RESEARCH REPORT

Field Study of the Indoor Environment in Mobile Homes: Final Contract Report

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FIELD STUDY OF THE INDOOR ENVIRONMENT IN MOBILE HOMES

FINAL CONTRACT REPORT

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Final Contract Report

CR-6038

Canadian Manufactured Housing Institute

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CLIENT REPORT

for

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Field Study of the Indoor Environment in Mobile Homes

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Canada

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This legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

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This publication is one of the many items of information published by CMHC with the assistance of federal funds. The analysis , interpretations and recommendations are those of the Consultant(s) and do not necessarily reflect the views of Canada Mortgage and Housing Corporation that assisted in the study and its publication.

Enquête sur le terrain - Milieu intérieur des maisons mobiles

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Des enquêtes effectuées antérieurement sur le terrain ont révélé des niveaux relativement élevés de formaldéhyde dans les maisons mobiles. L'Institut canadien de l'habitation usinée, en collaboration avec la SCHL, a commandé ces travaux en vue de trouver des moyens de remédier à ce problème dans les nouvelles maisons mobiles. En raison de la grande quantité de produits d'aggloméré que contiennent les maisons mobiles par rapport à leur taille et à leur taux de renouvellement d'air, la concentration de formaldéhyde y est grandement supérieure à celle des autres types d'habitations. L'enquête a examiné les écarts entre la force des sources de formaldéhyde, l'étanchéité à l'air de l'enveloppe et le taux de renouvellement d'air de plusieurs maisons mobiles dans chacune des deux usines de fabrication.

L'enquête a révélé que l'étanchéité à l'air variait de 4,33 renouvellements d'air à l'heure, à une pression de 50 pascals (surface de fuite normalisée de 1,21 cm^2/m^2), à 5,89 ra/h, pression 50 Pa, (sfn 1,82 cm^2/m^2). Ces taux traduisent une étanchéité inférieure à l'objectif des maisons R2000 qui était de 1,5 ra/h à 50 Pa (sfn 0,7 cm^2/m^2). Presque toutes les fuites se situaient au niveau du plancher près des installations de plomberie et des conduits. Étant donné que les fuites sont toutes au même niveau, les risques de fuites d'air naturelles sont faibles.

Le taux de renouvellement d'air et les concentrations de formaldéhyde ont été mesurés dans plusieurs maisons à l'usine. Dans les pièces dont les portes étaient fermées et où aucune installation mécanique ne fonctionnait, le taux de renouvellement d'air était d'environ zéro (moins de 0,01 ra/h). Ces conditions ne sont pas fréquentes mais se produisent dans des circonstances normales. Le taux de renouvellement d'air le plus élevé (0,78 ra/h maximum) a été observé lorsque le ventilateur-extracteur de la salle de bain et le ventilateur du générateur au gaz naturel fonctionnaient. Un conduit reliait la grille de reprise d'air du générateur de chaleur à l'extérieur. Sans fuite d'air naturelle ni ventilation mécanique, la concentration de formaldéhyde a atteint 0,9 ppm. Grâce à une installation mécanique de renouvellement d'air en service pendant 24 heures, la concentration de formaldéhyde a chuté à 0,31 ppm. La diminution de cette concentration se poursuivra mais pourrait ne pas être assez rapide pour répondre à la directive à court terme de Santé et Bien-être social de 0,1 ppm d'ici à l'occupation.

Les concentrations de formaldéhyde ont également été mesurées à la surface de divers produits d'aggloméré (scellés au polyéthylène) après 24 heures sans renouvellement d'air. Ces résultats variaient entre 0,00 et 8,01 ppm. Il semble évident qu'il existe une grande diversité parmi les produits et les façons dont ils sont utilisés. Malheureusement aucune méthode de sélection des produits n'est encore à la disposition des fabricants de maisons mobiles. En raison du taux de dégazage du formaldéhyde, la ventilation ne peut en réduire suffisamment les concentrations.

Avec un certain appui des organismes provinciaux, l'Institut canadien de l'habitation usinée et la Société canadienne d'hypothèques et de logement ont prolongé les travaux en vue d'élaborer des techniques de sélection des produits ainsi que des méthodes d'étanchéisation de certains produits et assemblages permettant d'éliminer le dégagement d'émanations. La SCHL compte également soutenir l'évaluation et l'étiquetage des produits à cette fin.

Ce résumé a été écrit par Tom Hamlin, Division de la recherche, Société canadienne d'hypothèques et de logement, à partir du rapport et des discussions ultérieures.

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Field Study of the Indoor Environment in Mobile Homes
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Canadian Manufactured Housing Institute

INTRODUCTION

The Institute for Research in Construction, Prairie Regional Station conducted a study of mobile homes on behalf of the Canadian Manufactured Housing Institute. The project involved field measurements of ventilation and air quality in manufactured homes at two manufacturing plants in Western Canada.

This report summarizes the field testing conducted from 30 Nov/89 to 03 Dec/89 at Shelter-Regent Industries Inc., Estevan, SK. and from 16 Mar/90 to 18 Mar/90 at Triple E Homes Ltd., Lethbridge, AB.

STUDY OBJECTIVES

The broad objectives of the study were to examine a cross section of new mobile homes and assess the "state of the art" with respect to the indoor environment. The project was very timely, since:

a) In 1987, Health and Welfare Canada released formal guidelines for specified indoor air pollutants (1). The indoor formaldehyde guideline limit was set at 0.1 ppm and a target level of 0.05 ppm was established.

b) The 1990 National Building Code (NBCC) revisions are complete (2) and contain revised requirements for ventilation. A 24 hour average mechanical ventilation rate (supply from or exhaust to outdoors) of 0.3 air changes per hour is required.

c) ASHRAE (3) has recently revised STD. 62-1989 Ventilation for Acceptable Indoor Air Quality. The standard contains a design procedure for control of specific pollutants when the basic specified ventilation rates are not adequate.

d) Many states in the U.S. have developed regulations for indoor air quality and ventilation for mobile homes and have identified formaldehyde as a specific pollutant of concern.

The study focused on examining the engineering parameters that influence the concentration of indoor air pollutants. These include; ventilation, building envelope air tightness and indoor pollutant sources - specifically formaldehyde.

Specific objectives were to:

1) Measure the air tightness of the building envelopes and identify areas where air leakage is occurring.

2) Measure the air exchange rate in two representative zones in the building under different ventilation conditions and discuss how code requirements for ventilation can be satisfied.

3) Measure the indoor formaldehyde concentration in two representative zones under typical operating conditions and discuss options for controlling levels to below 0.1 ppm.

4) Explore techniques for characterizing construction material sources of formaldehyde and use these techniques to measure the levels from a range of building materials used in the mobile homes.

DESCRIPTION OF TEST HOMES AND TEST PROTOCOL

1) <u>Shelter-Regent Industries Inc.</u>

Two mobile homes were studied during the field testing. In addition to the airtightness, ventilation and indoor formaldehyde concentration measurements, several techniques were used to assist in characterizing the potential indoor formaldehyde sources.

The homes were indoors in the finishing building for at least 24 hours prior to testing. The building was heated to approximately 20 C during the testing. The fan depressurization testing was done first and the homes were then set up and left to stabilize for an additional 24 hours prior to the ventilation and formaldehyde measurements. Testing of the mobile homes indoors proved to be very advantageous as the units were shielded from transient temperature and wind pressure effects.

The homes tested were both standard production units, complete and ready for shipping to customers. They were complete with all built in cabinets and shelves but did not contain any furniture.

The exterior walls were 38 x 138 mm wood studs with RSI 3.5 glass fibre batt insulation. All interior walls were sheeted with 8 mm vinyl finished gypsum board. The roof construction used wood trusses and was insulated with blown mineral wool. Four mil polyethylene was used as the vapour barrier for walls and ceiling. The ceiling was 15 mm gypsum board with sprayed on stipple throughout. The floor system used wood joists insulated with glass fibre batt insulation. Subfloor was oriented strand board in areas that were to be carpeted and "cres deck" in areas that were to be covered with vinyl flooring. The "cres deck" is claimed (by the manufacturer) to be a low formaldehyde emission particleboard manufactured in California and certified for use in mobile homes.

All of the kitchen cabinets, counter tops and vanities were manufactured at the plant from sheet materials.

Natural gas forced air furnaces were used in both units. The supply air is delivered downward into a rectangular duct running along the center of the unit for its entire length. Round branch ducts are taken off to serve the individual rooms and areas. There is no return air duct system so return air is taken from the kitchen where the furnaces are located. A 100 mm spiral wound flexible vinyl duct is used to introduce outdoor air into the return air cabinet of the furnace. The air flow through the duct is governed by the on/off cycling of the furnace and the available static pressure in the furnace cabinet.

Additional ventilation can be induced by the bathroom fan located in the ceiling and vented out of the roof. The fan operation is controlled by a humidistat located in the hallway. The outside vented range hood over the stove is equipped with a two speed fan.

Domestic hot water is supplied by an electric water heater.

2) Triple E Homes Ltd.

Two mobile homes were studied during the field testing. The same general test protocol used at Shelter-Regent Industries was used in the Triple E homes.

The homes were outdoors (unheated or mechanically ventilated) for at least one week prior to being set-up for testing. The furnaces were connected to temporary propane gas supplies and electrical power approximately 36 hours prior to testing. The house thermostats were set to 22°C and the furnaces were allowed to operate to bring the homes up to the desired indoor temperature.

Upon arrival to the site, the testing crew discovered that the furnaces had failed to function properly and the indoor air temperature in the houses was approximately 15°C. The furnaces would not operate properly with the furnace fans running continuously and therefore, the fans were changed to automatic and the houses were left an additional 24 hours to stabilize the indoor conditions. Frequent electrical power failures necessitated the use of a portable electrical generator to ensure an uninterrupted electrical supply.

Both of the homes were standard production units, complete and ready for delivery to the owners. They contained all of the built in cabinets and cupboards but were completely unfurnished.

Exterior and interior wall, roof and ceiling construction were similar to the Shelter Industries units. Floor construction was similar except that particleboard was used throughout for the subflooring.

All of the interior cabinets and cupboard units were manufactured at the plant from sheet materials. The cupboard doors and drawer fronts were pre-manufactured by a sub-contractor.

The heating systems were similar to the Shelter Industries units with the exception that the fresh air intake ducts were 100 mm galvanized metal extending straight from the furnace return air connection out through the roof.

The bathroom exhaust fans were interlocked with the bathroom light switch and with a humidistat. The range hood was vented outside. The homes also incorporated two passive vents located high in the side of the exterior walls and vented directly through the wall.

Electric water heaters are used to supply the domestic hot water.

BASIC BUILDING SCIENCE PRINCIPLES

In order to identify the important building factors and understand their relationship to the overall study objectives, a simple single zone mass balance model is presented:

$$C_i = C_o + \frac{\Sigma\ (S - R)}{K \cdot V} \qquad (1)$$

where:

C_i = indoor formaldehyde concentration ($\mu g/m^3$)
C_o = outdoor formaldehyde concentration ($\mu g/m^3$)
S = strength of indoor formaldehyde source ($\mu g/hr$)
R = strength of indoor formaldehyde sinks ($\mu g/hr$)
K = mixing efficiency of the outdoor air (%)
V = outdoor air exchange rate (m^3/hr)

Although equation 1 is shown as a steady state relationship, all of the individual parameters can be complex functions of time environmental conditions and the other parameters.

The outdoor air exchange rate of the building is influenced by the air leakage characteristics of the building envelope and the operation of the mechanical ventilation equipment. The relationship describing the overall air exchange rate created by different combinations of unbalanced air exchange mechanisms should be added in quadrature (4) as:

$$V = (\Sigma\ V_k^2)^{0.5} \qquad (2)$$

where:

V_k = air exchange rate of k^{th} air exchange mechanism

Equation 2 shows that the individual contributions of unbalanced air exchange mechanisms are not directly additive as allowed for in the 1990 NBCC. Thus, attempts to increase the air exchange rate must be large with respect to the existing air exchange rate, in order to create a substantial effect. As an example, the addition of a 20 L/s exhaust fan to a building with an existing 100 L/s exhaust fan would, by equation 2, result in a total exhaust of only 102 L/s. Excessive negative pressures within the building may also be created by unbalanced ventilation systems where the exhaust rate exceeds the supply rate.

MEASUREMENT TECHNIQUES

Air Tightness

The fan depressurization test apparatus (5) was used to measure the overall air leakage characteristics of the homes. For each test, the home was depressurized through the range of 15 - 60 Pa and a calibrated nozzle was used to measure the corresponding airflow. An initial test was conducted with the house "as is" and subsequent tests were done with various sealing measures done to evaluate the reduction in air leakage associated with the sealing.

Prior to the formal fan depressurization testing, the home was depressurized to -50 Pa and a walkthrough was done to identify points of air leakage (50 Pa walkthrough checklists - Appendix 1). While not a quantitative assessment, the observations are useful in identifying defects in the building envelope air barrier. The investigation included subjective assessment of the air barrier by physical inspection of the air flow through building components. This inspection was done by a team with extensive experience in fan depressurization testing of wood framed buildings. A smoke pencil was used to assist in characterizing the flow.

Three general categories of air leakage were used as descriptors. Noticeable but small air leaks were defined as slight. These leaks would be considered normal for typical wood frame construction. Moderate air leaks had an easily detectable airflow indicating an airleak larger than would be expected for a well sealed enclosure. Major air leaks were large airflows indicating a significant discontinuity in the air leakage control system. This magnitude of leakage is well above what could be expected with a well sealed enclosure.

Air Exchange Rate

For the ventilation and formaldehyde measurements, the mobile homes were split into two zones. Nominally, these were selected as; the livingroom/kitchen zone (LRK) characterized as a large open space and the bedroom zone (BR) characterized as a number of small enclosed spaces. Measurements were made in the center of the livingroom and master bedroom and the values were assumed to represent the average condition in the entire zone.

The outdoor air exchange rate was calculated using the tracer gas decay technique (6). Initially, a volume of pure nitrous oxide (N_2O) was discharged into the home to raise the indoor concentration to 60-100 ppm. After allowing approximately 15 minutes for the tracer gas to mix, four consecutive one litre air samples were collected in mylar gas sampling bags at 10-20 minute intervals.

A Beckman Model 865 infrared gas analyzer was used to measure the N_2O concentration in the air samples. Before each set of sample bags were analysed, the gas analyser was zeroed with outside air and factory calibrated gases of 30 ppm and 70 ppm were used to adjust the span. It was noted before analysis of the sample bags from manufacturer B (tests 3 and 4) that the gas analyser failed to zero and span properly and these concentration data were not recorded. All air samples were analyzed on site within one hour of sampling. The average air exchange rate, V_1 (air changes per hour, ach), was calculated as:

$$V_1 = \frac{\Delta \ln C_j}{\Delta t_j} \qquad (3)$$

where:

C_j = N_2O concentration at time (t_j)
t_j = time (hr)

The tracer gas technique was used to study the effect of various ventilation system operating scenarios. Conditions were set up to monitor the air exchange rate that could be obtained with some of the following conditions:

Test 1. Furnace fan ON/OFF, bathroom fan OFF, interior doors open.

Test 2. Furnace fan ON, bathroom fan ON, interior doors open.

Test 3. Furnace fan ON/OFF, bathroom fan OFF, interior doors closed.

Test 4. Furnace fan OFF, bathroom fan ON, interior doors closed.

A single injection of tracer gas was used for all decay measurements. In tests 1 and 3, after the first set of four grab samples were taken, the furnace fan was shut off and an additional set of four samples was taken.

As part of the ventilation study, the airflow characteristics of some of the furnace fresh air intake ducts were studied. Since some of the furnace rooms were completely filled with the furnaces, it was not always possible to measure the fresh air intake duct flow with the furnace room door closed as would be the normal operating situation. As an alternative, the duct flow was calculated using field measured duct flow characteristics and the measured negative pressure of the return air plenum of the furnace with the door closed.

To obtain the duct flow characteristic of the fresh air intake duct, the fan depressurization apparatus was used to depressurize the house. The air flow and corresponding negative pressure in the return air cabinet of the furnace (house pressure) were measured over a range of pressures from 15 - 60 Pa. This established the air flow characteristic of the duct. Using a digital manometer, the pressure difference between outdoors and the return air compartment of the furnace was measured with the furnace room door closed and the furnace fan operating. Using the operating pressure difference and the flow characteristic of the duct, the air flow through the fresh air intake duct with the furnace fan on was calculated.

Indoor Formaldehyde Concentration

The indoor formaldehyde concentration is related to the strength of the indoor sources. Therefore, information is needed on the individual component emissions and on the combined effect of all of the interior components.

Before each indoor formaldehyde measurement, the windows were closed and the home was allowed to stabilize for 24 hours. Since formaldehyde emissions from building materials are sensitive to changes in indoor formaldehyde concentration, ventilation, temperature and humidity, this preconditioning was essential to allow indoor conditions to reach a state of quasi-equilibrium.

Indoor concentrations were measured in two locations (master bedroom and livingroom) in each home under two different ventilation conditions. The initial condition was with the home "as is" and the furnace fan running continuously. In the second set-up, the furnace fan was off. These two conditions were selected to represent the extremes of "normal" operation. In the first condition the air circulation and overall air exchange rate would be high (the bathroom and range exhaust fans are not designed for continuous operation), in the second case the circulation and air exchange rate would be negligible. The fan off test could not be conducted on the Triple E houses since the furnace operation was required to heat the units.

Air exchange rate, temperature and humidity were measured simultaneously with the formaldehyde concentration over a period of 1½ to 2 hours.

The formaldehyde concentrations were measured using two different techniques:

The primary method used for measuring the indoor concentration was a passive technique (ATL Inc.) where the formaldehyde in the air diffused through a permeable barrier into a test tube containing an absorbing solution. The kit provided two different diffusion disks, allowing two or eight hour sampling periods. A nominal two hour period was used for the testing. Upon completion of the sampling, a reagent was added to the absorbing solution to induce a colour change that was detected by a photospectrometer and related to the formaldehyde concentration of the air.

As a supplementary method for comparison, Gastec formaldehyde detector tubes were used to sample the air in some areas of the mobile homes. The tubes were No. 91L with a measurement range of 0.2 - 5.0 ppm and a lower detection limit of 0.05 ppm.

Formaldehyde Source Characterization

The major sources of formaldehyde in mobile homes are thought to be from the construction materials, specifically the glues and resins used in panelling, fibreboard and particleboard. Research conducted on formaldehyde emissions from materials has resulted in the development of a number of different measurement techniques. Canadian manufacturers of particleboard have developed a test method for measuring the formaldehyde emissions from particleboards and have developed a voluntary standard of 2.0 milligrams per litre (1630 ppm) based on the Canadian Two-Hour Desiccator Test Method (7).

Surface coatings and treatments, cutting and processing of these "raw" boards into the cabinets, shelves and furnishings of a home will significantly affect the original materials' offgassing characteristics. These intermediate processes are done at various levels, including secondary manufacturers who apply surface coatings or laminates to the basic boards and mobile home manufacturers who produce a variety of sub-components "in house". This diverse usage increases the problems associated with predicting the performance of the materials. The most relevant information is the on-site emission potential of these materials and components.

Two experimental techniques were used to evaluate the emission potential of the materials:

1) In the mobile home

The equilibrium concentration of formaldehyde in the building products was measured in a number of areas in the mobile home. Polyethylene boxes with a volume of approximately one litre were sealed to the surface and allowed to remain there for 24 hours. Twenty-four hours was chosen as a standard time to allow the formaldehyde concentration in the box to reach equilibrium. Selected cupboards and drawers were left unopened for 24 hours to allow the formaldehyde concentration in the air in them to reach equilibrium. Gastec No. 91L detector tubes were used to measure the formaldehyde concentration of the air in the poly boxes or enclosures. A tube was inserted under the carpet underlay to sample the air directly above the subfloor material in the livingrooms. The temperature and humidity of the mobile home were measured before and after the testing so that values obtained under different conditions could be corrected to standard conditions (25°C and 50% relative humidity) using the Berge equation (8). The temperature and humidity of the sub-floor were assumed to be the same as for the interior of the mobile home.

2) At the manufacturing site

The second method of assessing the formaldehyde emissions involved selecting samples of certain components (cupboard doors, shelving panels, assembled components) and sealing them in 6 mil polyethylene bags for 24 hours prior to using the Gastec tubes to measure the formaldehyde concentration of the air inside of the bags. The temperature and humidity of the air when the samples were enclosed and when the measurements were taken were measured so that the results could be corrected to standard conditions.

This type of technique has merit since it could be used at the product specification stage to screen materials. In the absence of formal test methods and rating criteria (not in place in Canada) mobile home manufacturers could ask suppliers to submit samples of proposed materials for testing along with their price quotations. The formaldehyde emission information could be considered in the overall cost/benefit analysis of the product.

RESULTS

Table 1 summarizes some of the test conditions and basic measurements from the field study.

Air Tightness

The 50 Pa Walkthrough Checklists for the individual mobile homes are included in Appendix 1.

A number of major air leakage sites were identified and can be generally categorized as:

1) Defective air leakage control systems.

These include areas where attempts to seal have been made but were not successful.

Moderate to major air leaks occurred at most of the duplex receptacles, switches and light fixtures. Ceiling/wall penetrations for wiring at the electrical panel and furnace cabinet have major air leaks. Ceiling penetrations for the fresh air intake, range hood exhaust duct and furnace chimney have major air leaks. The junction of the exterior walls and ceiling have some moderate/major leakage, especially at corners and intersections with the cathedral/flat ceiling. Plumbing penetrations through the exterior walls had moderate air leakage.

2) Lack of air leakage control system.

These include areas where there does not appear to be a system in place to control air leakage.

Major leakage sites included plumbing penetrations through the floor for water lines and drains. The bathtub floor cut out was an opening approximately 0.2 m square.

Table 2 lists the air tightness test results for the homes tested as is and under several conditions of sealing specific leakage sites identified in the 50 Pa walkthrough. The values ranged from 3.7 to 5.8 ach @ 50 Pa with the openings sealed. For comparison, the Energy, Mines and Resources R-2000 program allows a maximum of 1.5 ach @ 50 Pa. A 1989 cross Canada study of 200 new site built houses showed a group average of 2.5 ach @ 50 Pa for the twenty Saskatchewan houses (9).

In the sequential sealing tests at manufacturer A, some of the penetrations were sealed at the interior surface. These tests included taping over electrical components to determine the leakage attributed with these areas. This sealing slightly reduced the leakage but is not a true indication of the severity of the leak since air will move relatively freely through the building walls (especially interior partitions) and under cabinets and vanities. Primary sealing must be done at the specified air barrier location, not as a post construction retrofit using gaskets.

For manufacturer A, the ELA's for the fresh air intake ducts were 0.0038 m^2 and 0.0039 m^2 as compared with 0.0011 m^2 and 0.0021 m^2 for manufacturer B.

Air Exchange Rate and Indoor Formaldehyde Concentration

The results of the air exchange rate and indoor formaldehyde concentration measurements are summarized in Tables 3a and 3b. A gas analyser failure prevented accurate analysis of the tracer gas concentration samples for the remaining tests noted in Table 3b.

Test 1 was conducted to show the air exchange rates and corresponding indoor formaldehyde concentrations that could be expected under ordinary heating season conditions of intermittent furnace fan operation. Long periods with no furnace fan operation could occur with the use of supplementary electric heaters or with a set-back in the space heating thermostat set point.

For both manufacturer A units, the fan on air exchange rate was approximately 0.4 ach with only slight differences between the living room and bedroom areas. The corrected indoor formaldehyde concentrations were also very similar (approximately 0.4 ppm) in all areas.

In units A1 and A2, the calculated air flow through the fresh air intake ducts (assuming straight addition of the flows as allowed by the NBCC) corresponds to air exchange rates of 0.32 ach and 0.36 ach respectively. These results agree reasonably well with the tracer gas measurements of 0.40 ach and 0.39 ach.

For manufacturer B, the fan on air exchange rate was approximately 0.2 ach with only slight differences between zones. The corrected indoor formaldehyde concentrations were also similar (0.3 ppm) with the exception of the bedroom in unit B1 which was almost 0.5 ppm.

It should be noted that the manufacturer A units were tested indoors and the outdoor air exchange rates do not include infiltration caused by wind and temperature gradients. The air exchange rates in the manufacturer B units include both infiltration and mechanical ventilation.

As the building envelope air leakage characteristics are quite similar for all of the units, the large difference in the Test 1 air exchange rates between manufacturer A and B is probably due to the ELA of the fresh air intake ducts. The manufacturer B units have more restrictive fresh air intake ductwork systems (ELA 0.0011 m^2 and 0.0021 m^2) compared to manufacturer A (approximately 0.004 m^2) and proportionally lower overall air exchange rates.

Test 3 used the same test conditions as Test 1 with the interior doors closed. With the furnace fan on, closing of the interior doors did not reduce the calculated air exchange rate. Consistent with some other tracer gas results (10), closing the interior doors resulted in an apparent increase in the tracer gas decay rate since the room air is forced to more thoroughly mix.

For manufacturer A test conditions with all fans off, the tracer gas tests gave air exchange rates of zero. These values are confirmed for the indoor houses since, in the absence of any temperature gradients or wind pressures (the mobile homes were located within a heated building), infiltration rates should be negligible.

In the case of the maximum ventilation (furnace and bathroom fan on, Test 2) the overall air exchange rate was 0.68 ach (0.28 ach increase over Test 1) for unit A1 and 0.76 ach (0.37) for unit A2. For bathroom fans with equal volume flow rates, a higher air exchange rate would be expected in unit A2 as it has a smaller volume than A1.

Test 2 in the manufacturer B houses resulted in average air exchange rates of 0.26 ach and 0.34 ach for units B1 and B2 respectively. The increase in air exchange rate from the Test 1 conditions were 0.006 ach for unit B1 and 0.13 ach for unit B2. The reason for the much larger air exchange rate induced by the manufacturer A bathroom fans is not immediately obvious since all of the units used similar residential bathroom exhaust fans (one in each manufacturer A home and two in each manufacturer B home). An examination of the fans and the exhaust ducting arrangement may reveal some systematic differences.

Formaldehyde Source Characterization

Table 4 shows the type of material and the measured and corrected values of the formaldehyde equilibrium concentration for either the poly box (4a), poly bag (4b and 4c) or enclosed space (4d) tests. For the poly box and enclosed space tests, the indoor conditions were close to standard conditions and the Berge equation correction were slight.

For manufacturer A, the combination of high winds and a failure of the building heating system allowed the building with the poly bag test samples to become quite cold and dry (15°C and 17% RH). For these test data, the correction to standard conditions produces a large increase in the equilibrium concentrations. The manufacturer B poly bag test specimens were stored in one of the test houses and were maintained at near standard conditions so the corrections were small.

Although there is substantial variation in the results, it is clear that there are different classes of materials in terms of their equilibrium concentrations and potential contribution to the indoor formaldehyde concentration. There were also significant differences between some materials used by the different manufacturers. Specific comparisons can be done using data from the tables, however some general comments are given.

In the poly box tests at manufacturer A, the particleboard in the kitchen cupboard shelving (even with the vinyl finish), underside of the counter tops and bedroom closet doors and shelving all exceeded the maximum 5.0 ppm range of the detector tubes. Similar results were obtained from the poly bag tests on the site built particleboard materials and prefinished cupboard doors. For manufacturer B, only the underside of the kitchen counter top exceeded 5.0 ppm.

The manufacturer A hardboard test in the poly bag did not show the presence of formaldehyde, yet it was detected in both locations in the poly box testing. One explanation for this is that high levels of formaldehyde in the cabinet enclosure penetrated the hardboard, causing it to become a secondary emitter. The poly bag test of the manufacturer B hardboard exceeded 3.5 ppm.

Surface emissions off the topside of all of the carpets showed low (0.4-0.6 ppm) formaldehyde levels. Only slightly higher levels (approximately 0.7 ppm) were measured under the carpet underpad of manufacturer A and levels below 0.3 ppm were measured at manufacturer B.

The enclosed space tests at manufacturer A showed cupboard interior formaldehyde levels at 3 - 4 ppm and cabinet drawers at approximately 2 ppm. For manufacturer B, the cupboard level was 0.85 ppm and the drawer level was 0.36 ppm.

DISCUSSION AND CONCLUSIONS

The fan depressurization testing highlighted several important areas regarding the building envelope.

Air leakage rates are much higher than the average for new site-built Saskatchewan houses. The 50 Pa walkthrough identified a number of areas where major air leakage was occurring and the subsequent depressurization tests with site sealing were conducted to examine the relative effect of these leaks on the overall air leakage of the building. The data in Table 2 show that, while the electrical outlets appeared moderately leaky in the subjective assessment of the walkthrough, taping them over did not significantly reduce the air leakage of the building. One possible explanation for this is that the air, after leaking through the polyethylene "air/vapor barrier" short circuited through stud spaces via wiring holes and out through cracks in the wallboard rather than being stopped by the tape. Since the construction allows for many alternate points of entry, the air control surface must be continuous.

Although it was not included in this study, the location of the neutral pressure plane (the vertical location in the building where the indoor/outdoor pressure difference is zero) is an important consideration. Areas of the building envelope below the neutral pressure plane will experience infiltration, areas above the neutral pressure plane will experience exfiltration. For this case of a moderately well sealed building envelope with large holes in the floor level, the neutral pressure plane would be near the elevation of the holes. The implications of this for mobile homes is that, if the sealing of the floor area can not be significantly increased, the maximum stack effect pressure drop will occur across the ceiling of the mobile home. This will result in the maximum potential for moisture penetration into the building envelope and subsequent damage.

The major indoor source of formaldehyde appears to be the particleboards.

With furnace fans operating continuously, the outdoor air exchange rates were below the base flow rate requirements (equivalent to 0.67 ach for unit A1 and 0.71 ach for unit A2) of CSA F326.1 (12). The CSA required flows could only be achieved with continuous operation of the furnace and bathroom exhaust fans.

The ASHRAE ventilation standard outlines two procedures for obtaining acceptable indoor air quality. The ventilation rate procedure follows the method of CSA F326.1 and the NBCC, whereby a outdoor air exchange rate is specified based on a "generic" pollutant load in the building. This method may result in unacceptable conditions when non-typical building conditions are present. The alternative method (IAQ procedure) addresses the known pollutant sources and uses them to calculate the required dilution ventilation. In buildings with relatively high specific pollutant sources (such as the formaldehyde sources these mobile homes), the IAQ procedure method will result in higher ventilation rate requirements. Equation 1 is one application of the IAQ procedure and highlights the need for accurate data on the pollutant sources.

With continuous furnace fan operation, indoor formaldehyde concentrations greatly exceeded the 0.1 ppm guideline limit established by Health and Welfare Canada. Indoor levels increased to in excess of 0.6 ppm with no fan operation.

The corrected indoor formaldehyde concentration and outdoor air exchange rate in manufacturer B units were lower than for manufacturer A. Initially, these data appear contrary, however an inspection of the indoor formaldehyde sources shows that, overall, the manufacturer B building components appear to have lower equilibrium levels of formaldehyde. Since the quantity, quality and distribution of the materials were different in each unit, this statement can not be quantified based on the data from this study and is included as a general observation only.

RECOMMENDATIONS

1) Develop construction design details and practice that will improve building envelope airtightness. Special consideration of the floor system is required since a major area of air leakage is through the floor. This will require research/measurements of thermal and moisture conditions in the floor systems. Industry members expressed concerns regarding the tightening of the floor system because of the potential problem of plumbing freezing. At present, uncontrolled air leakage and ductwork leakage are perceived to prevent plumbing freezing, however the efficacy of this process and the resulting energy consumption and moisture accumulation are not well understood.

   To enhance the development of improved air leakage control systems, three distinct steps must be taken:

   A comprehensive review of the design and construction process to identify the air leakage control system and ensure that it is continuous and properly located. This will require intensive review of the construction drawings and development of specific procedures to deal with all of the unique details. Documents including "Energy Efficient Housing - A Prairie Approach" (11) would provide a useful starting point for the review.

   Develop an educational program for transforming the design details into production practice.

   Create quality assurance procedures for evaluation of the finished product. This should include various levels of inspection and may require fan depressurization testing to assist in the development.

2) Develop simple techniques for manufacturers to evaluate the "potential" for formaldehyde emissions from building materials. Until consistent supplies of low emission products are found or a product rating system is in place, the poly bag testing may form the basis of an initial test that mobile home manufacturers could use to screen potential products.

3) Develop practical, cost-effective methods to reduce emissions of chemicals from the building materials. Techniques should be appropriate for not only raw boards, but manufactured components and assemblies as well. Research work by Godish (13) on the effect of surface treatments could form the basis for developing control technology.

4) Develop mechanical systems for outdoor air supply and distribution that are cost-effective and acceptable to the consumer. At present, mechanical system noise and energy

costs may be major deterrents to the continuous operation of the furnace fan which can increase the outdoor air exchange. The ELA of the fresh air intake ducts was significantly different for the two manufacturers and would result in the difference in outdoor air exchange rates with the furnace fans on.

These recommendations are all directed at improving the control over the production of mobile homes. The combination of unmeasured or regulated levels of air leakage, indoor pollutant sources and outdoor air exchange rates results in an unpredictable level of indoor air quality. Tightening of the building envelope will reduce the uncontrolled outdoor air exchange under certain conditions. This will decrease unnecessary over-ventilation of the building but will require the installation of a mechanical ventilation system to ensure adequate outdoor air exchange. By improving the control over these building factors, the range of resulting conditions can be narrowed.

OTHER RELEVANT ISSUES

Education is an important aspect of any quality assurance program. Development of a set of quality objectives is the first step in the process. Management must identify these objectives and then develop a sequential plan for transferring these objectives into executable tasks.

This study is an industry initiative to examine the present "state of the art" in defined areas of mobile home manufacturing. The observations and recommendations from this study should be considered by management and balanced with the many other factors involved in the production of mobile homes.

Translation of these technical concepts into results that will improve the product will require a substantial commitment of time and resources. As an example, spurred on by the energy crisis of the late 1970's, the development of fan depressurization technology lead to major changes in site-built house construction. While originally driven by energy conservation (which has faded somewhat) the research has resulted in an industry that can consistently build much tighter building envelopes. It is now apparent that the reduction of infiltration for the purpose of reducing heat loss was only one contribution. Thus, while the original driving force behind improved airtightness may have faded, the tangible benefits of these tightened envelopes (improved capability to handle interior moisture and resist concealed condensation damage and better control of outdoor air pollutants and noise) remain sufficient justification for the tightening measures.

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MANUF. CODE	YEAR BUILT	FLOOR AREA m2	INDOOR TEMP. deg. C (% RH)	ZONE VOLUMES BR (TOTAL) LRK m3	AIR TIGHTNESS ach @ 50 Pa	ELA m2	ENVELOPE AREA m2	NLA cm2/m2
A1	1989	90.58	24.5 (39)	115.19 (215.93) 100.74	4.61	0.0409	295.92	1.38
A2	1989	74.10	25.75 (39)	83.50 (176.84) 93.34	5.59	0.0426	233.97	1.82
B1	1990	101.98	26 (35)	94.83 (246.89) 152.06	4.33	0.0399	330.04	1.21
B2	1990	100.88	24 (37)	87.56 (242.07) 154.51	5.89	0.0562	328.07	1.71

Table 1. Mobile home data

MANUF. CODE	TEST NUMBER	AIR TIGHTNESS ach @ 50 Pa	C L/s.Pa^n	n	ELA m2	CONDITIONS
A1	1	4.61	24.448	0.6203	0.0409	As received-nat. gas pipe access hole taped. Basins plugged, overflows taped, water in toilet.
	2	4.58	25.763	0.6053	0.0417	Masking tape over switch plates and plug covers.
	3	4.05	22.658	0.6066	0.0368	Plumbing penetrations and electrical conduit caulked.
	4	3.70	19.715	0.6189	0.0329	Fresh air intake duct blocked.
A2	1	5.59	27.236	0.5905	0.0426	As received-nat. gas pipe access hole taped. Basins plugged, overflows taped, water in toilet.
	2	5.25	26.514	0.5813	0.0406	Masking tape over switch plates and plug covers.
	3	4.33	20.457	0.5988	0.0326	Plumbing penetrations and electrical conduit caulked.
	4	3.92	17.415	0.6141	0.0288	Fresh air intake duct blocked.
B1	1	4.33	20.729	0.6804	0.0399	As received-antifreeze in plumbing traps.
	2	4.32	19.447	0.6963	0.0388	Fresh air intake duct blocked.
B2	1	5.89	31.576	0.6465	0.0562	As received-antifreeze in plumbing traps.
	2	5.77	29.652	0.6573	0.0541	Fresh air intake duct blocked.

Table 2. Air tightness test results from fan depressurization testing

MANUF. CODE	TEST	CONDITIONS	BR AIR EXCHANGE RATE ach	LRK AIR EXCHANGE RATE ach	COMBINED BR/LRK AIR EXCHANGE RATE ach	HCOH BR (CORRECTED) ppm	HCOH LRK (CORRECTED) ppm
A1	1	FURNACE FAN ON/OFF BATHROOM FAN OFF INTERIOR DOORS OPEN	0.33/0.02	0.45/0.00	0.40/0.01	0.31/0.67 (0.40)/(0.85)	0.32/0.71 (0.41)/(0.90)
	2	FURNACE FAN ON BATHROOM FAN ON INTERIOR DOORS OPEN	0.66	0.70	0.68	--	--
	3	FURNACE FAN ON/OFF BATHROOM FAN OFF INTERIOR DOORS CLOSED	0.43/0.01	0.43/0.02	0.43/0.01	--	--
A2	1	FURNACE FAN ON/OFF BATHROOM FAN OFF INTERIOR DOORS OPEN	0.37/0.04	0.42/0.03	0.39/0.04	0.31/0.50 (0.40)/(0.61)	0.34/0.50 (0.38)/(0.61)
	2	FURNACE FAN ON BATHROOM FAN ON INTERIOR DOORS OPEN	0.78	0.75	0.76	--	--
	3	FURNACE FAN ON/OFF BATHROOM FAN OFF INTERIOR DOORS CLOSED	0.67/0.00	0.64/0.00	0.65/0.00	--	--
	4	FURNACE FAN OFF BATHROOM FAN ON INTERIOR DOORS CLOSED	0.57	0.36	0.46	--	--

Table 3a. Air exchange rates and indoor formaldehyde concentrations

MANUF. CODE	TEST	CONDITIONS	BR AIR EXCHANGE RATE ach	LRK AIR EXCHANGE RATE ach	COMBINED BR/LRK AIR EXCHANGE RATE ach	HCOH BR (CORRECTED) ppm	HCOH LRK (CORRECTED) ppm
B1	1	FURNACE FAN ON FURNACE DOOR OFF BATHROOM FANS OFF	0.18	0.21	0.20	0.41 (0.49)	0.26 (0.31)
	2	FURNACE FAN ON FURNACE DOOR ON BATHROOM FANS ON	0.28	0.24	0.26	--	--
	3	FURNACE FAN ON FURNACE DOOR ON BATHROOM FANS OFF	**	**	**	--	--
	4	FURNACE FAN OFF FURNACE DOOR ON BATHROOM FANS OFF	**	**	**	--	--
B2	1	FURNACE FAN ON FURNACE DOOR OFF BATHROOM FANS OFF	0.23	0.20	0.21	0.23 (0.33)	0.23 (0.33)
	2	FURNACE FAN ON FURNACE DOOR ON BATHROOM FANS ON	0.38	0.32	0.34	--	--
	3	FURNACE FAN ON FURNACE DOOR ON BATHROOM FANS OFF	**	**	**	--	--
	4	FURNACE FAN OFF FURNACE DOOR ON BATHROOM FANS OFF	**	**	**	--	--

**NRC equipment malfunction

Table 3b. Air exchange rates and indoor formaldehyde concentrations

MANUF. CODE	LOCATION (F) - finished surface (UF) - unfinished surface	HCOH CONC. ppm	HCOH CONCENTRATION CORRECTED ppm
A1	KIT CABINET SHELF (F)	>5.0	>5.00
	KIT COUNTER TOP (UF)	>5.0	>5.00
	LR CARPET SURFACE	0.4	0.57
	KIT CABINET SIDE (UF)	1.3	1.85
	CLOSET DOOR BACK (UF)	>5.0	>5.00
	KIT CABINET DOOR (F)	1.0	1.42
	BR SHELF PLYWOOD (UF)	0.1	0.14
	BR SHELF PBOARD (UF)	>5.0	>5.00
A2	KIT CABINET SHELF (F)	>5.0	>5.00
	LR CARPET SURFACE	0.3	0.56
	KIT CABINET SIDE	1.2	2.26
	CLOSET DOOR BACK (UF)	>5.0	>5.00
	KIT CABINET DOOR (F)	2.0	3.76
	KIT CABINET SHELF (F)	>5.0	>5.00
B1	KIT CABINET SHELF	2.0	2.39
	LR CARPET SURFACE	0.3	0.36
	KIT CABINET DOOR (F)	1.7	2.03
B2	KIT COUNTER TOP (UF)	5.0	7.11
	KIT CABINET DOOR (F)	0.25	0.36
	BR CLOSET SHELF (F)	0.5	0.71
	BR CLOSET DOOR (F)	1.6	2.28

Test conditions - A1 - 22.5 deg. C, 45% RH
Test conditions - A2 - 21.6 deg. C, 36.5% RH
Test conditions - B1 - 26 deg. C, 35% RH
Test conditions - B2 - 24 deg. C, 37% RH

Table 4a. Poly box formaldehyde emission test results

MANUF. CODE	MATERIAL	HCOH CONC. ppm	HCOH CONCENTRATION CORRECTED ppm
A	Finished particleboard-cupboard material	1.10	8.01
	Finished particleboard	0.25	1.82
	MDF board-finished	0.20	1.46
	Hardboard-finished (1 side)	0.00	0.00
	Particleboard-drawer sides-finished	0.30	2.19
	Particleboard shelving-MDF front	0.70	5.10
	Cabinet unit-MDF board	0.00	0.00
	Particleboard-cabinet door fronts-finished	>5.00	>5.00
	Cabinet door fronts	0.00	0.00
	Cresdeck-particleboard flooring	0.50	3.64

Test conditions - 15 deg. C, 17% RH

Table 4b. Poly bag formaldehyde emission test results

MANUF. CODE	MATERIAL	HCOH CONC. ppm	HCOH CONCENTRATION CORRECTED ppm
B	Cabinet unit - plywood	1.1	1.11
	One complete drawer - particleboard, MDF board	2.2	2.22
	Cabinet doors - particleboard with vinyl facing - four exposed edges	0.6	0.6
	Plywood veneer for cabinet sides	6.0	6.04
	Cabinet doors - all sides finished	1.2	1.21
	Drawer sides - MDF board	3.2	3.22
	Drawer bottom - hardboard	3.5	3.53
	Counter top material - particleboard	>5.0	>5.0
	Shelving, drawer back panels - particleboard	5.0	5.04
	Floor decking - particleboard	1.2	1.21

Test conditions - 28.25 deg. C, 32% RH

Table 4c. Poly bag formaldehyde emission test results

MANUF. CODE	CAVITY	HCOH CONC. ppm	HCOH CONCENTRATION CORRECTED ppm
A1	LR FLOOR BETWEEN UNDERLAY & SUBFLOOR	0.5	0.71
	KIT CABINET	2.2	3.13
	KIT CABINET DRAWER	1.1	1.57
A2	LR FLOOR BETWEEN UNDERLAY & SUBFLOOR	0.4	0.75
	KIT CABINET	2.2	4.14
	KIT CABINET DRAWER	1.0	1.88
B1	LR FLOOR BETWEEN UNDERLAY AND SUBFLOOR	0	0
	BEDROOM CABINET DRAWER	0.3	0.36
	WALL CAVITY BEHIND BUFFET	5.0	5.97
B2	LR FLOOR BETWEEN UNDERLAY AND SUBFLOOR	0.2	0.28
	KITCHEN CABINET	0.6	0.85

Test conditions - A1 - 22.5 deg. C, 45% RH
Test conditions - A2 - 21.6 deg. C, 36.5% RH
Test conditions - B1 - 26.0 deg. C, 35% RH
Test conditions - B2 - 24.0 deg. C, 37% RH

Table 4d. Enclosed space formaldehyde emission test results

WALKTHROUGH CHECK LIST

DATE 1989/11/30

INSPECTED BY DAF/JTM

Legend	
N	- not perceptible
S	- slight
MO	- moderate
MA	- major

MANUFACTURER A 1 MODEL # ______ SERIAL # ______

FAN DEPRESSURIZATION 50 Pa

WINDOWS:

TYPE/DESCRIPTION	LOCATION	SEALS	FRAME/ENVELOPE
1.	BEDROOM	S	S
2.	MAST. BEDROOM	S	S
3. SKYLIGHT	KITCHEN		S
4.			
5.			

DOORS:

TYPE/DESCRIPTION	LOCATION	SEALS	FRAME/ENVELOPE
1. METAL	BACK DOOR	N (S at corners)	MO
2.			
3.			

PLUMBING:

TYPE/DESCRIPTION	LOCATION	LEAKAGE
Water Heater		MA
Service Waterline		MA
Basin Drain/Waterlines	BATHROOM	S
Tub Drain/Waterlines		S
Sink Drain/Waterlines	KITCHEN	MO
Washing Machine Drain/Waterlines		MA

ELECTRICAL:

TYPE	LOCATION	INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Breaker Panel		MA	MA
Supply Conduit		MA	MA

ELECTRICAL (cont'd):

TYPE		LOCATION	INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Interior Wall Plug	1.	KITCHEN	MO	
	2.			
	3.			
Exterior Wall Plug	1.	LIVING ROOM	MO	MO
	2.			
	3.			
Ceiling light fixture	1.	LIVING ROOM	MO	
	2.	BEDROOM	MA	
	3.	HALLWAY	S	
Interior wall switches	1.	HALLWAY		MA
	2.			
	3.			
Exterior wall switches	1.	HALLWAY	MA	
	2.			
	3.			
Dryer Plug			MO	
Washer Plug			MO	

HEATING/VENTILATING:

TYPE		LOCATION	LEAKAGE
Floor register/floor	1.	MASTER BEDROOM	MA
	2.		
	3.		
Ductwork	1.		
	2.		
	3.		
Gas/Oil/Electricity Supply to Furnace		HOLE TAPED OVER FOR TEST	
Furnace Cabinet		CHIMNEY . WIRE PENETRATION	MO

		INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Bathroom Fans	1.	MO	MO
	2.		
Range Hood (outside vented)			MA

(LEAKING THROUGH BACKDRAFT DAMPER ALSO)

OTHER:

TYPE		LOCATION	LEAKAGE
Fireplace damper		N.A.	
Fireplace Chimney/Envelope Seal		N.A.	
Pressure Relief Vents	1.	N.A.	
	2.		

ENVELOPE DETAILS:

TYPE		LOCATION	LEAKAGE
Floor/exterior wall	1.	MASTER BEDROOM	S
	2.	LIVING ROOM	MO
	3.		
Ceiling/exterior wall	1.	MASTER BEDROOM	S
	2.	KITCHEN	MO
	3.		
Ceiling/interior wall	1.	HALLWAY	N
	2.		
	3.		

OTHER:

ELEC. WIRING THROUGH CEILING BY PANEL - MAJOR (INTERNAL)

TOILET SUPPLY WATER LINE - MODERATE

WALKTHROUGH CHECK LIST

DATE 1999/12/1

INSPECTED BY DAF / JTM

Legend	
N	not perceptible
S	slight
MO	moderate
MA	major

MANUFACTURER A2 MODEL # ______ SERIAL # ______

FAN DEPRESSURIZATION 50 Pa

WINDOWS:

	TYPE/DESCRIPTION	LOCATION	SEALS	FRAME/ENVELOPE
1.		BEDROOM	S at corners	
2.		all windows the same		
3.				
4.				
5.				

DOORS:

	TYPE/DESCRIPTION	LOCATION	SEALS	FRAME/ENVELOPE
1.	STEEL	BACK DOOR	MO	MO
2.				
3.				

PLUMBING:

TYPE/DESCRIPTION	LOCATION	LEAKAGE
Water Heater		MA
Service Waterline		
Basin Drain/Waterlines		MA
Tub Drain/Waterlines		MA
Sink Drain/Waterlines		MA
Washing Machine Drain/Waterlines		

ELECTRICAL:

TYPE	LOCATION	INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Breaker Panel			MA
Supply Conduit			MA

ELECTRICAL (cont'd):

TYPE		LOCATION	INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Interior Wall Plug	1.	KITCHEN	MO	
	2.			
	3.			
Exterior Wall Plug	1.	LIVING ROOM	MO	
	2.			
	3.			
Ceiling light fixture	1.	BEDROOM 2	MA	
	2.	MAST. BEDROOM	MA	
	3.			
Interior wall switches	1.	KITCHEN	MO	
	2.			
	3.			
Exterior wall switches	1.	HALLWAY	MO	
	2.			
	3.			
Dryer Plug			MO	
Washer Plug			MO	

HEATING/VENTILATING:

TYPE		LOCATION	LEAKAGE
Floor register/floor	1.		
	2.		
	3.		
Ductwork	1.		
	2.		
	3.		
Gas/Oil/Electricity Supply to Furnace			
Furnace Cabinet			
		FURNACE CHIMNEY	MA
		FURNACE F.A. INTAKE AT CEILING	MA
		FURNACE ELECTRICAL SUPPLY	MA

c:\wp50\admin\walk
16 November 1989

		INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Bathroom Fans	1.	MO	MO
	2.	(backdraft damper	not closing)
Range Hood (outside vented)			

OTHER:

TYPE		LOCATION	LEAKAGE
Fireplace damper		N.A.	
Fireplace Chimney/Envelope Seal		N.A.	
Pressure Relief Vents	1.	N.A.	
	2.		

ENVELOPE DETAILS:

TYPE		LOCATION	LEAKAGE
Floor/exterior wall	1.	LIVING ROOM (OUTSIDE CORNERS)	N
	2.	MASTER BEDROOM	N
	3.		
Ceiling/exterior wall	1.	MASTER BEDROOM (CORNERS)	MA
	2.	LIVING ROOM (CORNERS)	MA
	3.		
Ceiling/interior wall	1.	MASTER BEDROOM	MO
	2.		
	3.		

OTHER:

TOILET WATER SUPPLY LINE - MAJOR LEAKAGE

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16 November 1989

WALKTHROUGH CHECK LIST

DATE 1990/3/17

INSPECTED BY DAF / JTM

Legend	
N	- not perceptible
S	- slight
MO	- moderate
MA	- major

MANUFACTURER B 1 MODEL # ________ SERIAL # ________

FAN DEPRESSURIZATION 50 Pa

WINDOWS:

TYPE/DESCRIPTION	LOCATION	SEALS	FRAME/ENVELOPE
1.	FRONT BEDROOM		MO around frame at gasket
2.	LIVING ROOM		N
3.	MASTER BEDROOM		N
4.			
5.			

DOORS:

TYPE/DESCRIPTION	LOCATION	SEALS	FRAME/ENVELOPE
1.	BACK DOOR		S
2.			
3.			

PLUMBING:

TYPE/DESCRIPTION	LOCATION	LEAKAGE
Water Heater - PUTTIED		
Service Waterline - PUTTIED		
Basin Drain/Waterlines	BOTH BATHROOMS	MO
Tub Drain/Waterlines		
Sink Drain/Waterlines	KITCHEN	MO - through floor
Washing Machine Drain/Waterlines		MO to MA

ELECTRICAL:

TYPE	LOCATION	INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Breaker Panel } COVER ON		N	
Supply Conduit }		N	

ELECTRICAL (cont'd):

TYPE		LOCATION	INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Interior Wall Plug	1.	generally	N	
	2.			
	3.			
Exterior Wall Plug	1.	FRONT BEDROOM		MO
	2.	MASTER BEDROOM		MO
	3.			
Ceiling light fixture	1.	FRONT BEDROOM		MO
	2.			
	3.			
Interior wall switches	1.	FRONT BEDROOM		N
	2.	BEDROOM 3		N
	3.			
Exterior wall switches	1.	generally		MO
	2.			
	3.			
Dryer Plug			S	
Washer Plug			S	

HEATING/VENTILATING:

TYPE		LOCATION	LEAKAGE
Floor register/floor	1.		
	2.		
	3.		
Ductwork	1.		
	2.		
	3.		
Gas/Oil/Electricity Supply to Furnace		N	
Furnace Cabinet			

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16 November 1989

		INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Bathroom Fans	1.	S	
	2.	MO	
Range Hood (outside vented)			

OTHER:

TYPE		LOCATION	LEAKAGE
Fireplace damper		N.A.	
Fireplace Chimney/Envelope Seal		N.A.	
Pressure Relief Vents	1.	KITCHEN	MO
	2.		

ENVELOPE DETAILS:

TYPE		LOCATION	LEAKAGE
Floor/exterior wall	1.	LIVING ROOM	N
	2.	KITCHEN	N
	3.		
Ceiling/exterior wall	1.	BEDROOM	MO
	2.	LIVING ROOM	MO to MA
	3.	MASTER BEDROOM	MA
Ceiling/interior wall	1.	generally	N
	2.		
	3.		

OTHER:

TOILET WATER SUPPLY LINES - S

ACCESS PANEL TO BATHTUB - MA

c:\wp50\admin\walk
16 November 1989

WALKTHROUGH CHECK LIST

DATE 1990/3/17

INSPECTED BY DAF/JTM

Legend	
N	- not perceptible
S	- slight
MO	- moderate
MA	- major

MANUFACTURER B2 MODEL # ______ SERIAL # ______

FAN DEPRESSURIZATION 50 Pa

WINDOWS:

TYPE/DESCRIPTION	LOCATION	SEALS	FRAME/ENVELOPE
1.	MASTER BEDROOM	MO	MO
2.			
3.	LIVING ROOM	MA (AT CURVED WINDOWS)	
4.	KITCHEN	S	
5.	BEDROOM 3	MA (AT CURVED WINDOW)	

DOORS:

TYPE/DESCRIPTION	LOCATION	SEALS	FRAME/ENVELOPE
1.	BACK HALL -	NOT ADJUSTED	
2.			
3.			

PLUMBING:

TYPE/DESCRIPTION	LOCATION	LEAKAGE
Water Heater		
Service Waterline		
Basin Drain/Waterlines	MASTER BEDROOM	MA
Tub Drain/Waterlines	MASTER BEDROOM	MA
Sink Drain/Waterlines & TO STACK	KITCHEN	MA
Washing Machine Drain/Waterlines		MO

ELECTRICAL:

TYPE	LOCATION	INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Breaker Panel		N	N
Supply Conduit			

ELECTRICAL (cont'd):

TYPE		LOCATION	INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Interior Wall Plug	1.	ALL	N to S	
	2.			
	3.			
Exterior Wall Plug	1.	MASTER BEDROOM	S	
	2.	KITCHEN	S	
	3.	BEDROOM 2	S	
Ceiling light fixture	1.	MASTER BEDROOM	S	
	2.	BEDROOM 2	MD	
	3.	KITCHEN	S	
Interior wall switches	1.	MASTER BEDROOM	N	
	2.			
	3.			
Exterior wall switches	1.			
	2.			
	3.			
Dryer Plug			N	
Washer Plug				

HEATING/VENTILATING:

TYPE		LOCATION	LEAKAGE
Floor register/floor	1.		
	2.		
	3.		
Ductwork	1.		
	2.		
	3.		
Gas/Oil/Electricity Supply to Furnace			N
Furnace Cabinet			
CHIMNEY / FRESH AIR INTAKE			MA

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16 November 1989

		INTERNAL LEAKAGE	EXTERNAL LEAKAGE
Bathroom Fans	1.	MO	
	2.		
Range Hood (outside vented)		MA	

OTHER:

TYPE		LOCATION	LEAKAGE
Fireplace damper		N.A.	
Fireplace Chimney/Envelope Seal		N.A.	
Pressure Relief Vents	1.	BATHROOM 2	MA
	2.		

ENVELOPE DETAILS:

TYPE		LOCATION	LEAKAGE
Floor/exterior wall	1.	LIVING ROOM	N
	2.		
	3.		
Ceiling/exterior wall	1.	MASTER BEDROOM	MO
	2.	KITCHEN	MA
	3.		
Ceiling/interior wall	1.	KITCHEN	N
	2.	MASTER BEDROOM	N
	3.		

OTHER:

TOILET WATER SUPPLY LINE - MASTER BEDROOM - S