow Super Window - Humidity Controlled Air Inlet - Baseboard Heating (LAFSW/HCAI/BH) system which may offer an energy efficient means of supplying heat and ventilation air to houses.

To assess the performance of the LAFSW/HCAI/BH system, a demonstration house equipped with the system was constructed in Winnipeg. Airtightness, air infiltration, and indoor air quality measurements were made, and continuous occupied monitoring of temperatures, relative humidities, and exhaust fan flow rates was carried out. The demonstration project identified both the benefits and deficiencies of employing the LAFSW/HCAI/BH system in new energy efficient housing.

2.0 SYSTEM COMPONENTS

2.1 Laminar Air Flow Super Window (LAFSW)

2.1.1 Description

The LAFSW is a triple glazed window which draws outdoor air into the house between its middle and exterior panes and pre-warms this air with heat which would normally be lost through the window by conduction. From computer simulations, nighttime thermal resistance values as high as RSI = 2.5 m^2K/W

have been predicted for this window (based on a flow rate of 11 L/sec through a triple glazed window that is approximately 1 m high, by 1 m wide, and has an air flow gap width of 12.7 mm). For the windows installed in the demonstration house, where the air flow rate through each window is approximately 5 L/sec, a nighttime thermal resistance value of RSI = 0.8 m^2K/W has been predicted. As the airflow rate through the window is decreased from 11 L/sec to 5 L/sec, the thermal resistance value also decreases, since some of the heat that is picked up by the slower moving airstream is allowed to reach the outer pane and leave the house. In laboratory tests conducted by the National Research Council, the measured rise in air temperature through the LAFSW was found to be similar to that predicted when using computer simulations.

2.1.2 Fabrication

In a separate project carried out in 1988, a PVC - framed version of the LAFSW was designed. Basically, this involved the design of the sash top cross section, sash bottom cross section, and sash side cross section of the window. However, because the extrusion dies of the window have been considered too costly for the few windows to be manufactured in the near future, an alternate LAFSW was designed. This design was essentially a modified version of one of Willmar's Triple glazed openable windows. Because this version required three new extrusion molded components from extrusion dies that were relatively low in cost to make, the windows fabricated for use in the demonstration house were of this type. Assembly of the Laminar Air Flow Super Windows was similar to that of the conventional PVC-framed windows. However, some machining on the extrusions was required.

A cross-sectional drawing of the LAFSW used in the demonstration house is contained in Appendix A. The three new extrusion molded components are labelled.

2.1.3 Cost of the LAFSW

The Laminar Air Flow Super Window is estimated to cost approximately $40.00 more per m^2 of glazing than its conventional triple glazed equivalent. Putting this into perspective, the LAFSW is expected to cost 7 percent more than the conventional window.

2.1.4 Supplier of the LAFSW

Willmar Window Industries Ltd. of Winnipeg, Manitoba, designed and manufactured the Laminar Air Flow Super Windows used in the demonstration house. At present, Willmar Windows can manufacture and supply these windows in relatively small quantities. If demand for the LAFSW increases, Willmar Windows has the capability of expanding their production since extrusion dies for the window have already been designed. If windows are manufactured from sections using the proposed sash component designs, the cost of the LAFSW should be comparable to that of its conventional equivalent.

2.2 Humidity Controlled Air Inlet (HCAI) and Central Exhaust System

2.2.1 Description

The HCAI system consists of two elements, a central exhaust fan, and humidity controlled air inlets in each room that requires fresh ventilation air. The exhaust fan operates continuously, drawing air from the kitchen and bathroom, and maintaining a negative pressure in the house. The HCAIs in the other rooms open depending on the humidity level in each room. The negative pressure draws intake air into the house through the HCAIs which are located at the outlets of the LAFSWs. Depending on the openness of the HCAI's, this negative pressure ranges from 4 Pa to 7 Pa.

Literature on the multi-point mechanical ventilation exhaust system used in the demonstration house is contained in Appendix A.

2.2.2 Cost of the HCAI-Central Exhaust System

The contractor/dealer price for a HCAI-Central Exhaust system like the one installed in the demonstration house is $1096.00. This compares to $2,500.00 for an HRV system. It should be noted that by using a different exhaust fan and manually controlled air inlets the cost of the ventilating system can be reduced substantially.

2.2.3 Supplier of the HCAI-Central Exhaust System

American Aldes Ventilation Corporation of Sarasota, Florida, U.S.A., supplied the HCAI system used in the demonstration house. Their product is well established in Europe and is now readily available in North America.

2.3 Baseboard Heaters

2.3.1 Purpose of Baseboard Heating

The baseboard heaters supply the fluctuating heat demands of the rooms, and avoid the loss of ventilation efficiency which would be caused by the air mixing action of a central furnace. The HCAI system relies on diluting the indoor pollutants with fresh air rather than air from other areas of the house. It is important to note that any type of radiant heating system is also suitable for use with a LAFSW ventilating system.

2.3.2 Cost of the Baseboard Heating System

The baseboard heating equipment in the demonstration house is valued at approximately $450.00.

2.3.3 Supplier of the Baseboard Heating Equipment

Westcan Electrical Manufacturing Inc. of Mississauga, Ontario supplied the baseboard heating equipment that was installed in the demonstration house.

3.0 INSTALLATION OF THE LAFSW/HCAI/BH SYSTEM

3.1 Construction of the Demonstration House

House construction began on October 18, 1988 at 114 Payment Street, Winnipeg, Manitoba. By mid-February, 1989, construction of the demonstration house was complete with the exception of some of the exterior finish, including the stucco siding, which was applied in warmer weather. While the overall construction of the house was much the same as for other tract houses which Flair Homes builds, Yuill and Associates Ltd. provided the builder with technical assistance on installation of the components of the LAFSW/HCAI/BH system during the course of construction.

Because ventilation air is drawn through intentional openings in the building envelope by the negative pressure created by the central exhaust fan, it was important that the house be air-tight; so that most of the ventilation air would enter through the intentional openings (LAFSW/HCAI units). In the construction of the demonstration house, the following airtightening measures were taken:

1. continuous vapor barrier throughout (overlaps sealed with acoustical caulking);

2. Tyvec paper to seal woodframe-wall/concrete-wall interface;

3. urethane foam around windows and indoor-to-outdoor penetrations; and,

4. 6 mil poly under the concrete slab and joined to the vapor barrier on the walls in the basement with acoustical caulking.

The latter measure was incorporated to serve two purposes. The first was to increase the airtightness of the house and the second was to prevent the entry of radon into the house as a result of maintaining the house at a negative pressure.

The following sections briefly discuss the installation of the LAFSW/HCAI/BH system components.

3.2 Installation of the Laminar Air Flow Super Windows

Five Laminar Air Flow Super Windows were installed on the main floor of the demonstration house. Their locations are shown on the floor plan contained in Appendix A.2.

The procedure for installing the laminar air flow super window is no different than that for installing conventional windows, since the window frames on each type are the same. There is, however, one important precaution to take; especially, during cold weather installations. The outlets of the laminar air flow super windows must be sealed until the central exhaust system is up and running. This must be done because moisture generated during construction will leave the house through these windows if their outlets are not sealed. The net result of moisture leaving through these windows during cold weather is condensation freezing on the outside glazing.

3.3 Installation of the Humidity Controlled Air Inlets and Central Exhaust Fan System

The central exhaust fan and associated ducting can be installed during or after house construction, depending on whether the duct runs are located in the interior walls or in the attic. The central exhaust fan may be located either inside or outside the heated space. It is important to note, however, that when the fan is located outside the heated space it cannot be turned off in cold weather, since moisture in the air which leaves the house through the exhaust system may condense and freeze inside the fan unit. Despite this point, there are advantages to locating the van in the attic. They are lower noise levels in the living space, and shorter duct runs.

In the demonstration house the fan unit was located in the basement. This made it easier to make modifications to the system when testing. Also, by keeping the fan unit in the heated space, there are less penetrations through to the attic and thus, a greater probability of maintaining airtightness. Once the central exhaust fan was running, the seals on the laminar air flow super windows were removed and the humidity controlled air inlets were installed.

The fan unit was designed to exhaust air from the house at a rate of approximately 50 L/sec. At this flow rate, house depressurization would range from 4 Pa to 7 Pa, depending on the openness of the HCAI's. 50 L/sec corresponds to the minimum fresh air requirement for the demonstration house, as specified in CSA Standard F326.1.

The installation manual for the central exhaust system is contained in Appendix A of this report.

3.4 Installation of the Baseboard Heating System

Baseboard heaters were installed according to standard procedures.

3.5 Overall System Installation

In general, the LAFSW/HCAI/BH system was easy to install. The laminar air flow super windows were installed in the same fashion as conventional windows, and the baseboard heaters were installed according to standard practice. The central exhaust system which includes the fan unit, grills, humidity controlled air inlets, and all of the necessary ducting was supplied as a complete kit and was installed in approximately one day. Had the exhaust fan unit been located in the attic, the installation time would have been approximately one half day, since special ducting that was used in the wall stud space for connection to wall mounted exhaust grills would not have been required (for the attic installations, only flexible ducting is required for attachment to grills that penetrate the ceiling).

4.0 MONITORING THE PERFORMANCE OF THE LAFSW/HCAI/BH SYSTEM

4.1 Introduction

Monitoring the performance of the Laminar Air Flow Super Window - Humidity Controlled Air Inlet - Baseboard Heating system in the demonstration house involved conducting one time/pre-occupancy tests and continuous monitoring under normal occupancy conditions. Most of the one time/pre-occupancy tests were conducted in March, immediately following the construction of the demonstration house. During this month, the monitoring equipment was installed. The house was occupied by mid-April and continuous monitoring commenced thereafter.

Pre-occupancy tests included a series of airtightness tests and a series of air infiltration tests.

Occupied monitoring involved two months of continuous monitoring of various temperatures, relative humidities and air flow rates in the exhaust plenum. Radon levels in the basement and on the main floor were continuously monitored for several weeks. A time weighted average formaldehyde measurement was made on the main floor.

It is important to note that the two months of continuous monitoring was broken on several occasions due to intermittent breaks in electrical power. Monitoring was actually conducted over a period of three months during which approximately two months of meaningful data were collected. To present the findings from continuous monitoring, sets of unbroken data were selected from the entire set of data and imported into LOTUS files for graphing. Several weeks of data that were obtained during periods of warmer weather have not been presented as opening and closing of windows went unrecorded, thus, making it difficult to interpret some of the logged data.

The following sections describe the measurement instrumentation used and present the results from testing under pre-occupancy and normal occupancy conditions.

4.2 Test Methodology

4.2.1 Airtightness Tests

A blower door was used to conduct five fan depressurization tests on the demonstration house. Four were conducted in a previous study; one was conducted in the present study. Results from the first four tests have been included in the Appendix section of this report since the findings were of importance to the present project.

Testing was conducted according to the CGSB Standard, "Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method" (CAN/CGSB - 149.10 - M86). Tests were carried out for the following conditions:

1. all intentional openings sealed;
2. HCAI's in the fully closed position;
3. HCAI's in the half-opened position;
4. HCAIS in the fully opened position;
5. all intentional openings sealed (test 1 was conducted before the stucco siding was applied; test 5 was conducted after the stucco siding was applied).

To obtain conditions 2, 3 and 4, the HCAI's were manually fixed to the corresponding positions.

4.2.2 Air Infiltration Measurements

Air change rates were measured using the sulfur hexafluoride tracer gas decay technique. Four tests were conducted with measurements made in seven locations simultaneously, during each test. The locations were the living room/dining room, the kitchen, the master bedroom, the second bedroom, the third bedroom, the basement, and the exhaust plenum from the central exhaust fan unit. Knowing the room volumes and the measured air change rates in each room, weighted average air change rates for the house were determined.

It is important to note that the measured room air change rates were only approximate, since there is no means of dealing with the cross contamination that occurs when using this measurement technique. However, because the airflows in the house were from the rooms and toward the central points of exhaust, the potential for cross-contamination was minimized. The results obtained for the kitchen and bathroom may be suspect as air from other rooms passes through them.

As with the first four airtightness tests, the air infiltration measurements were conducted in a previous study. Due to their relevance to this study, the findings have been included in the Appendix section of this report.

4.2.3 Pressure/Flow Characteristics of the Laminar Air Flow Super Window - Humidity Controlled Air Inlet System.

Prior to the construction of the demonstration house, the pressure/flow characteristic curves for the Laminar Air Flow Super Window - Humidity Controlled Air Inlet system were determined. The purpose of determining these characteristics was to estimate the number of windows required in the demonstration house to meet ventilation requirements without causing significant house depressurization.

An axial fan and damper system was used to provide air to the window at various air flow rates. These air flow rates were measured with a calibrated bell-mouthed nozzle located upstream of the axial fan and damper system. One inclined manometer was used to measure the air flow rate at the throat of the nozzle (this was also the air flow rate through the window); another one was used to measure the pressure drop through the LAFSW/HCAI system.

The pressure/flow characteristics of the LAFSW/HCAI component of the system were measured in a previous study. Because of their relevance to the present study, they have been included in the Appendix section of this report.

4.2.4 Continuous Monitoring

To assess the performance of the LAFSW/HCAI/BH system and its impact on temperatures and relative humidities in the house, continuous monitoring under normal occupancy conditions was carried out. Twenty-six channels of a data acquisition system were utilized to measure the following:

- indoor temperatures at floor, mid-wall, and ceiling heights;
- outdoor temperatures;
- delivered air temperatures from LAFSWs;
- temperatures just below the HCAIs on the LAFSWs;

- relative humidities in four rooms;
- relative humidity at humidity sensor on an HCAI;
- air flow rates in the exhaust plenum.

The continuous monitoring instrumentation consisted of the following components:

a) IBM PC/XT complete with a 20 MB hard disk and battery backed time clock;
b) Sciemetric Instruments Model 8082A Electronic Measurement System interfaced to the IBM PC/XT by a Sciemetric Instruments IBM interface card;
c) Sciemetric Instruments Model 107 Relative Humidity Sensors;
d) Dwyer Instruments Model 602-1 Pressure Transducer and Van-EE flow sensor for measuring air flows in exhaust plenum; and,
e) type T thermocouple wire.

The data acquisition system was controlled by the Sciemetric Instruments Level 5 software. Each channel was scanned once every 30 seconds and the humidities and air flow rates through the exhaust plenum were stored on disk every hour (accumulative total and averaged). At the end of the day, the data file was closed and a new data file was opened for the new day. Thus, a separate data file was created for each day.

4.2.5 Radon and Formaldehyde Measurements

Radon. Radon levels in the demonstration house were continuously monitored for several weeks. Measurements were made in the basement and on the main floor. A Pylon Instruments Model AB-5 Radon Monitor was used to make the measurements.

Formaldehyde. A Berkeley PF-1 Formaldehyde Monitor was hung in a central location on the main floor of the house for approximately seven days. The monitor was then sent to a local laboratory for analysis.

rejected due to non-continuity or because it was obtained during warm weather when the data were less meaningful. As pointed out earlier, during warm weather, opening and closing of windows went unrecorded, making it difficult to interpret the data. Also, some of the data were meaningless during warm weather; for example, delivered air temperature from a window that was open.

Only two of the four data sets are referred to when discussing the results from monitoring. They are data sets 1 and 3. The other two sets (data sets 2 and 4) were obtained during warmer weather. No attempt at interpretation of these data has been made because the frequent opening and closing of windows and doors went unrecorded. The figures derived from all four data sets are contained in Appendix B.

The raw data were imported into LOTUS spreadsheets and the following figures were generated for each of the four monitoring intervals:

1. Temperature Profiles. Five temperatures are plotted. They are the outdoor temperature, the delivered air temperature from the LAFSW in bedroom no. 3, and the indoor temperature at the floor, mid-wall, and ceiling heights. The indoor temperature measurements were made along an opposite wall from the LAFSW.

2. Exhaust Fan Flow Rate. Hourly average airflow rates through the exhaust duct from the central exhaust fan unit are plotted.

3. Relative Humidity. The relative humidity at three locations in the house are plotted. These locations include the master bedroom, bedroom no. 2, and the bathroom. Relative humidity was continuously monitored in the dining room. However, the data for this location was rejected due to drifting in the readings.
4. Master Bedroom Relative Humidity. The relative humidity in the master bedroom, well away from the LAFSW/HCAI ventilator unit, is plotted with the relative humidity measured at the sensor on the humidity controlled air inlet.

5. Temperatures: Delivered and Below HCAI. Two temperatures continuously monitored at the living room LAFSW are plotted; the delivered air temperatures and the air temperatures immediately below the humidity controlled air inlet.

6. Delivered Air Temperature. The air temperature rise through the living room LAFSW is shown by plotting the outdoor air temperature and the delivered air temperature.

7. Surface Temperature Log. The inside surface temperatures of a laminar air flow super window and a conventional window of similar configuration are plotted.

In addition to the data plots described above, three additional plots were generated using data from the first data set (April 24, 1989 to April 30, 1989). These three additional plots show the heat exchanger effectiveness of the windows in bedroom no. 3, the living room and the dining room.

4.3.5 Results from Radon Monitoring

Radon levels were continuously monitored for approximately seven weeks. For four weeks, the radon monitoring instrumentation was placed in the basement. For three weeks, it was placed in the bedroom on the main floor.

A central air conditioning unit was installed on July 11, 1989. Prior to this date, radon monitoring was conducted at times when windows in the house were open much of the time. After July 11, the radon monitor was placed in the bedroom for approximately one week and then in the basement for approximately one week. The monitoring periods were July 13, to July 19 and July 19 to July 26 for the bedroom and basement, respectively. For these two monitoring periods, windows in the house were closed all of the time.

The results from radon monitoring are presented in Appendix D. For the three intervals where monitoring was conducted in the basement, the average radon levels were measured to be 23.2 pCi/L, 15.3 pCi/L and 6.8 pCi/L. For the two intervals where monitoring was conducted in the bedroom, the average radon levels were measured to be 1.0 pCi/L and 3.4 pCi/L. The latter figure for each location corresponds to the monitoring period where windows were closed. Putting these measurements into perspective, the Federal-Provincial Advisory Committee concerned with indoor air quality issues recommends that remedial measures be taken where the level of radon in the home is found to exceed 22 pCi/L as the annual average concentration in the normal living area.

4.3.6 Time Average Formaldehyde Level

A Berkeley PF-1 Formaldehyde monitor was hung at the hallway entrance to the living room from July 13, 1989 to July 19, 1989. The central air conditioning unit was running during this period. Thus, the measurement was made when all windows in the house were closed. The time average formaldehyde level was measured to be 0.128 ppm. This is slightly higher than Health and Welfare Canada's long-term exposure limit of 0.1 ppm.

The laboratory test report for this measurement is contained in Appendix E.

4.3.7 Review of the Results from Previous Work

To better understand the findings in the present project, the findings from previous related work have been included in Appendix F of this report. These findings are in both graphical and tabular form. They include the pressure/flow characteristic curves for the LAFSW/HCAI combined system component, and the results from a series of airtightness measurements and a series of air infiltration measurements.

As previously mentioned in Section 4.3.1, the series of airtightness tests revealed the following:

1. Approximately half of the ventilation air enters the house through the non-intentional openings.

2. The turn down ratio for the LAFSW/HCAI system component is relatively high. In other words, the difference in air flow rate through

the window with the HCAI fully closed and fully opened is relatively small.

The latter point was originally determined when measuring the pressure/flow characteristic curves of the LAFSW/HCAI combined system component.

The series of tracer gas tests produced a small set of data that was quite valuable for assessing the performance of the LAFSW/HCAI/BH system. These tests revealed the following:

1. The house, in general, is adequately ventilated. However, some areas of the house get too much ventilation air while other areas get too little.

2. Incremental opening of the humidity controlled air inlets has little effect on the overall ventilation rate; since the central exhaust fan unit attempts to maintain a constant exhaust flow rate regardless of the size of intentional and non-intentional openings in the house.

It should be noted that the overall air change rate in the house was found to decrease slightly with incremental opening of the humidity controlled air inlets. It was not due to the settings of the HCAIs, but due to the change in weather conditions over the course of testing. When the HCAIs were fully closed, wind conditions were such that the exhaust outlet from the house was on the leeward side and the LAFSWs were on the windward side. The opposite conditions occurred when the HCAIs were in the fully opened position.

4.4 Discussion of Results

Testing and monitoring generated a substantial amount of data for use in assessing the performance of the LAFSW/HCAI/BH system installed in the demonstration house. The data were obtained for both occupied and unoccupied conditions. Most of the data, obtained in the present project, were acquired during occupied conditions. While the house was not occupied until April when weather conditions were considerably warmer than in mid-winter, there were periods in April and May when outdoor temperatures were somewhat cooler than indoor temperatures and cold weather trends could be observed.

Appendices B.1 and B.3 contain sets of data from such periods. Two other sets of logged data are contained in Appendices B.2 and B.4. However, because they were obtained during warmer weather conditions, little reference is made to them in the following discussion.

The logged data contained in Appendices B.1, B.2, B.3, and B.4 correspond the monitoring periods, April 24 to April 30, May 10 to May 15, May 19 to May 25, and June 17 to June 22, respectively. For the remainder of this discussion the monitoring periods will be referred to as the first monitoring period, the second monitoring period, the third monitoring period, and the fourth monitoring period.

Prior to the commencement of this project, there was concern that the system may cause cold drafts because air entering the rooms through the LAFSWs is not necessarily pre-warmed to the same temperature as the room air. For example, it was predicted that if the outdoor air is -18°C, the temperature of the air entering the rooms through the LAFSWs is approximately -10°C. To address this concern, thermocouples were used to measure delivered air temperatures, air temperatures immediately below the inlets and air temperatures at the floor, mid-wall, and ceiling heights in rooms with LAFSWs. Figures 1, 2, and 3 in each subsection of Appendix A show the various temperatures mentioned above.

Figure 1, Temperature Profiles, shows the outdoor air temperature, the delivered air temperature and the vertical room air temperature for bedroom no. 3. Excluding times of solar gain, the average rise in temperature through the window was approximately 3°C. The average temperature difference between the floor and ceiling of the room was approximately 3°C. During the third monitoring period, solar gain caused the temperature of air flowing through the window to rise well above the indoor air temperature on several occasions.

Figure 2 in each subsection of Appendix B shows the delivered air temperature and the air temperature immediately below the HCAI on the living room LAFSW. Throughout the first and third monitoring periods (times of cooler weather), the temperature of the air immediately below the HCAI was considerably higher than the temperature of the air entering the room. On a few occasions during the first monitoring period, the air temperature immediately below the HCAI was much higher than the temperature of the air in the room. This was likely due to the presence of the baseboard heater immediately below the window.

Figure 3 shows the outdoor air temperature and the delivered air temperature from the living room LAFSW. The difference between these two temperatures is the temperature rise through the window. Excluding times of solar gain, the average rise in temperature through the window was approximately 3°C, consistent with that of the window in bedroom no. 3.

It is difficult to state whether or not the system creates cold drafts just by examining the plots in Figures 1, 2, and 3. While the two occupants of the house did not have any complaints about the system, they also did not occupy the house during extreme cold weather conditions. However, the field test personnel spent many hours in the house in March when outdoor temperatures were as cold as -28°C. They did not perceive any cold drafts.

Figure 4 shows the inside surface temperatures of two windows on the east side of the house (front). One window was a laminar air flow super window; the other was a conventional window. A review of the logged data reveals that the temperatures are approximately the same. However, during times of solar gain the LAFSW is slightly warmer.

Figure 5 shows the relative humidity at three locations in the house (the master bedroom, bedroom no.2, and the bathroom). A review of these plots suggests that relative humidity is not a good indicator of occupancy. There was no pattern in the relative humidity levels which indicate higher relative humidity in the bedroom at night and higher relative humidity in the living room/dining room during the day. The only indication of moisture generation was in the bathroom (likely due to shower activity).

A second concern, prior to the commencement of this project, was whether or not the sensor on the humidity controlled air inlet is capable of sensing the actual relative humidity in the room. Figure 6 shows the relative humidity in the master bedroom and the relative humidity at the sensor on the HCAI in the same room. The plots show that the relative humidity in the vicinity of the sensor tracks the relative humidity in the room rather well.

Figure 7, the final plot in each of the four monitoring periods, shows the hourly air flow rate from the central exhaust fan unit. The average flow rate on the "low flow" setting was measured to be approximately 55 to 60 L/sec. On the "high flow" setting, the flow rate was measured to be approximately 85 to 90 L/sec. When the exhaust fan flow log is placed over the relative humidity log (Figure 5), it is evident that the occupants of the house use the "high flow" exhaust whenever there is moisture generation in the bathroom.

Three additional figures are contained in Appendix B.1. In each, the heat exchanger effectiveness is plotted for a LAFSW in a different room. Figure 8 shows the heat exchanger effectiveness for the LAFSW in bedroom 3; Figure 9 shows the heat exchanger effectiveness for the living room LAFSW; Figure 10 shows the heat exchanger effectiveness for the dining room LAFSW. The average heat exchanger effectiveness of the bedroom window was measured to be 24.3 percent. For the living room and dining room windows, it was measured to be 26.9 percent and 26.5 percent, respectively. A heat exchanger effectiveness higher than 100 percent was sometimes evident during times of high solar gain.

Continuous monitoring of radon in the house showed that there is definitely a radon problem in the basement. On the other hand, radon levels on the main floor were measured to be below the United States Environmental Protection Agency's (U.S.E.P.A.) exposure guideline of 4 pCi/L. The finding of high radon levels in the basement was somewhat surprising, since considerable effort was made to ensure that the basement was tightly sealed from the surrounding soil. Fortunately, a precautionary measure was taken during the construction of the house. This measure was to install a perforated pipe under the slab which can be accessed through a single penetration in the floor near the central exhaust fan unit. The radon problem will likely be eliminated by using this point to employ subslab suction by utilizing the unused exhaust port on the central exhaust fan unit or, subslab pressurization by exhausting air from the fan unit beneath the slab.

The formaldehyde level in the house was measured to be 0.128 ppm, slightly above Health and Welfare Canada's long term exposure guideline of 0.1 ppm.

Since the higher level is likely due to off-gassing of formaldehyde from new building materials, it is expected that the formaldehyde level will drop to an acceptable level within a year or so.

Airtightness testing showed that the intentional opening area was, at best, one half of the total opening area (intentional and non-intentional). This means that all rooms having an external wall, ceiling or floor have a certain amount of non-intentional air leakage. While non-intentional air leakage has an undesirable affect on the overall control of ventilation airflow, it does ensure that excessive pressurization is not caused if air inlets that close completely are used. In the demonstration house, depressurization was approximately 4 Pa when all humidity controlled air inlets were wide open and 9 Pa when all humidity controlled air inlets were taped shut.

Air infiltration measurements showed that the system is capable of meeting the overall base ventilation requirement of 0.4 ACH (based on fresh air requirements for each room specified in the proposed CSA Standard F326.1). However, a review of the table which summarizes the results from tracer gas testing (Appendix F) indicates that some airtightening at the basement level will be required to meet ventilation requirements in every room. In the present house, the basement is receiving too much ventilation air while some of the rooms on the main floor are receiving too little. It is important to note, however, that the master bedroom LAFSW was not designed to meet the ventilation requirements because of limitations in the house model and the size of window used.

4.5 Implications

While the LAFSW/HCAI/BH system performed reasonably well in heating and ventilating the demonstration house, there were a few problems worthy of note.

It was observed that light frosting would occur on the leeward LAFSWs when there was a very strong wind. This was because the wind pressure on the windward side was sufficient to force in more air than was being withdrawn by the fan. This was not a major problem, since the frost disappeared as soon as the wind dropped. However, it was decided that a backdraft damper should be added to the LAFSW/HCAI combination, to eliminate the outflow.

A second practical problem which was noted in the prototype system was that the HCAIs were not long enough to direct the air past the window frame towards the ceiling. A short extension will be added to the air outlet on the window so that the air flow will clear the frame. This will make cold drafts in rooms even less likely.

As mentioned in the discussion, relative humidity was not a good indicator of occupancy. Even if it was, the turndown ratio on the HCAI proved to be inadequate. In future systems, manually controlled air inlets will be incorporated.

5.0 APPROPRIATENESS FOR THE INTENDED MARKET

Because of the problems mentioned above, the HCAI system tested is not appropriate for the intended market. The manually controlled air inlets mentioned above must be developed to make the system appropriate.

6.0 CONCLUSIONS

The conclusions reached as a result of this project were as follows:

1. While the overall base ventilation requirements of the house were met, some further development is required. The Humidity Controlled Air Inlets did not have a sufficient turndown ratio. It was also realized that a backdraft damper in the inlet system is necessary.

2. Slight depressurization of the house causes average radon levels in the basement to exceed the U.S.E.P.A. action level of 4 pCi/L, although they remain below Health and Welfare Canada's long-term exposure guideline of 20 pCi/L. Future work should involve testing of both subslab depressurization and subslab pressurization (either means of subslab ventilation should be incorporated directly into the central exhaust system).

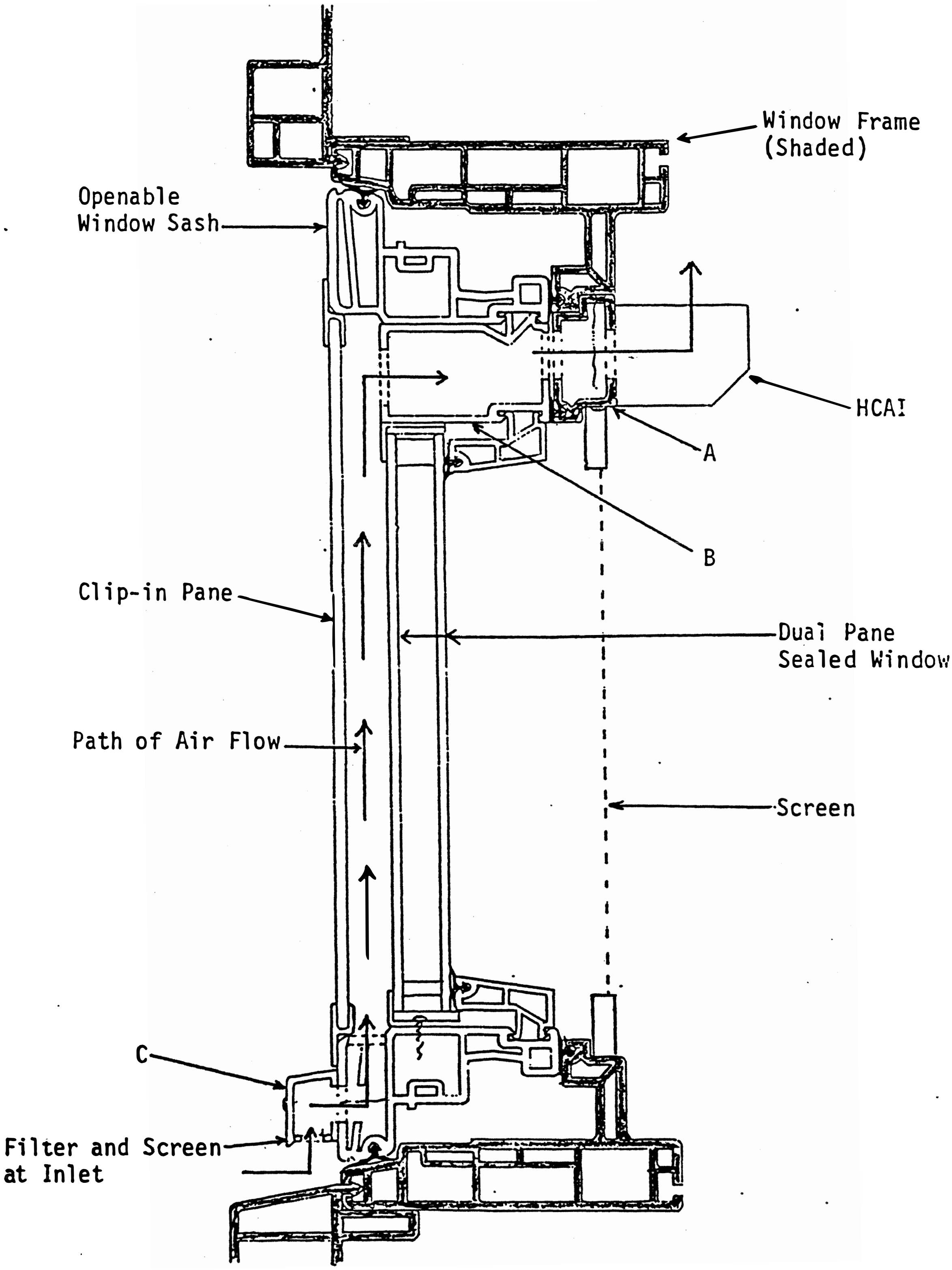
3. Relative humidity is not a good indicator of occupancy.

APPENDIX A

GENERAL INFORMATION

APPENDIX A.1

CROSS-SECTION OF THE LAMINAR AIR FLOW SUPER WINDOW

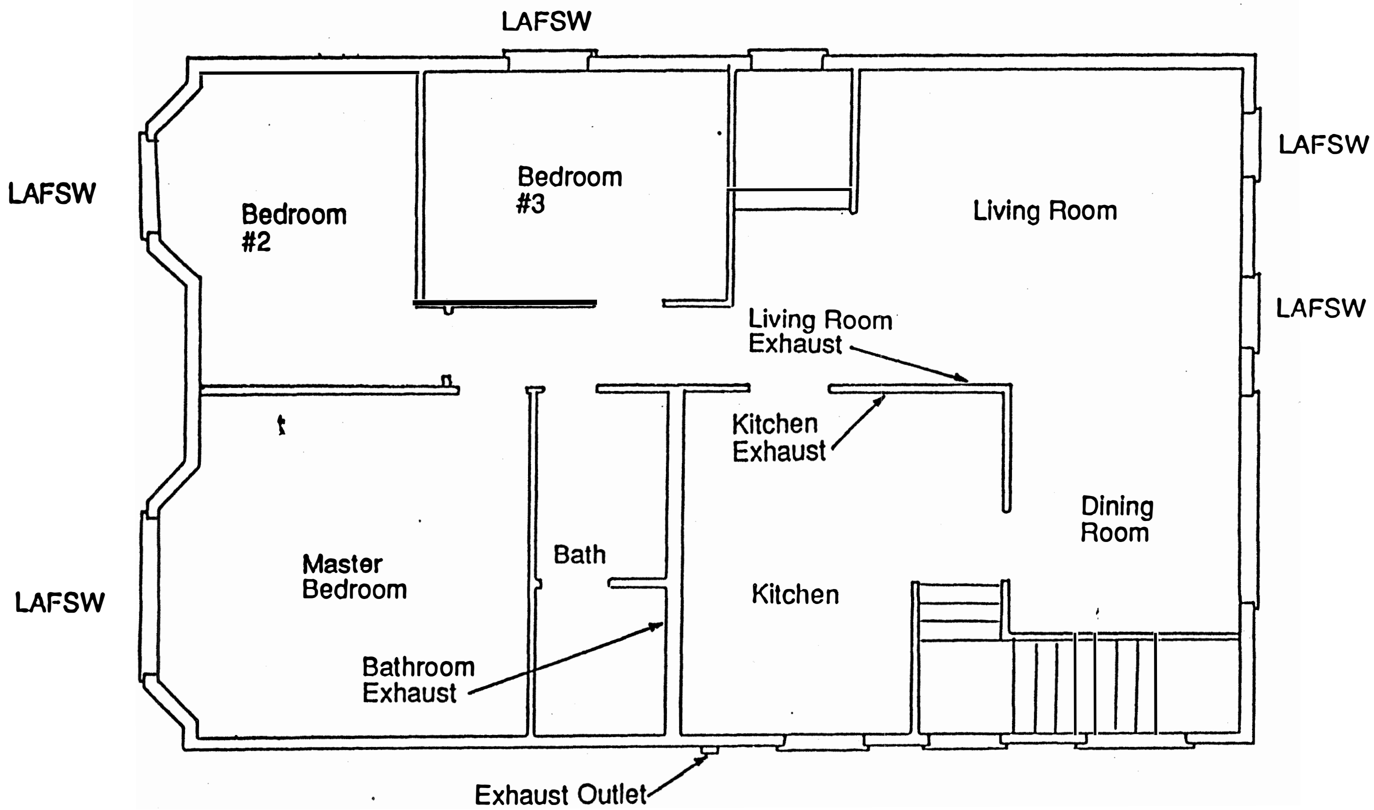


A, B and C are new extrusion molded components.

APPENDIX A.2

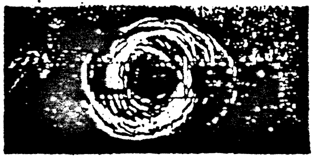
FLOOR PLAN OF THE DEMONSTRATION HOUSE

FLOOR PLAN OF DEMONSTRATION HOUSE



APPENDIX A.3

INSTALLATION, OPERATION AND MAINTENANCE MANUAL FOR THE MULTI-POINT MECHANICAL VENTILATION EXHAUST SYSTEM



VMP K MULTI-POINT MECHANICAL VENTILATION EXHAUST SYSTEM

INSTALLATION OPERATION MAINTENANCE

INSTALLATION, OPERATION, & MAINTENANCE

READ AND SAVE THESE INSTRUCTIONS

In addition to the following manufacturer's instructions, it is necessary to comply with Federal, State, and Local Government codes. Your purchase of the **American ALDES** Ventilation System represents an investment in the health and comfort of your family, as well as an investment in the protection of your home from mold and mildew damage caused by excessive humidity levels.

The **ALDES MODEL VMPK** multi-point exhaust system removes stale polluted air from bathrooms, kitchens, laundry and storage rooms, via exhaust grilles and ducting to a central fan, which in turn exhausts to the outdoors.

FRESH AIR SOURCE

Fresh makeup air may be supplied by air infiltration through building leakage areas, or through intentional designed makeup air systems. **American ALDES** provides designed air supply systems for use with forced air heating systems, with the **MAK** model air flow controls, regulating the amount of fresh air drawn from outdoors to the return ducting of the furnace. See **American ALDES** bulletin 8 U.S. 998 for more details.

In the case of hydronic or electric heat, without forced air, **ALDES** provides specially designed air inlets to regulate the fresh air delivered to each bedroom and living-dining area. Two types of inlets are available: the self-regulating type controls the airflow restricting the effect of wind pressure, maintaining a constant airflow, and the humidity-controlled inlet, which increases airflow to a room as the relative humidity of the room increases. A variety of configurations and installation details are possible, for use in window frame or through-the-wall applications. See **American ALDES** bulletin 8 U.S. 999 for further information.

INSTALLATION

As supplied, the standard system provides constant exhaust (with 3" fittings and ducting) from one to five rooms, (baths, laundry, etc.) and a low and high exhaust rate (with 6" duct and fittings) from one room (kitchen). The choice of which rooms are exhausted at a constant rate and which benefit from a boost rate is left to the designer. In many cases, the kitchen will have a vented range hood or similar high speed intermittent exhaust. In such a case, the 6-inch exhaust on the VMPK would be redundant in the kitchen. It might then be more desirable to utilize this high exhaust feature for a bathroom with a shower or spa (with a very high humidity level for short periods of time.) However, a constant exhaust of 20 CFM from the kitchen will still be beneficial in removing odors and humidity at times when the range hood is not in use.

It is also possible to specify several of the 3" connections to permit a boost rate, with a variable flow control. The airflows in these cases may be increased from 20 to 35 CFM on demand. In these cases, the fan speed would be controlled with a relay, and remote switches located in the bathrooms control the relay. Alternatively, a combination of SPDT switches may be used to control the airflows; see the wiring diagrams for details.

LOCATING THE FAN UNIT

The fan unit should be placed, when possible, close to the 6" grille, to limit excessive duct lengths that would limit the airflows. Similarly, try to locate in a central location with respect to the other duct runs. See the table on the next page for allowable lengths of duct. Avoid locating the unit over a bedroom, where transmitted noise might be objectionable when the home is otherwise very quiet.

The unit should be located within the heated envelope of the home, such as a basement or utility room, against a vertical surface. Three mounting holes in the base permit securing the fan unit to a plywood or masonry surface with appropriate screws. Avoid attaching directly to gypsum wallboard on a stud wall, to avoid objectionable noise and resonances.

COLD CLIMATE PRECAUTIONS:

IMPORTANT: FAILURE TO OBSERVE THE FOLLOWING WILL VOID THE WARRANTY. If installed in an unheated space in a cold climate, observe the following precautions:

- Mount the fan upside down; i.e., with the duct connections pointing down.
- Use insulated duct with interior vapor barrier.
- The fan must run continuously. Cycling the fan on and off may result in premature motor failure.

DUCTING

Ducting may be flexible or rigid, depending on local codes. It should conform to NFPA 90A and meet the requirements of Underwriters Laboratory as a class 0 or class 1 duct to specification UL 181, Standard for Factory-Made Air Ducts and Duct Connectors.

The length of ducting should be limited to the values in the following table. Otherwise reduced airflows will result from duct resistance.

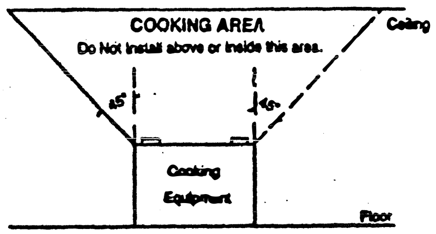
Table of Allowable Ducting Runs

	Smooth Round Duct	Flexible Round Duct	90 Elbow Equiv. length
3" from bathrooms to fan	92 ft	46 ft	2 ft
6" from 6" grille to fan	46	23	4
6" from fan to outdoors	28	14	4

When designing the ducting runs, include the effect of the elbows as follows: A 3" diameter duct run may have 3 elbows and 28 feet of straight runs. The total equivalent length is then 28 + 3 elbows X 2 ft per elbow, or 28 + 6 = 34 feet. That is well within the 46 foot limit for 3" flexible duct. For a run longer than 46 equivalent feet, it is necessary to switch to smooth duct or increase the duct diameter.

DO NOT INSTALL the kitchen exhaust grille above, or inside a 45-degree angle projected outwards from, the cooking equipment element closest to the grille. See the diagram below.

CAUTION



WALL CAP OR ROOF JACK

The exhaust duct from the fan must be connected to a wall cap or roof jack by a collar. The wall cap or roof jack must not create a pressure drop greater than 0.02 inches w.g. at 100 CFM.

ACCESSORIES

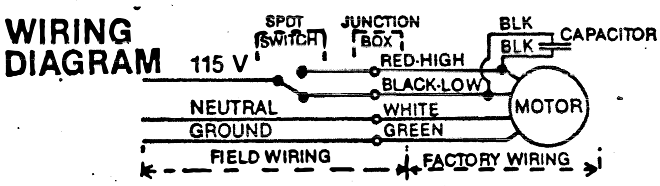
American ALDES offers a complete line of ducting and accessories to complete the installation. Request Bulletin B U.S. for further information.

ELECTRICAL DATA

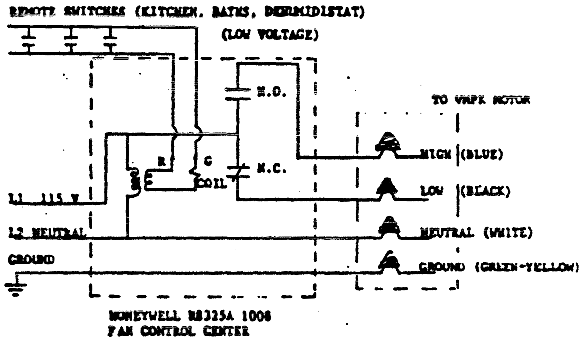
115 Volts AC, 60 Hz, single phase, reversing motor, 0.6/1.0 Amps; 8 F 250 V. capacitor.

ELECTRICAL WIRING

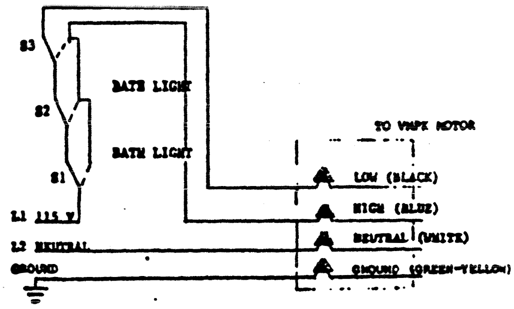
The wiring diagram for the standard installation is shown below. <u>For use when only one zone has a high boost rate.</u>



Alternative wiring diagrams for controlling airflows from two or more locations. <u>The fan must be fitted with variable flow controls for boost rate.</u>



<u>LOW VOLTAGE</u>



<u>LINE VOLTAGE: 3-WAY SWITCHES</u>

Electrical switches are not provided in the kit. A <u>UL</u> Listed General Use Switch is required, with a wall switch plate marked with the "High" and "Low" positions. These accessory switches may be ordered from American ALDES. Two switches are available: Part No. 29000, 3-way switch with pilot light, and Part Number 29020, 0-2hr timer switch. Both switches are UL listed and CSA certified.

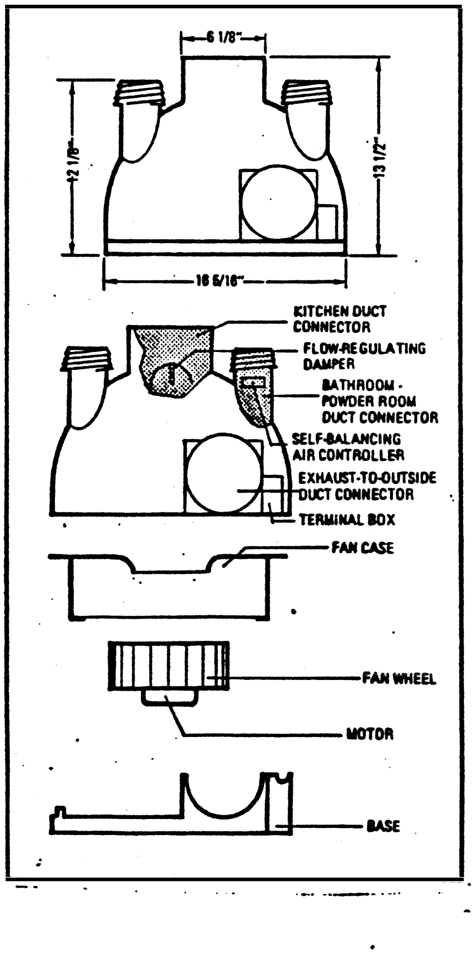
If the Low Voltage wiring option is used, for boost control from more than one location, a UL listed SPDT relay may be used, such as the Honeywell R8325A Fan Control Center (ALDES Part No. 28994), with timer switches in the boost locations. Wiring instructions are included with this relay.

MAINTENANCE

Monthly: Clean the kitchen grille, and filter, if so equipped.

Annually: Clean the bathroom and laundry room grilles.

Annually: To ensure maximum efficiency of the fan unit, it is recommended to clean the inside of the fan box as well as the fan wheel. Be sure to disconnect from the power supply before dismantling. The easiest way to accomplish this is to undo the exhaust duct to the outdoors at the fan unit. Otherwise, the fan unit may be taken apart by unscrewing the base. See the figure below for disassembly and reassembly.



DISCLAIMER: IT IS THE RESPONSIBILITY OF THE INSTALLER TO DETERMINE THE SUITABILITY OF THIS EQUIPMENT WITH RESPECT TO THE POTENTIAL FOR BACKDRAFTING NATURALLY VENTED FLUE DEVICES AND/OR AFFECTING RADON ENTRY.

BACKDRAFTING

In especially tight homes heated with naturally vented devices, the exhaust fan may produce sufficient negative pressure to induce backdrafting of flue gases. This is quite a common, though intermittent occurance, with conventional exhaust systems, such as vented range exhaust fans. In the case of continuous exhaust, even though lower flow, the potential for backdrafting the flue or fireplace does exist. The NATIONAL FUEL GAS CODE, available from the American Gas Association, Appendix H, provides a Recommended Procedure for Safety Inspection of an Existing Appliance Installation. This procedure should be followed to determine the adequacy of combustion air, while all exhaust fans are operating at maximum speed, and all doors and window are closed.

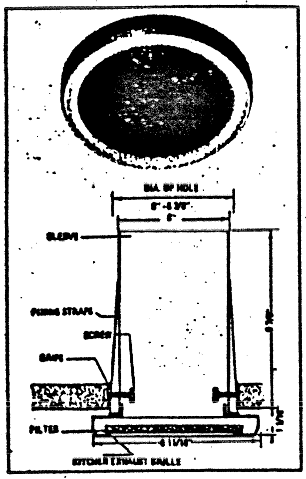
In the event that backdrafting occurs, steps must be taken to provide sufficient combustion air to the furnace or boiler, following the guidelines of the National Fuel Gas Code and all State and Local codes. In addition the draft hood may be fitted with a thermal switch to disable the exhaust fan under backdrafting conditions.

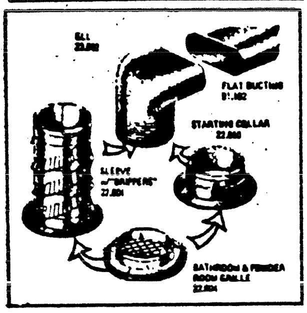
RADON

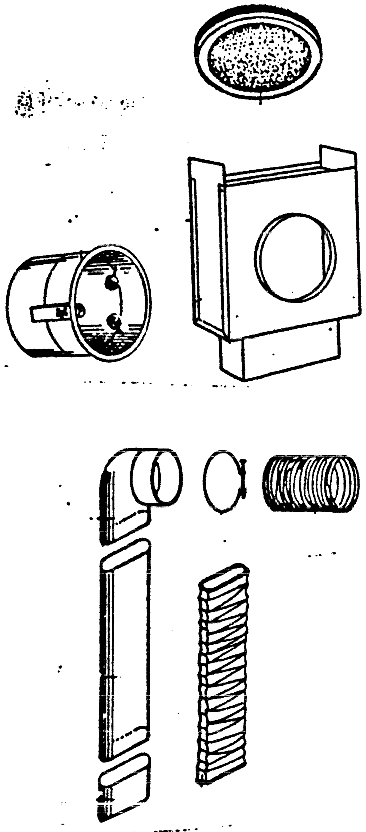
In recent years radon gas has been found to be of concern in some homes. While ventilation may be effective in reducing radon concentrations in the living space, the negative pressure induced also increases the rate of radon entry into the home. In most cases, ventilation reduces radon levels, but in some cases, the level of radon may be increased.

If sub-slab ducting has been installed in the basement, or if the soil under the slab is sufficiently porous, one or more of the three-inch connections on the VMPK fan may be used to depressurize the sub-slab or crawlspace in accordance with the Environmental Protection Agency's recommended procedures. Properly installed, the VMPK fan may provide effective radon control. Since a variety of mitigation methods are available and provide differing degrees of effectiveness, a specialist in radon mitigation must be consulted to determine the most effective mitigation method for the specific situation.

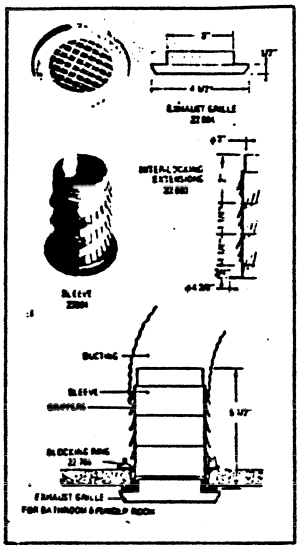
KITCHEN EXHAUST GRILLE 22 015
6" KITCHEN SLEEVE 22 013

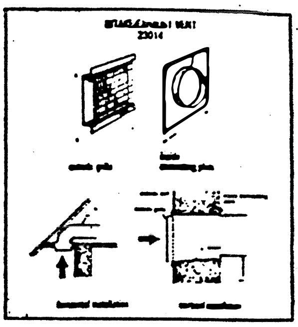


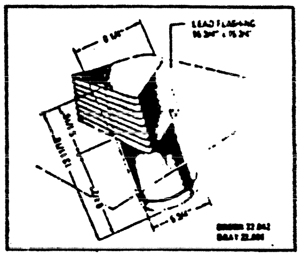




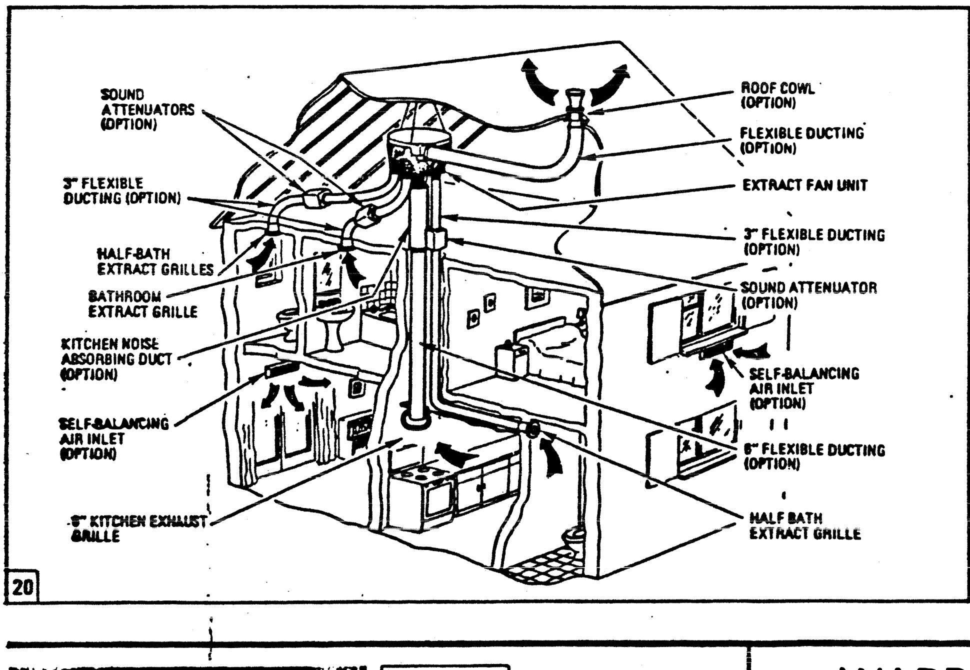
BATHROOM AND POWDER ROOM AIR OUTLETS





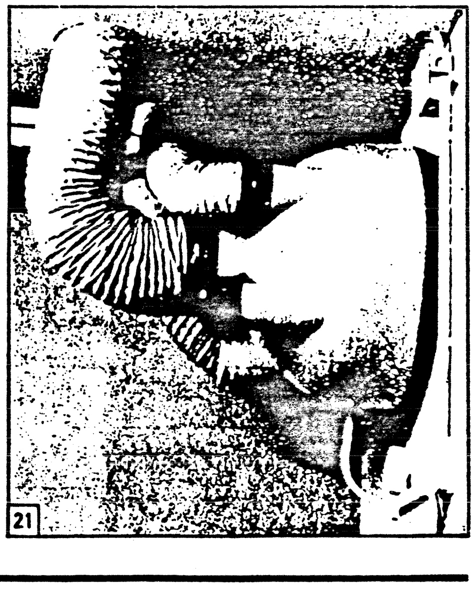


INSTALLATION LAYOUT



20

VMP-K UNIT INSTALLATION



21

AMERICAN ALDES VENTILATION CORPORATION
Northgate Center Industrial Park
4539 Northgate Court
Sarasota, Florida 33580-4864
Phone (813) 351-3441
Telex 756533

WARRANTY

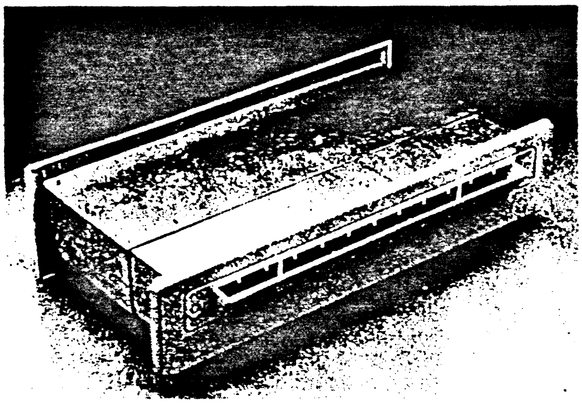
The entire unit is guaranteed for 2 years, from date of shipment, against all manufacturing defects provided the material has been installed and operated under normal conditions. This warranty is limited to the repair or replacement of the material upon its return freight paid to our factory.

We reserve the right to change specifications without notice.

FRESH AIR INLETS
Slot Ventilators For Make Up Air In Mechanical Ventilation Systems

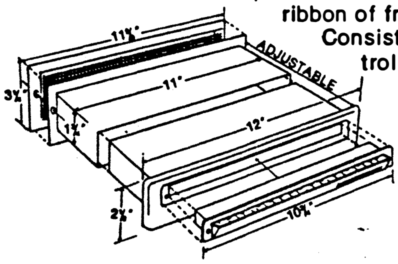
ALDES

DESCRIPTION
8 U.S. 999



Self-Regulating Through-Wall Inlet

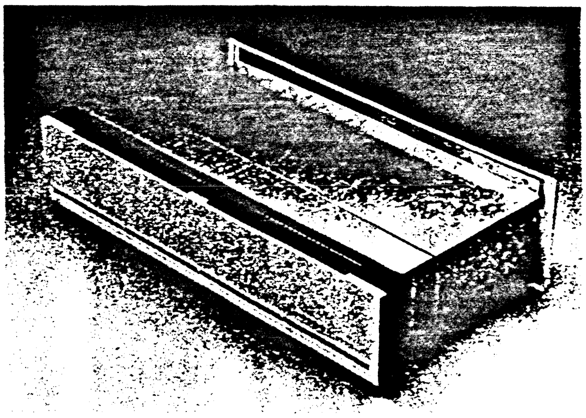
For installation in exterior walls. Designed to be used with ALDES ventilation systems. Controlling element is a plastic self-balancing damper that automatically adjusts free opening to provide a regulated 10 cfm or 20 cfm fresh air intake independent of wind pressure. Interior fixture deflects thin ribbon of fresh air towards ceiling.



Consists of white interior face plate with controlling element, adjustable galvanized sleeve with filter, and white exterior weather grille with mesh.

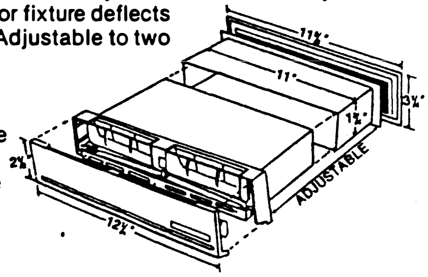
NON-BEVELED	BEVELED	
P/N 11 536	11 540	4½ to 8" sleeve 10 cfm
P/N 11 537	11 541	8" to 15" sleeve 10 cfm
P/N 11 538	11 542	4½ to 8" sleeve 20 cfm
P/N 11 539	11 543	8" to 15" sleeve 20 cfm

Humidity Controlled Through-Wall Inlet



For installation in exterior walls. Designed to be used with ALDES ventilation systems. Controlling element is a humidity sensitive device. Free opening varies from 0.78 sq. in. to 4.65 sq. in. and is determined by the relative humidity of the room in which the inlet is installed. Interior fixture deflects thin ribbon of fresh air towards ceiling. Adjustable to two relative humidity operating ranges:

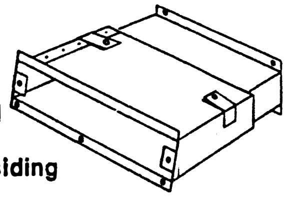
25% RH to 60% RH
40% RH to 75% RH



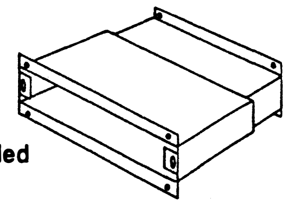
Consists of beige interior face plate with controlling element, adjustable galvanized sleeve with filter, and white exterior weather grille with mesh.

NON-BEVELED	BEVELED	
P/N 14 901	14 903	4½ to 8" sleeve
P/N 14 902	14 904	8" to 15" sleeve

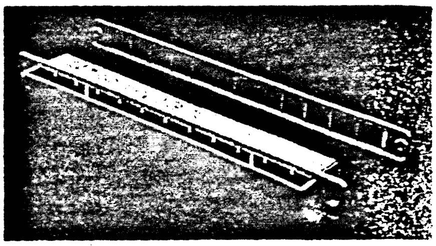
Optional Beveled or Non-Beveled Galvanized Sleeves for Exterior Facings



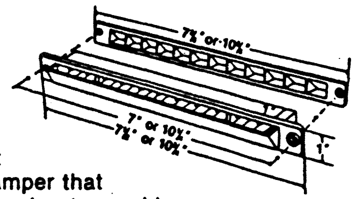
Beveled for use on beveled siding



Non-Beveled

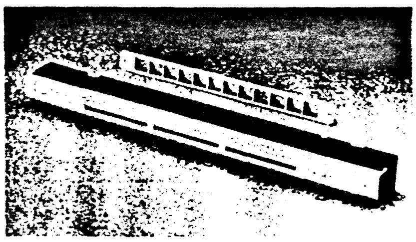


Self-Regulating Through-Window Sash Inlet

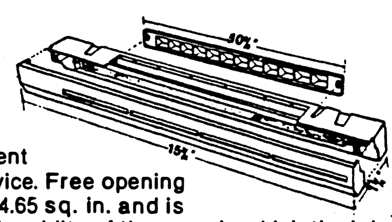


For installation in window sashes. Designed to be used with ALDES ventilation systems. Controlling element is a plastic self-balancing damper that automatically adjusts free opening to provide a regulated fresh air intake independent of wind pressure. Interior fixture deflects thin ribbon of fresh air towards ceiling. 10 cfm and 20 cfm models available in white or brown. Consists of white or brown face plate with controlling element and matching white or brown exterior weather grille.

P/N 11 517	10 cfm, white	6⅞" x ⅜" x ⅞" rough opening
P/N 11 525	10 cfm, brown	6⅞" x ⅜" x ⅞" rough opening
P/N 11 518	20 cfm, white	9⅞" x ⅜" x 1" rough opening
P/N 11 526	20 cfm, brown	9⅞" x ⅜" x 1" rough opening



Humidity Controlled Through-Window Sash Inlet



For installation in window sashes. Designed to be used with ALDES ventilation systems. Controlling element is a humidity sensitive device. Free opening varies from 0.78 sq. in. to 4.65 sq. in. and is determined by the relative humidity of the room in which the inlet is installed. Interior fixture deflects thin ribbon of fresh air towards ceiling. Adjustable to two relative humidity operating ranges:

25% RH to 60% RH
40% RH to 75% RH

Consists of beige or brown face plate with controlling element and white exterior weather grille.

P/N 14 106	beige interior face plate	9⅞" x ⅜" rough opening
P/N 14 108	brown interior face plate	9⅞" x ⅜" rough opening

APPENDIX B

DATA LOGS FROM CONTINUOUS MONITORING OF TEMPERATURES, RELATIVE HUMIDIT!ES, AND EXHAUST FAN FLOW RATES

APPENDIX B.1

Data Set 1
(April 24, 1989 - April 30, 1989)

FIGURE 1.1

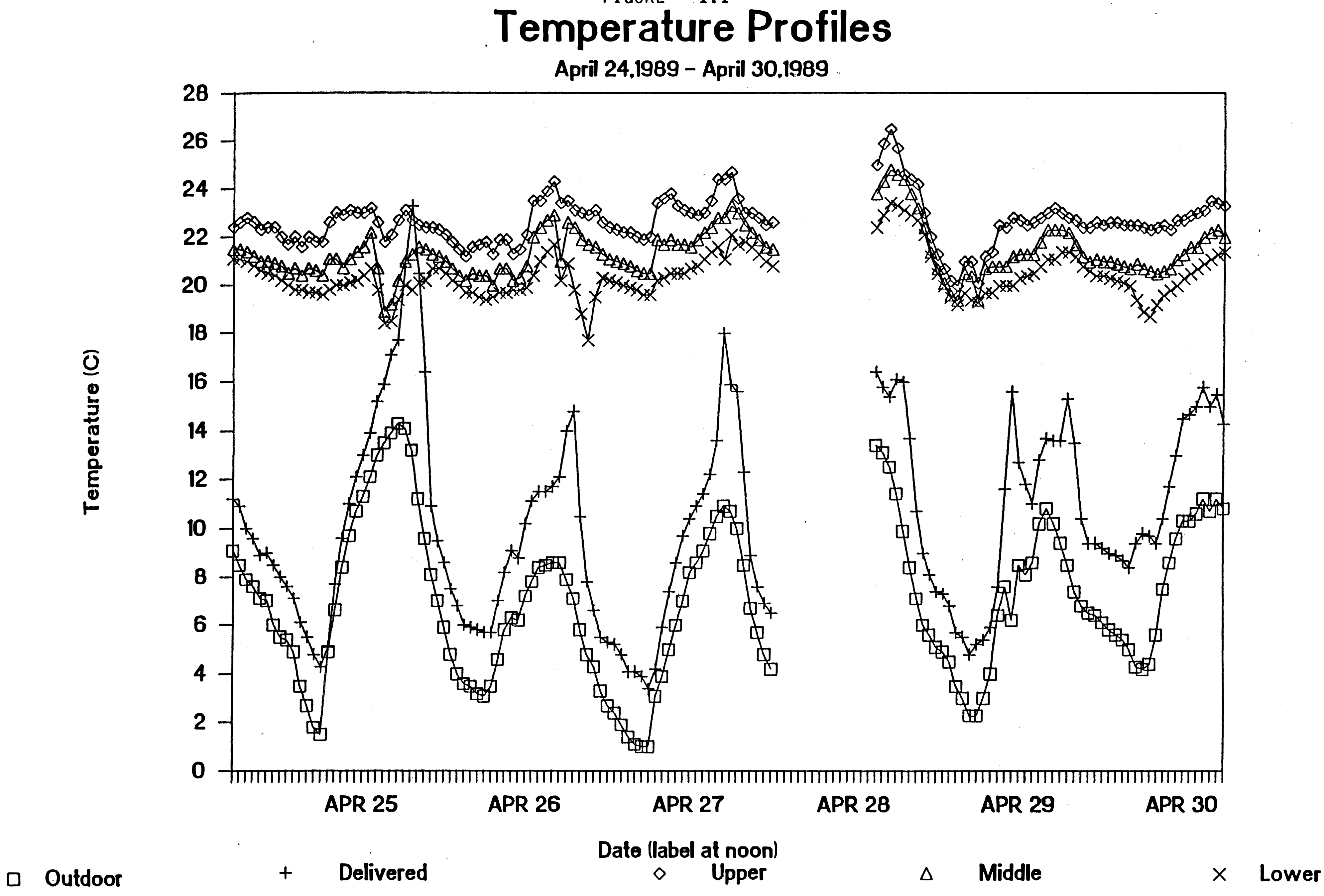

Temperature Profiles
April 24,1989 - April 30,1989
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Temperature (C)
APR 25
APR 26
APR 27
APR 28
APR 29
APR 30
Date (label at noon)
Outdoor
Delivered
Upper
Middle
Lower

FIGURE 1.2

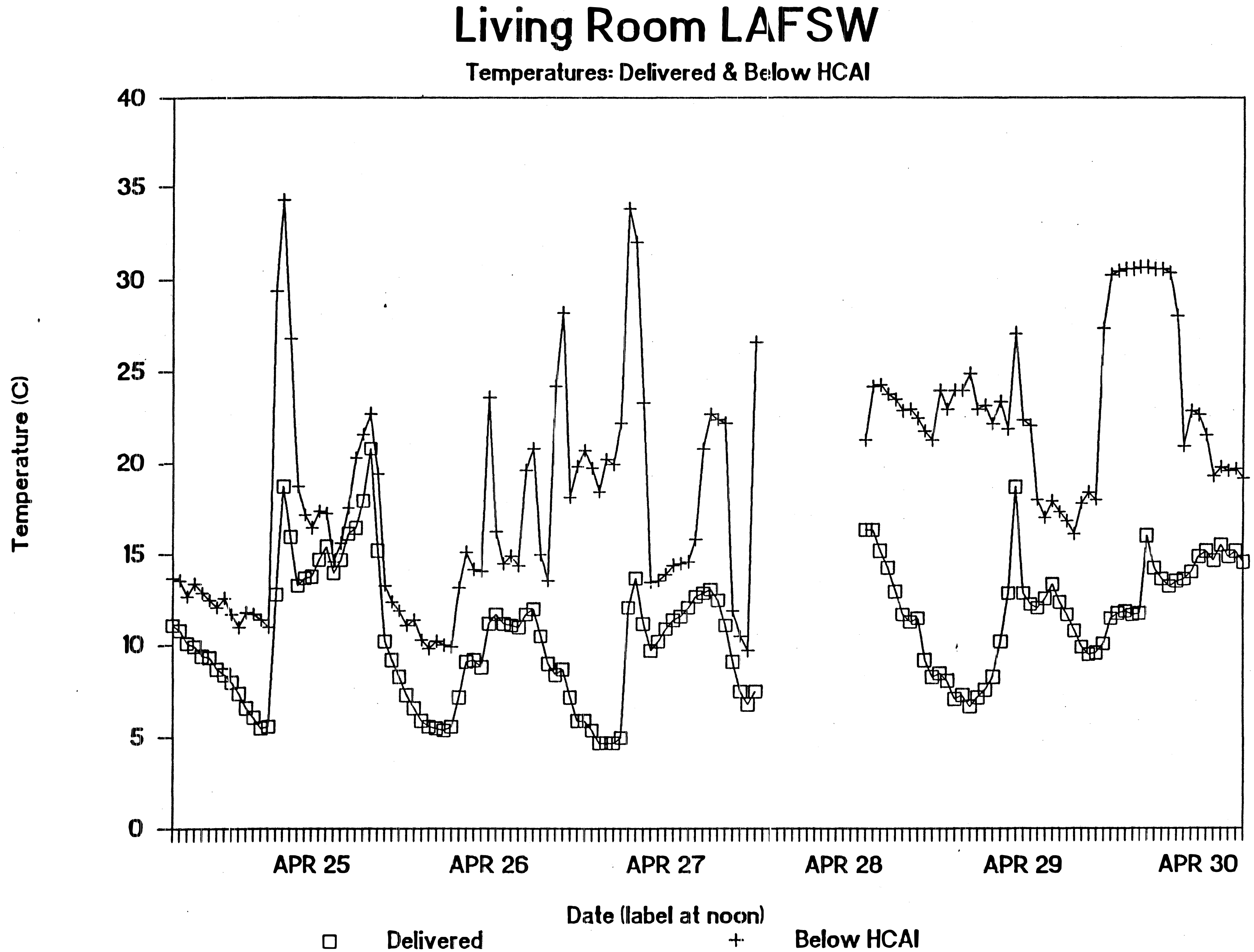

Living Room LAFSW
Temperatures: Delivered & Below HCAI
Temperature (C)
0
5
10
15
20
25
30
35
40
APR 25
APR 26
APR 27
APR 28
APR 29
APR 30
Date (label at noon)
Delivered
Below HCAI

FIGURE 1.3

Delivered Air Temperature Log

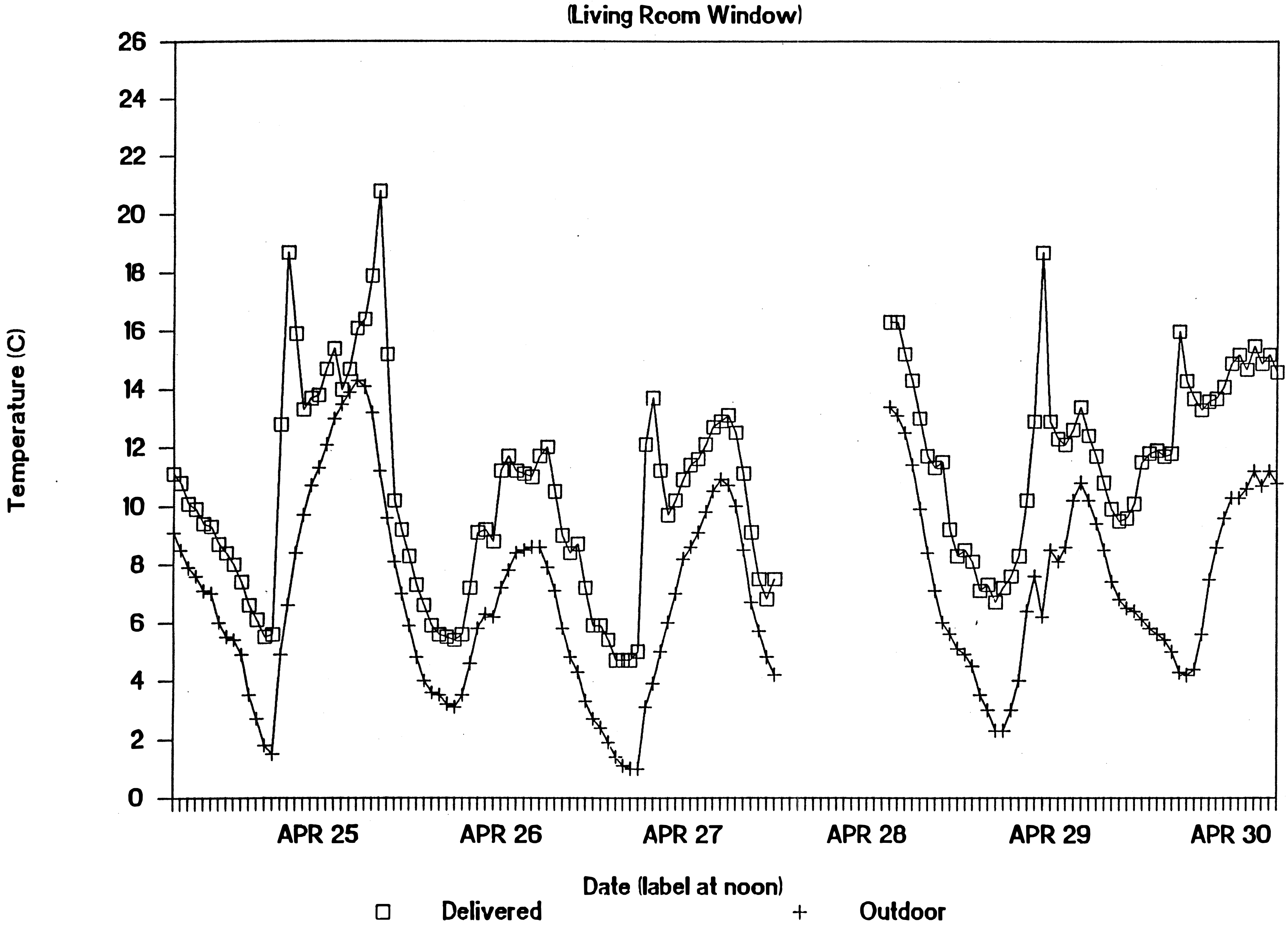


FIGURE 1.4

Surface Temperature Log

(Conventional Window and LAFSW)

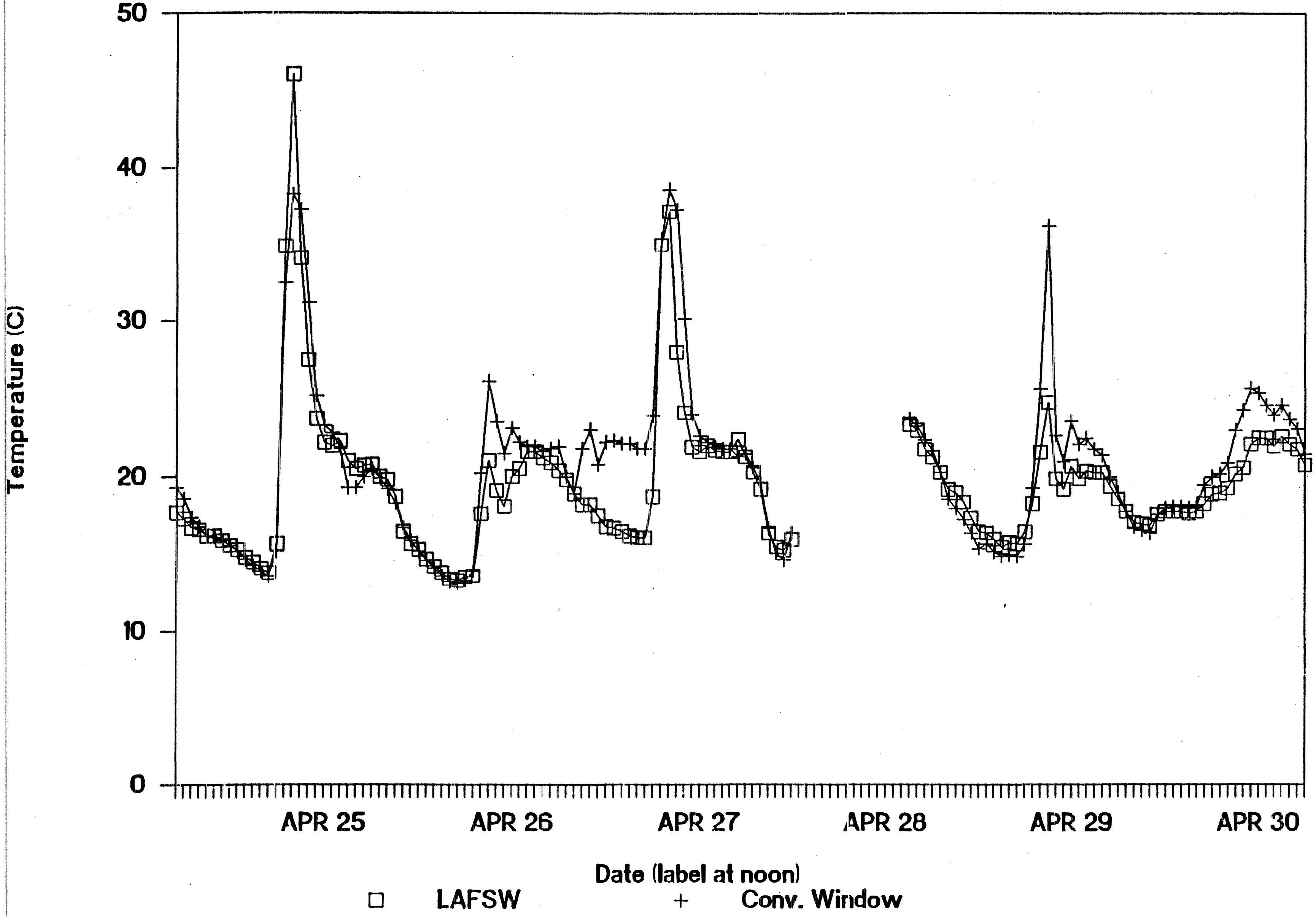
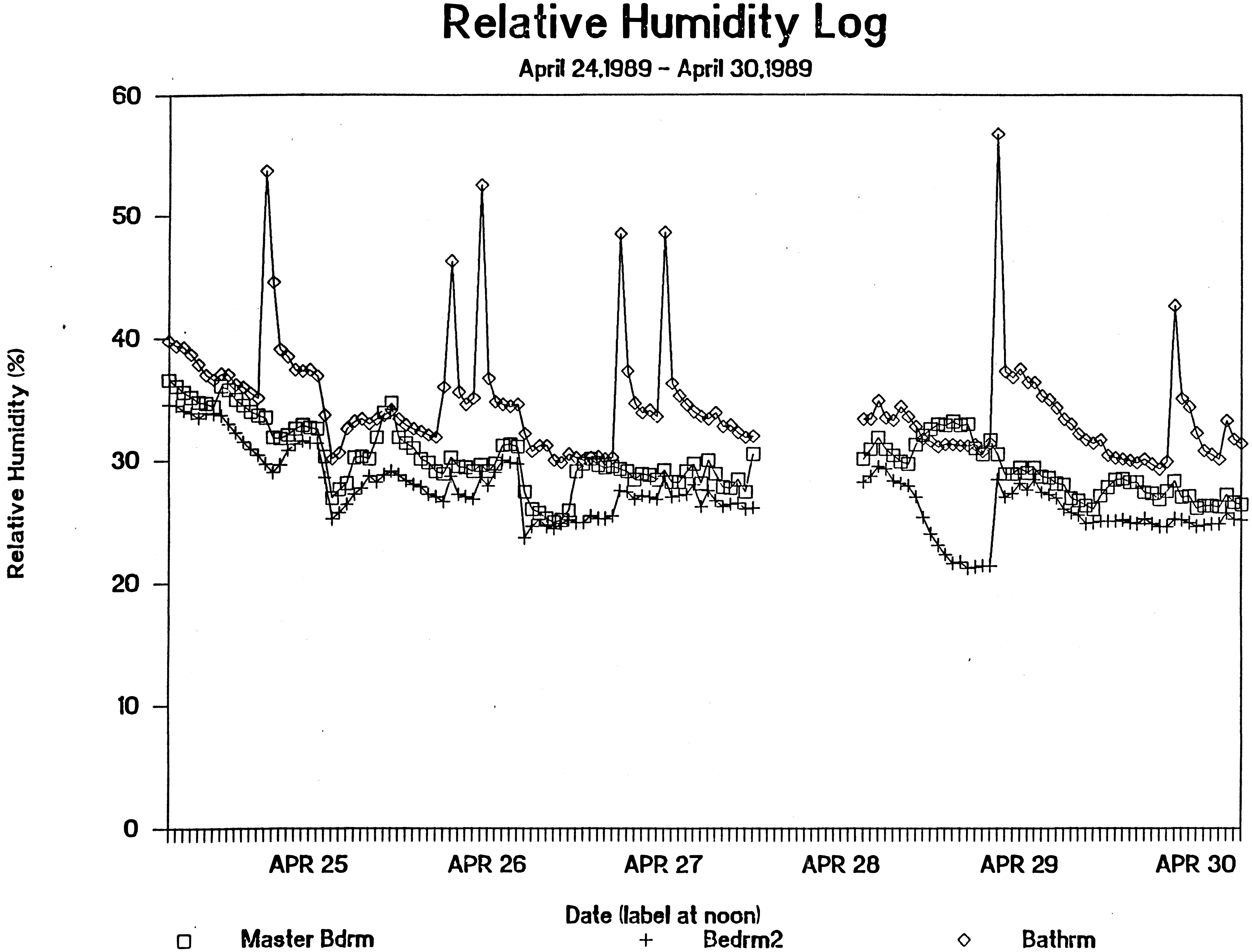


FIGURE 1.5



Relative Humidity Log
April 24,1989 - April 30,1989
60
50
40
30
20
10
0
Relative Humidity (%)
APR 25
APR 26
APR 27
APR 28
APR 29
APR 30
Date (label at noon)
Master Bdrm
Bedrm2
Bathrm

FIGURE 1.6

Relative Humidity Log - Master Bedroom

(at sensor on HCAI and in room)

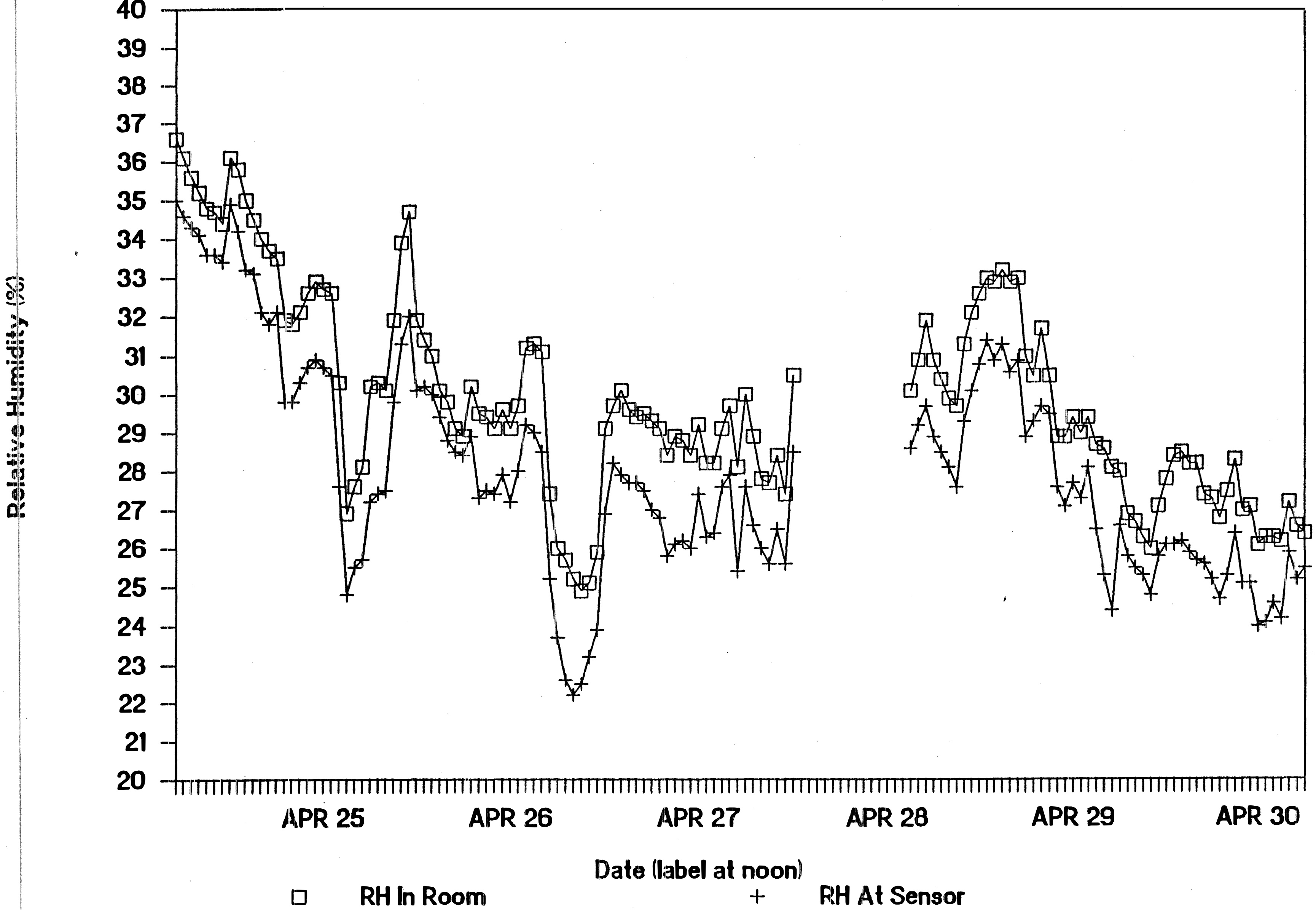


FIGURE 1.7

Exhaust Fan Flow Rate Log

April 24,1989 - April 30,1989

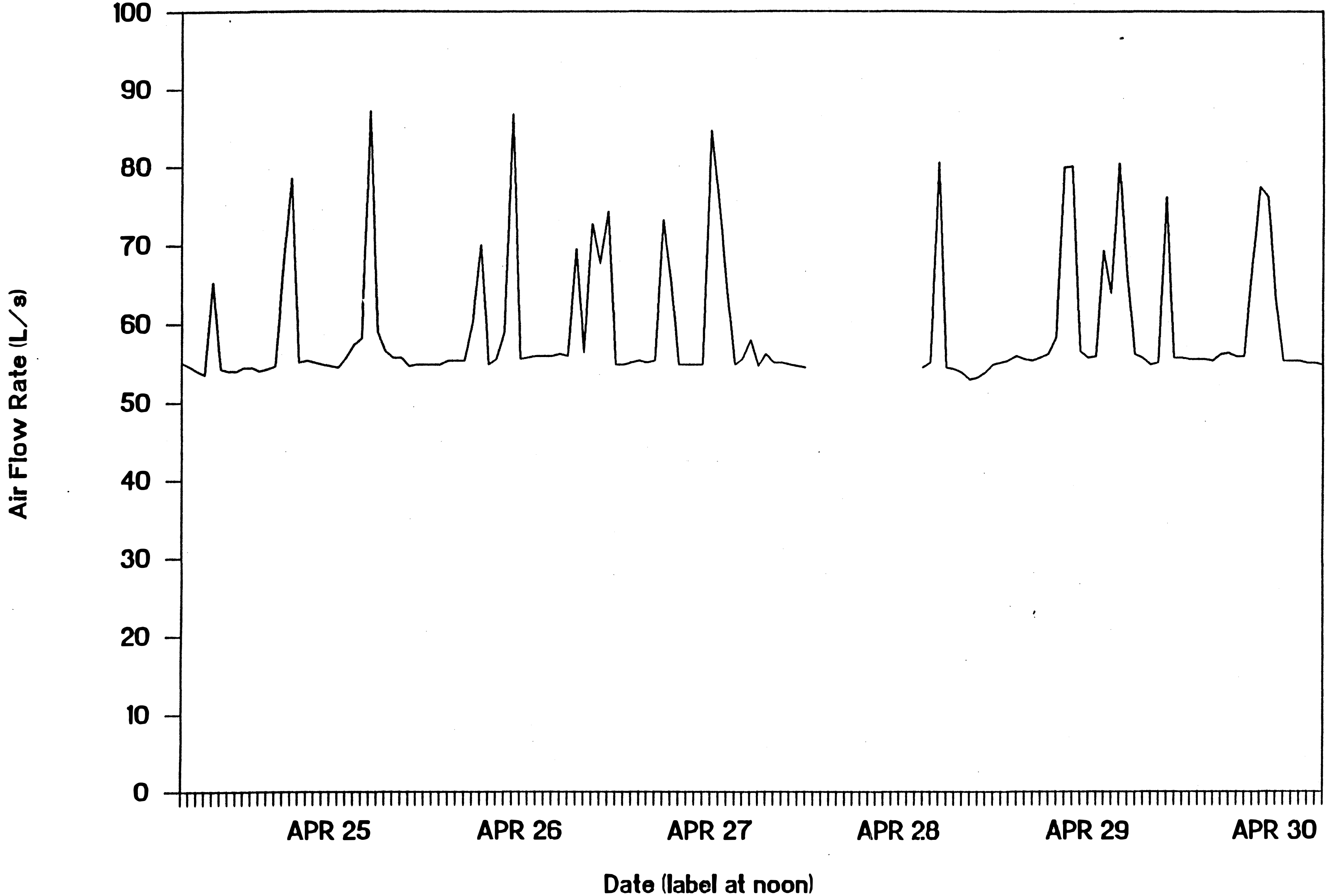


FIGURE 1.8

Heat Exchanger Effectiveness of LAFSW

Average = 24.3 Percent

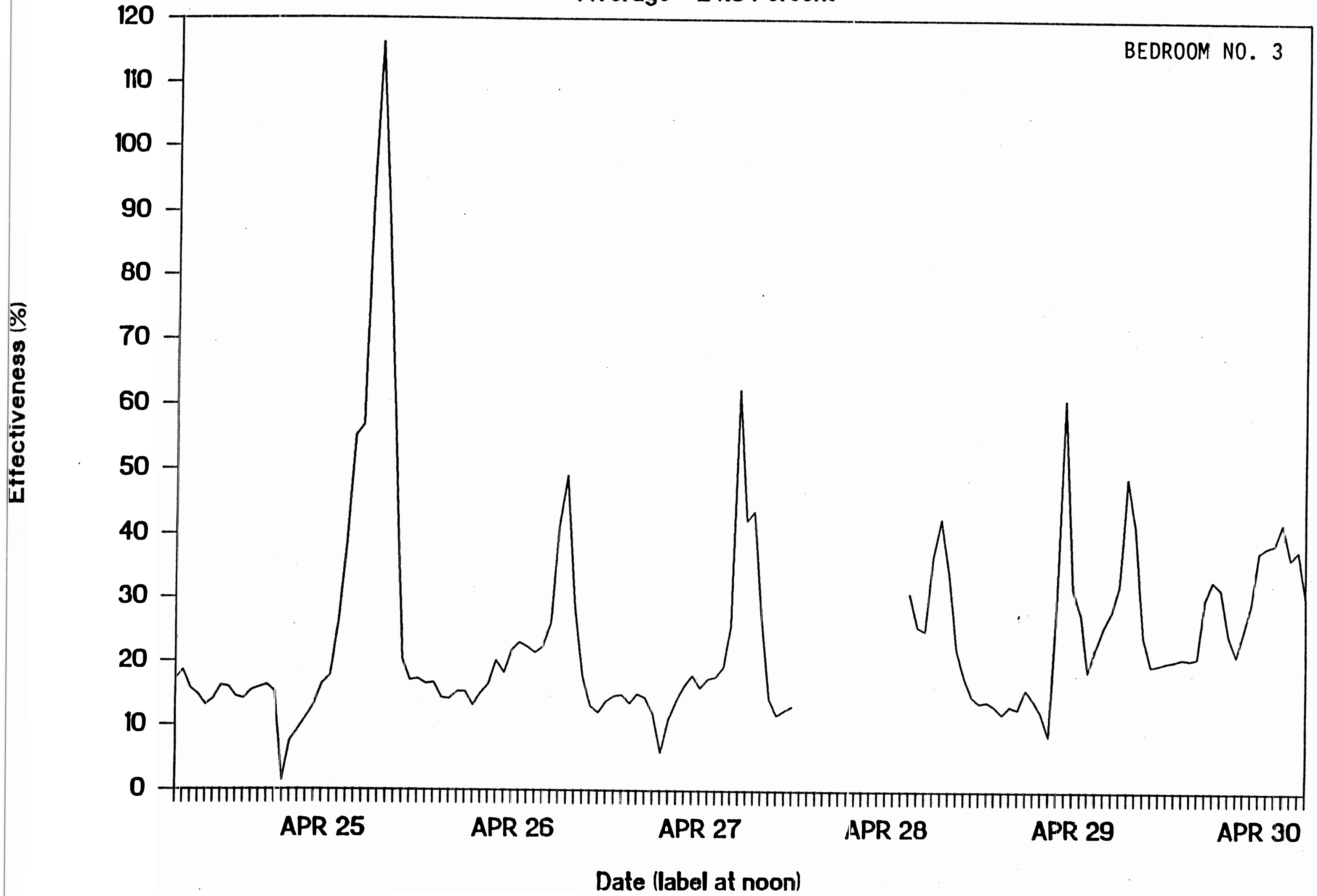


FIGURE 1.9

Heat Exchanger Effectiveness of LAFSW

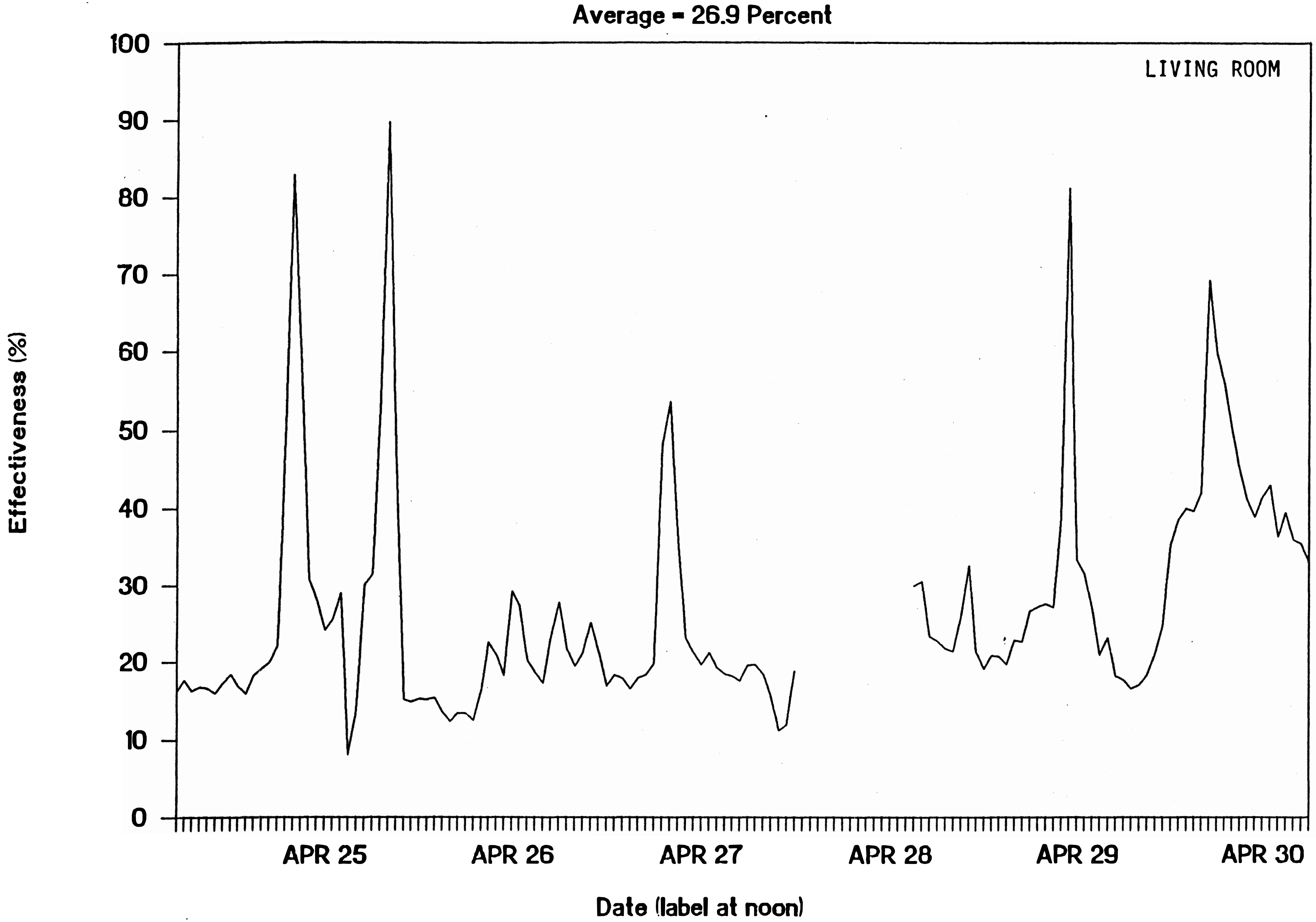
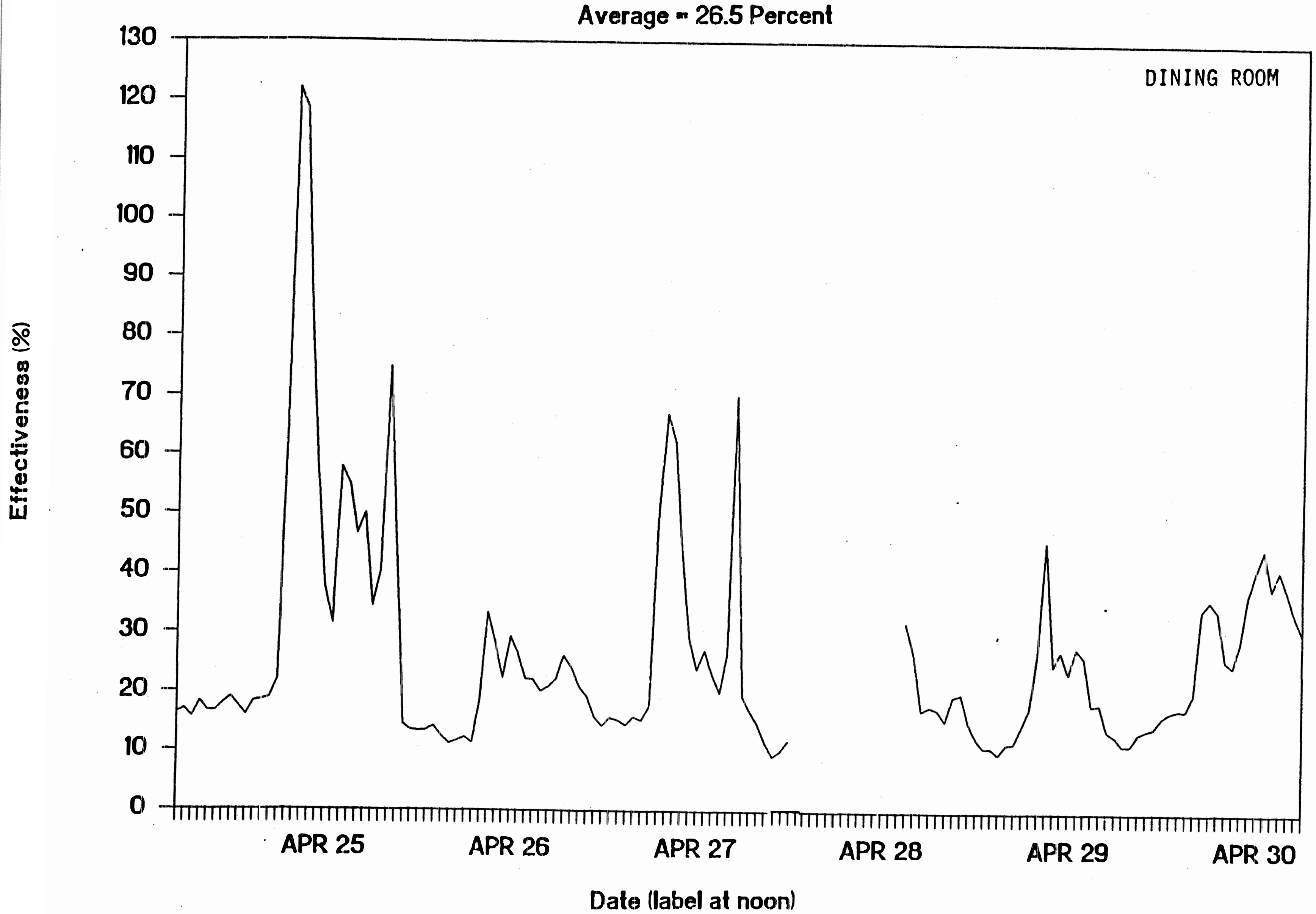


FIGURE 1.10

Heat Exchanger Effectiveness of LAFSW



APPENDIX B.2

Data Set 2

(May 10, 1989 - May 15, 1989)

FIGURE 2.1

Temperature Profiles

May 10,1989 - May 15,1989

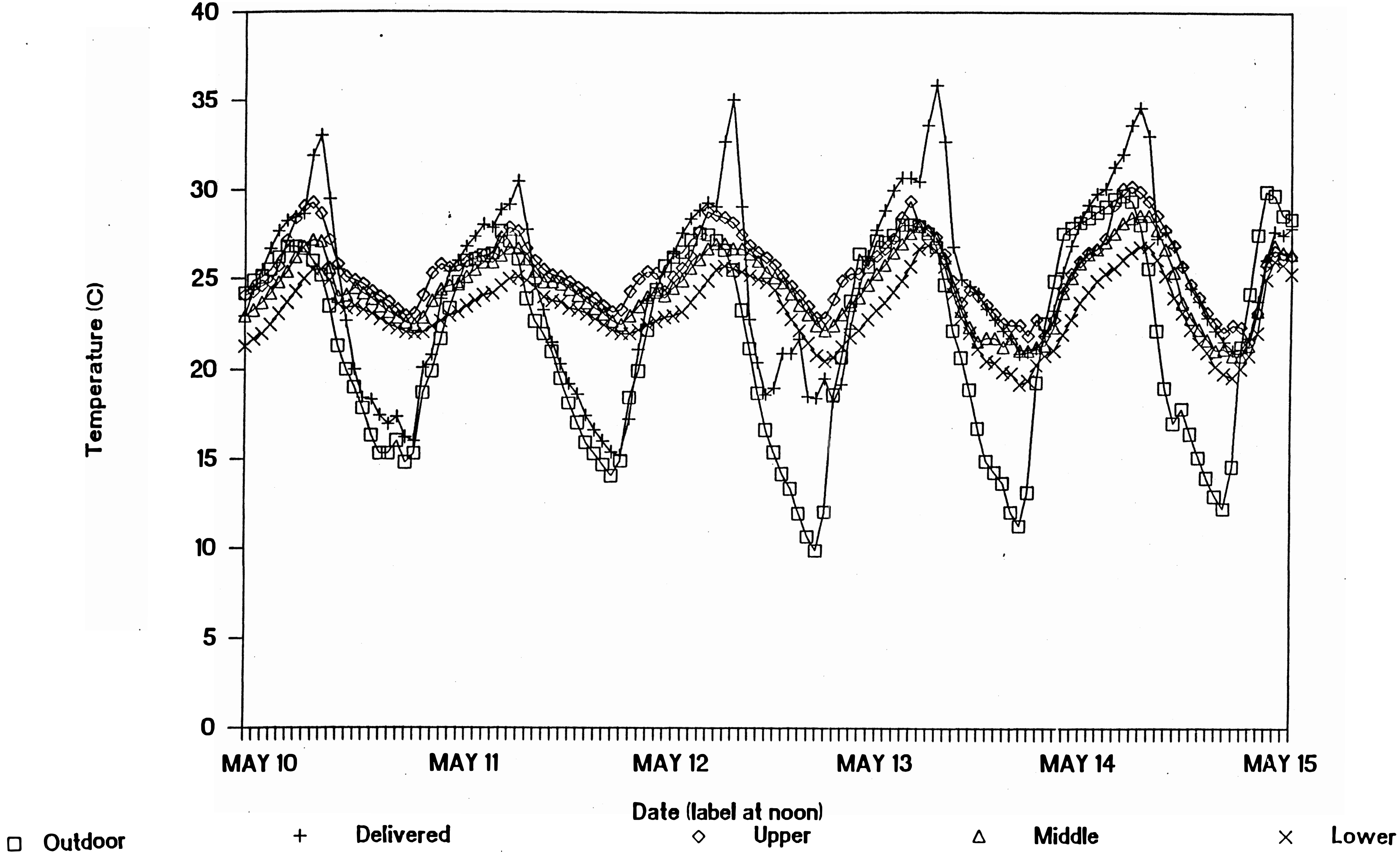


FIGURE 2.2

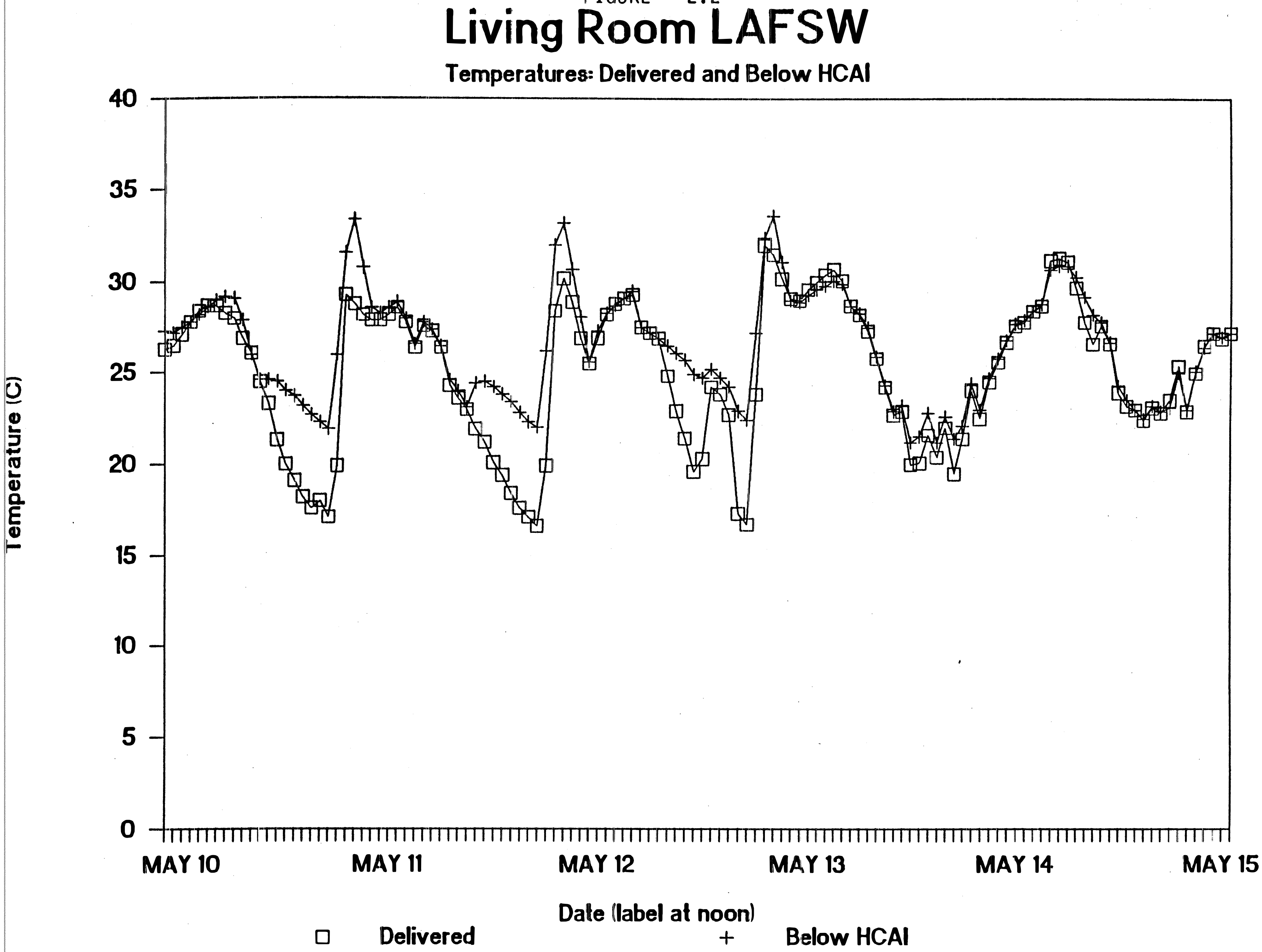
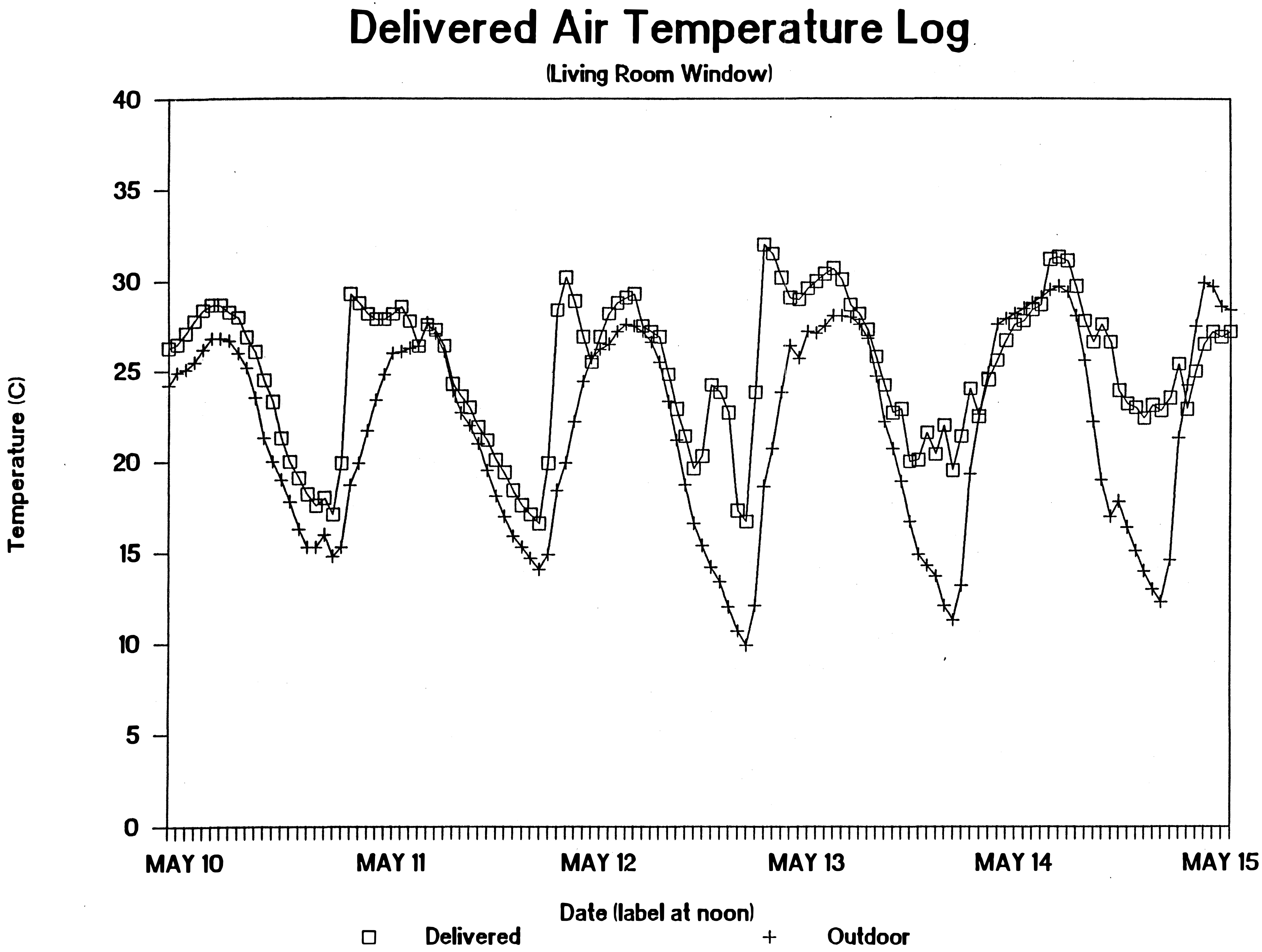

Living Room LAFSW
Temperatures: Delivered and Below HCAI
40
35
30
25
20
15
10
5
0
Temperature (C)
MAY 10
MAY 11
MAY 12
MAY 13
MAY 14
MAY 15
Date (label at noon)
Delivered
Below HCAI

FIGURE 2.3



Delivered Air Temperature Log
(Living Room Window)
40
35
30
25
20
15
10
5
0
Temperature (C)
MAY 10
MAY 11
MAY 12
MAY 13
MAY 14
MAY 15
Date (label at noon)
Delivered
Outdoor

FIGURE 2.4

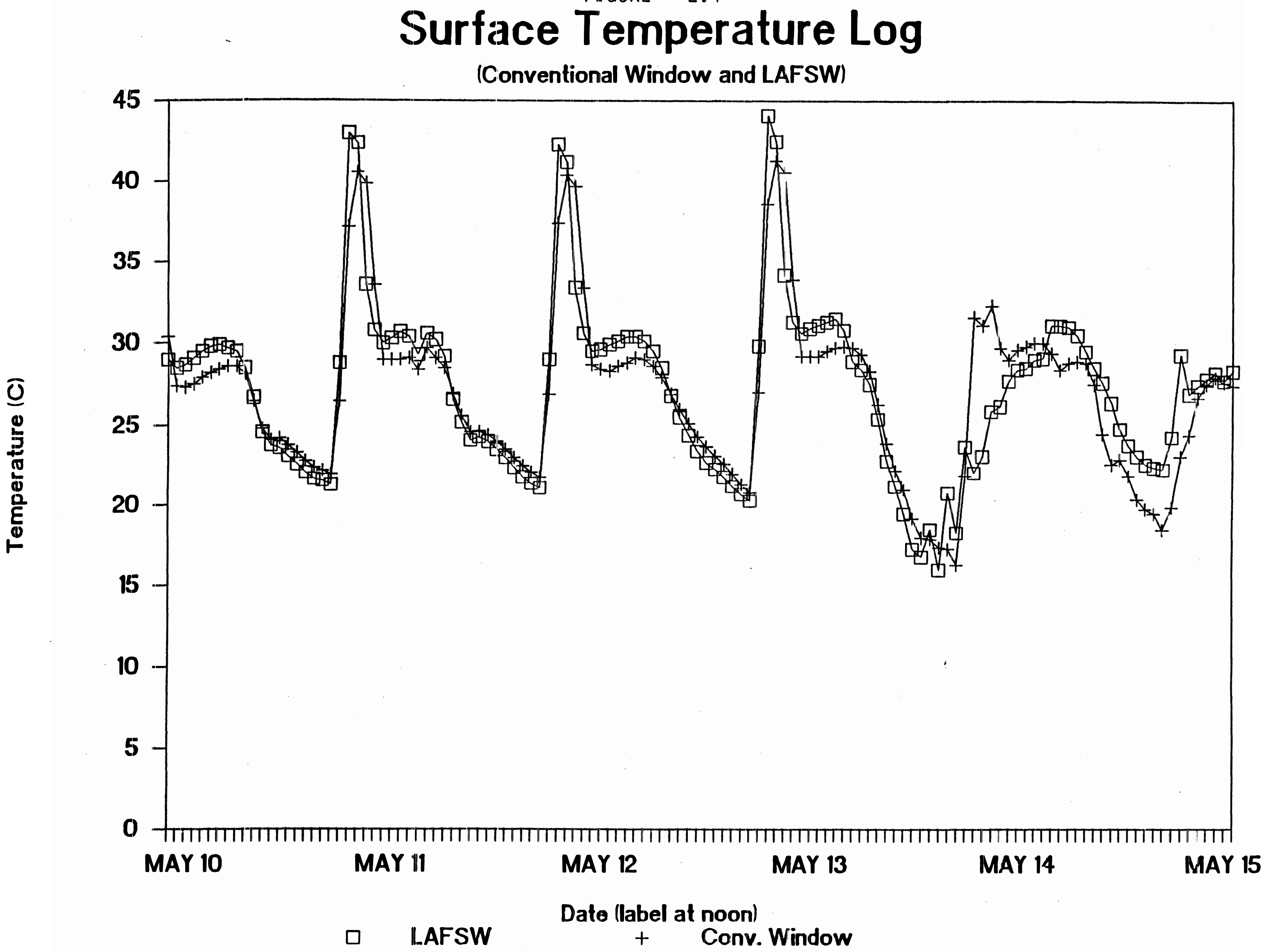

Surface Temperature Log
(Conventional Window and LAFSW)
Temperature (C)
45
40
35
30
25
20
15
10
5
0
MAY 10
MAY 11
MAY 12
MAY 13
MAY 14
MAY 15
Date (label at noon)
LAFSW
Conv. Window

FIGURE 2.5

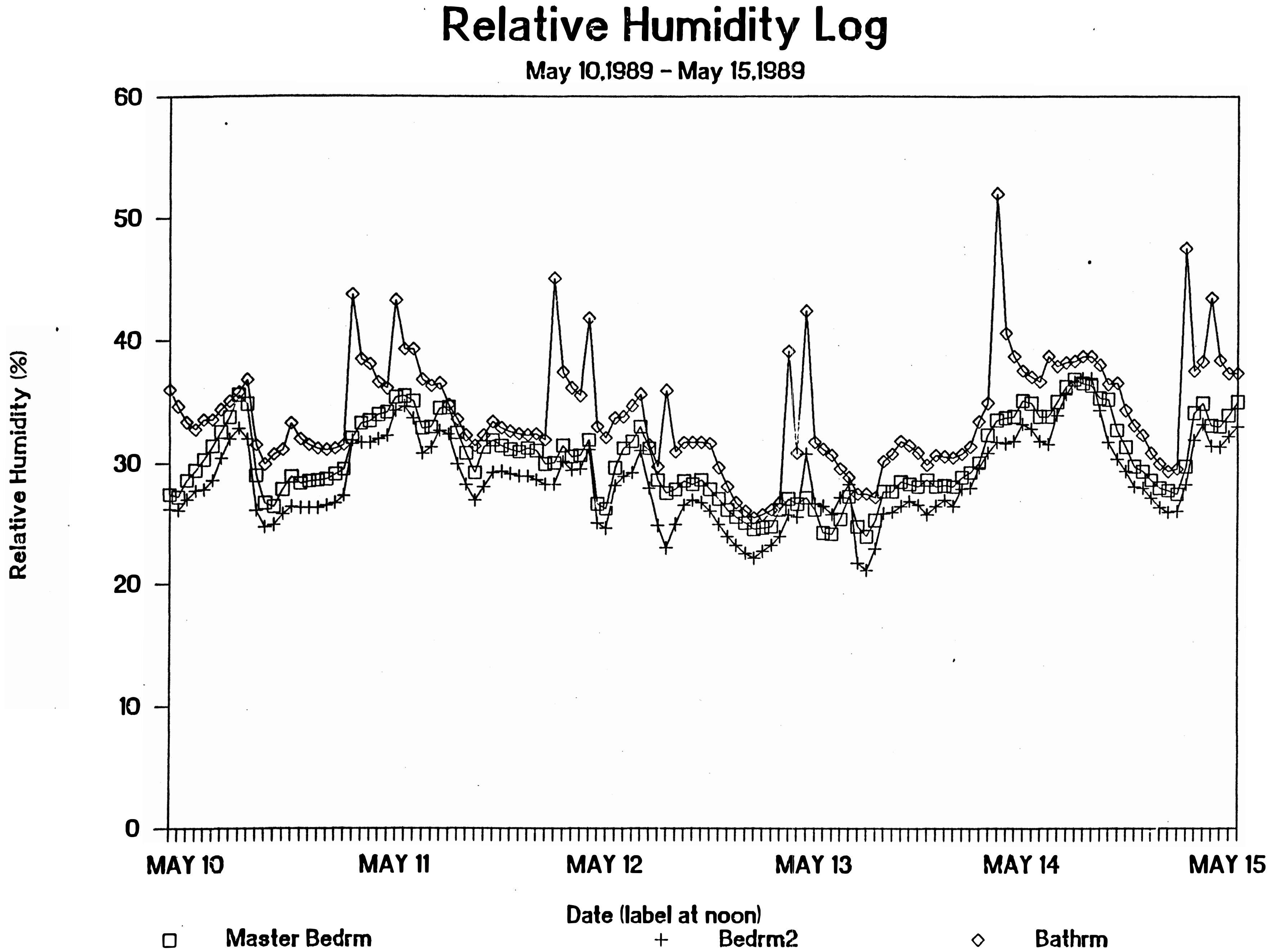

Relative Humidity Log
May 10,1989 - May 15,1989
60
50
40
30
20
10
0
Relative Humidity (%)
MAY 10
MAY 11
MAY 12
MAY 13
MAY 14
MAY 15
Date (label at noon)
Master Bedrm
Bedrm2
Bathrm

FIGURE 2.6

Relative Humidity Log - Master Bedroom

(at sensor on HCAI and in room)

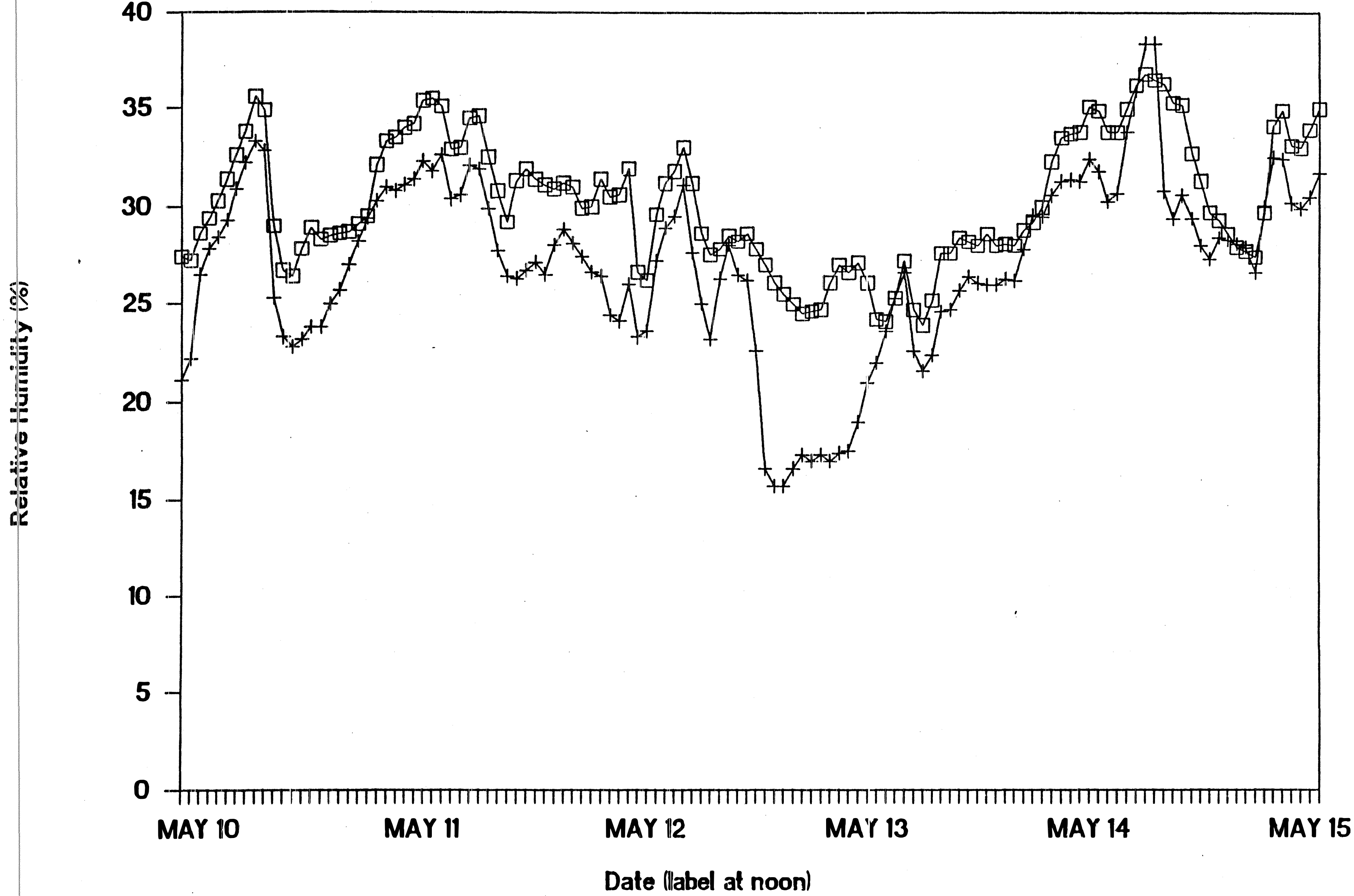
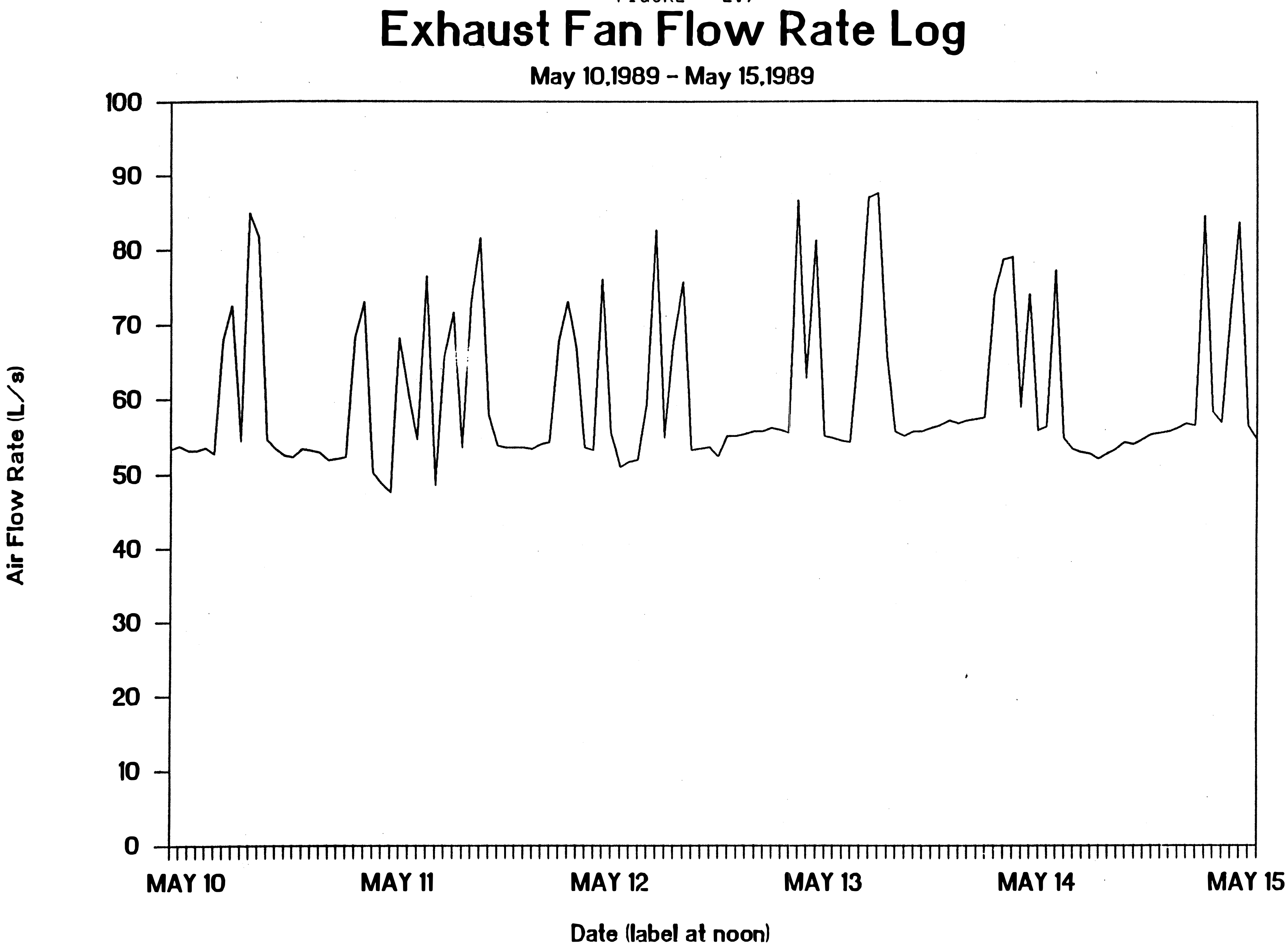


FIGURE 2.7



Exhaust Fan Flow Rate Log
May 10,1989 - May 15,1989
Air Flow Rate (L/s)
100
90
80
70
60
50
40
30
20
10
0
MAY 10
MAY 11
MAY 12
MAY 13
MAY 14
MAY 15
Date (label at noon)

APPENDIX B.3

Data Set 3

(May 19, 1989 - May 25, 1989)

FIGURE 3.1

Temperature Profiles

May 19,1989 - May 25,1989

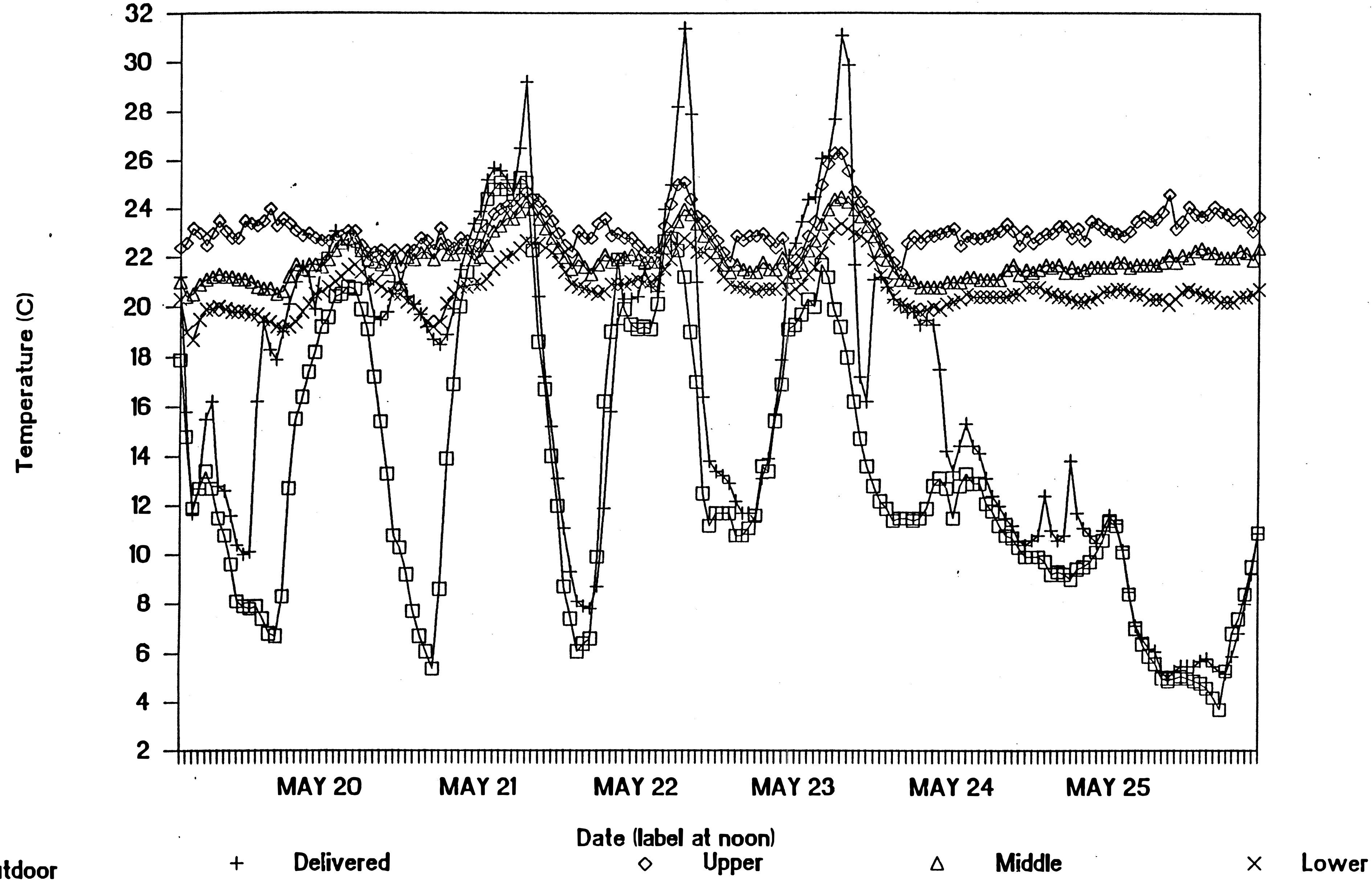


FIGURE 3.2

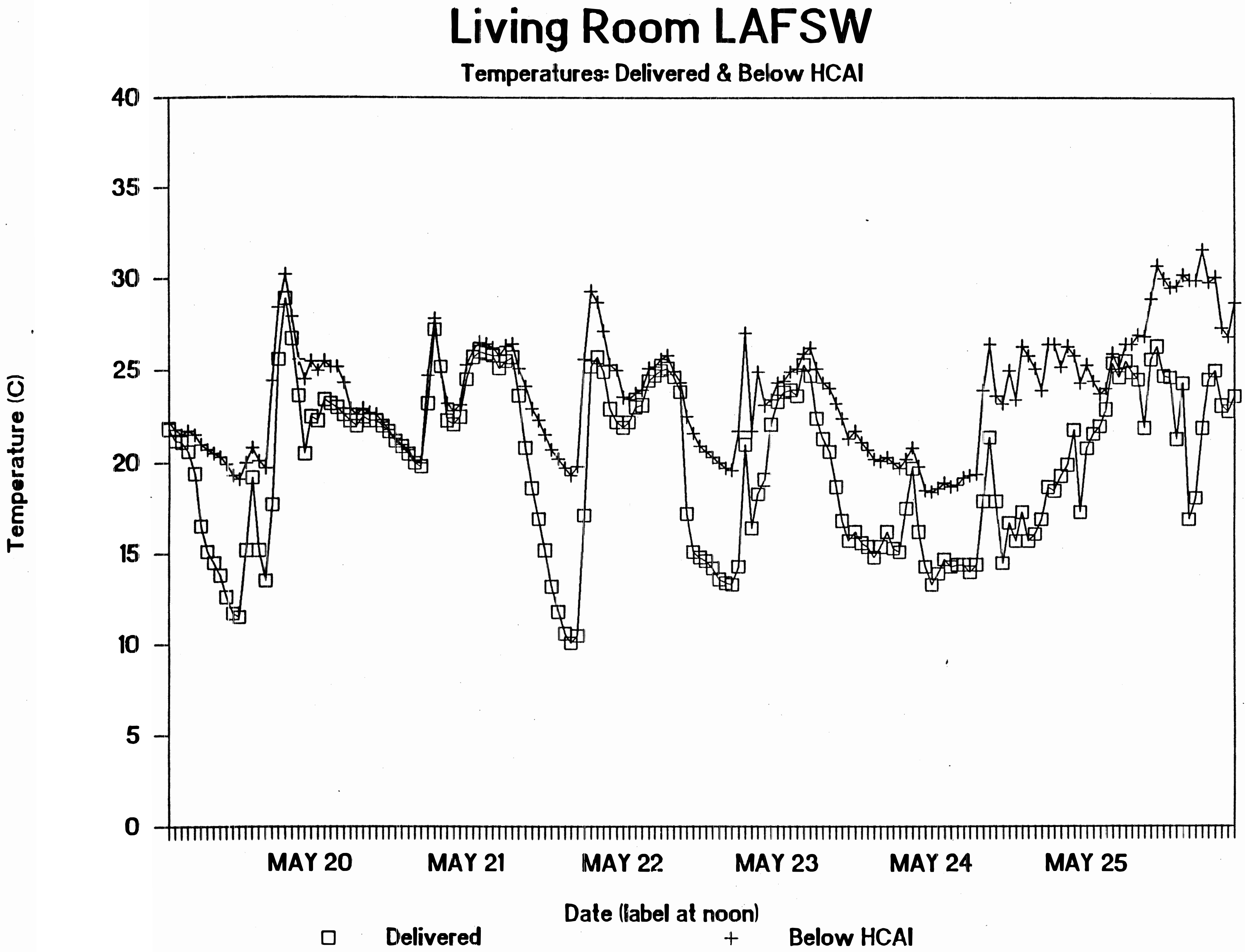

Living Room LAFSW
Temperatures: Delivered & Below HCAI
Temperature (C)
40
35
30
25
20
15
10
5
0
MAY 20
MAY 21
MAY 22
MAY 23
MAY 24
MAY 25
Date (label at noon)
Delivered
Below HCAI

FIGURE 3.3

Delivered Air Temperature Log

(Living Room Window)

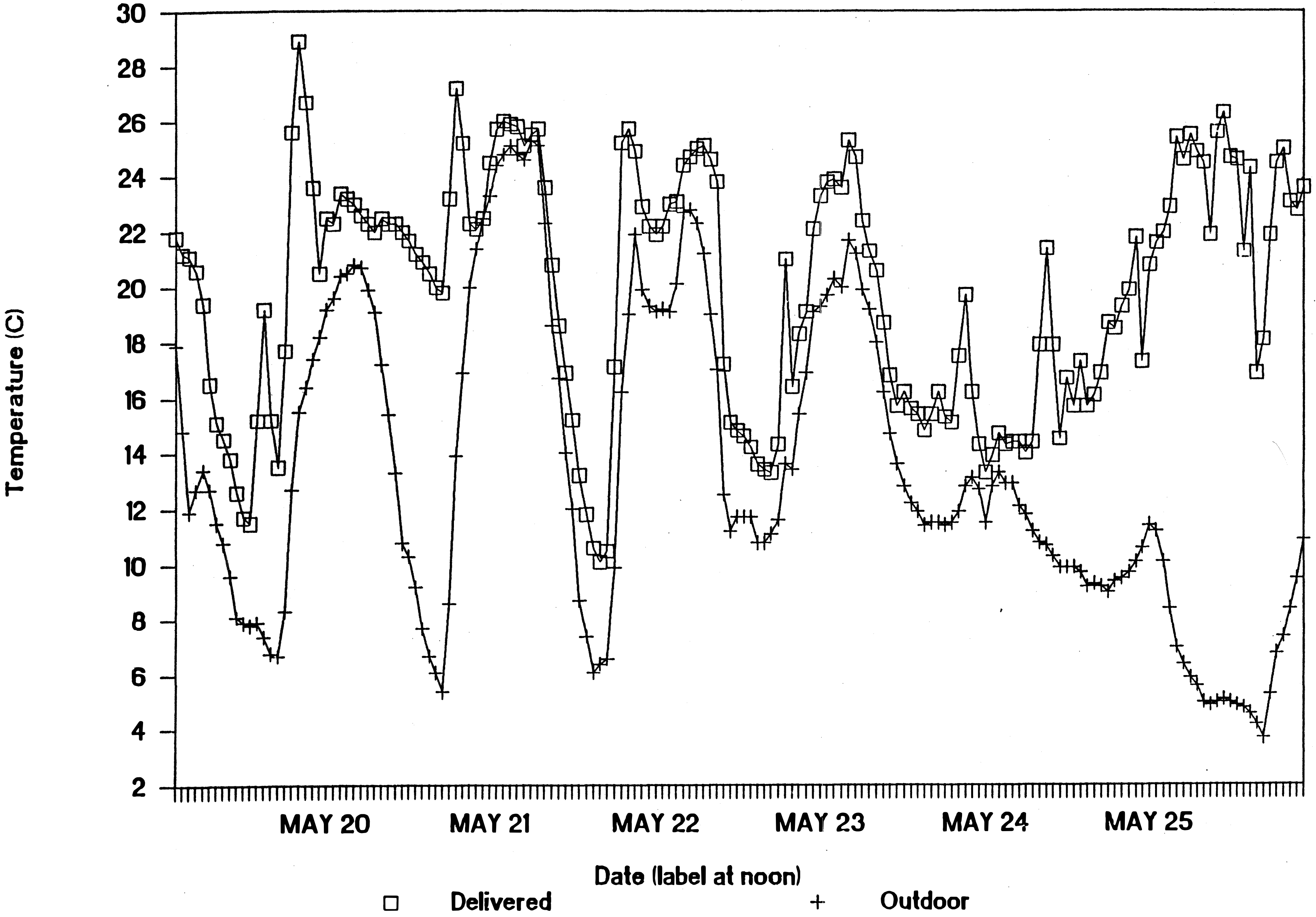


FIGURE 3.4

Surface Temperature Log

(Conventional Window and LAFSW)

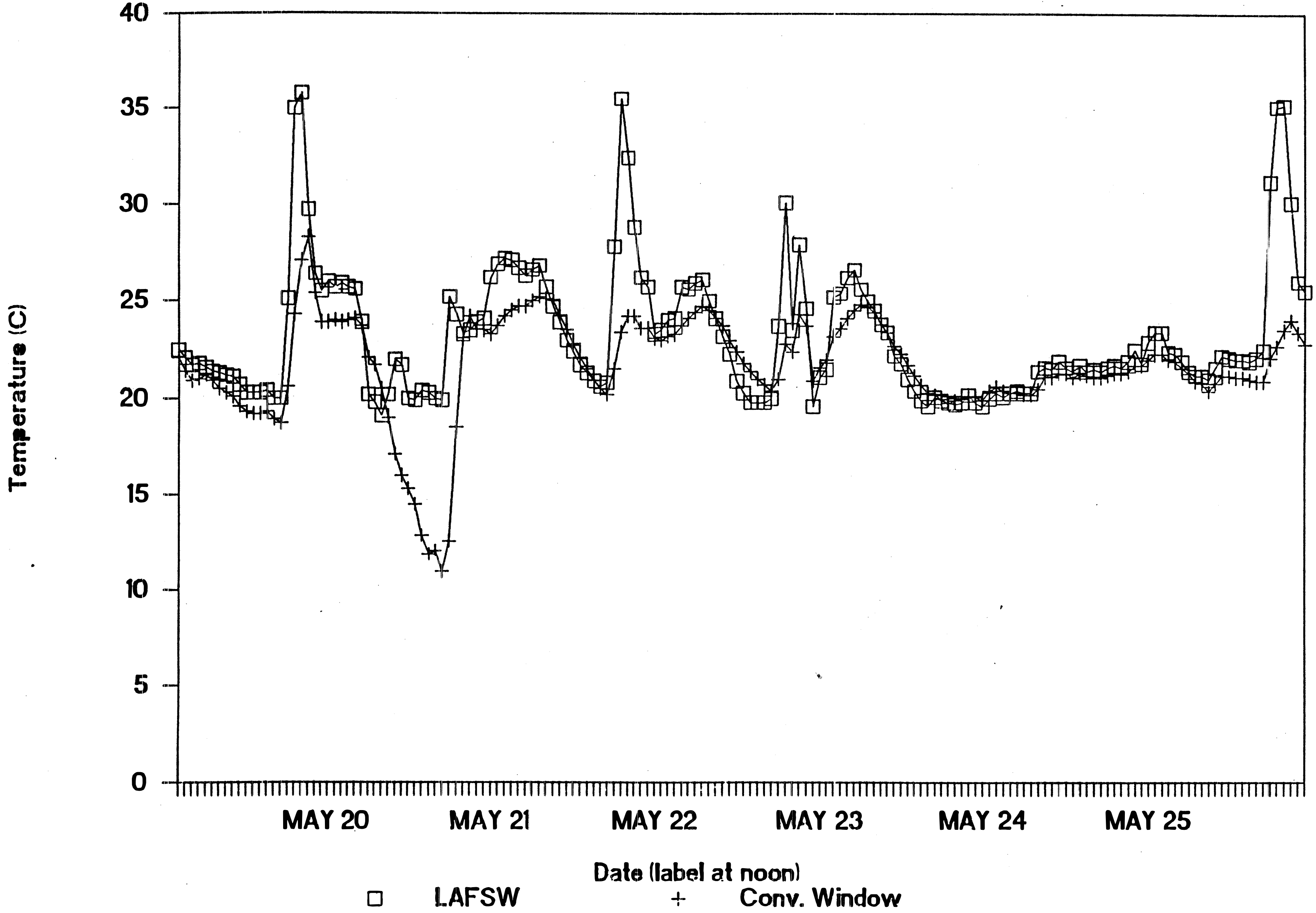


FIGURE 3.5

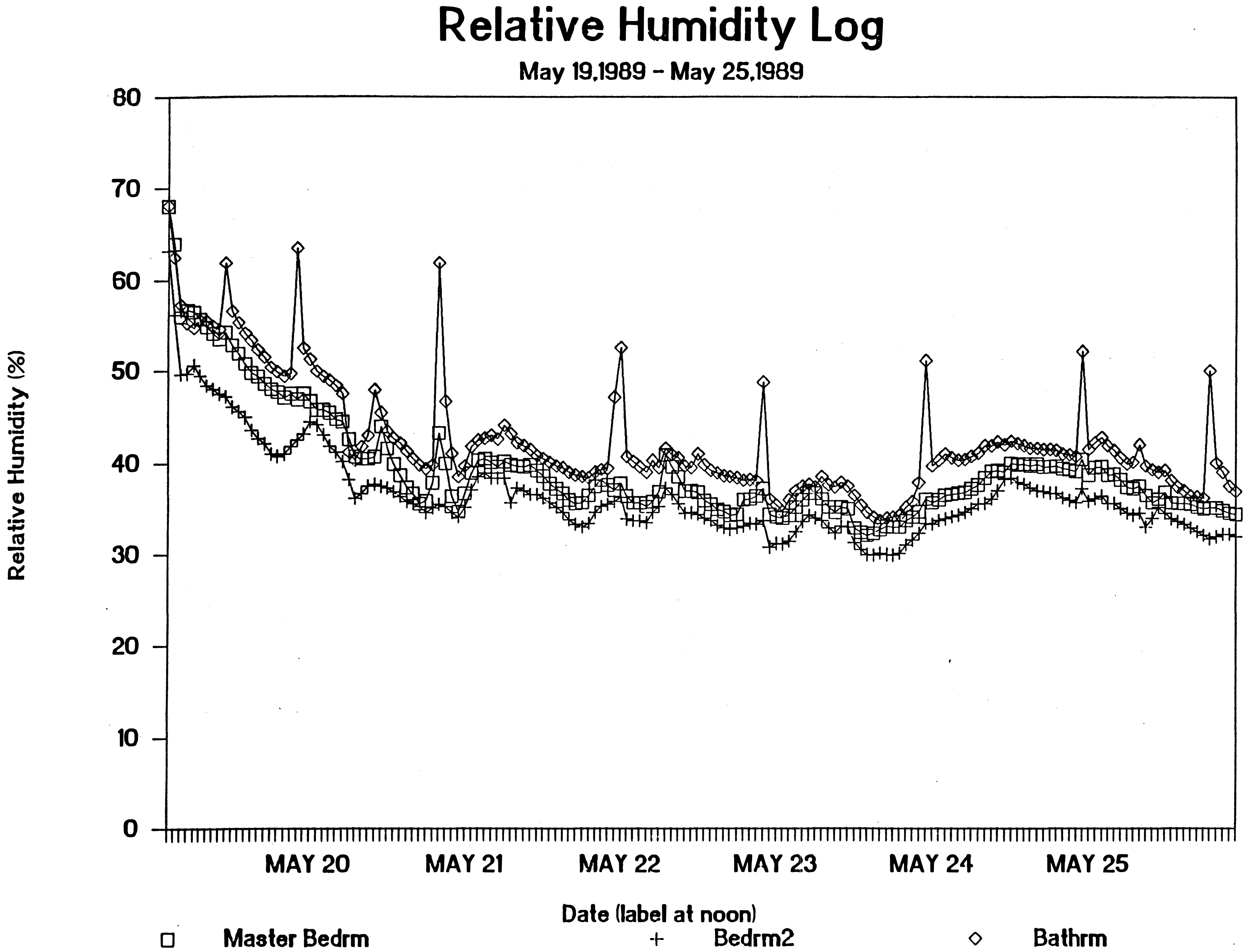

Relative Humidity Log
May 19,1989 - May 25,1989
80
70
60
50
40
30
20
10
0
Relative Humidity (%)
MAY 20
MAY 21
MAY 22
MAY 23
MAY 24
MAY 25
Date (label at noon)
Master Bedrm
Bedrm2
Bathrm

FIGURE 3.6

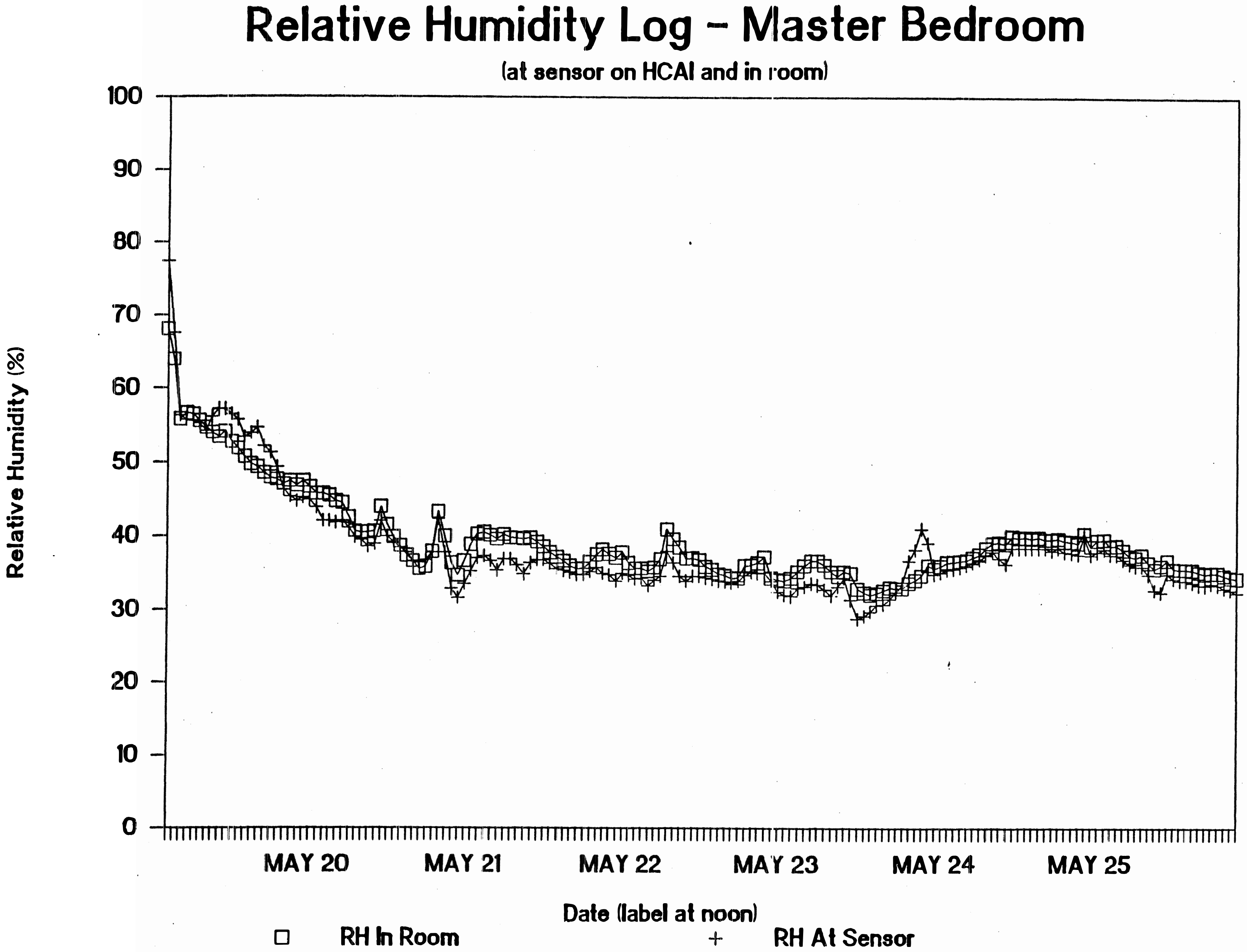
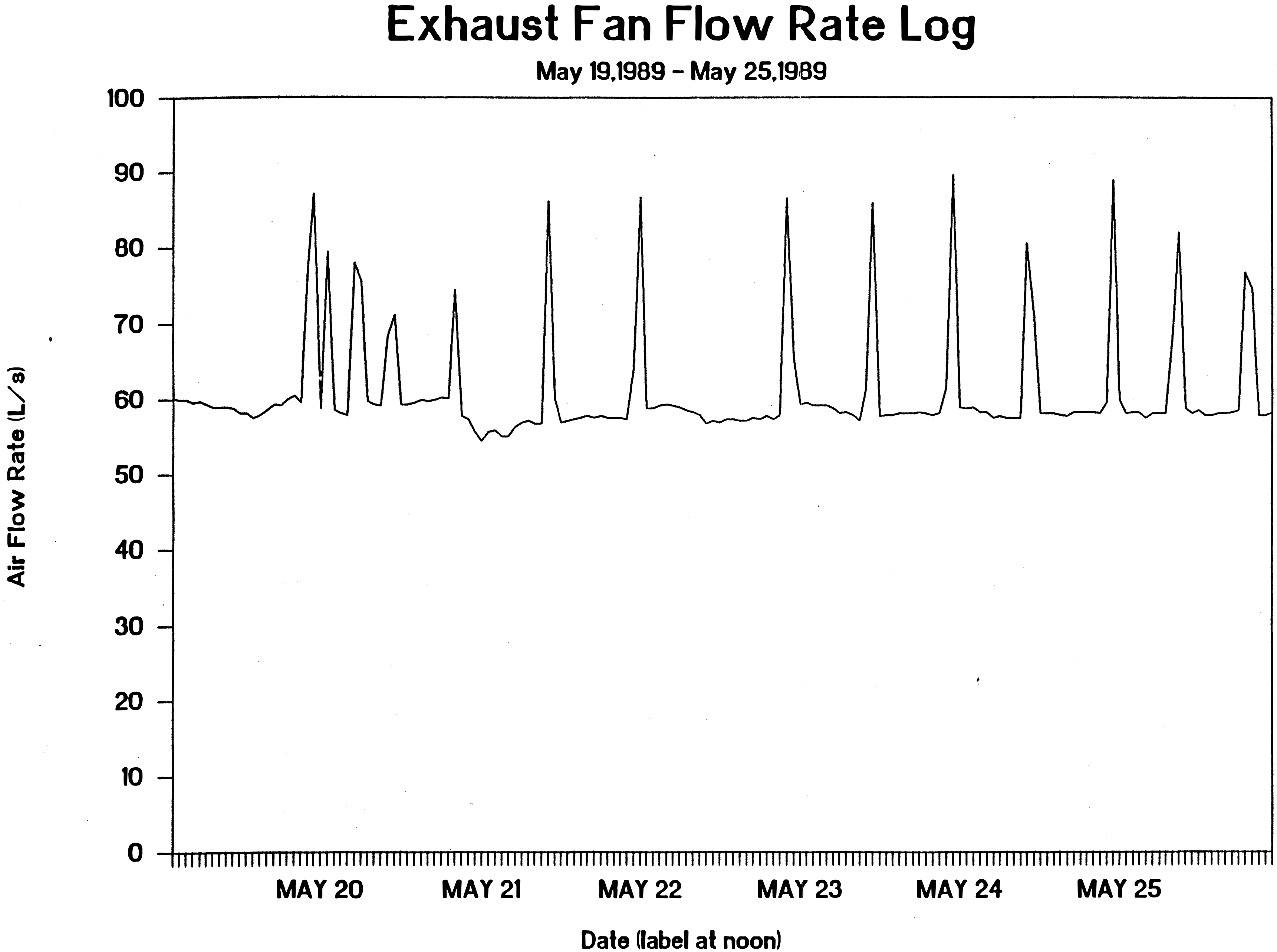

Relative Humidity Log - Master Bedroom
(at sensor on HCAI and in room)
100
90
80
70
60
50
40
30
20
10
0
Relative Humidity (%)
MAY 20
MAY 21
MAY 22
MAY 23
MAY 24
MAY 25
Date (label at noon)
RH In Room
RH At Sensor

FIGURE 3.7


Exhaust Fan Flow Rate Log
May 19,1989 - May 25,1989
100
90
80
70
60
50
40
30
20
10
0
Air Flow Rate (L/s)
MAY 20
MAY 21
MAY 22
MAY 23
MAY 24
MAY 25
Date (label at noon)

APPENDIX B.4

Data Set 4
(June 17, 1989 - June 22, 1989)

FIGURE 4.1

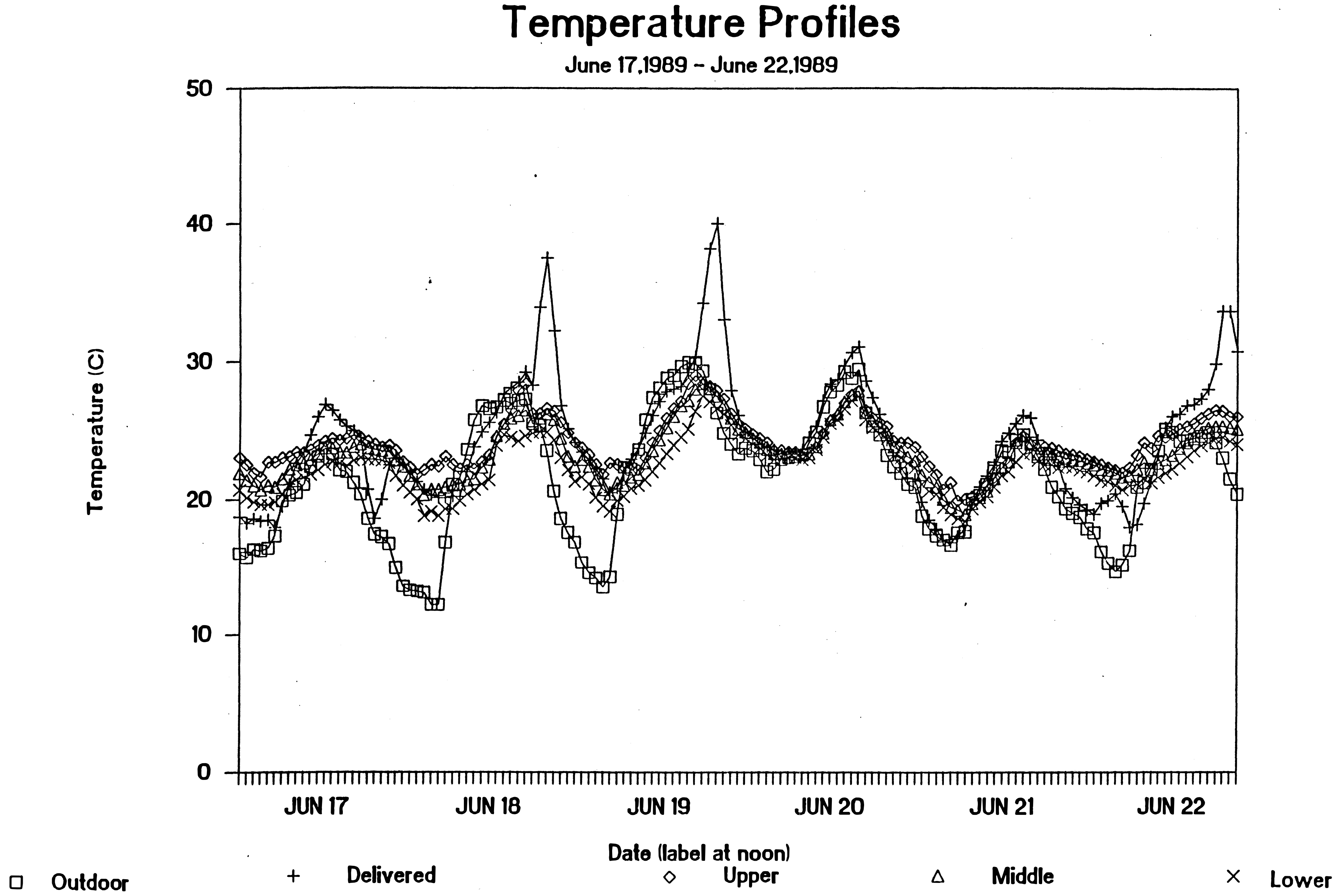

Temperature Profiles
June 17,1989 - June 22,1989
50
40
30
20
10
0
Temperature (C)
JUN 17
JUN 18
JUN 19
JUN 20
JUN 21
JUN 22
Date (label at noon)
Outdoor
Delivered
Upper
Middle
Lower

FIGURE 4.2

Living Room LAFSW

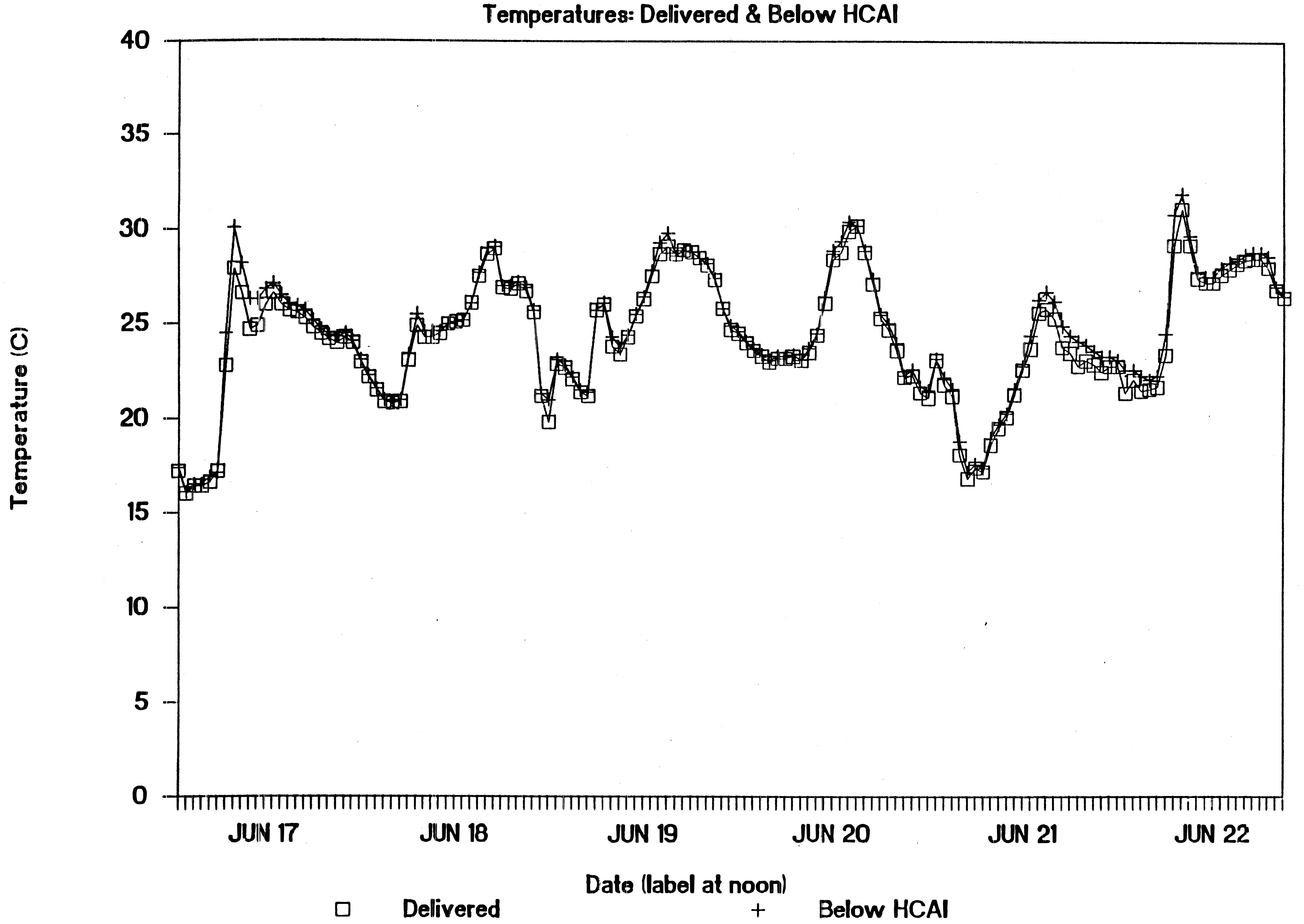


FIGURE 4.3

Delivered Air Temperature Log

(Living Room Window)

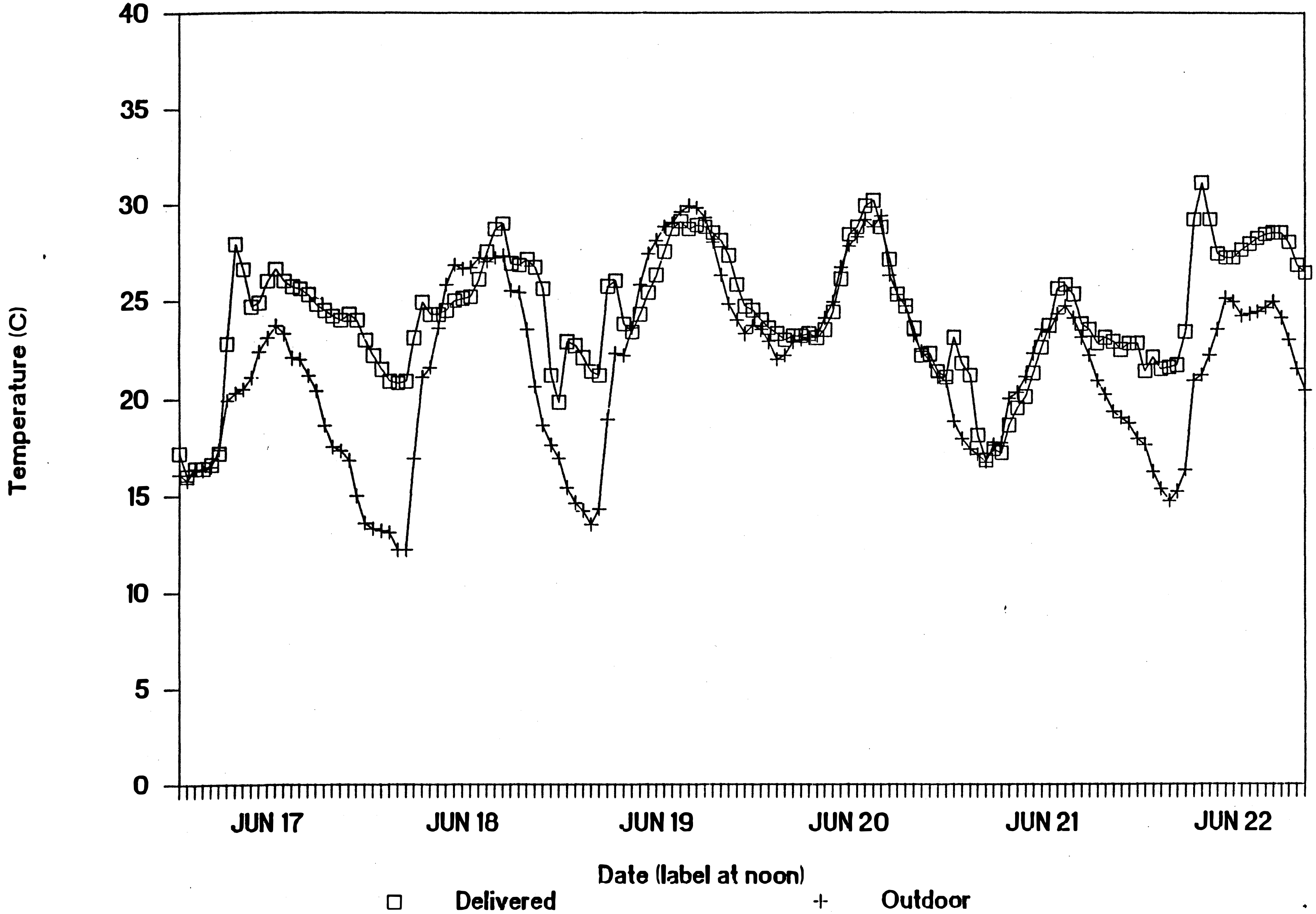


FIGURE 4.4

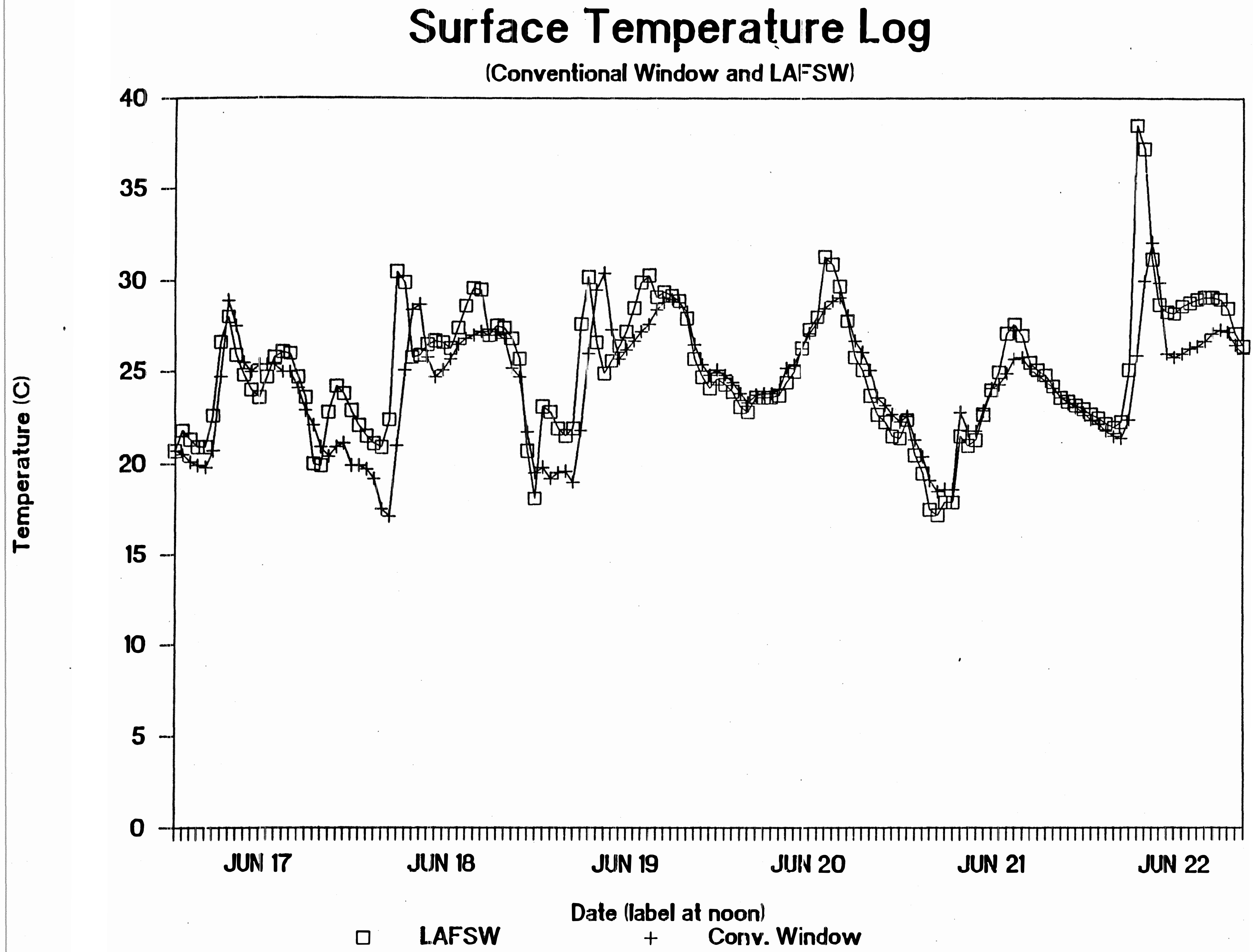
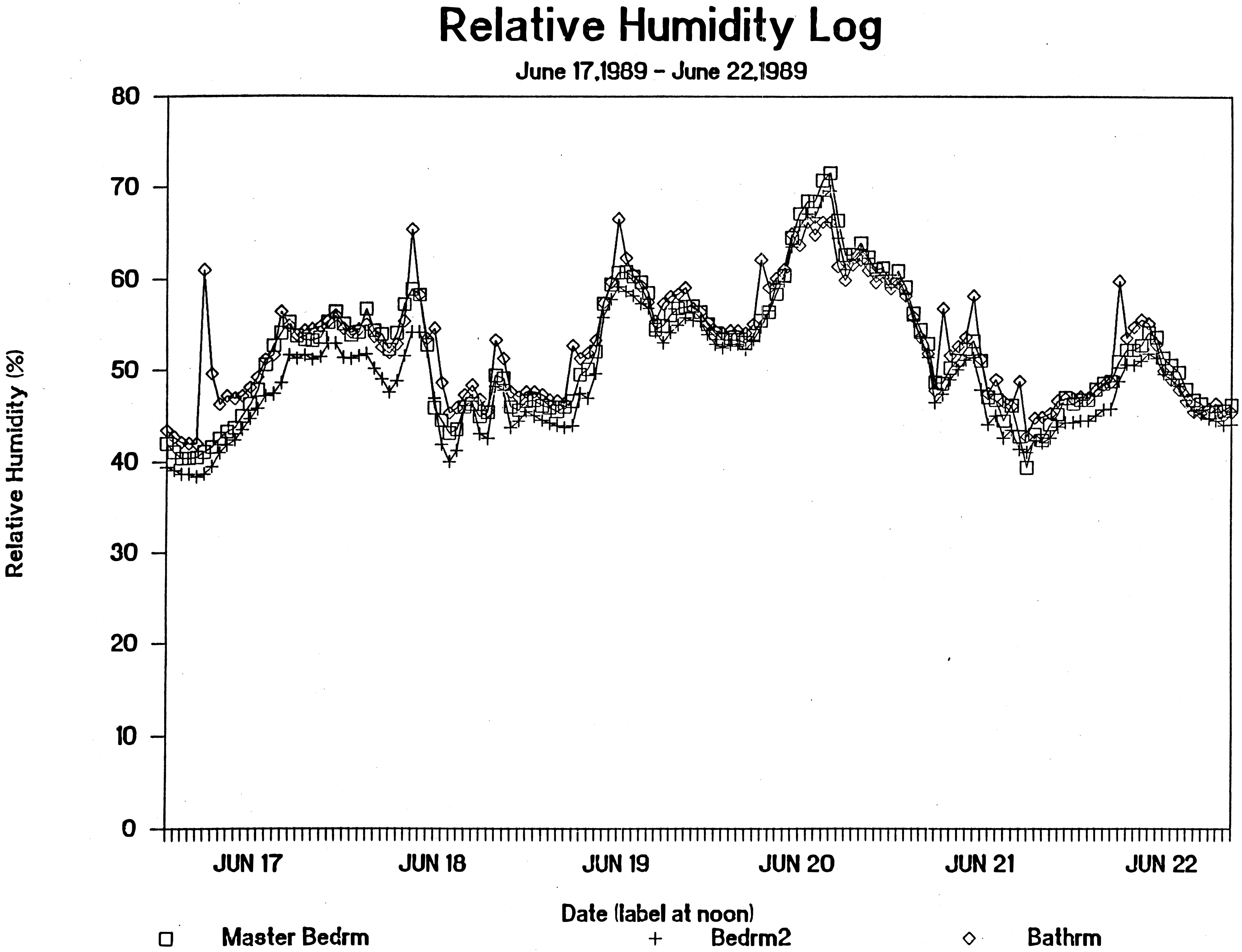

Surface Temperature Log
(Conventional Window and LAFSW)
Temperature (C)
40
35
30
25
20
15
10
5
0
JUN 17
JUN 18
JUN 19
JUN 20
JUN 21
JUN 22
Date (label at noon)
LAFSW
Conv. Window

FIGURE 4.5



Relative Humidity Log
June 17,1989 - June 22,1989
80
70
60
50
40
30
20
10
0
Relative Humidity (%)
JUN 17
JUN 18
JUN 19
JUN 20
JUN 21
JUN 22
Date (label at noon)
Master Bedrm
Bedrm2
Bathrm

FIGURE 4.6

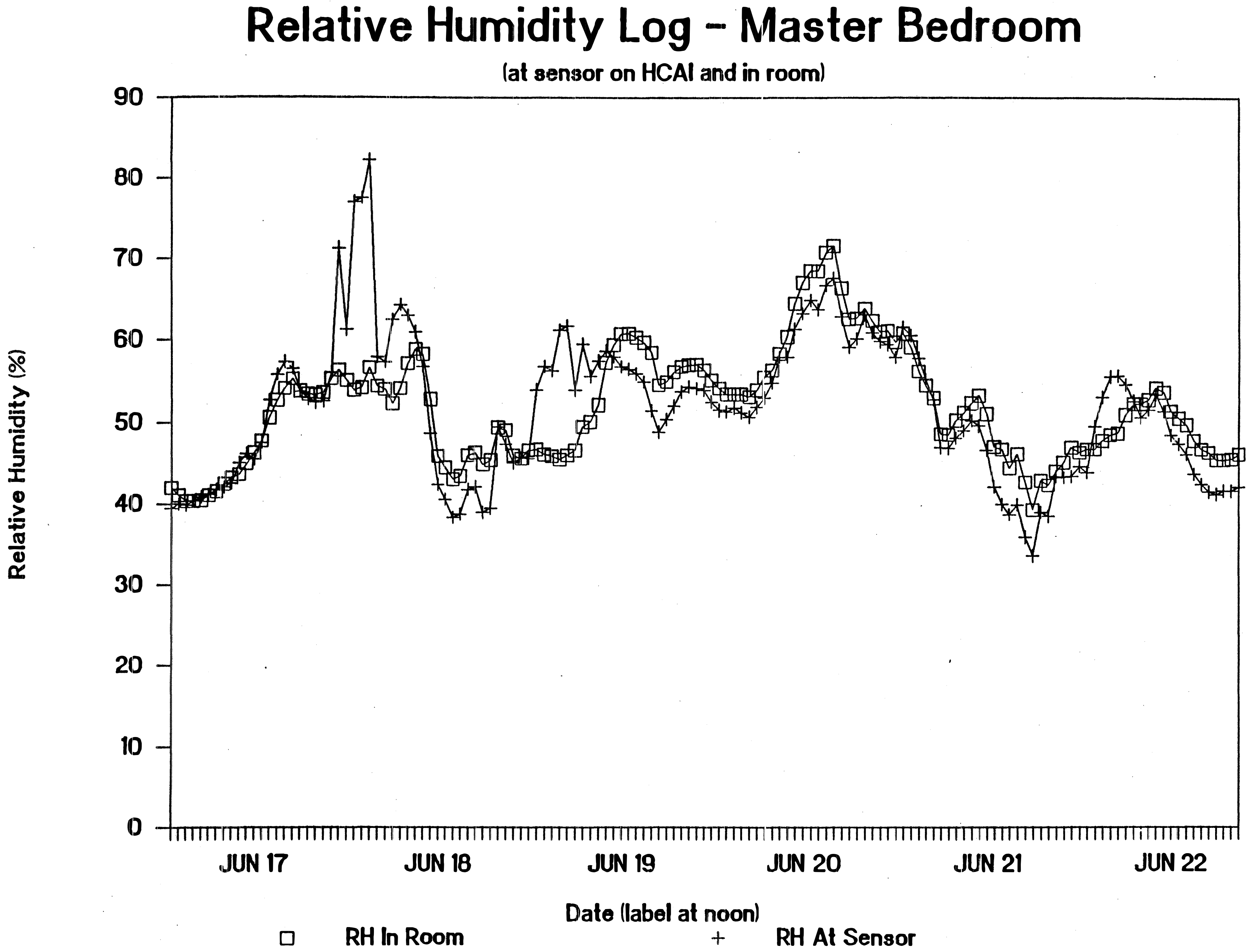
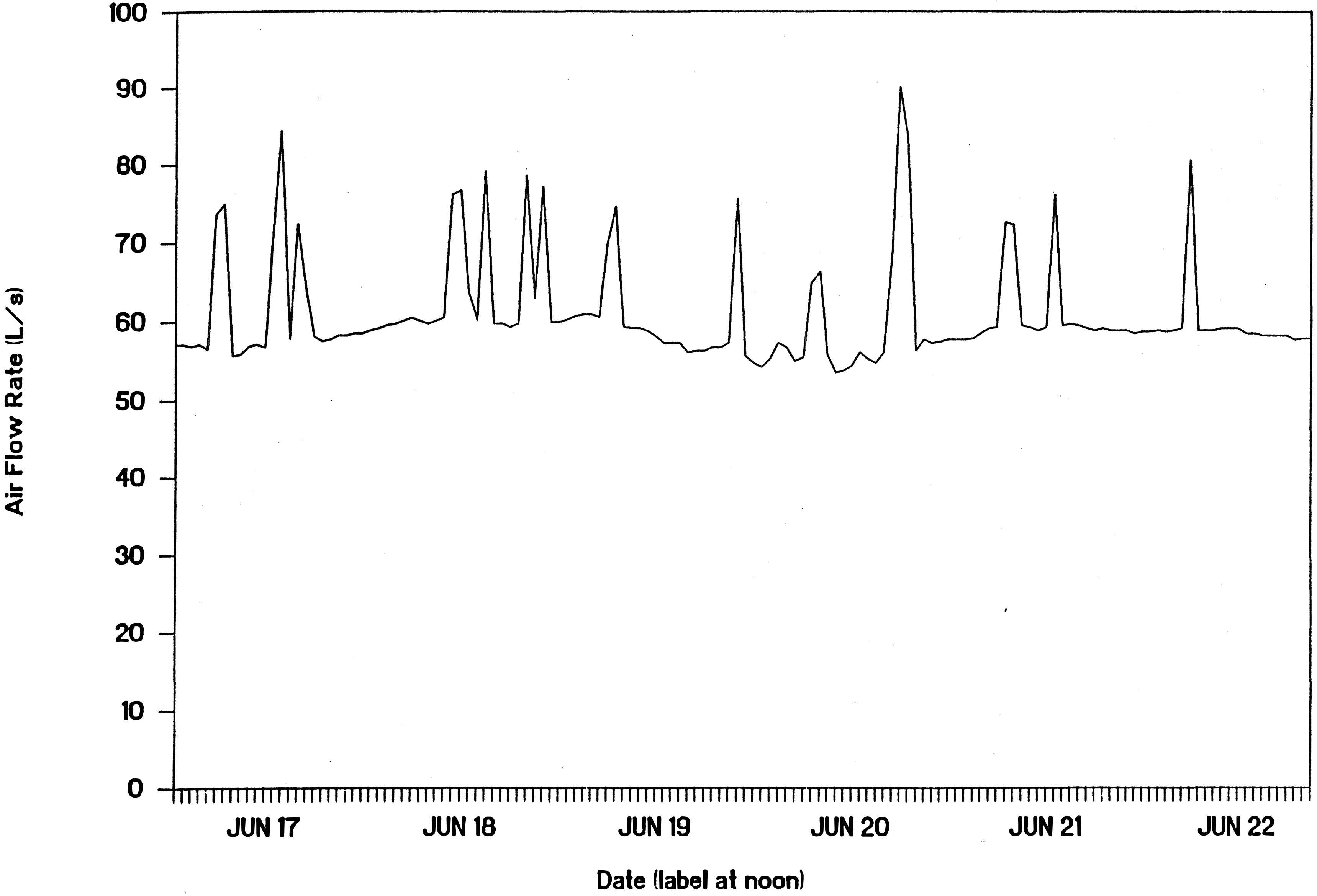

Relative Humidity Log - Master Bedroom
(at sensor on HCAI and in room)
Relative Humidity (%)
90
80
70
60
50
40
30
20
10
0
JUN 17
JUN 18
JUN 19
JUN 20
JUN 21
JUN 22
Date (label at noon)
RH In Room
RH At Sensor

FIGURE 4.7

Exhaust Fan Flow Rate Log

June 17,1989 - June 22,1989



APPENDIX C

AIRTIGHTNESS TEST REPORT FORM

SPECIMEN TEST REPORT

NAME OF CO. G.K. YUILL AND ASSOCIATES LTD.

ADDRESS OF CO. 1441 PEMBINA HWY

NAME OF TESTER G. Comeau / M. Jeanson

ADDRESS OF BUILDING 114 Payment Street, WINNIPEG, MB.

DATE OF TEST May 30, 1989 DATE OF REPORT May 30, 1989

WEATHER DATA

OUTDOOR TEMPERATURE 17 °C

WIND SPEED 4 km/h WIND DIRECTION NW

WIND VARIABILITY ______ R.H. 30% PRESS. 101.58↓

ENVELOPE

☐ BUILDING ENVELOPE ☐ OTHER ______

AREA 403.32 m² INTERIOR VOLUME 463.53 m³

BUILDING SKETCHES

MEASURED DATA

Δ P m (Pa)	Fan Speed (r/min) or Δ P nozzle (Pa) 6 HOLES PLUGGED	Qm (L/s)	ti (°C)
51	81	141.96	20
44	70	132.57	
39	59.5	122.84	
34.5	50	113.22	
30.5	42	104.33	
24.5	33	93.17	
21	25	81.79	
15.8	19	71.92	

CORRECTED DATA

Δ P (Pa)	Q_r (L/s)
51	141.96
44	132.57
39	122.84
34.5	113.22
30.5	104.33
24.5	93.17
21	81.79
15.8	71.92

RELATIVE ERROR

$\left\lvert \frac{\hat{Q}_{ri} - Q_{ri}}{Q_{ri}} \right\rvert$
0.009
-0.011
-0.007
0.001
0.008
-0.010
0.028
-0.015

$\Delta P_{o,i}$ Ø

$\Delta P_{o,f}$ Ø

CALCULATED DATA

C_r 13.49391 L/(s.Pa^n)

n 0.60088

r 0.998

ELA 0.02161 m^2

NLA 0.5358 cm^2/m^2

RELATIVE STANDARD ERROR 0.019

APPENDIX D

DATA LOGS FROM CONTINUOUS MONITORING OF RADON LEVELS

APPENDIX D.1

Basement Radon Levels

FIGURE 1.1

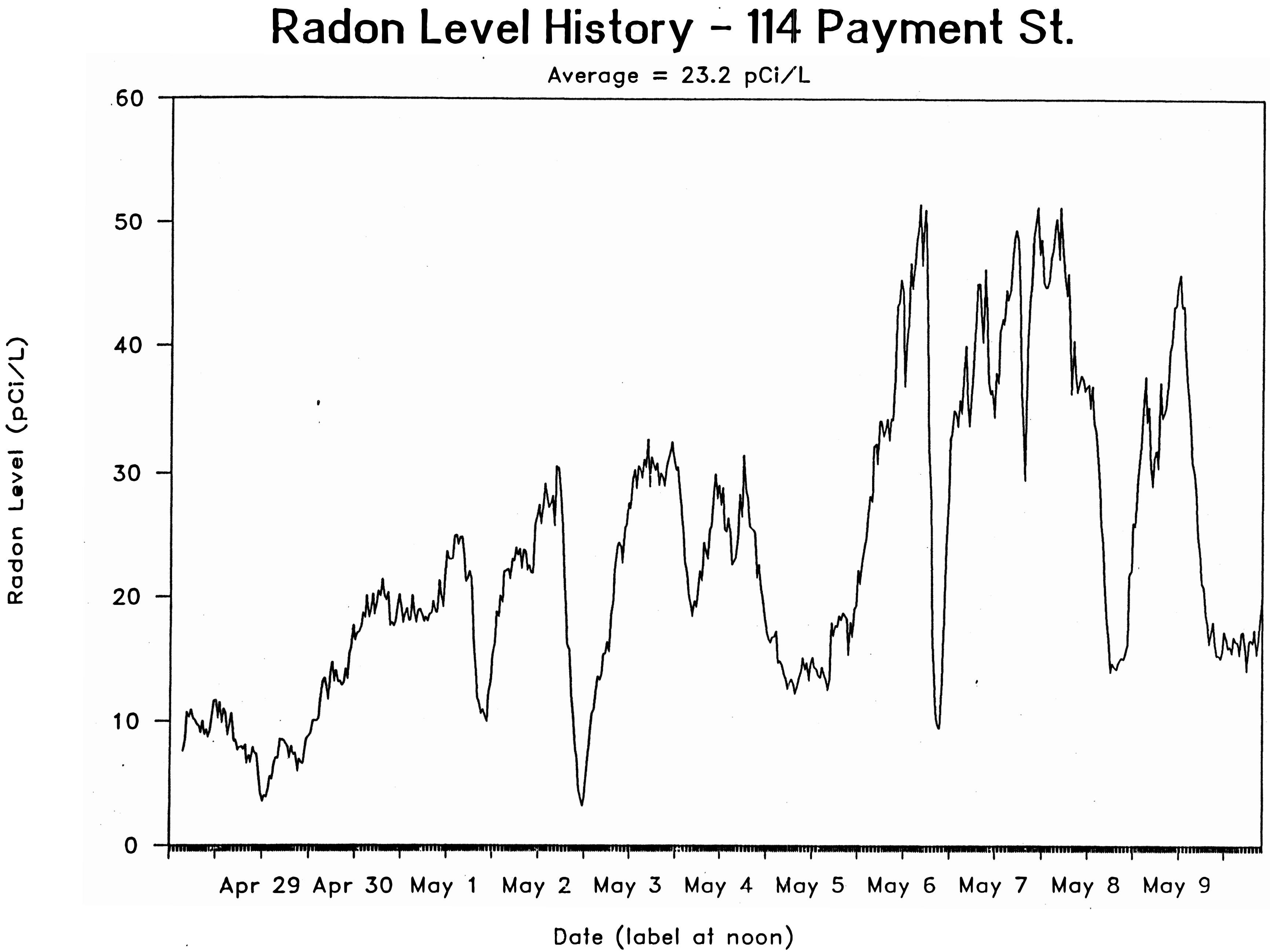

Radon Level History - 114 Payment St.
Average = 23.2 pCi/L
Radon Level (pCi/L)
0
10
20
30
40
50
60
Apr 29
Apr 30
May 1
May 2
May 3
May 4
May 5
May 6
May 7
May 8
May 9
Date (label at noon)

FIGURE 1.2

Radon Level History - 114 Payment St.

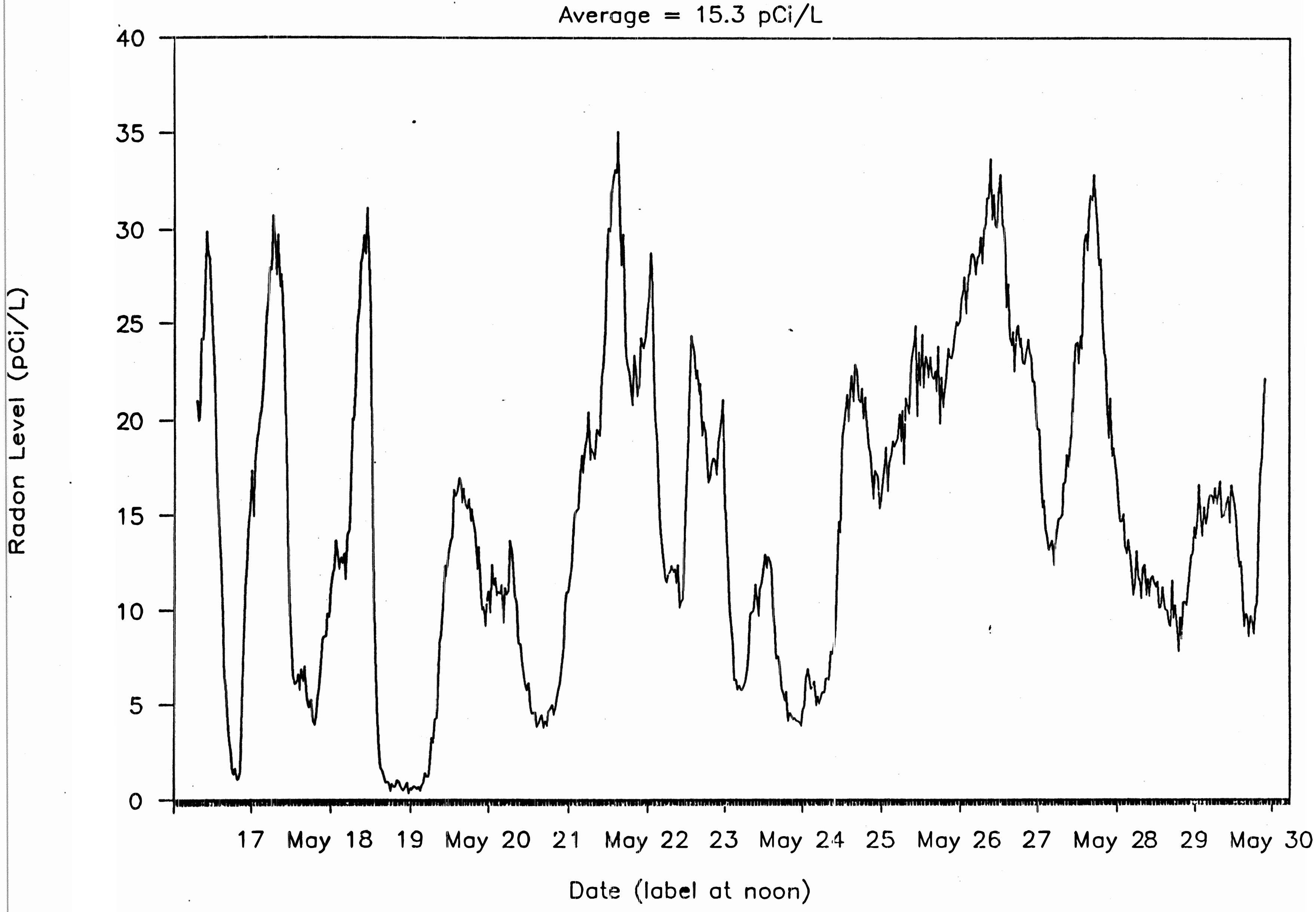
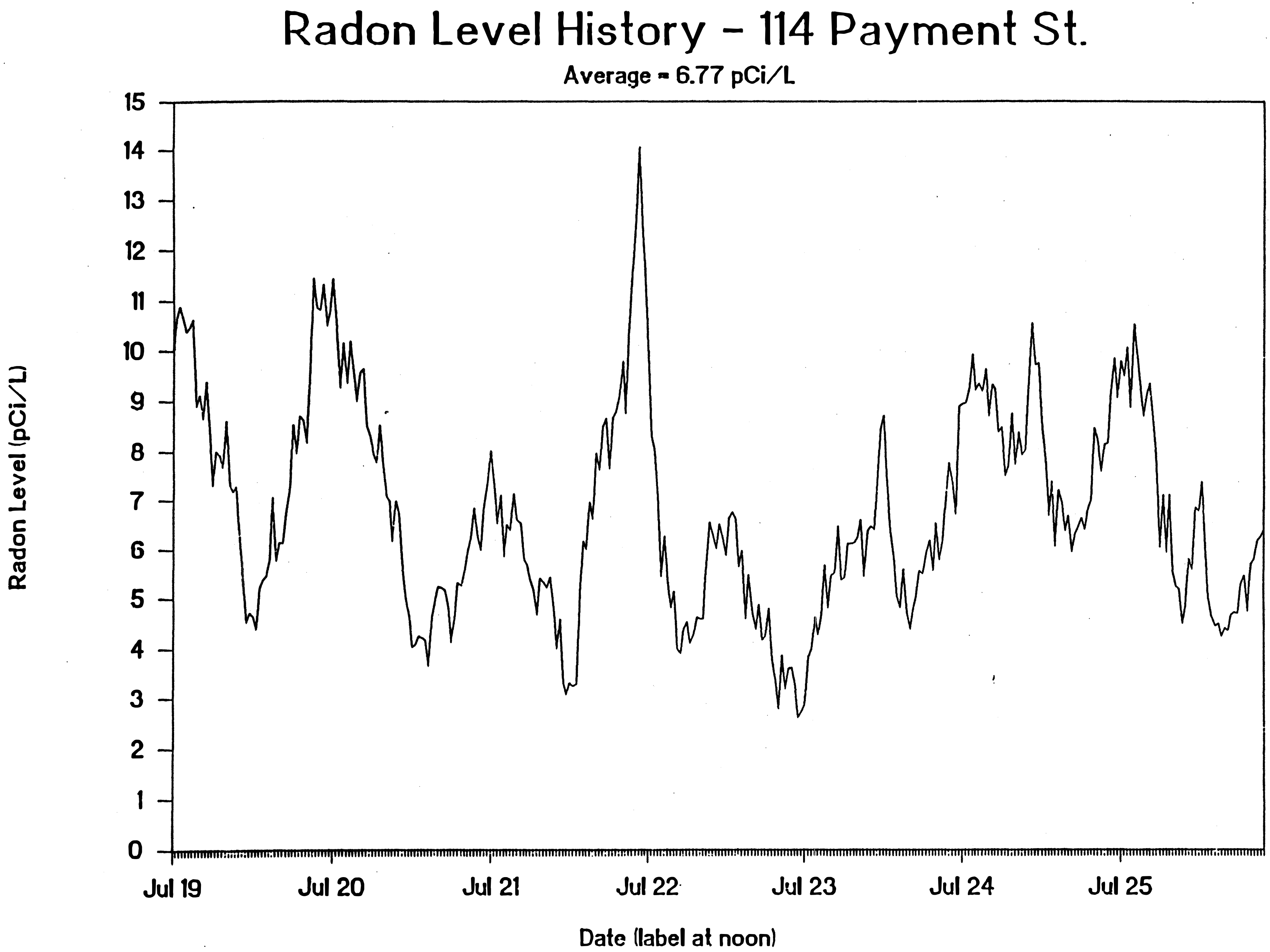


FIGURE 1.3

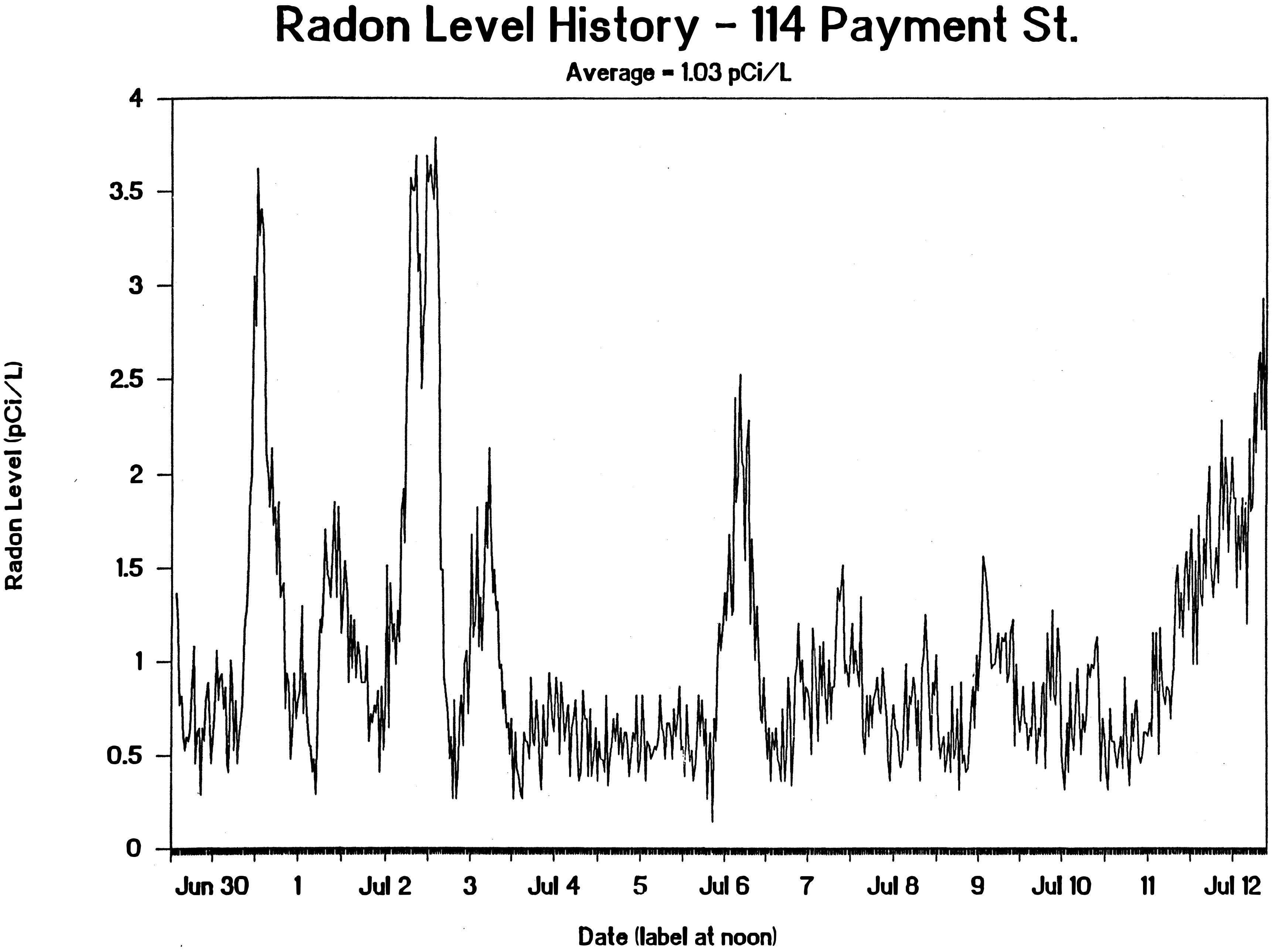


Radon Level History - 114 Payment St.
Average = 6.77 pCi/L
Radon Level (pCi/L)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Jul 19
Jul 20
Jul 21
Jul 22
Jul 23
Jul 24
Jul 25
Date (label at noon)

APPENDIX D.2

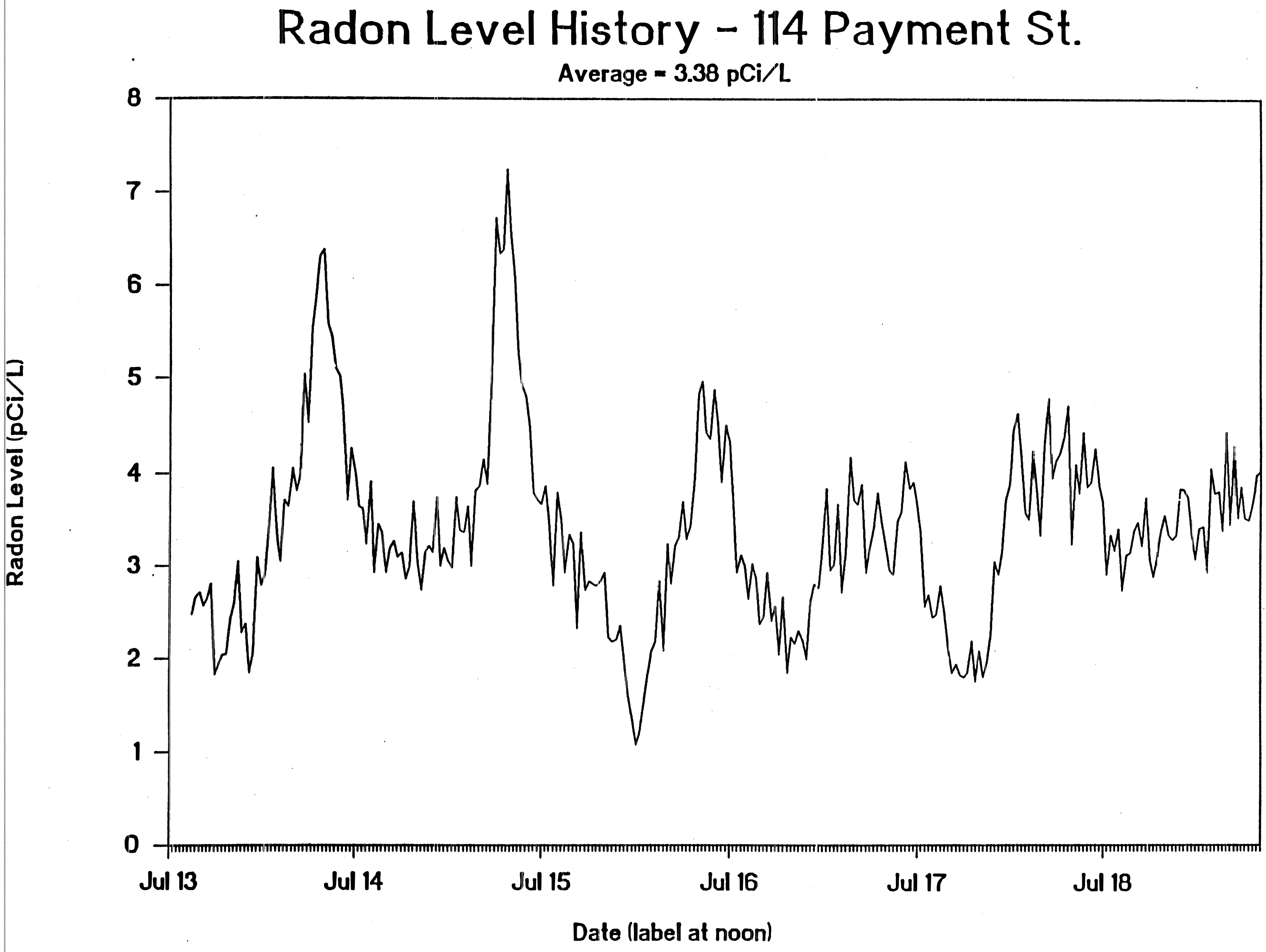
Bedroom Radon Levels

FIGURE 2.1



Radon Level History - 114 Payment St.
Average = 1.03 pCi/L
Radon Level (pCi/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Jun 30
1
Jul 2
3
Jul 4
5
Jul 6
7
Jul 8
9
Jul 10
11
Jul 12
Date (label at noon)

FIGURE 2.2



Radon Level History - 114 Payment St.
Average = 3.38 pCi/L
Radon Level (pCi/L)
0
1
2
3
4
5
6
7
8
Jul 13
Jul 14
Jul 15
Jul 16
Jul 17
Jul 18
Date (label at noon)

APPENDIX E

LABORATORY REPORT FOR FORMALDEHYDE MEASUREMENT

THE NATIONAL TESTING LABORATORIES LIMITED
Established in 1923
501-C Weston Street
Winnipeg, Manitoba R3E 3H4
Phone (204) 775-0383
Fax (204) 775-5226

July 25, 1989

G.K. Yuill & Associates Ltd.
1441 Pembina Highway
Winnipeg, Manitoba
R3T 2C4

Attn: Mr. Gord Comeau, P.Eng.

Project: C-2755
Formaldehyde levels
114 Payment

One Formaldehyde PF-1 monitor was hung in the residence at 114 Payment Street, Winnipeg, Manitoba, during the period from July 1, 1989, 10:15 a.m. to July 19, 1989, 10:15 a.m.

The Formaldehyde concentration in the Living Room was determined to be 0.128 ppm.

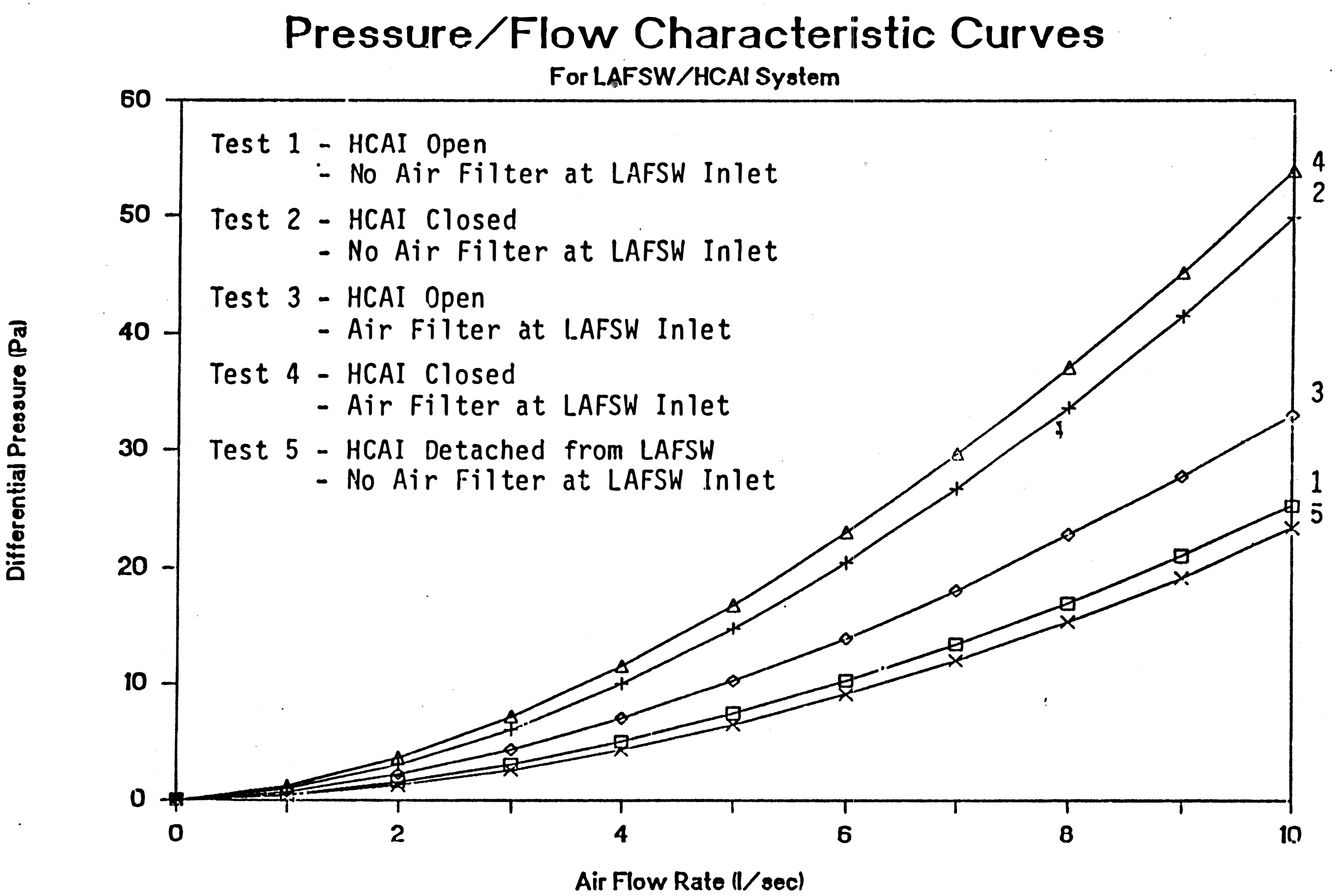
Health and Welfare Canada have recommended that 0.1 ppm of Formaldehyde in the room air is the acceptable limit for healthy people in the home environment.

Our test result indicates a level greater than the acceptable limit of 0.1 ppm (parts per million).

THE NATIONAL TESTING LABORATORIES LIMITED

Jack M. Dubovsky
Chief Chemist

JMD/sr



Pressure/Flow Characteristic Curves
For LAFSW/HCAI System
Test 1 - HCAI Open
- No Air Filter at LAFSW Inlet
Test 2 - HCAI Closed
- No Air Filter at LAFSW Inlet
Test 3 - HCAI Open
- Air Filter at LAFSW Inlet
Test 4 - HCAI Closed
- Air Filter at LAFSW Inlet
Test 5 - HCAI Detached from LAFSW
- No Air Filter at LAFSW Inlet
Differential Pressure (Pa)
Air Flow Rate (l/sec)
0
10
20
30
40
50
60
0
2
4
6
8
10
4
2
3
1
5

TABLE 1 - Summary of Results from Fan Depressurization Tests

Test Condition	Flow Coefficient C_r	Flow Exponent n	ELA m^2	NLA* cm^2/m^2	ACH @ 50
1	8.6154	0.6491	0.0154	0.3819	0.85
2	12.9027	0.6986	0.0259	N/A	N/A
3	14.2992	0.6688	0.0268	N/A	N/A
4	15.7454	0.6545	0.0285	N/A	N/A

* NLA calculated using the house envelope area

Note:

NLA and ACH@50 are not shown for test conditions 2, 3 and 4 because they are only used to indicate the airtightness of the house. In tests 2, 3 and 4, non-intentional openings (HCAIs) were left open.

TABLE 2 - SUMMARY OF RESULTS FROM TRACER GAS TESTING

TEST NO.	TEST COND.	VARIABLE	LIVING ROOM/ DINING ROOM	KITCHEN	MASTER BEDROOM	BEDROOM #2	BEDROOM #3	BASEMENT	EXHAUST PLENUM	WEIGHTED AVERAGE VALUE
1.	No	ACH	0.065	0.064	0.097	0.096	0.096	0.089		0.083
	Flow	L/sec	1.76	0.78	1.03	0.63	0.58	5.36	N/A	N/A
		in. conc. (ppb)	46.0	45.5	47.0	47.5	47.0	42.0		N/A
2.	HCAI's	ACH	0.382	0.470	0.486	0.501	0.341	0.470	0.453	0.447
	Fully	L/sec	10.32	5.70	5.14	3.29	2.05	28.32	58.31	N/A
	Closed	in. conc. (ppb)	39.5	41.5	41.5	40.0	38.5	38.0	39.5	N/A
3.	HCAI's	ACH	0.516	0.529	0.575	0.543	0.547	0.289	0.554	0.421
	Half-	L/sec	13.94	6.41	6.08	3.56	3.29	17.41	71.32	N/A
	Opened	in. conc. (ppb)	54.0	53.0	54.0	51.5	56.0	42.0	52.0	N/A
4.	HCAI's	ACH	0.384	0.394	0.426	0/420	0.589	0.404	0.403	0.413
	Fully	L/sec	10.37	4.78	4.50	2.75	3.54	24.34	51.83	N/A
	Opened	in. conc. (ppb)	33.0	33.0	30.5	30.0	32.5	30.5	31.0	N/A

WEATHER INFORMATION

Test	Temperature	Wind Speed	Wind Dir.	R.H.	Bar. Pres.
1	-25 °C	11 km/hr	WNW	55 %	103.01 kPa
2	-24 °C	11 km/hr	WNW	57 %	102.97 kPa
3	-22 °C	13 km/hr	WSW	50 %	102.82 kPa
4	-22 °C	13 km/hr	SW	51 %	102.77 kPa

* Weather information at time of first sample.