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UNIES LTD. — WINNIPEG, MANITOBA

#1219

AN EVALUATION OF THE EFFECTIVENESS OF AIR LEAKAGE SEALING

ENER-CORP MANAGEMENT LTD.

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MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program has a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

SUMMARY

A field study was carried out to evaluate the effectiveness of the air leakage sealing techniques employed by Ener-Corp Management Ltd. for reducing air infiltration in houses. Presealing and postsealing air leakage tests were performed upon 82 single detached houses which had been sealed by Ener-Corp Management Ltd. dealers. All of the houses were located in Winnipeg or southern Manitoba. The sample group consisted of 56 conventionally-constructed houses of varying size, style, occupancy and airtightness, and 26 nonstandard structures of smaller but identical size and age. This latter group was part of the Flora Place Project.

Based upon the results of the study, the median reduction in airtightness of the conventional structures, defined using the Equivalent Leakage Area at 10 Pascals (ELA_{10}), was 31.6% with significant variations occurring both between individual houses and between different types of construction. The median reduction in the ELA_{10} for the Flora Place houses was 42.5%, again with significant variations between houses despite their near-identical construction.

Using the air leakage test data and a recently developed correlation model, an estimate was made of the naturally-occurring air infiltration rates for all the test houses. This analysis indicated that the sealing produced a median reduction in the infiltration rate of 32.8% for the conventional houses and 46.1% for the Flora Place houses.

To relate the benefits of sealing in terms of its impact upon the space heating load, the air infiltration data was used in conjunction with standardized house descriptions to simulate five different styles of houses using the HOTCAN energy analysis program. This analysis indicated that air leakage sealing would produce reductions in the space heating load (and bill) ranging from 4.6% to 20.2%, although for most conventionally insulated houses, the reductions would generally average 10% to 15%.

Note however, that the results of this study are likely representative of houses constructed only in Manitoba and possibly Saskatchewan and Alberta. Since houses in the prairie provinces tend to have low air infiltration rates, the effects of air leakage sealing on houses in other parts of the country could be different from those found in this study.

RÉSUMÉ

Une expérience sur le terrain a été effectuée, afin d'évaluer d'efficacité des méthodes de calfeutrage employées par Ener-Corp Management Ltd. pour réduire les infiltrations d'air dans les maisons. Pour ce faire, des test furent effectués avant et après le calfeutrage, sur 82 maisons individuelles calfeutrées par des concessionnaires de Ener-Corp Management Ltd. Ces maisons étaient situées à Winnipeg ou dans les régions du sud du Manitoba et se divisaient en 2 groupes. Le premier était constitué de 56 maisons construites de facpon classique, de taille, d'architecture, d'élanchéité et d'aménagement différents. Le second regroupait 26 habitations non-classiques, plus petites que celles du premier groupe et identiques entre elles par la taille et l'âge. Ce groupe faisait partie du projet "Flora Place".

D'après les résultats de cette étude, la diminution moyenne d'infiltration de l'air dans les construction classique, définie à l'aide du taux d'infiltration pour une surface égale, à la pression de 10 kilos Pascals (ISE_{10}), était de 31,6% avec des variations importantes entre les différentes maisons et les différents modèles de constructions. La diminution moyenne d'infiltration, calculée avec le même ISE_{10}, pour ce qui est des maisons de Flora Place, était de 42,5%; ici aussi il y avait de grandes variations bien que ces habitations fussent de construction presque identique.

En utilisant les données du test d'infiltration d'air et un modèle récemment mis au point, on fit une estimation du taux d'infiltration naturel de l'air dans toutes ces maisons. L'analyse a démontré que le calfeutrage a produit une réduction moyenne du taux d'infiltration de l'ordre de 32,8% dans le cas des maisons de construction classique et de 46,1% dans le cas des maisons de Flora Place.

Afin d'établir un rapport entre les résultats du calfeutrage et leur répercussion sur les besoins en chauffage, les données sur l'infiltration d'air furent conjointement utilisées avec des descriptions normalisées d'habitation, pour simuler 5 modèles de maisons différentes. En se servant du programme d'analyse énergétique HOTCAN, on a démontré que le calfeutrage réduirait les besoins en chauffage (ainsi que les factures) de 4,6% à 20,2%. Pour la plupart des maisons isolées de la façon habituelle la réduction serait de l'ordre de 10% à 15%.

Notons toutefois que les résultats de cette étude se rapportent principalement aux maisons construites au Manitoba et probablement à celles de la Saskatchewan et de l'Alberta. En effet, les maisons des provinces des prairies ont tendance à avoir de faibles taux d'infiltration d'air, c'est pourquoi les résultats d'un calfeutrage effectué dans une autre région du pays risqueraient d'être différents de ceux qui sont décrits dans cette étude.

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INTRODUCTION

1.1 AIR INFILTRATION IN HOUSES

Air infiltration is generally acknowledged to represent a major component of the total heating load of houses. Depending upon the type of structure and its existing insulation levels, heat loss due to air infiltration may represent 5% to 50% of the annual heating cost. To the homeowner, this means an unwelcome expense which must be met every year. To the nation, it represents a significant component of the country's total energy needs. As a result, air infiltration represents both an existing liability and a potential opportunity for reducing energy costs.

To realize this opportunity in new construction, special procedures, products and techniques have been developed to reduce infiltration. The results to date have been very successful, with measured leakage rates in some new low energy houses a small fraction of those of conventional houses. However, for the approximately 256,000 existing houses in Manitoba and the 5.5 million in Canada, these developments are of value only if they can be adapted so that existing houses can be successfully retrofitted. Within the last few years, such techniques and procedures have been developed for the purpose of reducing uncontrolled air infiltration in existing houses. Several commercial concerns have been created to meet this market or have expanded their operations into it. One of these is Ener-Corp

Management Ltd. of Winnipeg who operate a nation-wide air leakage sealing company with dealers across Canada.

1.2 PURPOSE AND SCOPE

The project described in this report was carried out to determine the effectiveness of the air leakage sealing techniques employed by Ener-Corp Management Ltd. for reducing air infiltration in houses and to estimate the energy and dollar savings resulting from these measures. To quantify these results, presealing and postsealing air leakage tests were performed upon 82 houses which had been sealed by Ener-Corp Management Ltd. dealers. The houses represented a broad cross-section of age, style, construction, size and occupancy. All were located in Winnipeg or southern Manitoba.

1.3 INTERPRETATION OF RESULTS

Within the course of this project, a considerable volume of data was collected, refined and subsequently analyzed with the most relevant information ultimately being reported within this document. However, to satisfy the study objectives, it was not considered possible to express these results using a single parameter. Therefore, to assist the reader in interpretating the study results, a few words of explanation are offered at this point.

First, air infiltration and air leakage should be defined. Within this report, air infiltration is used to describe the movement of outdoor air into the interior living space of the house occurring solely due to natural forces, i.e. wind action , stack effect and exhaust fan/ventilation system operation. This air, of course, has to be heated to prevent lowering of the interior air temperature. As air infiltrates into the structure, an equal amount must flow outwards from the interior to the outdoors. This air movement is termed air exfiltration. Air leakage, on the other hand, is used to describe the movement of outdoor air into the house due to the action of the depressurization blower used in an air leakage test. Therefore, air leakage occurs only during the air leakage test and air infiltration/exfiltration occurs at all other times. Air leakage sealing and air infiltration sealing, however, may be treated as equivalent terms.

Airtightness (or air leakiness) is generally defined in terms of the Equivalent Leakage Area at 10 Pascals[1] (ELA_{10}). The primary value of such a parameter is that it allows direct and easy comparisons of airtightness to be made between houses since it is determined using (semi) standardized and accepted procedures. Prior to introduction of the ELA_{10} parameter, many air leakage test results were reported in terms of the number of air changes per hour (AC/HR) at various indoor-to-outdoor pressure differentials (typically 4, 10 or 50 Pascals). While these had the advantage of being easy to understand, they were also very prone to misinterpretation since many laymen thought they described the natural infiltration rate. As a result, considerable confusion has occurred in the public's mind as to the actual air infiltration rate of a typical house. To circumvent this problem, the community involved in air leakage testing adopted the ELA_{10}

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1. One Pascal = approximately 10^{-5} atmospheres.

approach to eliminate any misunderstanding. As a result, most air leakage tests, including those in this report, are now reported in terms of the ELA_{10}.

It was also recognized, however, that the ELA_{10} does not provide explicit information on the naturally-occurring air infiltration rate - the rate of air exchange resulting solely from natural forces and not from the depressurization blower used in the air leakage test. For energy estimating purposes, knowledge of the air infiltration rate is, of course, essential.

To provide this information, the air leakage test results were used to estimate the natural air infiltration rate using a recently-developed correlation model. Based upon the reported evidence, this model appears capable of predicting air infiltration rates within ±25% of measured values.

Unfortunately, a simple and repeatable relationship does not exist between the ELA_{10} and the natural air infiltration rate. As a result, direct comparisons of leakage test results, expressed by the two parameters, may appear inconsistent. While an undesirable outcome, this is indicative of the state of the art and our evolving understanding of air leakage/air infiltration in houses.

To offer some guidelines to the reader, it is therefore suggested that the air leakage test results, expressed using the ELA_{10}, be accepted simply as a means of comparing the airtightness of houses both within this and other studies. The predicted air infiltration rates (and subsequent predictions of energy and dollar savings) on the other hand, should be used to better appreciate the actual effects of air infiltration produced under natural conditions, acknowledging the accuracy limitations of the infiltration model.

CHAPTER 2

FUNDAMENTALS OF AIR INFILTRATION

2.1 CAUSES OF AIR INFILTRATION

Air infiltration is caused by pressure differentials which exist across the house envelope and result in the uncontrolled movement of outdoor air into the structure. These pressure differentials can be produced by three different driving forces:

1. stack effect,
2. wind action, and
3. exhaust fan/ventilation system operation.

Stack Effect - Since indoor and outdoor air are at different temperatures during the heating season, their densities and resulting buoyancies will be different. In the winter months, these buoyancy differentials create negative indoor-to-outdoor pressure differentials over the lower portions of the house envelope and positive pressure differentials over the upper portions. As a result, the stack effect attempts to induce infiltration across the lower portions of the envelope and exfiltration over the upper portions.

Wind Action - The most obvious effects of wind action are well understood by most people. The wind, blowing against a structure creates a pressure force on the windward side and a suction force on the leeward side which, if the walls contain any holes or cracks, causes air infiltration on the windward side and air exfiltration on the leeward side. In practice, the subtle dynamics of wind flow around buildings is considerably more complex. Distortions to these flow patterns caused by turbulence from adjacent structures, trees, etc., can result in air infiltration/exfiltration forces markedly different from those anticipated.

Exhaust Fan/Ventilation System Operation - Mechanical exhaust systems such as bathroom fans and dryer exhausts remove air from the building at high flow rates which induce infiltration forces over the entire house envelope. Since exhaust fans are usually only run intermittently, their effects are not felt continuously over the heating season. On an annual basis, their total impact upon the heating bill is usually slight. Ventilation system operation can also cause distortions to the naturally-occurring infiltration patterns, to a very small degree, by depressurizing rooms which contain return air grilles and by pressurizing rooms containing supply air registers. While the magnitude of these forces are believed to be small, they are applied for a major portion of the heating season.

The net pressure differential which a house is exposed to and hence the net air infiltration which it experiences at any time will be the sum of the three driving forces described in the foregoing. It is obvious that the pressure differentials and resulting air infiltration rates will vary throughout the year with outside temperature, wind speed and direction and exhaust fan/ventilation system operation. In general, however, the average indoor-to-outdoor pressure differentials experienced by a house during winter operation will be in the range of one to three Pascals.

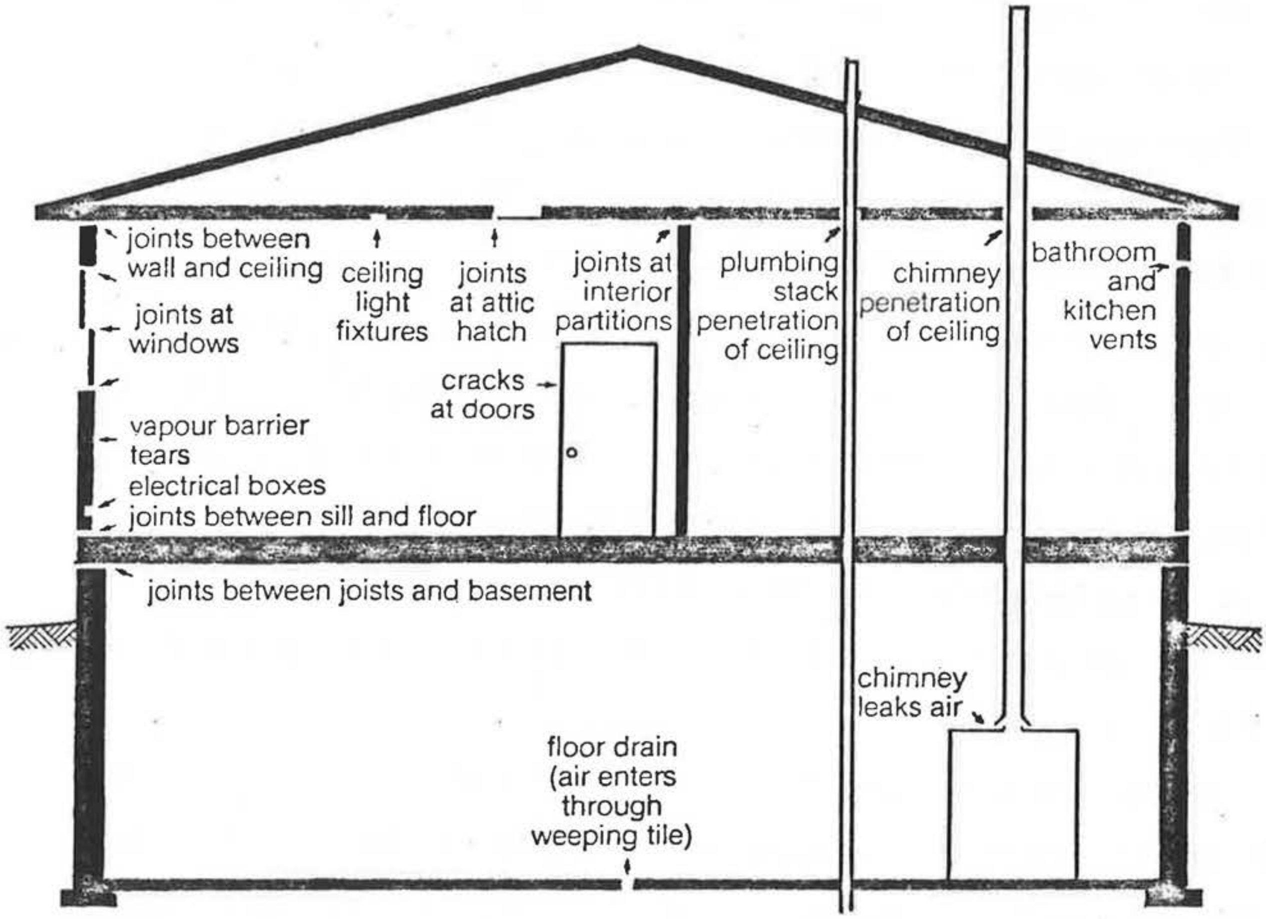
2.2 SOURCES OF AIR INFILTRATION

The locations of the most common sources of air infiltration in a conventional house are shown in Figure 1. Contrary to popular belief, windows and doors are not the major sources, usually only contributing about 25% of the total. Rather, joints between the main walls and the floor system, electrical outlets on exterior walls and ceiling penetrations for light fixtures, attic hatches, partition walls and plumbing fixtures constitute the major infiltration paths.

Most of these cracks, gaps and holes are "built into" the house during its construction. With lower energy prices, few builders felt the need to take specific measures to control air infiltration. Coupled with the perceived need to supply "adequate fresh air", the result has been that most older houses have unnecessarily high air infiltration rates.

2.3 THE EFFECTS OF AIR INFILTRATION

Uncontrolled air infiltration has several effects upon the operation and use of a house. The first and most obvious is increased heating costs. Any air which enters the building, beyond that required for respiration, furnace operation and humidity/air pollutant control, represents an



AIR INFILTRATION LOCATIONS IN A CONVENTIONAL HOUSE

FIGURE 1

additional and unnecessary heating load. In almost all older structures, the quantity of outdoor air delivered by air infiltration exceeds that which is required. This explains, for example, why most older homes suffer from dry air during the winter months.

Air infiltration can also affect the comfort level of the house. Uncontrolled drafts can cause discomfort, chills and potentially lead to health problems for the occupants. In very leaky structures, the low indoor relative humidity may also be responsible for respiratory problems. Cold drafts can also increase the heating bill beyond that actually necessary to warm outdoor air by causing the occupants to become "thermostat jockies", pushing up the thermostat setting whenever they feel a chill. In extreme cases, air infiltration coupled with a poorly balanced heating system, can cause some rooms of a house to become virtually uninhabitable during the winter months. For these reasons, many homeowners regard the degradation of indoor comfort levels as the most serious consequence of air infiltration.

The movement of warm, moisture-laden air outwards through the building shell due to exfiltration forces is responsible for the third major effect. As this air exfiltrates through the (colder) shell, its temperature drops and condensation can occur. If this moisture is not removed by evaporation or sublimation, it may lead to wetting of insulation and the structural elements. Many of the insulations found in older houses are vulnerable to moisture damage, which may cause settling and a reduction in their effective thermal resistance. If the moisture content of wood is raised above approximately 20% for extended periods of time (roughly two months) wood rot may also occur. Under extreme conditions this can, and has led to structural failure. Interior finish surfaces, particularly ceilings, are also vulnerable to moisture damage. Ceiling staining caused by moisture accumulation in the attic is common in some houses and in extreme cases, complete collapse of large sections of the ceiling can occur within a few years.

From the preceding discussion, it becomes obvious that under ideal circumstances, air infiltration should supply adequate air to meet the needs of the occupants and any combustion appliances without unduly adding to heating costs, reducing the comfort level of the house or creating moisture problems in the building shell. However, with the excessively high infiltration rates in most existing houses, some degree of air leakage sealing becomes necessary.

CHAPTER 3

DESCRIPTION OF THE AIR LEAKAGE TESTING PROGRAM

3.1 OVERVIEW

To evaluate the effectiveness of the anti-air infiltration measures employed by Ener-Corp Management Ltd., presealing and postsealing air leakage tests were performed upon 82 houses which were sealed by Ener-Corp Management Ltd. dealers operating in the Winnipeg or southern Manitoba areas.

Houses were selected from customers obtained in the normal course of business by various dealers. Once permission had been obtained from the homeowner, an initial air leakage test was performed by the dealer. A UNIES Ltd. technician, present during all tests, verified the results. An examination of suspected leakage areas was then performed during a walk-through inspection of the house while it was depressurized using the Infiltrometer (described later). In some cases, suspected leakage areas proved to be relatively airtight and were therefore left untouched. These examinations are a normal part of the Ener-Seal Program. Following the examination, the house was sealed according to Ener-Corp Management Ltd.'s specifications; identified and marketed as the "Ener-Seal" program. The specific measures carried out upon each house varied to meet individual requirements.

In general, however, these measures included:

Weatherstripping of:

- exterior doors
- windows

Caulking and sealing of:

- exterior doors
- windows
- electrical plugs and switches on exterior walls
- ceiling lights and electrical openings in the attic
- plumbing stacks, vents, and ducts passing through attics
- fireplace and furnace chimneys in the attic
- cracks along interior partitions
- attic hatch
- cracks between concrete walls and subfloor
- floor joist area
- perimeter of milk, mail and coal chutes
- general cracks and openings in walls (not including basement walls)

At the completion of the Ener-Seal, a second air leakage test was performed.

Permission slips were also obtained from each homeowner to allow monitoring of fuel bills after the sealing had been completed. However, subsequent investigations by the report authors indicated that the uncertainty of resolving the reductions in the energy consumption, due to sealing, from those resulting from modest changes in the occupants' lifestyle would probably exceed those actually resulting from the sealing. Therefore verifications using the fuel records were not pursued.

3.2 AIR LEAKAGE TEST PROCEDURE

The procedure used for conducting the air leakage tests was based upon the draft of a standard specification currently being developed by the

Canadian General Standards Board (CGSB), Ref. 1. At the time of writing, this Standard was in its fifth draft and will be identified on finalization as CGSB Standard 149-GP-10M "Determination of Airtightness by the Fan Depressurization Method".

Air leakage tests were performed using the "Infiltrometer", developed by Ener-Corp Ltd. The Infiltrometer is a blower door assembly which is installed in an appropriate exterior doorway and exhausts air from the structure through a calibrated flow nozzle. By depressuring the house, a negative indoor-to-outdoor pressure differential is created which induces air leakage into the structure. The air leakage test consists of subjecting the house to a number of different pressure differentials while measuring the rate at which air is exhausted. Using these data, a characteristic air leakage curve can be calculated which describes the leakage at any pressure differential. In this manner, changes in the airtightness of the house can be determined by conducting identical leakage tests before and after implementation of any anti-infiltration measures.

It should be noted that the air leakage tests were not performed in strict conformance with the (draft) Standard, largely because many of the tests were carried out prior to release of the draft and because of changes between subsequent drafts. However, to improve confidence in the results of this study, a review of the test data was carried out. This resulted in data for approximately 20 houses being rejected because of suspect results or procedures. Reasons for rejection included: results which were physically impossible (flow exponents in the regression equation whose values were not within the range of 0.5 to 1.0), insufficient number of data points per test or a correlation coefficient for the regression equation which was less than the (then) accepted minimum of 0.9800. The remaining 82 houses formed the basis of the study.

3.3 DESCRIPTION OF TEST HOUSES

A description of the 82 test houses, broken down by age and type of construction and showing the air leakage sealing measures which were applied to each, is shown in Table 1. Notice that 26 identical single-storey structures constructed in 1940 are included. These were part of the Flora Place Project which was a demonstration program carried out to evaluate the effects of various energy conservation retrofits applied to identical structures. These structures were significantly smaller than conventional houses and were thus grouped separately from the other houses of the study.

Although the remaining houses were selected at random from Ener-Corp Management Ltd. customers, it should be noted that they may not necessarily be representative of the housing population since, in all cases, their occupants or owners perceived a need for reducing air infiltration. It is therefore possible that this selection process tended to skew the results towards the inclusion of predominately leakier houses.

Table 1 - Description of Test Houses and Air Leakage Sealing Measures

CONVENTIONAL HOUSES				SEALING MEASURES															
				ATTIC			CEILING		WALLS						BASEMENT				
HOUSE NUMBER	HOUSE TYPE	YEAR OF CONSTRUCTION	HEATED VOLUME (m^2)	PLUMBING STACK	ATTIC HATCH	OTHER PENETRATIONS	LIGHT FIXTURES	ATTIC HATCH	BASEBOARDS	WALL PLUGS	WALL SWITCHES	WINDOWS	DOORS	WALL PENETRATIONS	FLOOR PENETRATIONS	JOIST-HEADER AREA	WINDOWS	WALL CRACKS	WALL PENETRATIONS
1	2	1902	209	X	X				X	X	X	X	X	X	X	CRAWL SPACE			
2	Split Level	1926	500	X	X				X	X	X	X	X	X		¼X	x	¼X	X
3	2	1925	501	X	X	X			X	X	X	X	X	X		X	X	X	X
4	2	1916	594	X	X				X	X	X	X	X	X		¼X	X	¼X	X
5	1½	1954	471	X	X	X			X	X	X	X	X	X		½X	X	½X	X
6	1	1952	423	X	X				X	X	X	X	X	X		X	X	X	X
7	1½	1920	554				X		X	X	X	X	X	X		X	X	X	X
8	1½	1948	350	X	X	X			X	X	X	X	X	X		X	X	X	X
9	1	1955	554	X	X	X			X	X	X	X	X	X		X	X	X	X
10	Split Level	1960	455	X	X	X			X	X	X	X	X	X		X	X	X	X
11	1	1947	634	X	X	X			X	X	X	X	X	X		X	X	X	X
12	1	1976	684	X	X	X			X	X	X	X	X	X		¼X	X	¼X	X
13	1	1964	464	X	X	X			X	X	X	X	X	X		X	X	X	X

CONVENTIONAL HOUSES				SEALING MEASURES															
				ATTIC			CEILING		WALLS						BASEMENT				
HOUSE NUMBER	HOUSE TYPE	YEAR OF CONSTRUCTION	HEATED VOLUME (m^2)	PLUMBING STACK	ATTIC HATCH	OTHER PENETRATIONS	LIGHT FIXTURES	ATTIC HATCH	BASEBOARDS	WALL PLUGS	WALL SWITCHES	WINDOWS	DOORS	WALL PENETRATIONS	FLOOR PENETRATIONS	JOIST-HEADER AREA	WINDOWS	WALL CRACKS	WALL PENETRATIONS
14	1	1958	441	X	X	X			X	X	X	X	X	X		X	X	X	X
15	1	1975	678	X	X	X			X	X	X	X	X	X		2/3X	X	2/3X	X
16	1½	1950	376	X	X	X			X	X	X	X	X	X		X	X	X	X
17	1	1951	270	X	X	X			X	X	X	X	X	X	X		SLAB FLOOR		
18	1	1976	695	X	X	X			X	X	X	X	X	X		X	X	X	X
19	1	1953	400	X	X				X	X	X	X	X	X			X		
20	1	1969	554	X	X	X			X	X	X	X	X	X		X	X	X	X
21	2	1923	431	X	X	X			X	X	X	X	X	X		½X	X	½X	X
22	1	1927	386	X	X	X			X	X	X	X	X	X		X	X	X	X
23	Split Level	1973	593	X	X				X	X	X	X	X	X		X	X	X	X
24	2	1970	630				X	X	X	X	X	X	X	X		½X	X	½X	X
25	Split Level	1977	750				X		X	X	X	X	X	X			X		X
26	1	1940	396						X	X	X	X	X	X					

CONVENTIONAL HOUSES				SEALING MEASURES															
				ATTIC			CEILING		WALLS						BASEMENT				
HOUSE NUMBER	HOUSE TYPE	YEAR OF CONSTRUCTION	HEATED VOLUME (m^2)	PLUMBING STACK	ATTIC HATCH	OTHER PENETRATIONS	LIGHT FIXTURES	ATTIC HATCH	BASEBOARDS	WALL PLUGS	WALL SWITCHES	WINDOWS	DOORS	WALL PENETRATIONS	FLOOR PENETRATIONS	JOIST-HEADER AREA	WINDOWS	WALL CRACKS	WALL PENETRATIONS
27	1	1932	297	X	X				X	X	X	X	X	X		X	X	X	X
28	Split Level	1974	380				X	X	X	X	X	X	X	X			X		X
29	1	1946	351	X	X	X			X	X	X	X	X	X		X	X	X	X
30	1½	1947	334	X	X	X			X	X	X	X	X	X	Panelling Sealed				
31	1	1966	498	X	X	X			X	X	X	X	X	X		X	X	X	X
32	Split Level	1975	451	X	X	X			X	X	X	X	X	X		½X	X	½X	X
33	1	1954	453				X	X	X	X	X	X	X	X		½X	X	½X	X
34	1	1962	478	X	X	X			X	X	X	X	X	X			X		X
35	1	1922	484				X	X	X	X	X	X	X	X			X		X
36	2	1940	465	X	X	X			X	X	X	X	X	X		X	X	X	X
37	Split Level	1962	585	X	X	X			X	X	X	X	X	X		½X	X	½X	X
38	1½	1953	435				X		X	X	X	X	X	X		X	X	X	X
39	Split Level	1974	471	X	X	X			X	X	X	X	X	X		X	X	X	X

CONVENTIONAL HOUSES				SEALING MEASURES															
				ATTIC			CEILING		WALLS						BASEMENT				
HOUSE NUMBER	HOUSE TYPE	YEAR OF CONSTRUCTION	HEATED VOLUME (m^2)	PLUMBING STACK	ATTIC HATCH	OTHER PENETRATIONS	LIGHT FIXTURES	ATTIC HATCH	BASEBOARDS	WALL PLUGS	WALL SWITCHES	WINDOWS	DOORS	WALL PENETRATIONS	FLOOR PENETRATIONS	JOIST-HEADER AREA	WINDOWS	WALL CRACKS	WALL PENETRATIONS
40	1	1968	288	X	X	X			X	X	X	X	X	X		3/4X	X	3/4X	X
41	1	1946	255	X	X	X			X	X	X	X	X	X	X	Crawl Space Skirting Done			
42	2½	1925	637	X	X	X			X	X	X	X	X	X		X	X	X	X
43	2	1902	789				X		X	X	X	X	X	X		½X	X	½X	X
44	1½	1950	468				X		X	X	X	X	X	X		½X	X	½X	X
45	2½	1926	521	X	X	X			X	X	X	X	X	X		X	X	X	X
46	1	1976	557	X	X				X	X	X	X	X	X			X		X
47	1	1951	254	X	X				X	X	X	X	X	X	X				
48	2½	1930	803	X	X	X			X	X	X	X	X	X		½X	X	½X	X
49	Split Level	1980	606	X	X	X			X	X	X	X	X	X		½X	X	½X	X
50	Split Level	1968	506	X	X	X			X	X	X	X	X	X		X	X	X	X
51	1	1962	324	X	X	X			X	X	X	X	X	X			X		X
52	1	1957	638				X		X	X	X	X	X	X		X	X		X

CONVENTIONAL HOUSES				SEALING MEASURES															
				ATTIC			CEILING		WALLS						BASEMENT				
HOUSE NUMBER	HOUSE TYPE	YEAR OF CONSTRUCTION	HEATED VOLUME (m^2)	PLUMBING STACK	ATTIC HATCH	OTHER PENETRATIONS	LIGHT FIXTURES	ATTIC HATCH	BASEBOARDS	WALL PLUGS	WALL SWITCHES	WINDOWS	DOORS	WALL PENETRATIONS	FLOOR PENETRATIONS	JOIST-HEADER AREA	WINDOWS	WALL CRACKS	WALL PENETRATIONS
53	1	1960	330				X		X	X	X	X	X	X		X	X	X	X
54	1-Trailer	1973	182				X		X	X	X	X	X	X	X				
55	1	1962	648	X	X	X			X	X	X	X	X	X		½X	X	½X	X
56	2½	1930	465	X	X	X			X	X	X	X	X	X		X	X	X	X
57-82	1	1940	106				X		X	X	X	X	X		X				

CHAPTER 4

AIR LEAKAGE TEST RESULTS

4.1 DATA PRESENTATION

Air leakage test results are frequently reported using several different parameters. The one which is most commonly used and the one which was adopted for this report, as previously explained, is the Equivalent Leakage Area at 10 Pascals (ELA_{10}).

The ELA_{10} is the size of the equivalent hole, in units of square meters, which would produce the same net leakage as the randomly distributed leakage paths normally found in a house. It is calculated for a pressure differential of 10 Pascals and is independent of the size of the house.

4.2 AIR LEAKAGE TEST RESULTS - CONVENTIONAL HOUSES

Results are separated for the 26 Flora Place units and the remaining 56 conventional houses. A summary of the air leakage test results for the 56 conventional houses is shown in Table 2 and Figure 2. A further breakdown of the data, based upon type of house is given in Table 3. Notice that the ELA_{10}'s given in Table 3 are median values. Median rather than mean values were used for all averaging in this report because air leakage test data for houses does not follow a normal (i.e. standard) distribution and is more accurately described the median.

TABLE 2

SUMMARY OF PRESEALING AND POSTSEALING
AIR LEAKAGE TESTS - CONVENTIONAL HOUSES

House Number	House Type (# of Storeys)	Year Of Construction	ELA_{10} (m^2)		Percentage Reduction in ELA_{10}
			Presealing	Postsealing	
1	2	1902	0.07926	0.05526	30.3
2	Split Level	1926	0.06008	0.04388	27.0
3	2	1925	0.09482	0.07815	17.6
4	2	1916	0.11522	0.10028	13.0
5	1½	1954	0.06346	0.05280	16.8
6	1	1952	0.09517	0.06686	29.7
7	1½	1920	0.12973	0.09581	26.1
8	1½	1948	0.08703	0.06228	28.4
9	1	1955	0.12382	0.08115	34.5
10	Split Level	1960	0.09138	0.06184	32.3
11	1	1947	0.05473	0.05124	6.4
12	1	1976	0.06196	0.03597	41.9
13	1	1964	0.10304	0.05720	44.5
14	1	1958	0.07486	0.04413	41.1
15	1	1975	0.08843	0.06419	27.4
16	1½	1950	0.04876	0.04070	16.5
17	1	1951	0.14112	0.05475	61.2
18	1	1976	0.06748	0.04280	36.6
19	1	1953	0.09126	0.05345	41.4
20	1	1969	0.09032	0.04803	46.8
21	2	1923	0.14578	0.12032	17.5
22	1	1927	0.19256	0.14243	26.0
23	Split Level	1973	0.09076	0.06227	31.4
24	2	1970	0.08979	0.05089	43.3
25	Split Level	1977	0.09755	0.05183	46.8
26	1	1940	0.10971	0.05936	45.9
27	1	1932	0.06247	0.03838	38.6
28	Split Level	1974	0.04004	0.03619	9.6
29	1	1946	0.04438	0.03178	28.4
30	1½	1947	0.09205	0.06680	27.4
31	1	1966	0.04614	0.01980	57.1
32	Split Level	1975	0.08016	0.03834	52.2
33	1	1954	0.05668	0.04272	24.6
34	1	1962	0.04440	0.03481	21.6
35	1	1922	0.09711	0.06105	37.1
36	2	1940	0.12632	0.09555	24.4
37	Split Level	1962	0.10348	0.08031	22.4
38	1½	1953	0.12560	0.05143	59.1
39	Split Level	1974	0.06718	0.05275	21.5
40	1	1968	0.05869	0.03984	32.1
41	1	1946	0.13322	0.08542	35.9
42	2½	1925	0.25560	0.13084	45.8
43	2	1902	0.26276	0.19217	26.9
44	1½	1950	0.07642	0.04904	27.6
45	2½	1926	0.17859	0.14270	20.2
46	1	1976	0.05120	0.03600	28.0
47	1	1951	0.07973	0.04339	32.6
48	2½	1930	0.30209	0.17236	42.9
49	Split Level	1980	0.12155	0.10335	15.0
50	Split Level	1968	0.06501	0.04049	37.7
51	1	1962	0.04621	0.03762	18.6
52	1	1957	0.08765	0.03694	57.9
53	1	1960	0.11005	0.06638	39.7
54	1	1973	0.10964	0.06826	37.8
55	1	1962	0.06513	0.04092	37.1
56	2½	1930	0.25405	0.17340	31.7

EQUIVALENT LEAKAGE AREAS BEFORE AND AFTER SEALING - CONVENTIONAL HOUSES

FIGURE 2

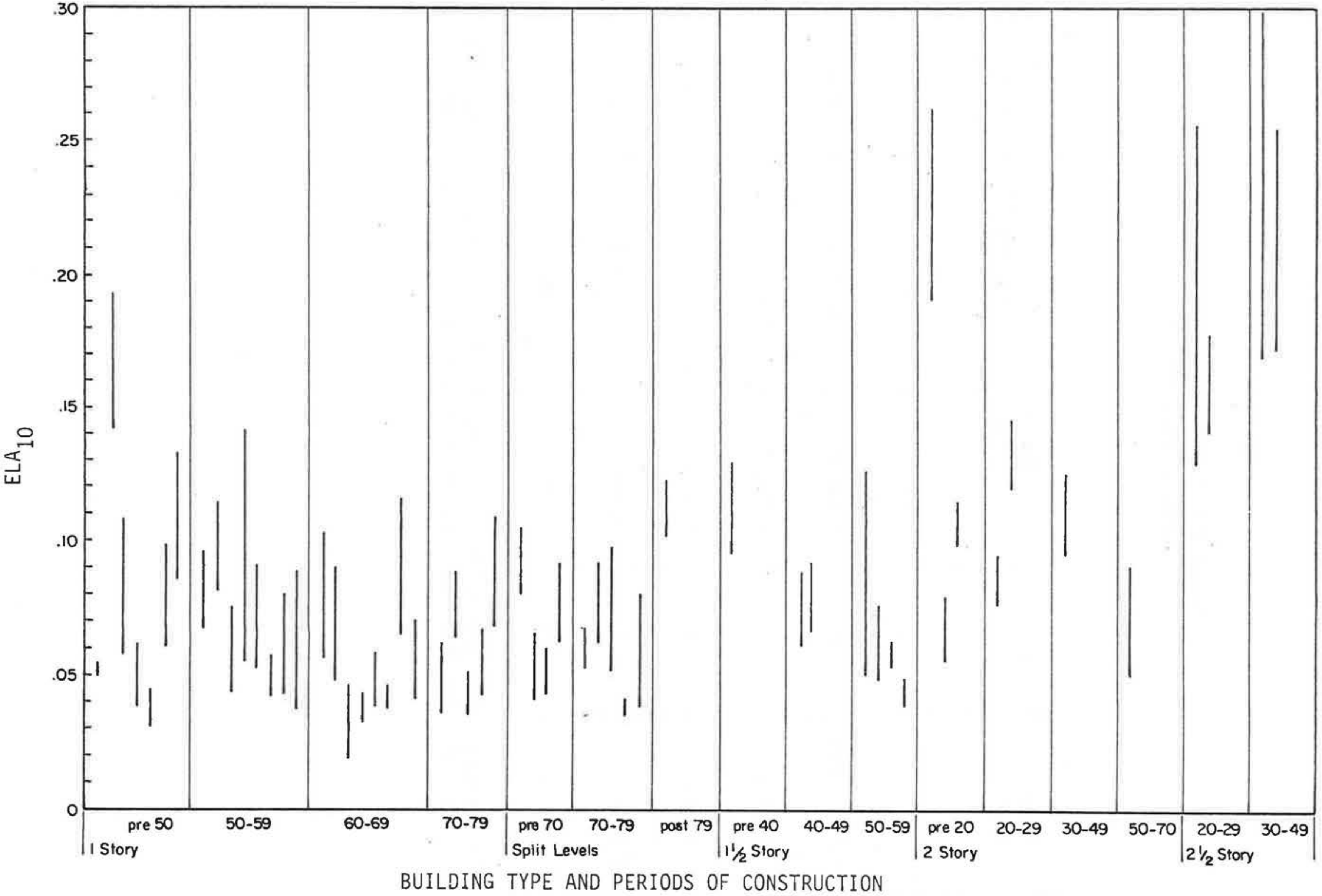


TABLE 3

EQUIVALENT LEAKAGE AREAS (ELA_{10}) CONVENTIONAL HOUSES

House Type	Sample Size	Median ELA_{10} (m^2) Presealing	Postsealing(1)	Median Percentage Reduction (%)
1 Storey	28	0.08369	0.05281	36.9%
Split Levels	10	0.08546	0.06051	29.2%
1½ Storey	7	0.08703	0.06318	27.4%
2 Storey	7	0.11522	0.08714	24.4%
2½ Storey	4	0.25483	0.15978	37.3%
All Houses	56	0.09054	0.06193	31.6%

(1) Calculated by subtracting the median value of the percentage reductions recorded for the individual houses from the median presealing ELA_{10}.

As is evident from Tables 2 and 3 and Figure 2, considerable variation was encountered in both the initial air leakiness of the structures and in the effectiveness of the sealing. However, based upon the 56 houses studied, the median reduction in the ELA_{10} due to the air leakage sealing was 31.6%.

4.3 AIR LEAKAGE TEST RESULTS - FLORA PLACE HOUSES

A summary of the air leakage test results for the 26 Flora Place houses is shown in Table 4 and Figure 3. Once again, considerable variations were encountered in the airtightness of the structures and in the effectiveness of the sealing. This is a rather interesting result since the houses were virtually identical in size, construction and age. The median reduction in the ELA_{10} due to the air leakage sealing was 42.5% for the 26 houses.

TABLE 4

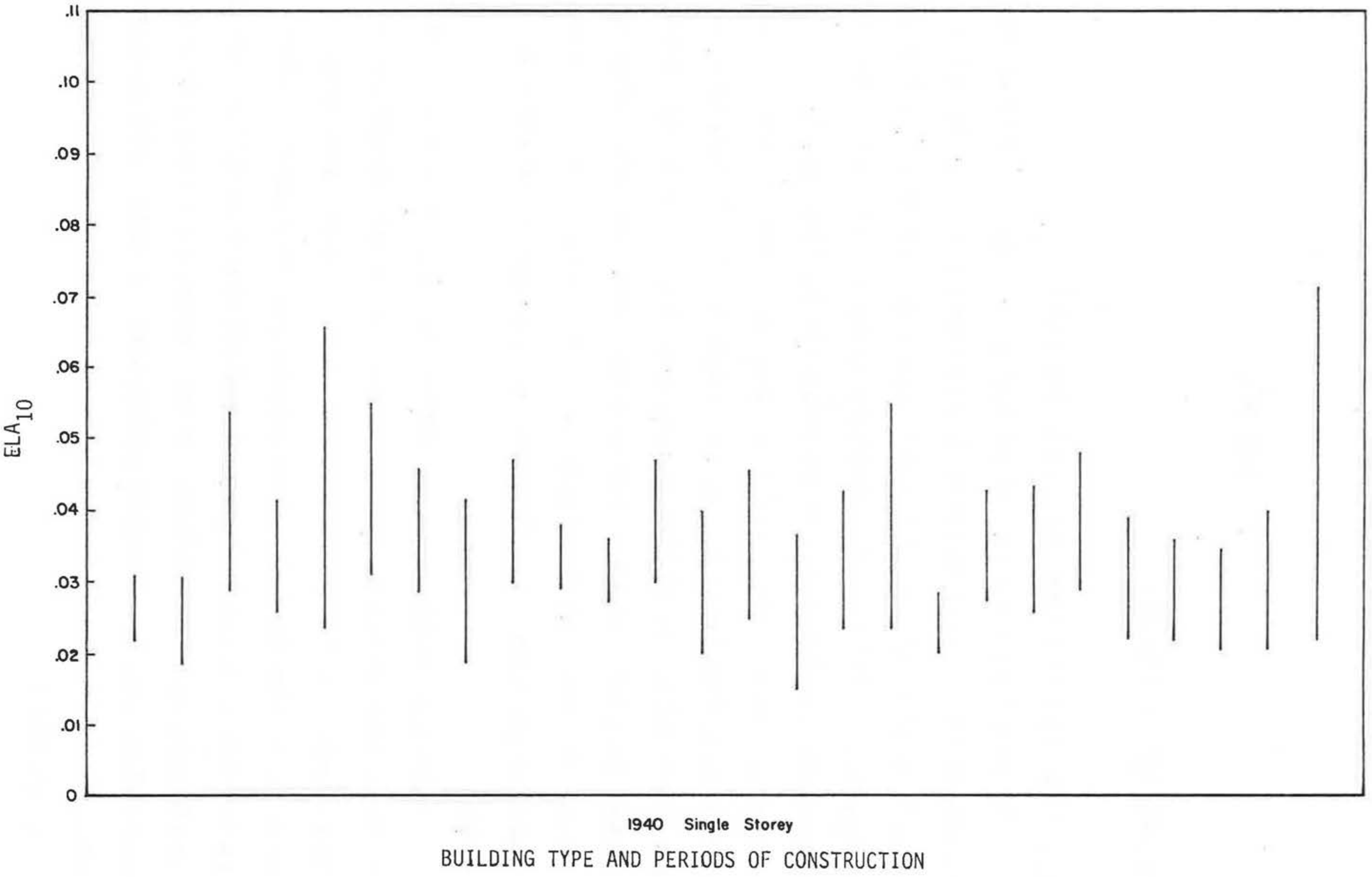
SUMMARY OF PRESEALING AND POSTSEALING AIR LEAKAGE TESTS - FLORA PLACE HOUSES[1]

House Number	ELA$_{10}$ (m^2)		Percentage Reduction (%)
	Presealing	Postsealing	
57	0.03088	0.02244	26.9
58	0.03135	0.01789	42.1
59	0.05402	0.02924	45.5
60	0.04097	0.02581	36.2
61	0.06623	0.02414	63.6
62	0.05450	0.03085	41.3
63	0.04564	0.02850	26.9
64	0.04104	0.01837	55.1
65	0.04683	0.03004	35.8
66	0.03848	0.02869	25.1
67	0.03637	0.02698	44.5
68	0.04656	0.02993	36.8
69	0.04048	0.01984	27.2
70	0.04589	0.02490	45.2
71	0.03672	0.01536	58.4
72	0.04172	0.02357	43.6
73	0.05532	0.02358	57.4
74	0.02849	0.02011	29.4
75	0.04232	0.02651	50.2
76	0.04314	0.02594	39.3
77	0.04787	0.02803	44.2
78	0.03922	0.02243	42.8
79	0.03612	0.02146	40.6
80	0.03471	0.02088	39.9
81	0.04047	0.02087	48.7
82	0.07182	0.02162	69.8

[1] All single storey with no basement, constructed in 1940.

EQUIVALENT LEAKAGE AREAS BEFORE AND AFTER SEALING - FLORA PLACE HOUSES

FIGURE 3



CHAPTER 5

NATURAL AIR INFILTRATION

5.1 PREDICTION OF NATURAL AIR INFILTRATION RATES

To determine the benefits of air leakage sealing, some estimate must be made of the reduction in naturally-occurring air infiltration which results from the sealing. Unfortunately, a single parameter, such as the ELA_{10}, while useful for defining relative changes in air leakage does not necessarily describe changes in the annual air infiltration rate accurately. At present, several researchers are developing predictive models which allow the results of air leakage tests to be used to estimate air infiltration. One of these models, described in Ref. 2, was used to analyze the effects of the sealing upon the natural air infiltration rates for the 82 houses studied in the project. According to Ref. 2 the model is capable of predicting air infiltration rates within ±25% of measured values.

Using this procedure, the air infiltration was simulated for each house for each hour of the year by using environmental data and air leakage test results. Wind speed and direction, outdoor temperature, house orientation, plus the house's flow exponent (n), flow coefficient (c) (determined in the air leakage test), and volume were used to predict the infiltration rate. By modelling the house twice, using presealing and postsealing data, the effects of sealing were estimated. With knowledge of the outdoor temperature, heating loads attributable to infiltration were also determined.

In its present form, the infiltration model does not account for combustion or dilution air drawn into the house for furnace operation in nonelectrically-heated houses. However, furnace air requirements can be accounted for by using seasonal, rather than steady-state, furnace efficiencies for houses using gas or oil heating.

The weather data used to produce the hour-by-hour simulations was that recorded by Atmospheric Environment Services for 1976 for Winnipeg. Data for 1976 was selected because it corresponded closely to long-term averages and was therefore considered to be a representative weather year for modelling purposes.

Since only the infiltration occuring during the winter months contributes to the heating load, the predictions of infiltration rates were defined as the effective/average values for the period between September 16th and May 15th.

5.2 PREDICTED AIR INFILTRATION RATES - CONVENTIONAL HOUSES

A summary of the presealing and postsealing air infiltration rates for the 56 conventional houses as predicted using the technique described is shown in Table 5 and Figures 4, 5 and 6. A further breakdown of the data, based upon type of house, is given in Table 6. Notice that average values are once again described using medians. The postsealing infiltration rates in Table 6 were calculated by subtracting the median of the individual house percentage reductions from the median presealing infiltration rate,

TABLE 5

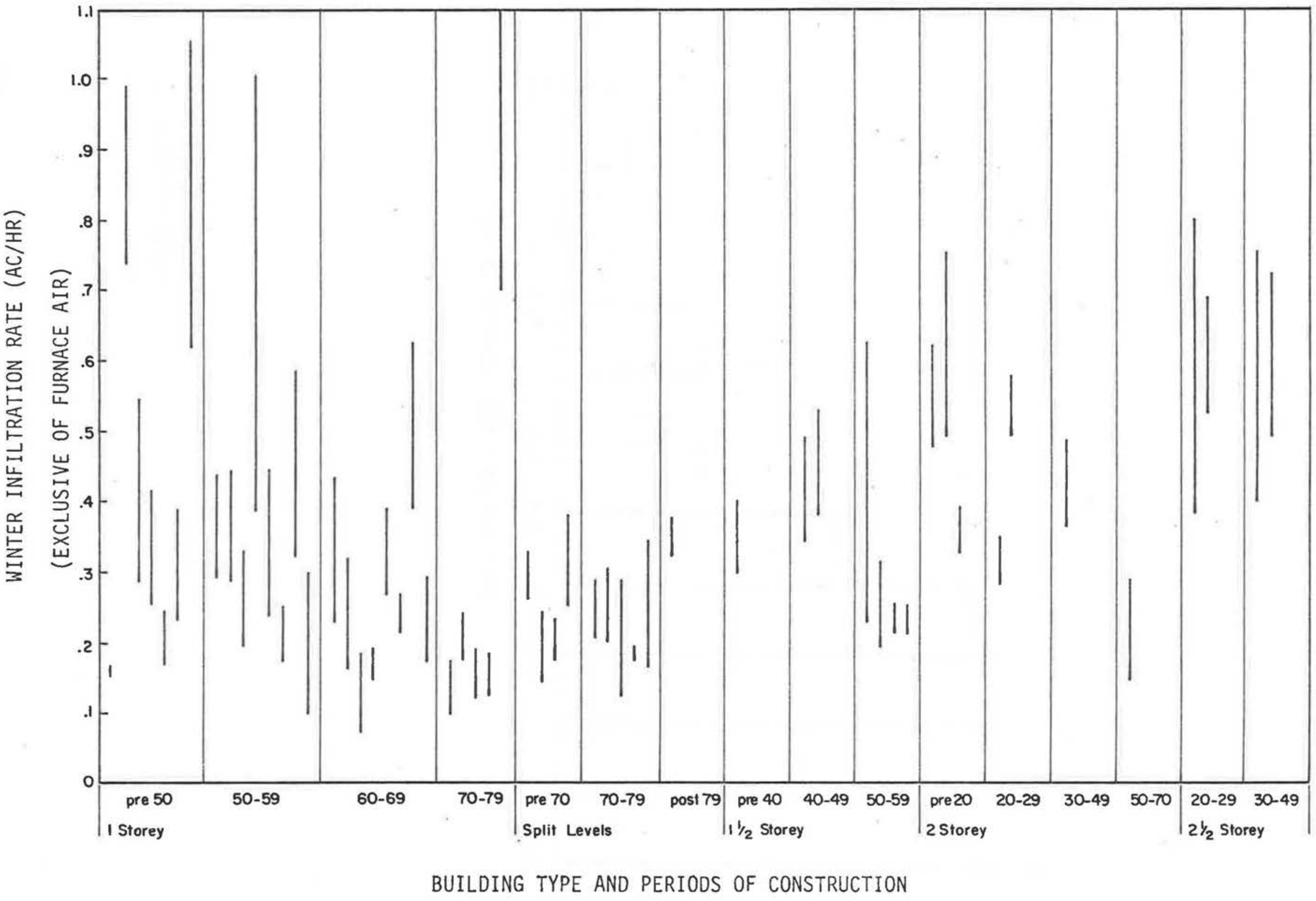
SUMMARY OF PREDICTED PRESEALING AND POSTSEALING AIR INFILTRATION RATES - CONVENTIONAL HOUSES

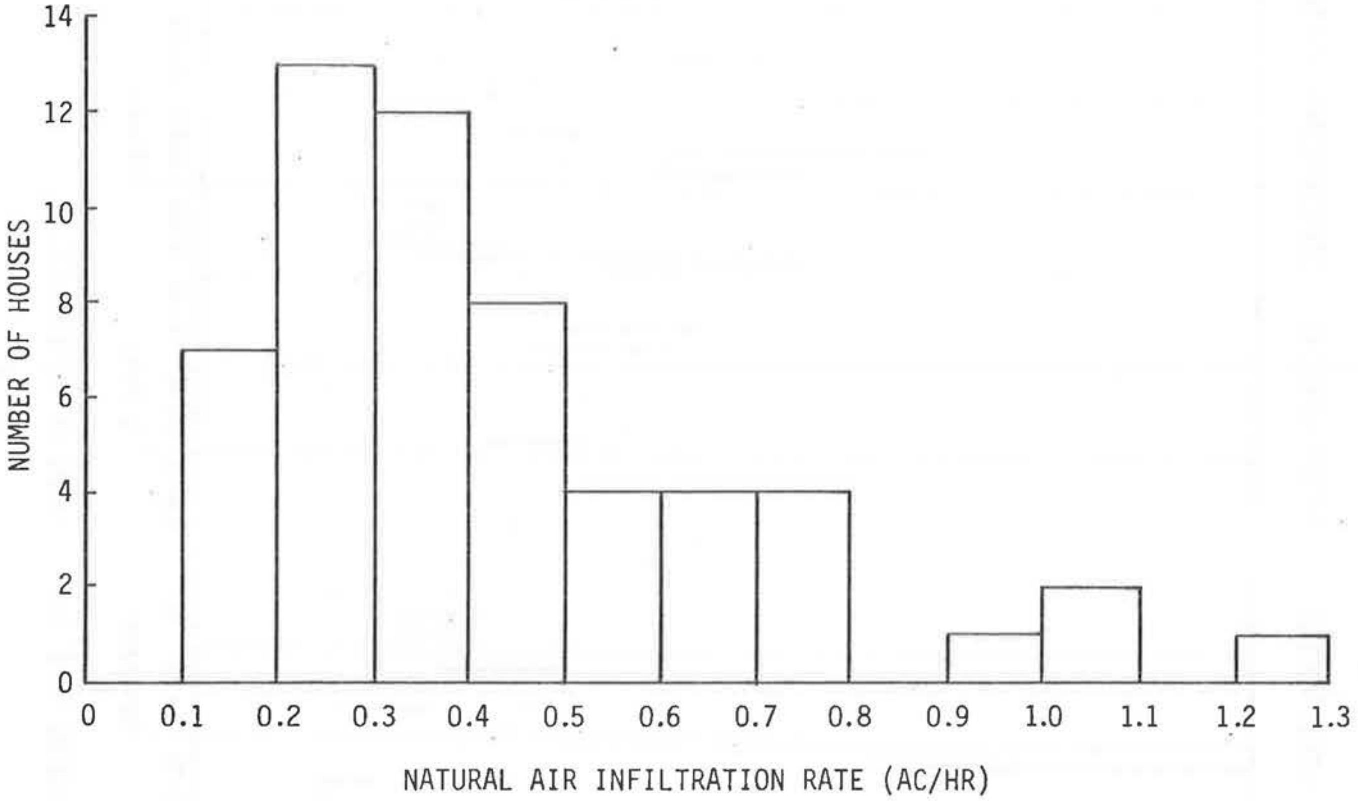
House Number	House Type	Age	Predicted Air Infiltration[1] (AC/HR)		Percentage Reduction (%)
			Presealing	Postsealing	
1	2	1902	0.754	0.493	34.6
2	Split Level	1926	0.235	0.162	31.2
3	2	1925	0.350	0.284	18.9
4	2	1916	0.391	0.327	16.2
5	1½	1954	0.250	0.212	15.4
6	1	1952	0.432	0.294	31.8
7	1½	1920	0.407	0.300	26.1
8	1½	1948	0.491	0.351	28.5
9	1	1955	0.441	0.284	35.5
10	Split Level	1960	0.369	0.251	31.8
11	1	1947	0.162	0.156	4.2
12	1	1976	0.175	0.100	42.9
13	1	1964	0.431	0.231	46.3
14	1	1958	0.328	0.194	40.9
15	1	1975	0.239	0.173	27.8
16	1½	1950	0.254	0.212	16.6
17	1	1951	1.014	0.383	62.3
18	1	1976	0.190	0.117	38.3
19	1	1953	0.442	0.242	45.3
20	1	1969	0.316	0.167	47.1
21	2	1923	0.589	0.498	15.4
22	1	1927	0.989	0.738	25.4
23	Split Level	1973	0.307	0.206	32.8
24	2	1970	0.289	0.153	47.2
25	Split Level	1977	0.272	0.131	51.9
26	1	1940	0.542	0.286	47.3
27	1	1932	0.415	0.251	39.6
28	Split Level	1974	0.196	0.183	6.6
29	1	1946	0.243	0.172	29.2
30	1½	1947	0.533	0.383	28.1
31	1	1966	0.183	0.074	59.6
32	Split Level	1975	0.347	0.161	53.6
33	1	1954	0.249	0.178	28.4
34	1	1962	0.187	0.150	19.9
35	1	1922	0.385	0.230	40.2
36	2	1940	0.486	0.364	25.1
37	Split Level	1962	0.330	0.256	22.4
38	1½	1953	0.628	0.221	64.8
39	Split Level	1974	0.270	0.213	20.9
40	1	1968	0.384	0.259	32.7
41	1	1946	1.060	0.623	41.2
42	2½	1925	0.799	0.382	52.2
43	2	1902	0.620	0.466	24.7
44	1½	1950	0.306	0.192	37.2
45	2½	1926	0.684	0.537	21.6
46	1	1976	0.181	0.122	32.6
47	1	1951	0.585	0.327	44.1
48	2½	1930	0.761	0.398	47.7
49	Split Level	1980	0.384	0.324	15.5
50	Split Level	1968	0.241	0.141	41.5
51	1	1962	0.258	0.216	16.2
52	1	1957	0.298	0.104	65.0
53	1	1960	0.622	0.383	38.4
54	1 - Trailer	1973	1.239	0.704	43.2
55	1	1962	0.280	0.172	38.5
56	2½	1930	0.715	0.491	31.4

[1] Exclusive of furnace air.

WINTER INFILTRATION RATES BEFORE AND AFTER SEALING - CONVENTIONAL HOUSES

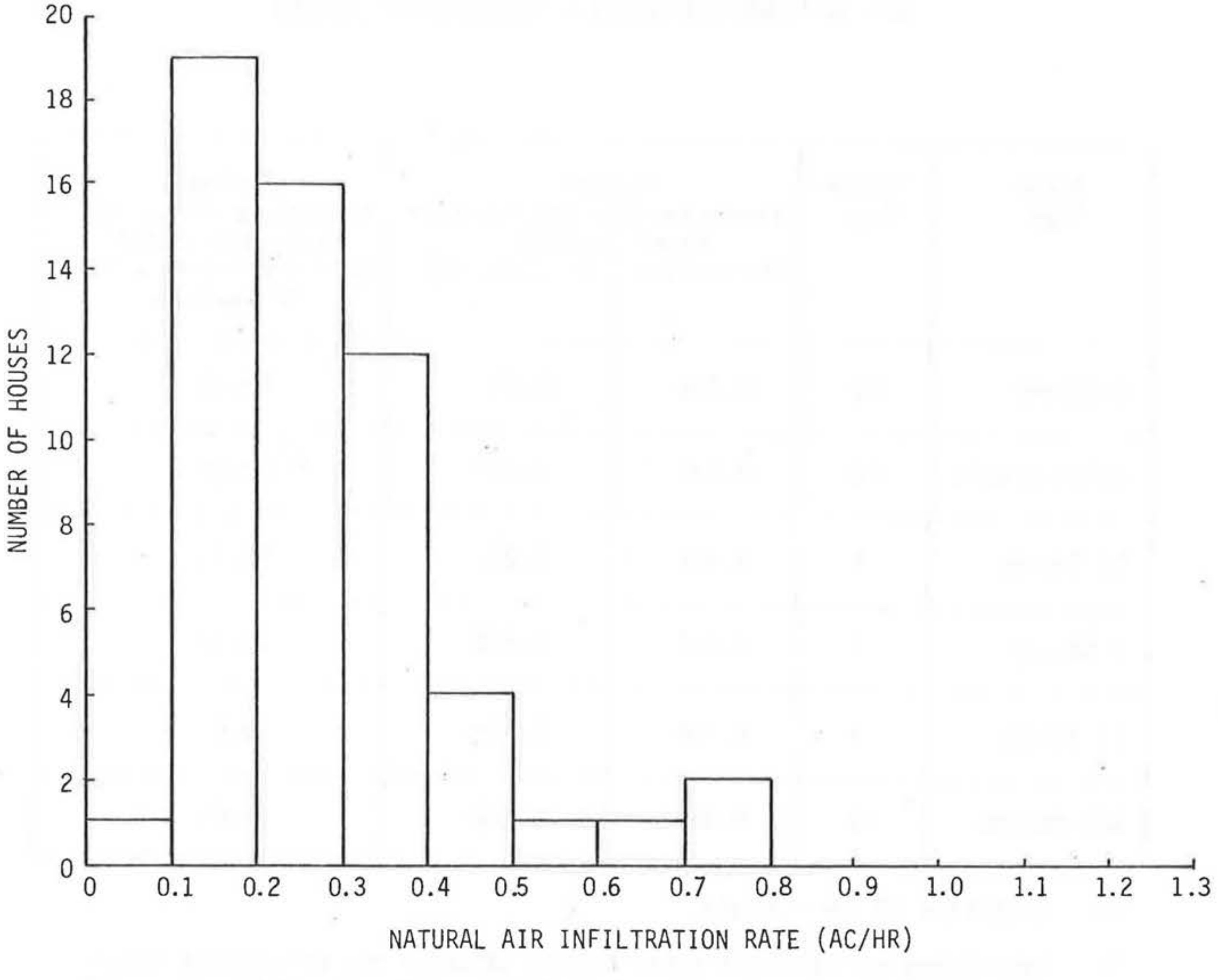
FIGURE 4





PRESEALING PREDICTED AIR
INFILTRATION RATES*
CONVENTIONAL HOUSES
(*EXCLUSIVE OF FURNACE AIR)

FIGURE 5



POSTSEALING PREDICTED AIR
INFILTRATION RATES*
CONVENTIONAL HOUSES
(*EXCLUSIVE OF FURNACE AIR)

FIGURE 6

TABLE 6

PREDICTED PRESEALING AND POSTSEALING AIR INFILTRATION RATES - CONVENTIONAL HOUSES

House Type	Sample Size	Median Predicted Air Infiltration Rate[1] (AC/HR) Presealing	Median Predicted Air Infiltration Rate[1] (AC/HR) Postsealing[2]	Median Percentage Reduction In Predicted Air Infiltration Rate Due To Sealing
1 Storey	28	0.356	0.217	39.1%
Split Levels	10	0.290	0.199	31.5%
1½ Storey	7	0.407	0.293	28.1%
2 Storey	7	0.486	0.366	24.7%
2½ Storey	4	0.738	0.446	39.6%
All Houses	56	0.384	0.258	32.8%

1. Exclusive of furnace air.
2. Calculated by subtracting the median value of the percentage reductions recorded for the individual houses, from the median presealing rate.

for each category of house. Infiltration rates are defined in terms of the time required to replace the contained volume in air changes per hour (AC/HR).

Predicted median infiltration rates, exclusive of furnace air, prior to sealing for the 56 conventional houses was 0.384 AC/HR, with split levels having the lowest rate, 0.290 AC/HR, and 2½ storey houses the highest at 0.738 AC/HR. However, a degree of caution should be exercised when interpreting the results for 2½ storey houses due to the relatively small sample size of 4 houses.

Although the success of the air leakage sealing varied with type of house, the median reduction in predicted air infiltration for all categories of houses was 32.8%. The greatest reductions occurred with 1 and 2½ storey houses and the smallest reductions with 1½ and 2 storey houses. A possible explanation for the poorer results is that older 1½ and 2 storey houses were predominately built using balloon frame construction which is typically much more difficult to seal at the floor/attic interface. Although older 2½ storey houses also generally use balloon frame construction, the 4 houses studied in this project may not have been representative of typical 2½ storey houses.

Note also that the results of this study are likely only applicable to houses located in Manitoba and possibly Saskatchewan and Alberta. Houses in the prairie provinces tend to have roughly similar styles of construction and hence similar air infiltration rates. Houses outside this region tend to generally have higher air infiltration rates. As a result, the effects of air leakage sealing upon structures outside the prairie provinces may be different from those found in this study.

5.3 PREDICTED AIR INFILTRATION RATES - FLORA PLACE HOUSES

A summary of the predicted presealing and postsealing air infiltration rates for the 26 Flora Place houses is shown in Table 7 and Figures 7, 8 and 9. The study of these houses offered a unique opportunity to investigate the variation in effectiveness of sealing since all of these structures were of nominally identical size, shape, age and configuration. However, despite the similarity between the houses, considerable variation was discovered, both in the initial air infiltration rates and in the effectiveness of the sealing.

The median predicted presealing air infiltration rate for these houses was 0.816 AC/HR while the median reduction in the air infiltration rate was 46.1%.

TABLE 7

SUMMARY OF PREDICTED PRESEALING AND POSTSEALING AIR INFILTRATION RATES - FLORA PLACE HOUSES[1]

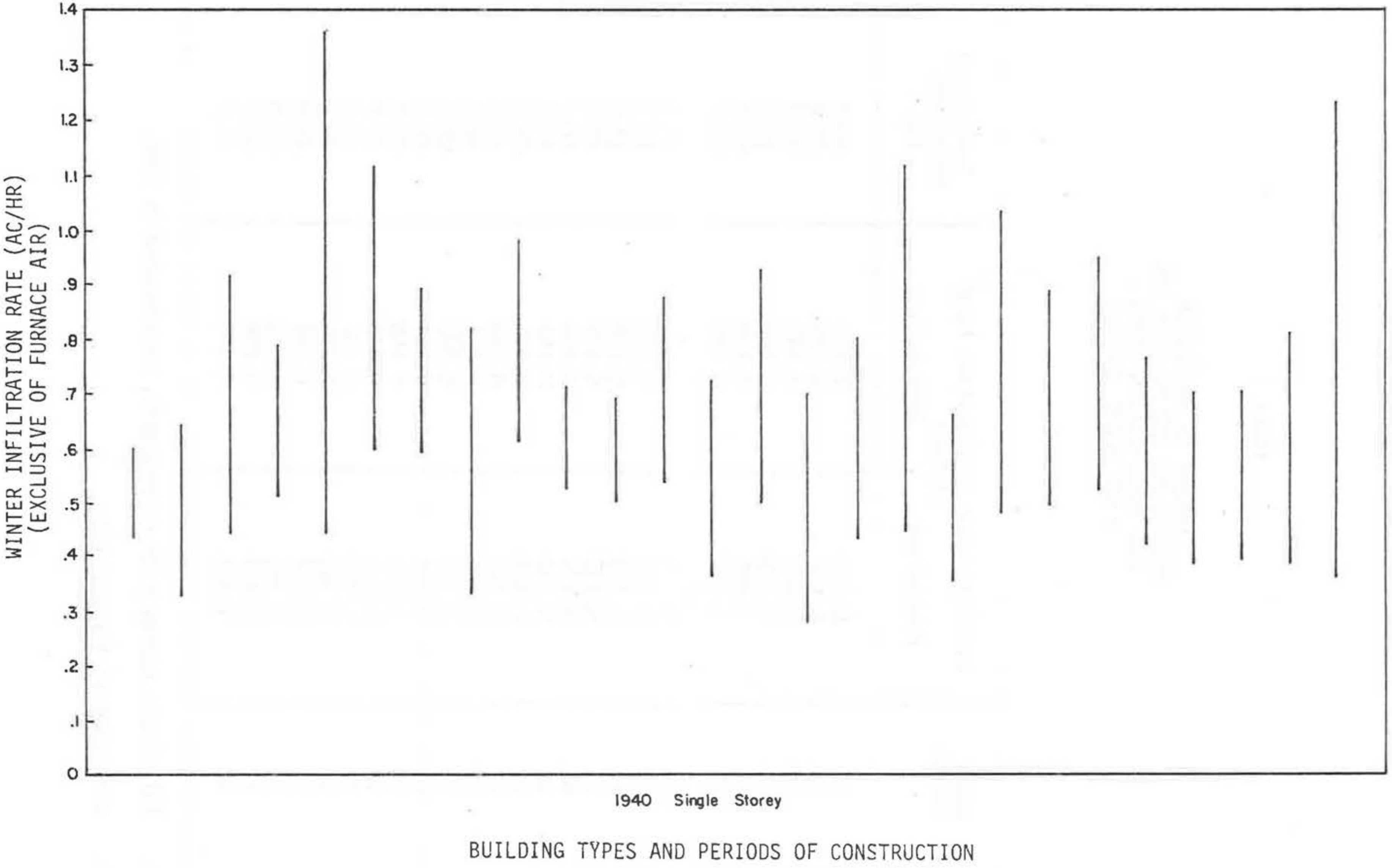
House Number	Predicted Air Infiltration Rate[2] (AC/HR)		Percentage Reduction (%)
	Presealing	Postsealing	
57	0.604	0.433	28.3
58	0.637	0.326	48.8
59	0.922	0.440	52.3
60	0.779	0.506	35.0
61	1.361	0.438	67.8
62	1.109	0.596	46.2
63	0.893	0.576	35.5
64	0.819	0.327	60.1
65	0.972	0.612	37.1
66	0.710	0.528	25.6
67	0.693	0.498	28.2
68	0.871	0.543	37.7
69	0.716	0.362	49.4
70	0.928	0.501	46.0
71	0.701	0.268	61.8
72	0.797	0.426	46.5
73	1.112	0.443	60.2
74	0.657	0.351	46.6
75	1.041	0.468	55.0
76	0.875	0.475	45.8
77	0.953	0.532	44.2
78	0.763	0.423	44.6
79	0.699	0.381	45.5
80	0.701	0.393	43.9
81	0.812	0.384	52.7
82	1.225	0.346	71.7

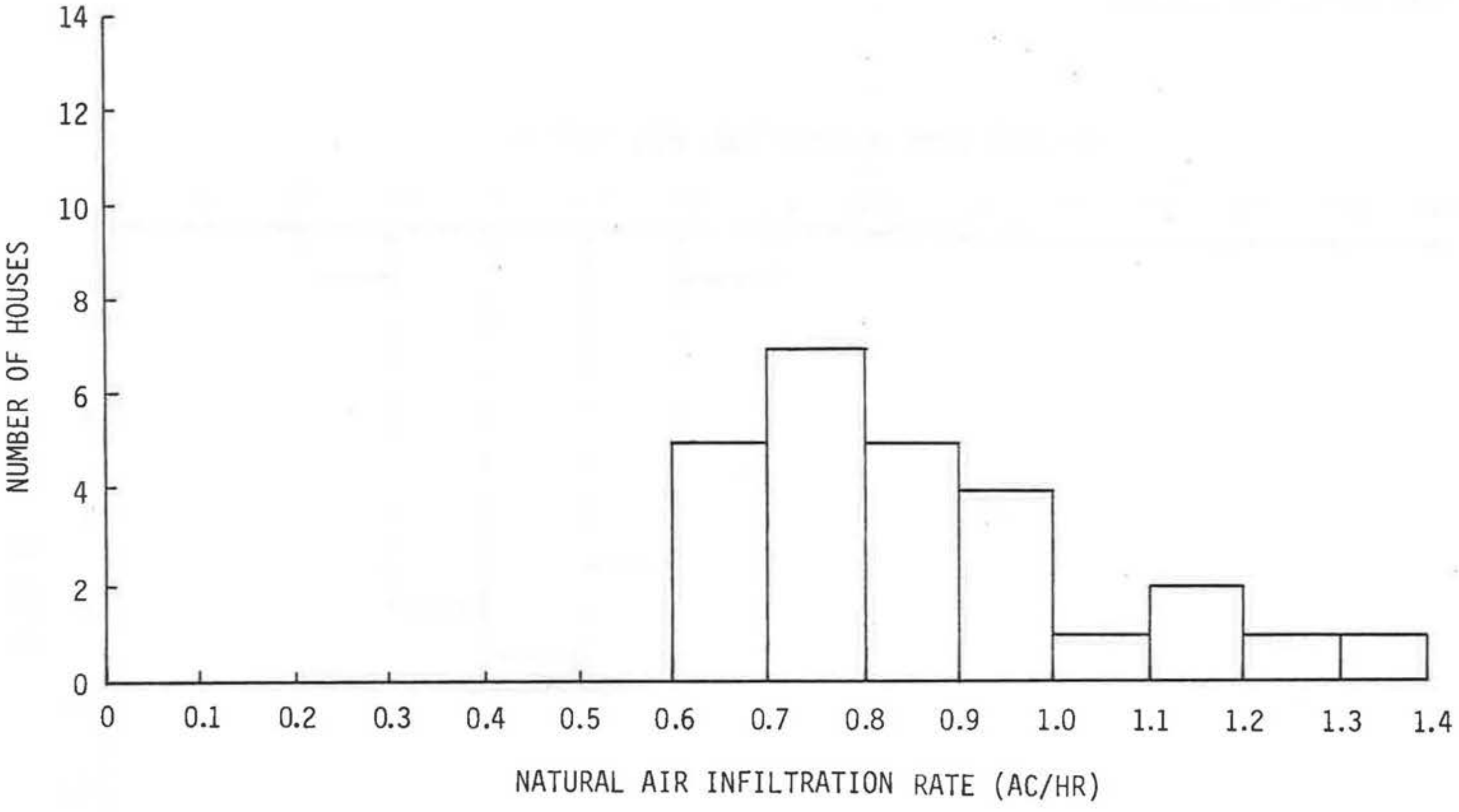
1. All single storey with no basement, constructed in 1940.

2. Exclusive of furnace air.

WINTER INFILTRATION RATES BEFORE AND AFTER SEALING - FLORA PLACE HOUSES

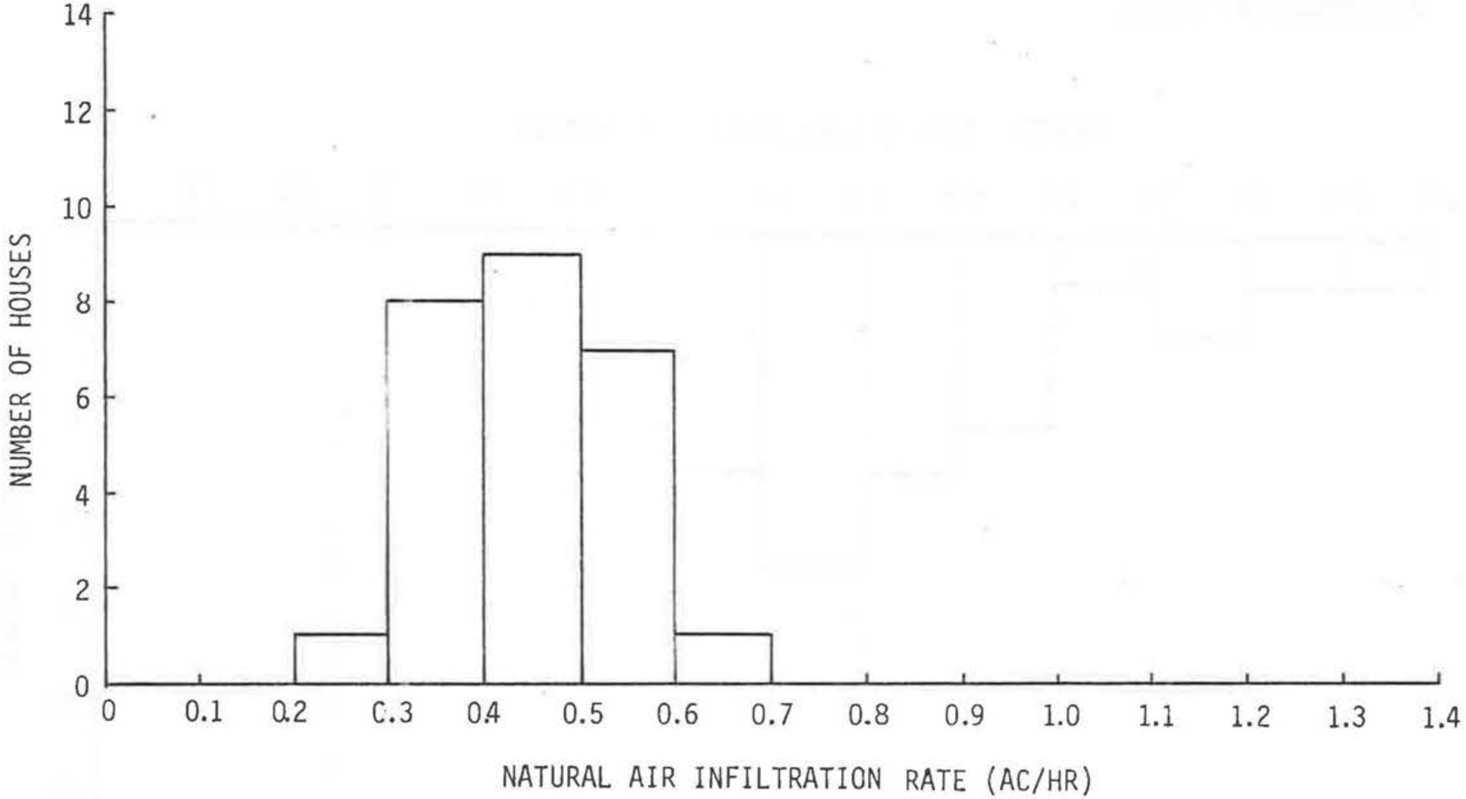
FIGURE 7





PRESEALING PREDICTED
AIR INFILTRATION RATES*
FLORA PLACE HOUSES
(*EXCLUSIVE OF FURNACE AIR)

FIGURE 8



POSTSEALING PREDICTED
AIR INFILTRATION RATES*
FLORA PLACE HOUSES
(*EXCLUSIVE OF FURNACE AIR)

FIGURE 9

CHAPTER 6

THE EFFECTS OF AIR LEAKAGE SEALING UPON THE SPACE HEATING LOADS AND COSTS

6.1 PREDICTION OF SPACE HEATING LOADS

For most consumers, the benefits of a conservation measure such as air leakage sealing, is usually described in terms of the reduction in the annual heating bill which the measure produces. While the use of such a parameter has inherent limitations due to the wide variations in housing style, age, construction and existing conservation levels which are apt to be encountered, it was concluded that expression of the results of this study in such a manner would be of value.

To perform the analysis in a representative and standardized manner, a series of typical houses with varying degrees of insulation levels were modelled using the HOTCAN energy analysis program. Although verification studies on HOTCAN's accuracy are continuing, all the initial indications are that it's accuracy is acceptable for studies of the kind described in this report. Reference 3 contains comparisons between the measured space haeting consumption and the HOTCAN predictions for a group of 14 occupied houses located in Saskatoon. For these structures, HOTCAN was able to predict the annual space heating consumption within +24% and -17%. Further non published work by the authors of this report is in general agreement with the results reported in Ref. 3. The five different house types described in Chapter 5, were each modelled with two different insulation levels, and with both the presealing and postsealing air infiltration rates shown in Table 6. The two insulation levels modelled represented the range normally encountered in conventional construction; the extreme case of a house with no wall or basement insulation and only small amounts in the attic, and the case of a traditionally well-insulated structure with full stud width wall and basement insulation and extra amounts in the attic. Double glazing was assumed for the uninsulated cases and triple glazing for the insulated examples. In all other respects, the houses (within a given house type category) were assumed to be of identical size, configuration, occupancy and exposure to solar radiation. All the structures were sized to be representative of conventional housing stock. Note that the air infiltration rates for the insulated and uninsulated cases for each category of house, were assumed equal (as shown in Table 6). In practice this would likely not occur, with the infiltration rates of the insulated structures typically 25% to 30% lower than those of the uninsulated houses. To avoid confusing the issue however, the air infiltration rates were assumed equal. This would not affect the study's findings. A more detailed description of the houses is given in Table 8.

6.2 REDUCTION OF SPACE HEATING LOADS AND COSTS DUE TO AIR LEAKAGE SEALING - CONVENTIONAL HOUSES

A summary of the predicted reductions in space heating loads due to air leakage sealing, as determined using the HOTCAN analysis is shown in Table 9. The reductions in the air infiltration rate due to sealing used in the analysis were the median values given in Table 6. The most striking

TABLE 8

DESCRIPTION OF REPRESENTATIVE HOUSES MODELLED TO DETERMINE EFFECTS OF AIR LEAKAGE SEALING UPON SPACE HEATING LOADS

House Type	Floor Area (m^2)	House Volume[1] (m^3)	Insulation Levels[2] (RSI) Walls	Basement	Ceiling	Type Of Windows[3]
1 Storey						
Uninsulated	89	435	0	0	5.28	D.G.
Insulated	89	435	2.11	2.11	7.04	T.G.
Split Levels						
Uninsulated	178	462	0	0	5.28	D.G.
Insulated	178	462	2.11	2.11	7.04	T.G.
1½ Storey						
Uninsulated	100	398	0	0	5.28	D.G.
Insulated	100	398	2.11	2.11	7.04	T.G.
2 Storey						
Uninsulated	134	510	0	0	5.28	D.G.
Insulated	134	510	2.11	2.11	7.04	T.G
2½ Storey						
Uninsulated	165	571	0	0	5.28	D.G.
Insulated	165	571	2.11	2.11	7.04	T.G.

1. Including basement.
2. Insulation only, does not include effect of framing members, sheathing, etc.
3. D.G. - double glazed; T.G. - triple glazed.

TABLE 9

PREDICTED REDUCTIONS IN SPACE HEATING LOAD DUE TO AIR LEAKAGE SEALING

House Type	PRESEALING			POSTSEALING			% Reduction in Annual Space Htg. Load
	Air Infiltration Rate (AC/HR)	% of Annual Space Htg. Load	Annual Space Htg. Load (kWh)	Air Infiltration Rate (AC/HR)	% of Annual Space Htg. Load	Annual Space Htg. Load (kWh)	
1 Storey							
Uninsulated	0.356	13.7%	44,845	0.217	8.8%	41,824	6.7%
Insulated	0.356	25.9%	19,388	0.217	17.6%	16,428	15.3%
Split Levels							
Uninsulated	0.290	11.1%	45,342	0.199	7.9%	43,271	4.6%
Insulated	0.290	20.6%	19,624	0.199	15.1%	17,614	10.2%
1½ Storey							
Uninsulated	0.407	13.9%	46,302	0.293	10.4%	44,045	4.9%
Insulated	0.407	25.3%	21,334	0.293	19.6%	19,132	10.3%
2 Storey							
Uninsulated	0.486	16.8%	60,243	0.366	13.2%	57,198	5.1%
Insulated	0.486	31.7%	27,181	0.366	25.9%	24,194	11.0%
2½ Storey							
Uninsulated	0.738	23.3%	75,698	0.446	15.5%	67,419	10.9%
Insulated	0.738	39.5%	40,305	0.446	28.3%	32,151	20.2%

observation, although not unexpected, is the wide variation in reductions both between house types and within a given category. The lowest predicted reductions, 4.6% for uninsulated split levels reflected their relatively low initial air infiltration rates. The greatest reductions in the space heating load, 20.2% for insulated 2½ storey houses is indicative of both their high initial infiltration rates and the large reductions in air leakage produced by the sealing in the houses studied. Again, however, the results obtained for the (small sample size of) 4 2½ storey houses may not be representative of the larger population. To results quite clearly show the difficulty of attempting to describe a "typical" house.

For a given type of house, the reduction in heating load varied by a factor of approximately two. This large variation reflected the differing percentages of the total heat loss which was attributable to air infiltration as the insulation levels of the house were increased since the actual energy savings between the insulated and uninsulated case, for a given category of house, were essentially equal.

To provide an indication of the economic benefits of the sealing, the energy savings were translated into dollar savings using three different types of fuel. These are summarized in Table 10. The fuel costs for natural gas and oil were the current Winnipeg prices at the time of writing while the electrical rate was the (then) recently announced residential run-off rate planned to become effective May 15th, 1983. Seasonal furnace efficiencies of 60% were used for gas and oil heating.

In general, the dollar savings produced by sealing were solely dependent upon the existing natural air infiltration rate, the ability of the

TABLE 10

PREDICTED REDUCTIONS IN SPACE HEATING COSTS DUE TO AIR LEAKAGE SEALING

House Type	Annual Space Heating Load (kWh)		Reduction In Space Heating Load Due To Sealing (kWh)	Reduction In Annual Space Heating Costs Due To Sealing		
	Presealing	Postsealing		Natural Gas @ $0.4783/ccf	Oil @ $0.332/l	Electricity @ 2.77/kWh
<u>1 Storey</u>						
Uninsulated	44,845	41,824	3,021	$ 82	$154	$ 84
Insulated	19,388	16,428	2,960	$ 81	$151	$ 82
<u>Split Levels</u>						
Uninsulated	45,342	43,271	2,071	$ 56	$106	$ 57
Insulated	19,624	17,614	2,010	$ 55	$103	$ 56
<u>1½ Storey</u>						
Uninsulated	46,302	44,045	2,257	$ 61	$115	$ 63
Insulated	21,334	19,132	2,202	$ 60	$113	$ 61
<u>2 Storey</u>						
Uninsulated	60,243	57,198	3,045	$ 83	$156	$ 84
Insulated	27,181	24,194	2,987	$ 81	$153	$ 83
<u>2½ Storey</u>						
Uninsulated	75,698	67,419	8,279	$225	$423	$229
Insulated	40,305	32,151	8,154	$222	$417	$226

sealing to reduce this rate, and the type of fuel. The dollar savings were essentially independent of the existing insulation levels, although as noted earlier the insulation levels would affect the initial air infiltration rates.

As illustrated, the dollar savings ranged from a low of \$55 per year for an insulated split level hours heated with natural gas to a high of \$423 for an uninsulated 2½ storey house heated with oil. Once again though, the predicted results for the 2½ storey houses should be viewed cautiously because of the small sample size.

Although a detailed cost/benefit analysis was beyond the scope of this project, it should be noted that the true value of any savings resulting from sealing can only be evaluated with knowledge of the costs of such work. Since the cost of sealing is roughly proportional to the size of the house, it is evident that there would be considerable variation in the price of sealing the different types of houses studied.

It should also be noted that the benefits listed in Table 10 are those resulting solely from the direct reduction in the heating load. Additional benefits due to increased comfort levels, fewer cold drafts (with possible additional energy savings from lowered thermostat settings) and potentially reduced moisture damage problems, could also result.

6.3 REDUCTION OF SPACE HEATING LOADS DUE TO AIR LEAKAGE SEALING - FLORA PLACE HOUSES

A summary of the predicted reductions in space heating loads and costs for the 26 Flora Place houses is shown in Table 11. Since these houses were atypical of conventional housing stock, the savings in energy costs were only calculated for electric heating, the existing type of heating in all the structures. The median predicted reduction in space heating loads and costs due to the air leakage sealing was 17.5%.

To illustrate the variation in both the initial air infiltration rates and the success of the sealing, two additional simulations were prepared using air infiltration rates for the two houses which experienced the smallest and the greatest reductions in their air infiltration rates. These are also shown in Table 11. Note the wide variation in energy and dollar savings for ostensibly identical sealing on near identical houses.

On average, the percentage reduction in air infiltration was greater for the Flora Place houses than the conventional structures studied. This reflected the much smaller size of these buildings, their simple style of construction and most notably the absence of continuous wall/floor system interfaces that occur in houses with basements or more than 1 storey. Such interfaces are generally quite difficult to seal properly.

TABLE 11

PREDICTED REDUCTIONS IN SPACE HEATING COSTS DUE TO AIR LEAKAGE SEALING - FLORA PLACE HOUSES

Case	Annual Space Heating Load (kWh)		Reduction In Space Heating Load Due To Sealing (kWh)	Reduction In Space Heating Costs Due To Sealing (Electricity @ 2.77¢/kWh)
	Presealing	Postsealing		
1. Flora Place house with median predicted presealing infiltration rate of 0.816 AC/HR and median predicted reduction due to sealing of 46.1%.	10,899	8,994	1,905	$ 53
2. Flora Place house which experienced the smallest predicted reduction in air infiltration due to sealing of 25.6%.	10,360	9,438	922	$ 26
3. Flora Place house which experienced the largest predicted reduction in air infiltration due to sealing of 71.7%.	12,985	8,523	4,462	$124

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