THE ECONOMIC IMPACTS OF ANCILLARY HOUSING EXPENDITURES

SUMMARY REPORT

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SUMMARY REPORT: THE ECONOMIC IMPACTS OF ANCILLARY HOUSING EXPENDITURES

Report submitted to Canada Mortgage and Housing Corporation

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Summary

This study develops up-to-date estimates of the economic impacts of a variety of housing-related ancillary expenditures. It is intended to complement an earlier series of studies commissioned by CMHC in 1997/98 that estimated the economic impacts of basic housing construction and renovation. In the present case, economic impacts are obtained for ancillary expenditures (rather than direct construction) from three related types of housing expenditure: initial construction preparation (hereafter, 'new construction'), the sales of newly-constructed dwelling units held in stock, and the sales of existing dwellings. A variety of ancillary expenditures are considered, including, where possible, infrastructure and land development, selling costs, professional fees and financing.

It is useful to divide the economic impacts of any type of expenditure into three types: direct, indirect and induced. **Direct** impacts are the actual recorded expenditures of (in this case) home buyers and home builders. In the present study a variety of ancillary expenditures are considered, including, where possible, infrastructure and land development, selling costs, professional fees and financing. **Indirect** impacts are the economic activity generated by these purchases from supplier industries, and they from their suppliers, back along the production chain. Thus, for example, direct expenditure on infrastructure construction will have an indirect impact on the cement production industry, which in turn will have an indirect impact on quarrying. Finally, **induced** effects are the impacts of the flows of income resulting from the direct and indirect effects as they proceed through the economy as a whole (the 'macroeconomy'), and their impacts on consumption sales, profits, foreign trade, financial markets, taxes and government balances.

In this study, these induced or macroeconomic impacts are calculated under a range of settings for both the underlying state of the economy (low vs. high unemployment) and for alternate monetary-policy reactions and the total impacts (direct+indirect+induced) are estimated over a multi-year horizon and with full regard for the many simultaneous interactions of key variables.

Estimation of the **direct** detailed ancillary expenditures listed required an intimate knowledge of the housing sector and related activities and complete familiarity with the various data sources available from both the public sector and the industry. Clayton Research, as one of the leading housing-market research organizations in Canada, had the expertise to undertake this phase of the research with great accuracy and in a cost-effective manner. They prepared the second section of the report, under the direction of lead researcher Peter Norman.

For determination of the detailed **indirect** economic impacts of an expenditure shock, there is effectively no substitute for the Input-Output (I/O) databases and models developed by Statistics Canada. The Policy and Economic Analysis Program (PEAP), using its own "in-house" version of the I/O tables at the "Large" industry level of disaggregation (165 industries), was responsible for translating the detailed direct impacts estimated by Clayton Research into I/O category inputs and for developing the I/O model estimates of indirect impacts.

Estimation of the **induced** impacts of housing-related ancillary expenditures required a Canadian macroeconometric model. The FOCUS macroeconometric model, built and maintained by PEAP,

is one of the few such models outside the government sector, and the only such academic model maintained on a current basis. The induced (and total) impacts of the ancillary expenditures were calculated both in a "high" capacity and "low" capacity economic environment and with two alternative assumptions about the reactions of the monetary authorities.

Several "counterfactual" simulations were also run with the model to determine how the Canadian economy would have differed from its historical performance in the 1990s if ancillary housing expenditures had been held at 1989 levels or had displayed less volatility over the decade.

While the most important results of a study such as this are in the details as estimated, a few general conclusions can be drawn: As with the earlier CMHC study of temporary increases in new housing construction or alterations, the simulations have shown that a temporary increase in new housing construction activity can have important induced effects on the economy through the ancillary expenditures that accompany it, and that stimulus of this sort could be considered as a weapon of countercyclical fiscal policy during a slump or recession. Ancillary expenditures related to sales of new or existing dwellings were found to have a much smaller effect and would be correspondingly weaker as counter-cyclical tools. The study also finds that, when the stimulus is of significant size, it will have an effect beyond the temporary period when it is directly in effect. For countercyclical policy, therefore, it is important that a housing stimulus be introduced *early* or, as much as possible, in anticipation of the downturn. If the housing stimulus is introduced well after the downturn has begun, the lags in its operation could perhaps overheat a recovery.

Counterfactual simulation tests over the 1990s confirm these basic conclusions and show that, especially, ancillary expenditure associated with new housing construction, would have played a small, but significant and consistent, counter-cyclical role through the decade if new housing construction itself could have been smoothed or kept at late-1980s levels.

The study finds that a temporary stimulus of this kind develops its *own* contractionary aftershock within 3 to 4 years (or somewhat longer under the interest-rate target). If the object of countercyclical policy is to soften recessions and also to suppress booms in recovery, then a temporary housing stimulus works on *both*, since the shock creates first positive and then negative stimulus to GDP and employment.

The simulations also show that the state of the underlying economy matters for the impacts of a temporary housing shock. The higher the base level of the unemployment rate, the less inflationary impact there will be, and the smaller will be the later contractionary impact. However, for the ancillary expenditures we have examined, the inflationary impacts have all been found to be very small.

Finally, the simulations show that the impacts of a temporary spending shock associated with ancillary spending from housing activity cannot be considered in a policy vacuum: the impacts can vary significantly with the policy stance of the Bank of Canada. The more the Bank is prepared to accept additional stimulus, and the inflation it can bring, the larger the impacts will be.

Résumé

Dans le cadre de cette étude, les chercheurs ont mis au point des estimations à jour des impacts économiques de diverses dépenses accessoires liées au logement. L'étude vise à compléter une série antérieure d'études commandées par la SCHL en 1997-1998, qui avait permis d'établir des estimations des impacts économiques de la construction et de la rénovation de base de logements. Dans le cas actuel, on détermine les impacts économiques des dépenses accessoires (plutôt que de la construction directe) pour trois types connexes d'activités liées au logement : la préparation de la construction initiale (ci-après appelée la «construction neuve»), la vente de logements nouvellement construits faisant partie des stocks et la vente de logements existants. On tient compte de diverses dépenses accessoires, y compris, autant que possible, des coûts de l'infrastructure et de l'aménagement du terrain, des frais de vente, des honoraires professionnels et des frais de financement.

Il est utile de diviser les impacts économiques de n'importe quel genre de dépenses en trois types : directs, indirects et secondaires. Les impacts **directs** sont les dépenses réellement enregistrées des acheteurs et constructeurs de maisons (dans ce cas particulier). Dans l'étude dont il est ici question, on tient compte de diverses dépenses accessoires, y compris, autant que possible, les coûts de l'infrastructure et de l'aménagement du terrain, les frais de vente, les honoraires professionnels et les frais de financement.

Les impacts **indirects** sont l'activité économique engendrée par ces achats aux industries en amont, et par les achats de ces dernières à leurs fournisseurs, et ainsi de suite en remontant le long de la chaîne de production. Ainsi, par exemple, les dépenses directes pour la construction d'infrastructure auront un impact indirect sur l'industrie cimentière, ce qui, à son tour, aura un impact indirect sur l'exploitation des carrières. Enfin, les effets **secondaires** sont les impacts des flux de revenu découlant des effets directs et indirects, à mesure qu'ils se propagent dans l'économie toute entière (la «macroéconomie»), et leurs impacts sur les ventes d'articles de consommation, les profits, le commerce extérieur, les marchés financiers, les taxes et les soldes du secteur public.

Dans le cadre de cette étude, ces impacts secondaires ou macroéconomiques sont calculés pour un éventail de scénarios, tant pour la situation économique sous-jacente (chômage faible c. élevé) et pour diverses réactions possibles au niveau de la politique monétaire, et les impacts totaux (directs + indirects + secondaires) sont estimés sur un horizon temporel de plusieurs années et en tenant pleinement compte des nombreuses interactions simultanées des variables clés.

L'estimation des dépenses accessoires détaillées **directes** énumérées nécessitait une connaissance approfondie du secteur du logement et des activités connexes et une connaissance parfaite des diverses sources de données disponibles dans le secteur public et dans l'industrie. Clayton Research, une des principales organisations de recherche sur le marché du logement au Canada, avait les compétences nécessaires pour entreprendre cette étape de la recherche avec une très grande précision et d'une manière efficiente. L'entreprise a préparé la deuxième section du rapport, sous la direction du chercheur principal Peter Norman.

Pour déterminer les impacts économiques **indirects** détaillés d'une dépense, rien ne peut remplacer les bases de données et modèles des entrées-sorties mis au point par Statistique Canada. Le Policy and Economic Analysis Program (PEAP) [programme d'analyse économique et des politiques], en utilisant sa propre version «interne» des tables des entrées-sorties au niveau de désagrégation du «grand» secteur (165 industries), a été chargé de traduire les impacts directs détaillés estimés par Clayton Research en données d'entrées-sorties et de mettre au point les estimations des impacts indirects au moyen du modèle des entrées-sorties.

Un modèle macroéconométrique canadien était nécessaire pour estimer les impacts **secondaires** des dépenses accessoires liées au logement. Le modèle macroéconométrique FOCUS, mis au point et maintenu par le PEAP, est un des rares modèles de ce genre qui existent à l'extérieur du secteur public et le seul modèle universitaire qui soit régulièrement mis à jour. Les impacts secondaires (et totaux) des dépenses accessoires ont été calculés dans un contexte économique de «forte» capacité et de «faible» capacité et en appliquant deux hypothèses différentes concernant les réactions des autorités monétaires.

On a aussi fait plusieurs simulations «hypothétiques» au moyen du modèle afin de déterminer comment la situation économique canadienne aurait différé des résultats enregistrés dans les années 1990 si les dépenses accessoires liées au logement avaient été maintenues au niveau de 1989 ou avaient été moins volatiles pendant la décennie.

Bien que les résultats les plus importants d'une étude de ce genre se situent au niveau des détails tels qu'estimés, on peut néanmoins en tirer quelques conclusions générales. Comme l'avait montré l'étude antérieure de la SCHL sur les hausses temporaires de l'activité de construction neuve ou de rénovation, les simulations ont indiqué qu'une augmentation temporaire de la construction neuve peut avoir des effets secondaires importants sur l'économie en raison des dépenses accessoires qui l'accompagnent, et qu'un stimulant de ce genre pourrait être considéré comme un instrument de politique financière contracyclique pendant les périodes de marasme ou de récession économique. Les chercheurs ont constaté que les dépenses accessoires liées à la vente de logements neufs ou existants ont un effet beaucoup moins important et seraient donc des outils contracycliques plus faibles. Ils ont aussi constaté qu'un stimulant d'une ampleur considérable continuera d'avoir un effet au-delà de la période temporaire pendant laquelle il est en vigueur. Par conséquent, pour la politique contracyclique, il importe qu'un stimulant dans le secteur du logement soit introduit *tôt* ou, dans la mesure du possible, dès qu'un ralentissement est prévu. Si le stimulant dans le secteur du logement est introduit bien après le début du ralentissement, le retard avec lequel il commence à opérer pourrait entraîner une surchauffe au moment de la reprise.

Les tests de simulation hypothétique pour les années 1990 confirment ces conclusions de base et montrent que les dépenses accessoires liées à la construction neuve, notamment, auraient joué un rôle contracyclique petit, mais important et uniforme tout au long de la décennie, si l'activité même de construction neuve avait pu être régularisée ou maintenue au niveau qui prévalait à la fin des années 1980.

L'étude a permis de constater qu'un stimulant temporaire de ce genre produit son *propre* impact de contraction après trois ou quatre ans (après une période un peu plus longue selon le taux d'intérêt visé). Si le but de la politique contracyclique est d'atténuer les récessions et aussi de supprimer les boums pendant la reprise, alors un stimulant temporaire dans le secteur du logement fonctionne dans *les deux cas*, puisque le choc agit d'abord positivement, puis négativement sur le PIB et l'emploi.

En plus, les simulations montrent que l'état de l'économie sous-jacente a une incidence sur les impacts d'un choc temporaire dans le secteur du logement. Plus le niveau de base du taux de chômage est élevé, moins l'impact inflationniste sera grand et plus l'impact de contraction ultérieur sera faible. Toutefois, pour les dépenses accessoires que nous avons examinées, les impacts inflationnistes constatés étaient tous très faibles.

Enfin, les simulations montrent que les impacts d'un choc temporaire lié aux dépenses accessoires découlant de l'activité de logement ne peuvent pas être examinés sans tenir compte des politiques. En effet, les impacts peuvent varier considérablement selon la position adoptée par la Banque du Canada. Plus la Banque est disposée à accepter des stimulants supplémentaires de même que l'inflation qu'ils peuvent amener, plus les impacts seront importants.

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Contents:

1. Introduction

This study develops up-to-date estimates of the economic impacts of a variety of housing-related ancillary expenditures. It is intended to complement an earlier series of studies commissioned by CMHC in 1997/98 that estimated the economic impacts of basic housing construction and renovation.[1] In the present case, economic impacts are to be obtained for ancillary expenditures (rather than direct construction) from three related types of housing expenditure: initial construction preparation (hereafter, 'new construction'), the sales of newly-constructed dwelling units held in stock, and the sales of existing dwellings. A variety of ancillary expenditures are considered, including, where possible, infrastructure and land development, selling costs, professional fees and financing.

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[1]The earlier studies were conducted by Informetrica, Inc., which examined both indirect and induced impacts of housing construction, using an Input-Output model and an annual macroeconometric model, and the Policy and Economic Analysis Program (PEAP) of the University of Toronto. The latter organization used the Input-Output estimates of Informetrica for their own macroeconometric model calculations. The PEAP study was entitled "The Macroeconomic Impacts of Housing Construction Activity: Simulations with the FOCUS Model", by Peter Dungan, March, 1998.

policy reactions and the total impacts (direct+indirect+induced) are estimated over a multi-year horizon and with full regard for the many simultaneous interactions of key variables.

Estimation of the **direct** detailed ancillary expenditures listed required an intimate knowledge of the housing sector and related activities and complete familiarity with the various data sources available from both the public sector and the industry. Clayton Research, as one of the leading housing-market research organizations in Canada, had the expertise to undertake this phase of the research with great accuracy and in a cost-effective manner. They prepared the second section of the report, under the direction of lead researcher Peter Norman.

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Next, estimation of the **induced** impacts of housing-related ancillary expenditures required a Canadian macroeconometric model. The FOCUS macroeconometric model, built and maintained by PEAP, is one of the few such models outside the government sector, and the only such academic model maintained on a current basis. It has been widely used for such analyses in the past (for example, in the earlier housing-construction impact study by CMHC). It also includes switches for a variety of monetary responses, making the analysis of sensitivities relatively straightforward. PEAP carried out the estimation of total (including induced) impacts of the various ancillary expenditures (and under alternative assumptions) using the FOCUS model. The results are presented in Section 4. Several "counterfactual" simulations were also run with the model to determine how the Canadian economy would have differed from its historical performance in the 1990s if ancillary housing expenditures had been held at 1989 levels or had displayed less volatility over the decade. These results are summarized in Section 5. While the most important results of a study such as this are in the details as estimated, a few general conclusions are presented in Section 6.

Note: This report is a non-technical summary of the methods used in the study and of the major findings. For detailed descriptions of the research methods and of the results readers should consult the companion technical report.

2. Estimating the Direct Impacts of Ancillary Housing Expenditures - by Clayton Research

Housing transactions in Canada generate significant economic activity. The purchase of new and existing homes and the construction of new dwellings, generate fees for professionals such as lawyers, appraisers, real estate agents, surveyors, etc., as well as taxes and fees to various levels of government. In addition housing construction generates demand for serviced lots which in turn generates a number of economic transactions both in terms of fees, levies, taxes and development costs.

In this section of the report, Clayton Research provides estimates of direct ancillary housing expenditures both on a typical per-unit basis and in aggregate as they related to three specific scenarios:

- $1 billion annual increase in residential construction expenditure;
- $1 billion annual increase in sales of newly-built dwellings; and
- $1 billion annual increase in the sales of existing dwellings.

The estimates are for 1997, the last year for which complete data were available. The estimation procedure draws from a large array of sources and makes use of a number of assumptions, rules of thumb, and standard estimation techniques. The estimates that are produced reflect national averages, and thus the aggregates represent national aggregate direct impacts. From a methodological standpoint, however, the estimates are first generated on a regional bases (three broad regions are defined) and then a weighted average is generated based on the relative levels of construction in the base year in each region. In effect, this methodology assumes that the specific events being investigated, that is, $ 1 billion in 1997 in additional activity in certain housing markets, would be distributed among the regions of Canada in the same proportion as regular housing activity took place in 1997.

The estimates reflect activity and expenditures which occurred in 1997 and are expressed in 1997 dollars. This base year was chosen as it was early enough to ensure the availability of data, but late enough that the data reflect relatively current market conditions and policy environments.

Although the estimates are produced as a per-unit average, these are transformed into aggregates related to the three standardised scenarios. For each of the three this transformation procedure is described below:

- **$1 billion annual increase in residential construction expenditures**. In 1997 total residential construction expenditures on new dwellings equalled $21.8 billion. Residential construction starts in 1997 totalled 148,224 units, for an average value of construction of $147,000.[2] For the purposes of our transformation, therefore, we are assuming that an additional $1 billion in spending would generate new construction of 6,800 new residential units.

- **$1 billion annual increase in sales of newly-constructed dwellings**. Sales of newly constructed dwellings also include land. Total sales volume in 1997 was $29.2 billion for an average (based on starts) of $197,100 per dwelling (includes ownership and rental dwellings). For the purposes of our transformation, therefore, we are assuming that an additional $1 billion would generate sales of 5,070 new residential units.

- **$1 billion annual increase in sales of existing dwellings**. In 1997, according to the Canadian Real Estate Association, existing homes sales through the MLS system averaged $156,500 in value. For the purposes of our transformation, therefore, we are assuming that an additional $1 billion in spending would generate sales of 6,400 existing residential units.

Table 2.1 illustrates the estimates of average and aggregate direct ancillary spending associated with the three specific scenarios of housing activity.

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[2]The National Accounts data on construction measure "work put in place" which will differ from work started in terms of timing. The pattern of both starts and construction expenditure in the 1996-1998 period, however, suggests that this calculation will not present too large a bias.

Table 2.1
Direct Ancillary Expenditure in 1997

Residential Construction	Average $	Aggregate* $000
6,800 units		
Land Development	6,504	44,228
Infrastructure (on-site)	10,409	70,784
Land Transactions	319	2,171
Infrastructure (off-site)	9,709	66,020
Total	**26,942**	**183,202**
Sales of Newly Constructed Dwellings		
5,070 units		
Relating to Purchase	14,156	71,773
Relating to Sale	1,726	8,750
Relating to Finance	182	921
Total	**16,064**	**81,444**
Sales of Existing Dwellings		
6,400 units		
Relating to Purchase	2,984	19,101
Relating to Sale	5,770	36,930
Relating to Finance	165	1,056
Total	**8,920**	**57,087**

* Generated by $1 billion in activity
Source: Clayton Research

In total there is an average ancillary expenditure associated with a **new residential dwelling** of $26,900. Under the specific event of an additional $1 billion in 1997 on new residential construction, therefore, direct related ancillary spending is estimated to be $183.2 million.

In total there is an average ancillary expenditure associated with **sales of new residential dwellings** per unit of $16,000. Under the specific scenario of an additional $1 billion in 1997 on sales of newly constructed residential dwellings, therefore, direct related ancillary spending is estimated to be $81.4 million.

Finally, in total there is an average ancillary expenditure associated with **sales of existing residential dwellings** per unit of $8,900. Under the specific scenario of an additional $1 billion in 1997 on sales of existing residential dwellings, therefore, direct related ancillary spending is estimated to be $57.1 million.

3. Indirect Impacts of Ancillary Housing Expenditures

In this section we estimate the *indirect* economic impacts of the three categories of ancillary housing expenditures. These indirect impacts are based upon the direct impacts estimated in Section 2, and are also, effectively, for a $1 billion expenditure in 1997.

Indirect, or "upstream", impacts are the economic activity necessary to supply all inputs to a given expenditure. They also include all inputs required to produce these inputs, and so on back along the production chain. For example, if a consumer purchases an automobile, the services of an auto dealer are typically required, as are transportation services necessary to get the auto to the dealer. Of course, the automobile must also be manufactured, generating economic activity in the manufacturing sector. Production of an automobile requires steel, rubber and glass, and a host of other inputs. These inputs too must be produced and transported. Production of steel, now several steps down the production chain, will require iron ore and coal. Production of the other inputs will require yet additional inputs, and so on. Each additional production step will generate economic activity and employment.

In the case of ancillary housing expenditures, the production chain is generally less elaborate than it is for a complex manufactured good like an automobile. Still, construction requires the input of construction materials and cement while construction machinery will need gasoline and maintenance. Real-estate, legal and other professionals will themselves need the services of others such as accountants. Thus, even for ancillary housing expenditures indirect impacts can be considerable.

The standard method for estimating indirect economic impacts is the Input-Output (I/O) model. The I/O model is built around a "snapshot" of detailed economic activity for a particular year. This study uses the Statistics Canada I/O model for 1995 - the latest year available. Data have been collected by Statistics Canada on industry sales to and from each other and into final expenditures for a total of over 160 industries. Other associated data detail, by industry, indirect taxes and wages and salaries paid, profits earned and number of workers employed. By using these data, and some mathematical manipulation, it is possible, for any given expenditure, to work out all the inputs and economic activity required through the entire production chain.

Use of the Statistics Canada I/O model required that the various categories of expenditure identified by Clayton Research be first translated into their equivalents in I/O industry categories. Not surprisingly, this resulted in some aggregation of the expenditure categories, as not all of the highly detailed expenditures identified by Clayton Research are available within the I/O system. Once the necessary aggregations had been done, the expenditures by I/O industry category were fed into the I/O model. The detailed industry impacts are presented below, together with aggregate impacts on Gross Domestic Product (GDP) wages and salaries, indirect taxes, imports, and employment. The results are displayed both for the total of direct and indirect impacts and for direct and indirect impacts separately.

An additional bonus of using the I/O system is that a rough estimate of *direct* employment impacts is also obtained. While Clayton research was able to obtain detailed *dollar* direct impacts of ancillary housing expenditures, no means existed for determining the employment that would be directly associated with these impacts. The 1995 I/O tables however, record employment for the 160 industries distinguished, and it is a simple matter to calculate for each industry the ratio of employment to output (the 'employment ratios') and apply these ratios to the outputs estimated by Clayton Research to obtain rough estimates of *direct* employment impacts. The same ratios are used as part of the I/O calculations to determine indirect employment impacts by industry from indirect output impacts.

Indirect Impacts of Ancillary Expenditures from New Residential Construction.

For new residential construction, the results of the I/O model calculations are summarized in Table 3.1 Two estimates of impacts are shown. One excludes the direct impact of ancillary expenditures on indirect taxes (sales taxes, property taxes and government fees) as estimated by Clayton Research, and the other includes these indirect taxes. For ancillary expenditures on new residential construction, the difference is small, but especially for sales of new dwellings it is large, and both estimates are necessary to give a full impression of direct and indirect impacts.

Table 3.1: Summary: Impacts of Ancillary Expenditures of New Residential Construction
$ 1 Billion of New Residential Construction in 1997

($ 97 '000)	Total:	Direct	Indirect
Initial Direct Expenditure (see Table 2.1)	183202	183202	0
Indirect (Sales, etc.) Taxes on Direct Expenditure	2354	2354	0
Initial Direct Expenditure less Indirect Taxes	180849	180849	0
Excluding indirect taxes on direct expenditure:			
Impact on:			
Gross Domestic Product	146810	80386	66424
of which:			
Value Added	134627	72195	62432
Wages and Salaries	96087	57164	38923
Indirect Taxes	13043	8354	4689
Imports	34039	1249	32790
Employment (person-years)	2593	1398	1195
Including indirect taxes on direct expenditure:			
Impact on:			
Gross Domestic Product	149164	82740	66424
Indirect Taxes	15397	10708	4689

As can be seen, the indirect impacts of the ancillary expenditures associated with residential construction are considerable. The model estimates that the total impact on GDP of ancillary expenditures is just under $147 million. Of this, $66 million, or about 45%, is generated *in*directly. The total impact on employment is approximately 2600 person years - almost 1200 (46%) of which are again generated through indirect economic activity.

Note that the total impact on GDP, at $147 million when indirect taxes from expenditure are excluded, is about $34 million less than the initial expenditure of $181 million. The difference is accounted for by imports - almost all of which are generated by the provision of indirect inputs. In an economy as open as Canada's, even expenditures that have virtually no initial foreign content can end up generating considerable import activity as intermediate inputs are required along the production chain.

Ancillary expenditures associated with residential construction in 1997 also generate just over $13 million in indirect tax revenues, *in addition to* the $2.6 million in indirect taxes paid as part of the ancillary expenditures themselves. The latter are included in the alternative calculations of GDP and indirect taxes in the bottom two lines of Table 3.1. Of the $13 million in indirect tax revenue generated by the initial non-tax expenditures, $8 million is paid on the direct expenditures and a further $4.7 million in indirect tax revenues is generated or paid by industries back along the production chain.

Indirect Impacts of Ancillary Expenditures from New Dwelling Sales

Considered next are the ancillary expenditures associated with $1 billion of new dwelling sales. For this category of expenditure, there is relatively little direct impact on industrial sectors. Of the $81 million of expenditure identified by Clayton Research (line 1 in Table 3.2), over $66 million is accounted for simply by federal and provincial indirect taxes (line 2). This leaves just under $15 million of goods and services to be provided by the economy.

Table 3.2: Summary: Impacts of Ancillary Expenditures of New Dwelling Sales
$ 1 Billion of New Dwelling Sales in 1997

($ 97 '000)	Total:	Direct	Indirect
Initial Direct Expenditure (see Table 2.1)	81444	81444	0
Indirect (Sales, etc.) Taxes on Direct Expenditure	66476	66476	0
Initial Direct Expenditure less Indirect Taxes	14968	14968	0
Excluding indirect taxes on direct expenditure:			
Impact on:			
Gross Domestic Product	12426	9483	2943
of which:			
Value Added	11232	8546	2686
Wages and Salaries	7105	5472	1633
Indirect Taxes	1386	1101	285
Imports	2542	1463	1079
Employment (person-years)	228	174	54
Including indirect taxes on direct expenditure:			
Impact on:			
Gross Domestic Product	78902	75959	2943
Indirect Taxes	67862	67577	285

Not surprisingly, the indirect economic impact of these expenditures is relatively small - but not negligible. As can be seen in Table 3.2, just over $12 million of GDP is generated by these expenditures, of which approximately one-quarter occurs through indirect economic activity. Roughly the same proportion holds for the 228 person years of employment generated directly or indirectly by these ancillary expenditures.

In summary, ancillary expenditures associated with $1 billion in new dwelling sales are considerably smaller than those associated with new construction (or, as we shall see, even those associated with sales of existing dwellings). Nonetheless, the impacts are not negligible and indirect inputs percolate through a wide range of business service sectors. Still, the largest single impact on GDP from ancillary expenditures on new dwelling sales is simply from the collection of indirect taxes at the federal and provincial levels.

Indirect Impacts of Ancillary Expenditures from Sales of Existing Dwellings

Considered finally are the impacts of ancillary expenditures associated with the sales of existing dwellings. The Clayton Research estimates of direct impacts is just over $57 million. While this figure is the smallest of the three types of expenditure, it is composed much less of indirect taxes than is ancillary expenditure on new dwellings. As a result, ancillary expenditure on sales of existing dwellings has a much larger indirect impact on GDP and employment than the latter.

Estimates of total, direct and indirect impacts on GDP, employment and other indicators are shown in Table 3.3. As can be seen, the indirect impacts on GDP and employment generated are about half the size of the direct impacts - again, not negligible, but also not as large in proportion as the indirect impacts of ancillary expenditures on residential construction. Import "leakages", not surprisingly, are also very much smaller in proportion, since fewer goods and more services are involved in ancillary expenditures of this type.

Table 3.3: Summary: Impacts of Ancillary Expenditures of Existing Dwelling Sales
$ 1 Billion of Existing Dwelling Sales in 1997

($ 97 '000)	Total:	Direct	Indirect
Initial Direct Expenditure (see Table 2.1)	57087	57087	0
Indirect (Sales, etc.) Taxes on Direct Expenditure	10740	10740	0
Initial Direct Expenditure less Indirect Taxes	46347	46347	0
Excluding indirect taxes on direct expenditure:			
Impact on:			
Gross Domestic Product	39589	29530	10059
of which:			
Value Added	34697	25470	9227
Wages and Salaries	20596	14920	5676
Indirect Taxes	5552	4621	931
Imports	6758	3443	3315
Employment (person-years)	605	418	188
Including indirect taxes on direct expenditure:			
Impact on:			
Gross Domestic Product	50329	40270	10059
Indirect Taxes	16292	15361	931

Summary for Indirect Impacts

Overall, it can be concluded that the largest direct and indirect impacts on economic production and employment come from the ancillary expenditures associated with $1 billion of expenditure on new residential construction. This category also has the most wide-ranging impact on different industrial sectors. The smallest impacts come from ancillary expenditures on sales of new dwellings, since the greatest part of these is made up of indirect taxes. Much larger impacts, largely in business services, are forthcoming from ancillary expenditures associated with $1 billion in sales of existing dwellings.

4. Induced and Total Impacts of Ancillary Housing Expenditures

In this section we examine the induced or "downstream" economic impacts of ancillary expenditures associated with the various forms of housing activity. These induced effects will last for a period of years beyond the one-year, one-time direct expenditure. We then put all three impacts together (direct, indirect and induced) to come up with total impact measures for the initial year of the expenditure and for several subsequent years.

Induced impacts result when the direct and indirect impacts identified in the sections above are diffused throughout the economy. To take several examples: Workers employed and paid as a result of direct or indirect economic impacts will spend at least part of their earnings on additional consumer goods, thereby stimulating additional economic activity. Profits earned by firms in supplying direct or indirect requirements may be used to finance additional economic investment. Imports required to provide direct or indirect expenditures may have an impact on the foreign exchange rate, and changes in economic activity may cause the Bank of Canada to alter interest rates. Finally, direct, indirect and induced expenditures may alter government tax revenues or spending having an effect on government balances and debts. Each of these changes in turn may cause additional impacts throughout the economy. Induced impacts, in short, go beyond of the direct a provision of goods and services, and the additional goods and services needed to produce them, to consider as many possible additional interactions that may occur in the wider economy. Further, these induced effects will likely occur over a period of years, even if the initial direct and indirect expenditure impact occurs in only one year.

Estimation of induced impacts over time requires a model of the entire macroeconomy. Typically, a "macroeconometric" model is used for this purpose. A macroeconometric model attempts to embody all the major interactions of a national economy and to estimate their relative sizes through statistical techniques ("econometrics"). The present study uses the FOCUS macroeconometric model developed and maintained at the Institute for Policy Analysis, University of Toronto. Using this tool, the study investigates not only the induced impacts of ancillary housing expenditures, but also how the size of this impact is affected by whether the economy is at or below full employment, and how the Bank of Canada responds to the increase the Bank of Canada responds to the increase in economic activity. For additional description of the model and its properties, please see the accompanying Technical Report.

Detailed Inputs for the Simulations

The initial detailed inputs to the FOCUS model simulations are provided in the Totals columns of the tables showing the summary of direct and indirect impacts for the three types of ancillary expenditures (Tables 3.1 - 3.3). These tables show the total of direct and indirect impacts on elements such as GDP, wages and salaries paid, gross profits earned (value added less wages and salaries), indirect taxes paid (and to which level of government) and employment.

A major further adjustment was required to the figures of the three summary tables before they could be entered into FOCUS. Specifically, the analysis for sections 2 and 3 has been for ancillary expenditures from an additional $1 billion in spending in *1997*, while our earlier study of the impact of housing expenditures was for a $1 billion increase in *1986* dollars, to take place in 1999. We decided to use 1997 expenditures for sections 2 and 3 of this report because 1997 was the latest year for which full data were available. However, for comparability with the earlier study the direct and indirect impacts of ancillary expenditures had to be converted into those equivalent to $1 billion of expenditure in *1986* dollars (which is larger than an expenditure in 1997 dollars due to inflation over 1986-97). Several additional adjustments were also needed to take into account changes in prices and in labour productivity between 1997 and 1999 (when the simulations with the macroeconometric model begin).

The adjusted direct+indirect impacts prepared for input to the model for the three ancillary expenditures are shown in Table 4.1. Some inputs to the model are entered in "real" or "inflation-adjusted" terms which, in the base cases used for this study, translates into millions of 1986 dollars. It will be seen that the figures in the first three lines of Table 4.1 are equal to values in Tables 3.1 - 3.3 above, except that, being now in *1986* dollars, they are equivalent to direct+indirect impacts from a $1 billion expenditure in *1986* dollars - an amount comparable to the earlier study. The employment figures and 1999 dollar figures in Table 4.1 are higher than those in Tables 3.1 - 3.3 because the real shock is bigger (again, because $1 billion 1986 dollars is more than $1 billion 1997 dollars).

Table 4.1 Inputs to FOCUS for Direct + Indirect Impacts of Ancillary Expenditures

Direct + Indirect Impacts from Section 3 adapted to $ 1 billion (1986$) expenditure in 1999
Ancillary expenditures associated with $1 billion (1986$) increase in:

1999 Changes in:	New Residential Construction	Sales of New Dwellings	Sales of Existing Dwellings
Residential Investment ($86 Mill)	180.8	15.0	46.3
GDP at Factor Cost ($86 Mill)	134.6	11.2	34.7
Imports ($86 Mill)	33.8	2.5	6.7
Employment ('000)	3.672	0.323	0.857
Residential Investment ($99Mill)	277.0	124.0	86.2
Imports ($99 Mill)	51.1	3.8	10.1
Wages and Salaries ($99 Mill)	145.3	10.7	31.1
Unincorporated Income ($99 Mill)	12.7	1.5	4.4
Operating Surplus ($99 Mill)	45.5	4.8	16.9
Federal Indirect Taxes ($99 Mill)	9.2	72.0	3.4
Provincial Indirect Taxes ($99 Mill)	11.8	31.1	19.6
Municipal Indirect Taxes ($99 Mill)	1.1	0.0	0.0

Nominal figures (which are denoted by "($99 Mill)") are in the dollars of 1999; they have been adjusted for inflation between 1986 and 1999. For further details on assumptions and settings behind the simulations, please see the detailed technical report.

It was specified in the study terms of reference that high-growth and low-growth base cases would be used for the impact experiments - in large part to capture non-linearities in responses of the model (and the economy) to new demand when the economy has experienced low growth and is far from full employment (more output generated, and less impact on prices and wages) and when it is close to full employment (economy can provide little new output itself: prices, wages and imports rise instead). For comparability with the earlier CMHC study of the impact of new housing construction, the two base cases are identical to the ones used in that study. Table 4.2 summarizes the unemployment rate in each scenario:

Table 4.2

Unemployment Rates in the High Growth and Low Growth Base Cases

	"High Growth"	"Low Growth"
1999	7.94	10.56
2000	7.83	10.67
2001	7.70	10.68
2002	7.39	10.78
2003	7.50	10.89

For 1999, when the simulated ancillary housing expenditure shocks will be deemed to occur, the difference between the unemployment rates in the two base cases averages 2.7 percentage points.

The remainder of section 4 describes the simulation results. A total of twelve simulations were conducted, each for the five-year period 1999-2003. There are three basic shocks: the ancillary expenditures associated with (1) New Residential Construction, (2) Sales of New Dwellings and (3) Sales of Existing Dwellings. Each is conducted on both the High-Growth and Low-Growth Bases noted above. Finally, each is also conducted using two monetary targets. Typically, the ancillary housing expenditure increases raise imports and put downward pressure on the Canadian dollar.

Under the 'exchange-rate target' for monetary policy, the Bank of Canada raises interest rates to bring money into the country and support the value of the dollar. The higher interest rates, however, also dampen economic activity. Under the 'interest-rate target' the Bank of Canada keeps short-term interest rates unchanged from the base case and the dollar is allowed to depreciate, generally reinforcing the stimulus to the economy. All possible combinations therefore yield 3x2x2=12 simulations. However, only one set of results is discussed in detail, while summary results only are presented for the othersl, in order to bring out important comparisons.

Interpreting the Simulation Outputs

We begin with a brief section on how to read and interpret the results. First, note that all the results presented in the tables (like Table 4.3) and charts are in terms of *changes* from the base case. It is the total impact of the extra ancillary activity that we are interested in. Levels of growth or employment could always be obtained by taking the changes and adding them to the base-case figures presented in the Technical Report, but generally this is uninteresting- especially when shocks are, as in this case, not huge.

The tables present two kinds of changes from base: Many are percentage changes from the base; these are marked "% Change" or "% Ch". Others are changes in units, with the units being specified beside the variable description (e.g.: "Change in $ Mill" or "Change in % Pts" (that is, 'change in percentage points')). Some variables are presented in both fashions: for example, in Table 4.3 below, in 1999 real GDP is simulated to have risen .04% above base due to the ancillary expenditure associated with extra housing construction; this is $246 million in 1986 dollars or $316 million in 1996 dollars. (1996 dollar figures are presented for comparability with the earlier study).

The description of Simulation 1 (Ancillary Impacts from Housing Construction / High Base / Exchange rate Target) is the most detailed and is presented in the main body of this report. Detailed outputs and brief descriptions of the other eleven simulations are presented in an appendix to the Technical Report. Following the description of Simulation 1 below, we compare the simulations across the three major categories of differences (Type of Ancillary Expenditure, High or Low Base, and Monetary Target).

Ancillary Expenditure: New Construction - High Base - Exchange Rate Target

Detailed results for this simulation are presented in Table 4.3 and Chart 4.1. We first describe the simulation results and then provide explanations for the major movements in variables observed.

In the first year of the simulation, *GDP* rises almost *$250 million in 1986 dollars* (just over *$300* million in 1996 dollars); this is an increase of about .04% in GDP (which is estimated to have grown well over 4% in 1999). The "multiplier" for this shock with the exchange-rate target money rule is about 1.36 (calculated as the final GDP impact of $86 246 million over the direct+indirect expenditure increase of $86 180.8 million from Table 4.1). In the second and subsequent years of the shock, the initial expenditure impulse is removed (there is no direct or indirect impact) and the economy is adjusting back through its various lags.[3] The positive impact of the 1999 expenditure shock still carries over to the second year (2000), with GDP still up by about a third of what it was in 1999. In years 3 through 5 GDP sinks below base-case levels, but not quite to the same extent that it rose above base in years 1 and 2. Experience with FOCUS has shown us that in years past year 5 GDP and employment impacts will rise and fall again in a damped oscillating pattern until a zero incremental impact is left.

Employment has a similar pattern to GDP, but with something of a lag. The ancillary expenditure associated with new housing construction creates 4500 additional person-years of employment in year 1, and smaller, but still positive, impacts in years 2 and 3.. There are some losses relative to base in years 4 and 5, but these are much smaller than the positive gains in the earlier years. As with GDP, the model over a longer time frame will show damped oscillations towards the base case. The lagged response of employment can be seen in the fact that the percentage increase in employment in year 1 is less than the percentage change in GDP - or, put alternatively, labour productivity temporarily increases. The positive impact on employment *stimulated by stronger GDP in years 1 and 2 carries* over to year 3 despite the fact that GDP in that year is falling away; alternatively, labour productivity then falls below base. In years 4 and 5, employment declines are less in proportion to GDP declines,

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[3]In comparing these results with those of the previous study of new housing construction it is important to note that the current impacts, by request of CMHC, are sustained for only one year, while the impacts of the earlier study were sustained for two years.

Table 4.3

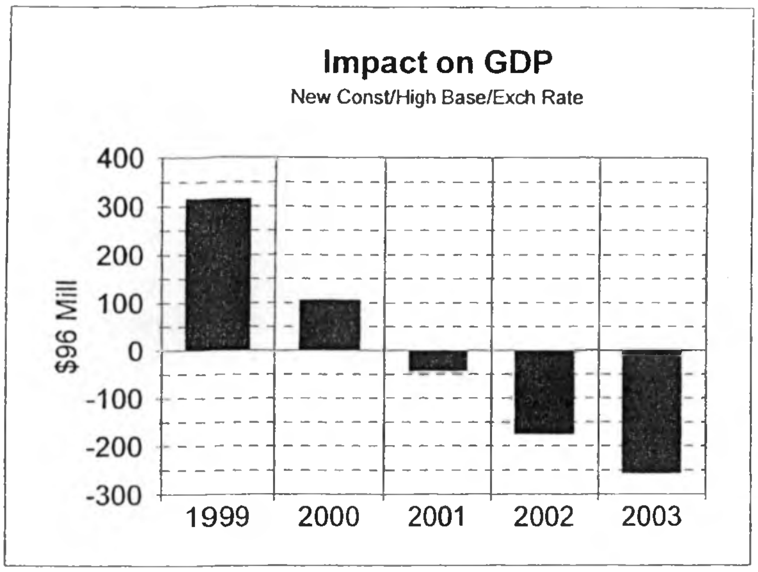
Incremental Impacts of Ancillary Expenditures From $1 Billion ($86) Increase in New Housing Construction in 1999

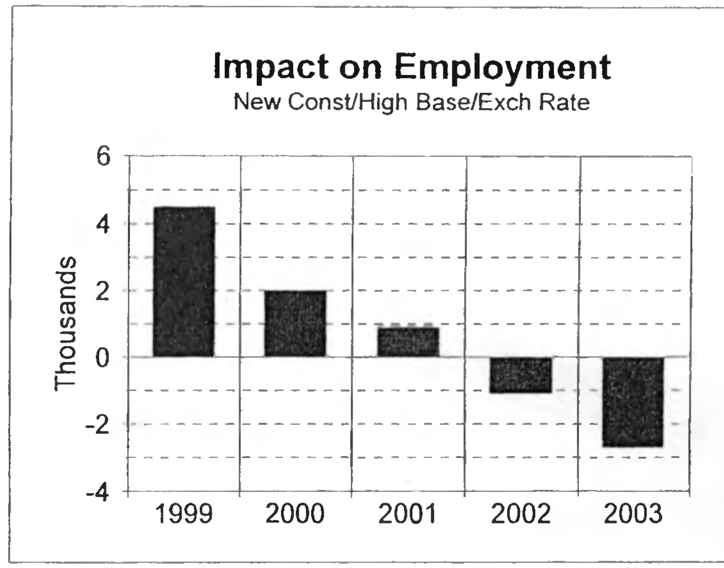
(High Base / Exchange Rate Target for Monetary Policy)

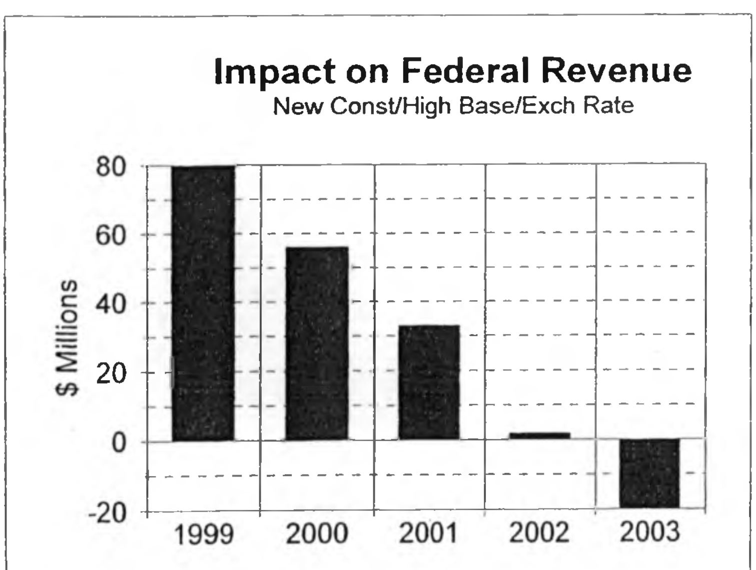
	1999	2000	2001	2002	2003	Sum 1999-2003	Average 1999-2003
Real GDP (Change in $96 Million)	316	106	-43	-176	-258	-41	-8.2
Real GDP (Change in $86 Million)	246	82	-33	-136	-200	-55	-11
Real Gross Domestic Product (% Change)	0.04	0.01	0.00	-0.02	-0.03	0.00	0.00
Personal Consumption (%Ch)	0.03	0.04	0.01	-0.01	-0.03	0.04	0.01
Government Curr & Capital Exp. (%Ch)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Investment Expenditure (%Ch)	0.14	0.00	-0.01	-0.02	-0.03	0.08	0.02
Residential Construction (%Ch)	0.56	0.01	0.00	-0.03	-0.07	0.47	0.09
Non-Residential Construction (%Ch)	0.00	0.01	0.00	-0.01	-0.01	-0.01	-0.00
Machinery and Equipment (%Ch)	0.01	-0.01	-0.02	-0.02	-0.02	-0.06	-0.01
Exports (%Ch)	0.00	-0.01	-0.01	-0.01	-0.01	-0.04	-0.01
Imports (%Ch)	0.03	0.02	0.01	0.00	0.00	0.06	0.01
Consumer Price Index (% Change)	0.00	0.01	0.01	0.02	0.02	0.06	0.01
CPI - Inflation Rate (Change in % Pts)	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Unemployment Rate (Change in % Pts)	-0.02	-0.01	0.00	0.01	0.01	-0.01	-0.00
Employment (% Change)	0.03	0.01	0.01	-0.01	-0.02	0.02	0.00
Employment (Change in '000)	4.5	2.0	0.9	-1.1	-2.7	3.6	0.7
Short-Term Interest Rate (Ch in % Pts)	0.01	0.01	0.00	0.00	0.00	0.02	0.00
Balance on Current Account (Ch in $ Mill)	-109	-104	-78	-47	-20	-358	-72
Federal Gov't: Revenues (Ch in $ Mill)	80	56	33	2	-20	151	30
Balance (Surp(+),Def(-)) (Ch in $ Mill)	81	36	28	-5	-49	91	18
Provincial Gov'ts: Revenues (Ch in $ Mill)	62	50	26	2	-13	127	25
Balance (Surp(+),Def(-)) (Ch in $ Mill)	66	38	6	-25	-42	43	9

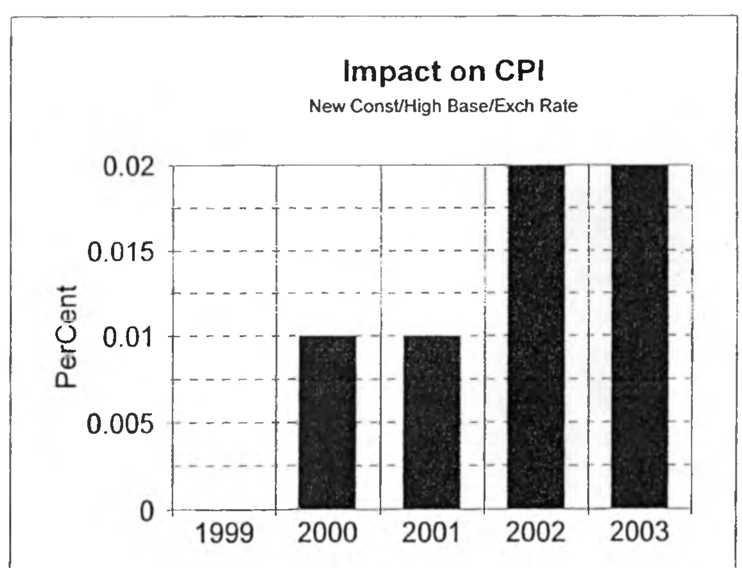
Impact Disaggregation for 1999	Total	Direct	Indirect	Induced
GDP ($86 Mill)	246	80	66	99
Employment ('000)	4.5	2.0	1.7	0.8

Chart 4.1 Ancillary Expenditure from New Construction
High Base - Exchange Rate Target









again because of "labour hoarding" behaviour that causes employment to adjust only with a lag to changes in output.

There is a variety of patterns across the main components of GDP: Consumption is slow to respond to the output shock and slow to fall away after - much in the fashion of employment. Government current and capital expenditure is fixed in real terms and so does not change under the shock. The movement in residential investment is, of course, largely exogenous in year 1; in years 4 and 5 there is a decline. Finally, exports show a very small negative impact under the demand stimulus throughout the five years, while imports show a pronounced increase in years 1 and 2, with the impact falling back to zero by year 5.

The expenditure shock is generally speaking so small that there is almost no noticeable increase in inflation - at least with the Bank of Canada targeting the exchange rate. By year 5, the CPI has risen by only .02% above base - a negligible increase.

The Bank of Canada is targeting the base-case exchange rate in this simulation and, as can be seen from the small negative impact on the Current Account of the Balance of Payments, ordinarily the housing demand shock would be putting downward pressure on the Canadian dollar. To keep the overall Balance of Payments at zero change under the base-case exchange rate, the Bank must raise interest rates very slightly: as can be seen, the Finance Company 90-Day rate goes up a maximum of 1 basis point in the first and second years of the shock, with longer bond rates rising an equivalent amount. This slight rise in rates is sufficient to bring in enough extra capital inflow to offset the worsened Current Account.

Finally, both the federal and aggregate provincial budget balances are improved by the demand stimulus: In the first year, federal revenues are up by almost $80 million, and the government balance improved by $81 billion. The impact on the provinces is slightly smaller, with an improvement of $62 million in revenue in the first year - and this despite the fact that the direct+indirect impacts on indirect tax revenues are slightly larger for the provinces (see Table 4.3). As the effect of the shock wears off and the economy turns temporarily negative, the revenue and budget balance impacts are similarly reduced, and small negatives appear for each item.

The remaining eleven simulation are summarized in Table 4.4 and discussed in detail in the Technical Report. These remaining results are best discussed comparatively, which is done the following sub-sections.

The Three Types of Ancillary Expenditures: Relative Impacts

We turn now to examine the importance of the various alternatives embodied in the range of simulations conducted. The first to be considered is the relative impact of the three types of ancillary housing-related expenditures: Their impacts on the main economic indicators over a five year span are compared under the common assumption of a High-capacity base case and exchange-rate monetary target in Table 4.5 and Chart 4.2.

As can be seen, and which is not surprising given the Clayton estimates of direct impacts, the total impacts of ancillary expenditures on new residential construction dwarf those from the sales of either new or existing dwellings - at least for GDP. Ancillary spending on new construction has almost ten times the impact of ancillary spending on sales of new dwellings, and over four times the GDP impact of ancillary spending related to sales of existing dwellings. Roughly the same ratios apply for employment as well. Of course, the smaller the initial impact, the smaller is the negative counter-reaction in later years - again, both for GDP and employment.

For the CPI there is almost no impact for any of the shocks, but those for new construction are of course larger than those of the sales of both dwelling types.

Table 4.4 Summary of Simulations for Key Indicators

	1999	2000	2001	2002	2003
1. New Housing / High Base / Exchange Rate Target					
Real GDP - Ch in $86 Mill	316	106	-43	-176	-258
Employment - Ch in '000	4.5	2	0.9	-1.1	-2.7
CPI - Ch in %	0	0.01	0.01	0.02	0.02
Fed. Revenue - Ch in $Mill	80	56	33	2	-20
Prov'l Revenue - Ch in $Mill	62	50	26	2	-13
2. New Housing / High Base / Interest Rate Target					
Real GDP - Ch in $86 Mill	388	197	83	-53	-176
Employment - Ch in '000	4.8	2.7	2.1	0.4	-1.5
CPI - Ch in %	0	0.01	0.02	0.03	0.03
Fed. Revenue - Ch in $Mill	73	55	52	37	17
Prov'l Revenue - Ch in $Mill	57	50	46	37	25
3. New Housing / Low Base / Exchange Rate Target					
Real GDP - Ch in $86 Mill	314	116	4	-105	-179
Employment - Ch in '000	4.4	1.9	1.2	-0.4	-1.8
CPI - Ch in %	0	0	0	0.01	0.01
Fed. Revenue - Ch in $Mill	72	39	18	-7	-22
Prov'l Revenue - Ch in $Mill	55	35	13	-5	-14
4. New Housing / Low Base / Interest Rate Target					
Real GDP - Ch in $86 Mill	380	190	89	-27	-129
Employment - Ch in '000	4.8	2.7	2.2	0.7	-0.9
CPI - Ch in %	0	0.01	0.01	0.02	0.02
Fed. Revenue - Ch in $Mill	71	44	36	19	2
Prov'l Revenue - Ch in $Mill	54	39	31	19	9
5. New Home Sales / High Base / Exchange Rate Target					
Real GDP - Ch in $86 Mill	25	11	-6	-21	-29
Employment - Ch in '000	0.4	0.2	0.1	-0.1	-0.3
CPI - Ch in %	0	0	0	0	0
Fed. Revenue - Ch in $Mill	79	4	2	-2	-6
Prov'l Revenue - Ch in $Mill	36	4	1	-3	-5
6. New Home Sales / High Base / Interest Rate Target					
Real GDP - Ch in $86 Mill	29	19	5	-11	-26
Employment - Ch in '000	0.4	0.2	0.2	0	-0.2
CPI - Ch in %	0	0	0	0	0
Fed. Revenue - Ch in $Mill	78	4	3	1	-2
Prov'l Revenue - Ch in $Mill	36	4	3	2	0
7. New Home Sales / Low Base / Exchange Rate Target					
Real GDP - Ch in $86 Mill	25	10	-5	-19	-26
Employment - Ch in '000	0.4	0.2	0.1	-0.1	-0.3
CPI - Ch in %	0	0	0	0	0
Fed. Revenue - Ch in $Mill	78	1	-1	-4	-7
Prov'l Revenue - Ch in $Mill	35	2	-1	-3	-5

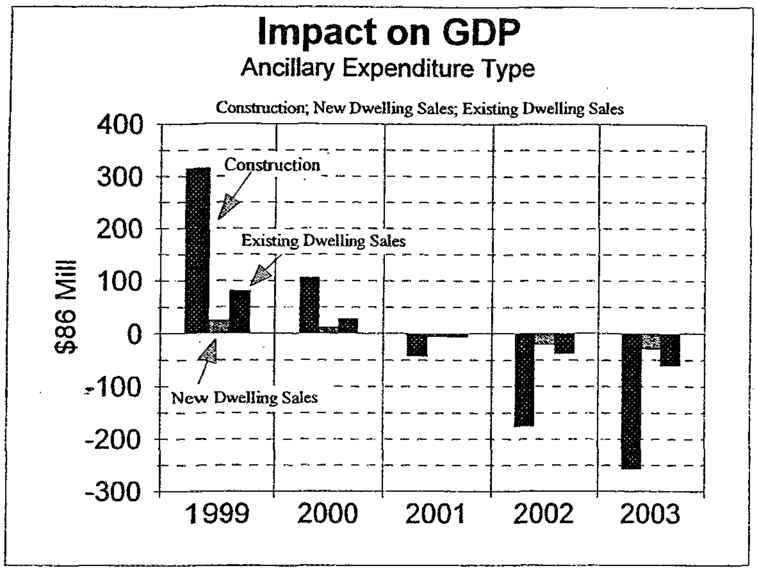
8. New Home Sales / Low Base / Interest Rate Target					
Real GDP - Ch in $86 Mill	28	16	3	-12	-25
Employment - Ch in '000	0.4	0.2	0.2	-0.1	-0.2
CPI - Ch in %	0	0	0	0	0
Fed. Revenue - Ch in $Mill	78	1	1	-2	-5
Prov'l Revenue - Ch in $Mill	35	2	1	-1	-3
9. Existing Home Sales / High Base / Exchange Rate Target					
Real GDP - Ch in $86 Mill	81	28	-7	-39	-61
Employment - Ch in '000	1	0.5	0.2	-0.2	-0.6
CPI - Ch in %	0	0	0	0	0
Fed. Revenue - Ch in $Mill	20	14	9	1	-5
Prov'l Revenue - Ch in $Mill	32	12	7	1	-3
10. Existing Home Sales / High Base / Interest Rate Target					
Real GDP - Ch in $86 Mill	97	50	24	-9	-41
Employment - Ch in '000	1.1	0.7	0.5	0.2	-0.3
CPI - Ch in %	0	0	0	0.01	0.01
Fed. Revenue - Ch in $Mill	19	13	13	10	4
Prov'l Revenue - Ch in $Mill	31	12	12	10	6
11. Existing Home Sales / Low Base / Exchange Rate Target					
Real GDP - Ch in $86 Mill	81	30	4	-23	-41
Employment - Ch in '000	1	0.5	0.3	-0.1	-0.4
CPI - Ch in %	0	0	0	0	0
Fed. Revenue - Ch in $Mill	19	10	5	-1	-5
Prov'l Revenue - Ch in $Mill	30	9	4	-1	-4
12. Existing Home Sales / Low Base / Interest Rate Target					
Real GDP - Ch in $86 Mill	95	48	25	-3	-29
Employment - Ch in '000	1.1	0.7	0.6	0.2	-0.2
CPI - Ch in %	0	0	0	0	0
Fed. Revenue - Ch in $Mill	18	11	9	5	0
Prov'l Revenue - Ch in $Mill	30	10	8	5	2

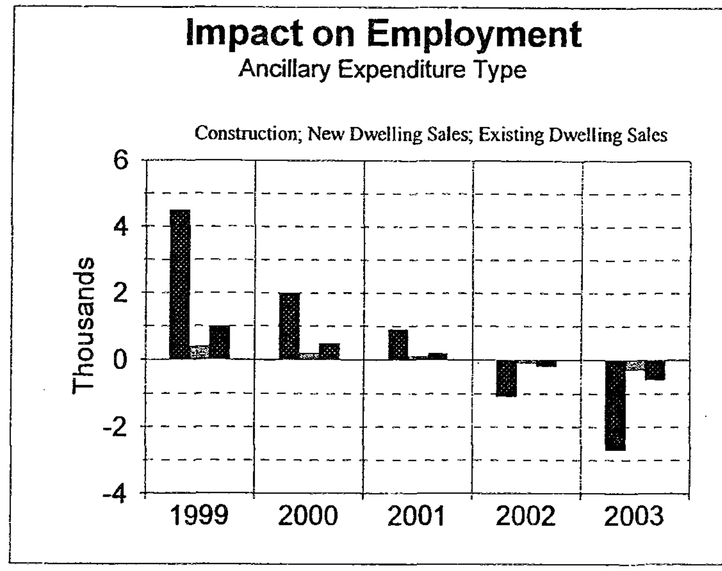
Table 4.5 Comparing Simulation Results for Expenditure Type

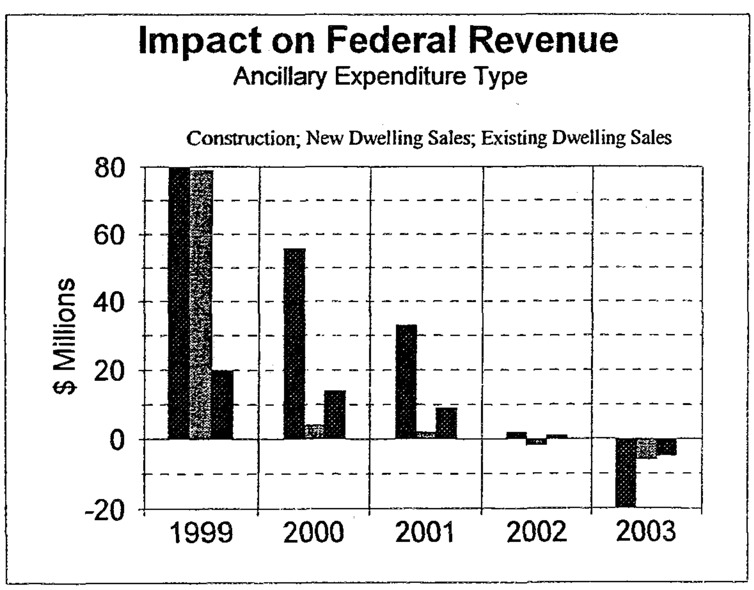
(High Base - Exchange Rate Target)

	1999	2000	2001	2002	2003
Ancillary Expenditure from:					
Real GDP - Ch in $86 Mill					
New Housing Construction	316	106	-43	-176	-258
Sales of New Dwellings	25	11	-6	-21	-29
Sales of Existing Dwellings	81	28	-7	-39	-61
Employment - Ch in '000					
New Housing Construction	4.5	2.0	0.9	-1.1	-2.7
Sales of New Dwellings	0.4	0.2	0.1	-0.1	-0.3
Sales of Existing Dwellings	1.0	0.5	0.2	-0.2	-0.6
CPI - Ch in %					
New Housing Construction	0.00	0.01	0.01	0.02	0.02
Sales of New Dwellings	0.00	0.00	0.00	0.00	0.00
Sales of Existing Dwellings	0.00	0.00	0.00	0.00	0.00
Fed. Revenue - Ch in $Mill					
New Housing Construction	80	56	33	2	-20
Sales of New Dwellings	79	4	2	-2	-6
Sales of Existing Dwellings	20	14	9	1	-5
Prov'l Revenue - Ch in $Mill					
New Housing Construction	62	50	26	2	-13
Sales of New Dwellings	36	4	1	-3	-5
Sales of Existing Dwellings	32	12	7	1	-3

Chart 4.2 Ancillary Expenditure of Different Types Compared
High Base - Exchange Rate Target







Only for federal revenues is the ranking of the economic impacts at all changed. Because there is a large direct impact of sales of new dwellings on the GST, the impact of this ancillary expenditure is almost the same on federal revenue in the first year as is the impact of ancillary expenditure on new construction, despite the very different impacts on GDP and employment. In the second and following years, however, the impact of new construction is much greater than for new dwelling sales because this impact on federal revenue is induced by ongoing economic activity, while the direct impact related to new dwelling sales is entirely gone after the first year.

High and Low Employment Base Cases - Relative Impact

Total impacts for High and Low bases are compared for the case of ancillary expenditure from new construction, and under the exchange-rate target, in Table 4.6 and in Chart 4.3. As can be seen, real output and employment impacts are virtually identical in the first year of the shock, but are higher thereafter in the Low base. Note, however, that even for the Low base the impact of the expenditure shock eventually turns negative; it is simply much less negative than under the High base case.

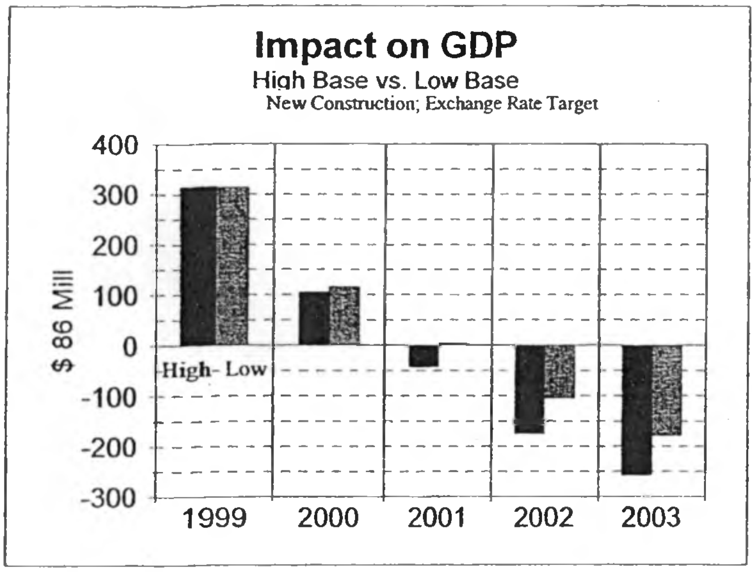
This difference in real impacts is as we would have expected, given that in the Low base there is a larger unemployment gap and therefore less pressure on wages when employment is created. With less effect on wages, the demand for labour is higher and higher employment helps increase the positive aftershock of the initial expenditure in later years. It also means that less of an increase in unemployment is required in still later years to move wages back to base-case levels once the "extra" demand is gone. Under the exchange-rate monetary target the lower inflation puts less downward pressure on the dollar and requires less of an interest-rate increase to defend it, further helping to extend the real impact.

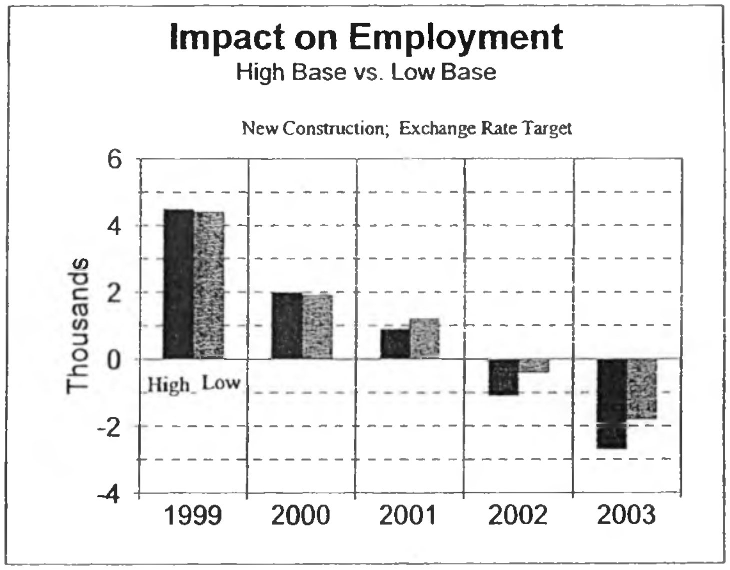
As for impacts on CPI inflation, we would have predicted that these would be higher under the High base, and this is invariably the case in the results shown in Table 4.6.

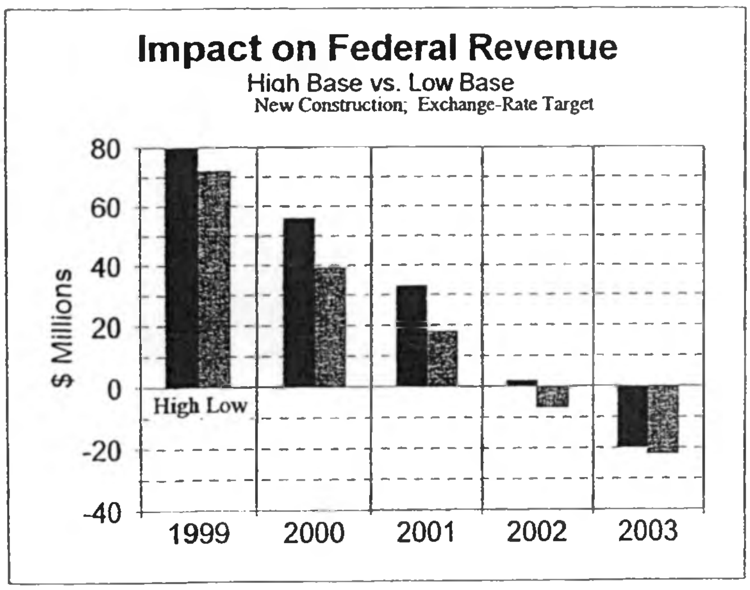
Table 4.6 Comparing Simulation Results for Base-Case Conditions

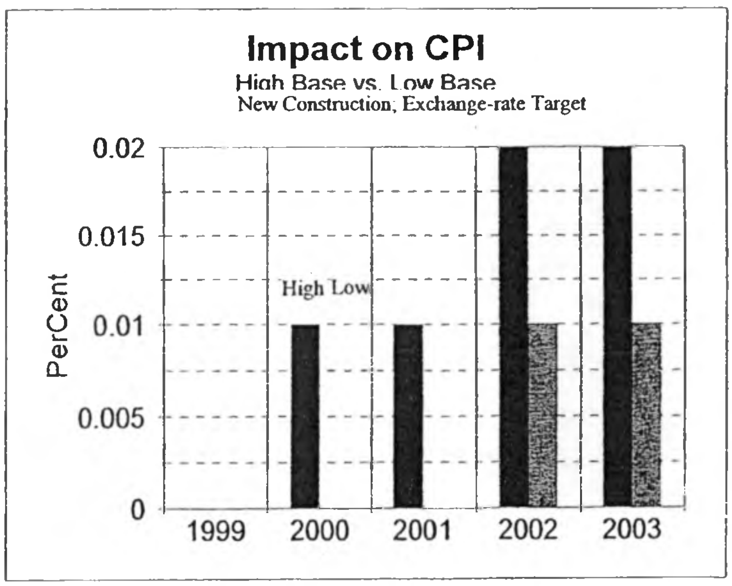
		1999	2000	2001	2002	2003
Ancillary Expenditure from Residential Construction - Exchange Rate Target						
Real GDP - % Change	High Base	316	106	-43	-176	-258
	Low Base	314	116	4	-105	-179
	Diff	2	-10	-47	-71	-79
Employment - Ch in '000	High Base	4.5	2.0	0.9	-1.1	-2.7
	Low Base	4.4	1.9	1.2	-0.4	-1.8
	Diff	0.1	0.1	-0.3	-0.7	-0.9
CPI Inflation - Ch in % pts	High Base	0	0.01	0.01	0.02	0.02
	Low Base	0	0	0	0.01	0.01
	Diff	0	0.01	0.01	0.01	0.01
Fed. Revenue - Ch in $Mill	High Base	80	56	33	2	-20
	Low Base	72	39	18	-7	-22
	Diff	8	17	15	9	2
Prov'l Revenue - Ch in $Mill	High Base	62	50	26	2	-13
	Low Base	55	35	13	-5	-14
	Diff	7	15	13	7	1

Chart 4.3 Impact of Alternative Base Cases Compared
New Construction - Exchange Rate Target









Finally, it will be observed that federal revenues are almost invariably *higher* under the High base than the Low base, despite weaker real economic impacts. This is because federal expenditures (especially with a major component fixed in real terms and some other components indexed) is more sensitive to the higher inflation generated under the High base case. Inflation-adjusted, or real, revenues would be lower in the High base simulation in outer years due to the weaker economic activity.

Exchange-Rate Target vs. Interest-Rate Target - Relative Impact

Differences between the two monetary response assumptions are highlighted for the case of Ancillary Expenditure from New Construction in the High base case in Table 4.7 and Chart 4.4.

As can be seen, the choice of monetary response assumption yields considerable differences in impacts. For the most part, the differences are also consistent across all years of the simulation. When the base interest rate is targeted, real GDP impacts are higher by 20-30% in the initial two years of the simulation, and higher still in later years as there is less of an "overshoot" to lower GDP to draw wages and prices down when the Bank is only targeting the nominal interest rate. The same pattern applies to employment: there is more gain in the initial year when the Bank of Canada does not lean into the shock to keep the exchange rate from depreciating, and there is a much smaller loss of employment relative to base in later years, because the Bank is willing to accept a slightly higher wage (and price) level and the accompanying lower exchange rate.

Of course, the price to be paid for the extra impact under the interest-rate target is additional inflation. Differences in impacts on the CPI are greatest in the later years of the shock. Nonetheless, the CPI impacts obtained for the shock are small, never exceeding three one-hundredths of a per cent of base through the fifth year.

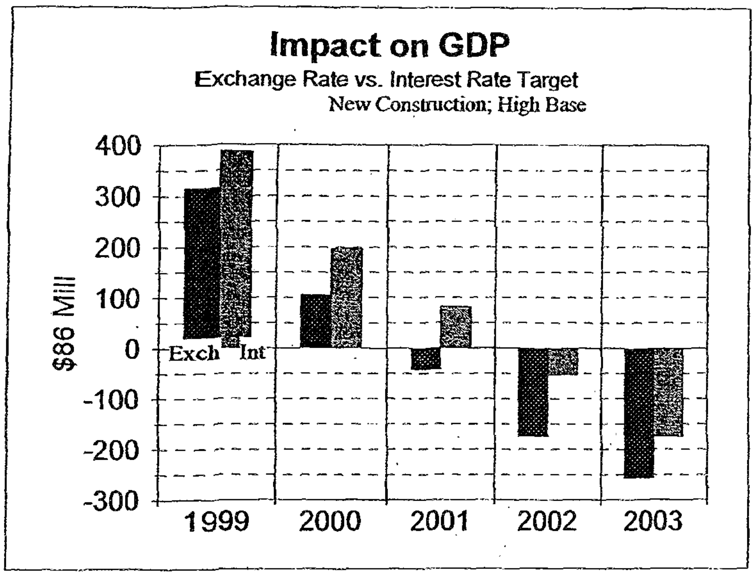
Finally, since there is higher impact on both output and inflation under the interest-rate target, it is no surprise that generally federal revenues are much higher under this alternative, especially in later years when differences in the price and activity levels have become more pronounced. In years 1 and

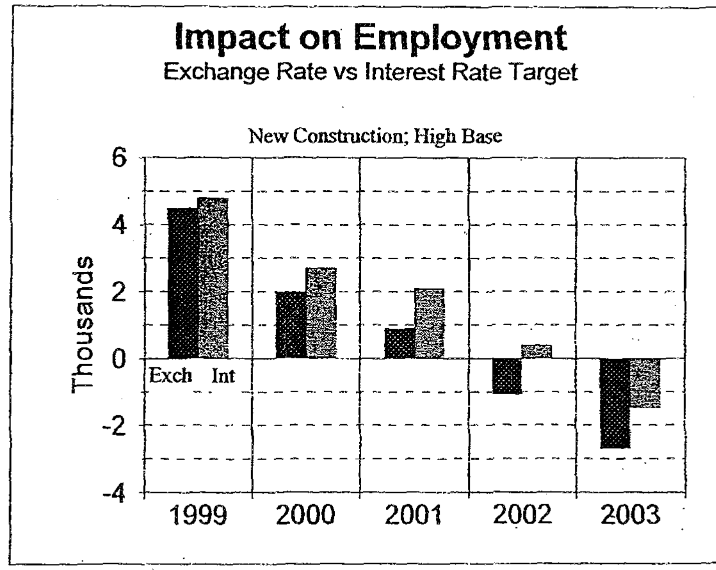
Table 4.7 Comparing Simulation Results for Monetary Targets

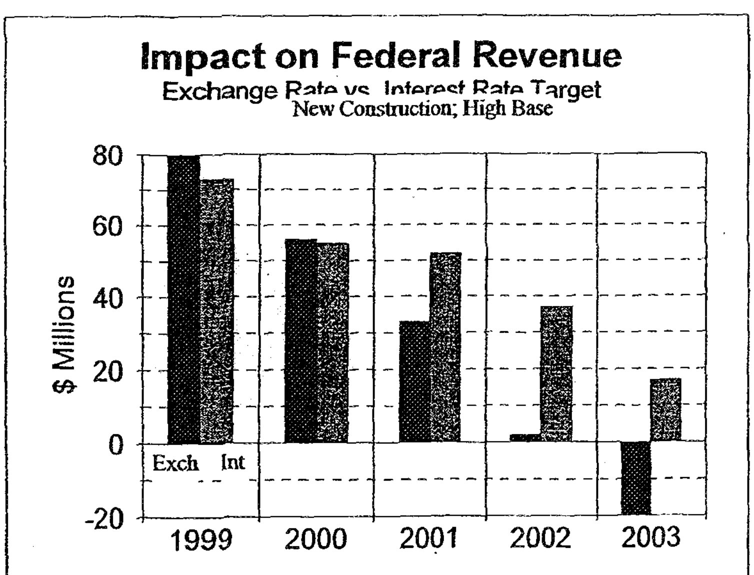
		1999	2000	2001	2002	2003
Ancillary Expenditure from Residential Construction - High Base						
Real GDP - % Change	Exchange Rate Target	316	106	-43	-176	-258
	Interest Rate Target	388	197	83	-53	-176
	Diff	-72	-91	-126	-123	-82
Employment - Ch in '000	Exchange Rate Target	4.5	2.0	0.9	-1.1	-2.7
	Interest Rate Target	4.8	2.7	2.1	0.4	-1.5
	Diff	-0.3	-0.7	-1.2	-1.5	-1.2
CPI Inflation - Ch in % pts	Exchange Rate Target	0	0.01	0.01	0.02	0.02
	Interest Rate Target	0	0.01	0.02	0.03	0.03
	Diff	0	0	-0.01	-0.01	-0.01
Fed. Revenue - Ch in $Mill	Exchange Rate Target	80	56	33	2	-20
	Interest Rate Target	73	55	52	37	17
	Diff	7	1	-19	-35	-37
Prov'l Revenue - Ch in $Mill	Exchange Rate Targe	62	50	26	2	-13
	Interest Rate Target	57	50	46	37	25
	Diff	5	0	-20	-35	-38

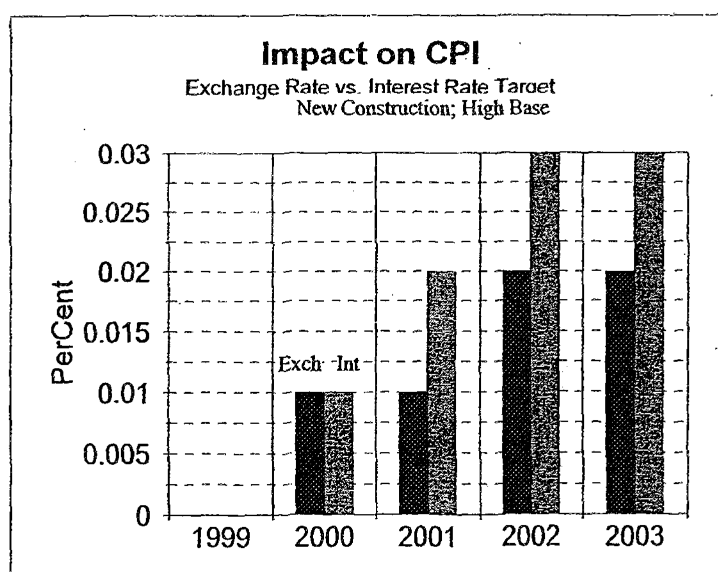
Chart 4.4

Alternative Monetary Responses Compared
New Construction - High Base









2, the exchange-rate target generates slightly more federal revenue. This is because the interest-rate target generates relatively more activity through net exports via an exchange-rate depreciation, and changes in net exports have no effect on federal GST revenues.

Summary of Impacts - Comparative Multipliers

Finally, by way of a last summary of the twelve simulations, we examine the first-year multipliers generated by each. By multiplier, we mean the ratio of the initial expenditure impact (this is the change in 'Residential Investment' in $86 in Table 4.1) to the total impact on GDP in $86. Table 4.8 presents the GDP impacts and the multipliers.

As can be seen, these multipliers are all roughly of the same order of magnitude. Those for the ancillary expenditure for new residential construction are largest, followed closely by those for sales of existing dwellings. Since so much of the ancillary expenditure for sales of new dwellings immediately leaks into taxes, their multipliers are the lowest. There is virtually no difference between multipliers under the High and Low bases; as we have seen, the differences between the two bases show up in later years, when the shock has gone but employment, wage and price effects are still working their way through the model's various lags. Finally, the multiplier is clearly higher if the Bank of Canada is not offsetting the impact of increased demand with (slightly) higher interest rates - that is, when it is following a fixed interest-rate target.

Table 4.8 Summary of First-Year GDP Impact 'Multipliers'

	New Residential Construction	Sales of New Dwellings	Sales of Existing Dwellings
Initial Expenditure Impact ($86 Mill) (See Tab. 4.1)	181	15	46
First-Year GDP Impact Under:			
High Base / Exchange-Rate Target	246	20	63
High Base / Interest-Rate Target	302	23	75
Low Base / Exchange-Rate Target	244	20	63
Low Base / Interest-Rate Target	295	22	74
First-Year GDP Multipliers:			
High Base / Exchange-Rate Target	1.36	1.33	1.36
High Base / Interest-Rate Target	1.67	1.53	1.62
Low Base / Exchange-Rate Target	1.35	1.33	1.36
Low Base / Interest-Rate Target	1.63	1.47	1.60

5. Counter-factual Impacts of Ancillary Housing Expenditures

Several simulations have been run, based on the information acquired above, to determine what the Canadian economy might have looked like if ancillary housing-related expenditures had followed different paths from 1989 through 1998 - which constitutes, roughly, a complete economic cycle. These 'counterfactual' or 'what-if?' experiments show the potential scope for economic stabilization through the encouragement or discouragement of housing-related demand.

CMHC has requested a total of four counterfactual experiments. The numerical details are presented in Table 5.1. The first two experiments examine ancillary expenditures related to new housing construction. The first column of panel A of Table 5.1 shows actual $86 dollar construction over 1989-1998. As can be seen, construction fell away sharply from the 1989 peak in 1990 and 1991 and then recovered to a much lower peak in 1994. It then fell away again in 1995 and 1996 before recovering in 1997 and 1998. The first counterfactual experiment assumes that real housing spending could have been maintained at 1989 levels from 1990 through 1999. This yields the additional housing demand in column 3, panel A of Table 5.1. For example, under this counterfactual, housing construction expenditure would have been $6.1 billion (1986) dollars higher in 1991. Of course, we are only simulating the impacts of *ancillary* expenditures to this additional construction, and ancillary expenditures to new construction are in the order of $181 million per $1 billion of construction (see Table 4.3).

The second counterfactual asks instead what would have happened if housing construction had been held at its 1989-1998 annual average through the entire period. This average is shown in column 4, panel A of Table 5.1, and the difference with respect to history in column 5. As can be seen, new construction would have been much lower (by $4.9 billion (1986 dollars)) in 1989 under this counterfactual, and also lower than history in 1990, but considerably above history in 1991 and in 1995-96.

Table 5.1

Inputs to Counter-factual Simulations

A. New Construction ("Value of New Construction": National Accounts)

	Value of New Construction in $86 Mill	Counter-factual: Remains at 1989 level ($86 Mill)	Change ($86 Mill)	Counter-factual: Remains at 1989-98 average	Change ($86 Mill)
1989	20579	20579	0	15706	-4873
1990	18297	20579	2282	15706	-2590
1991	14521	20579	6058	15706	1185
1992	15798	20579	4781	15706	-91
1993	15066	20579	5513	15706	641
1994	16225	20579	4354	15706	-519
1995	12570	20579	8009	15706	3136
1996	13033	20579	7546	15706	2674
1997	15540	20579	5039	15706	167
1998	15436	20579	5143	15706	270

B. Value of Resale Activity (from Residential MLS Sales, Canada Totals)

	Value of Resale Activity in $86 Mill	Counter-factual: Remains at 1989 level ($86 Mill)	Change ($86 Mill)	Counter-factual: Remains at 1989-98 average	Change ($86 Mill)
1989	39265	39265	0	34222	-5043
1990	28409	39265	10856	34222	5814
1991	34824	39265	4441	34222	-602
1992	37743	39265	1522	34222	-3521
1993	34999	39265	4267	34222	-776
1994	33971	39265	5294	34222	251
1995	27646	39265	11619	34222	6576
1996	34804	39265	4461	34222	-582
1997	36294	39265	2971	34222	-2071
1998	34269	39265	4996	34222	-46

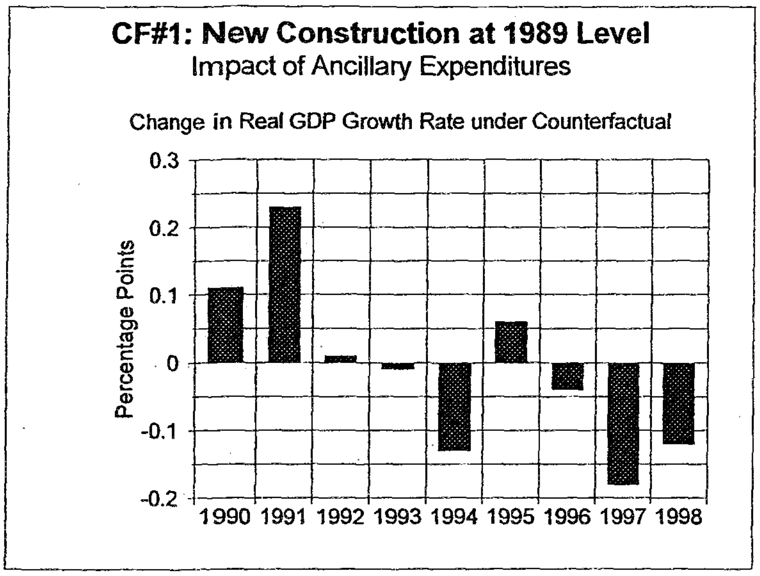
The third and fourth counterfactuals examine the impact of ancillary expenditure related to resales of existing dwellings. The historical value of resales, converted to 1986 dollar, is shown in column 1 of panel B of Table 5.1. From a peak of just over $39 billion in 1989, these also fell away sharply in 1990 before recovering in 1991 and 1992 almost to 1989 levels. There was another major decline from 1993 through a trough in 1995 and then another recovery to levels close to, but still under, those of 1989. The third counterfactual holds the value of resales constant at 1989 levels for 1990 -1998, resulting in increases in resale values in all years (relative to history), but especially in 1990 and 1995, when the differences amount to over $10 billion. Again, however, it should be recalled that we are estimating only the impact of ancillary expenditures to these changes in sales. From Table 4.3 it can be seen that a $1 billion change in resales results in just over $46 million in actual economic demand. A $10 billion change in resales therefore will result, initially, in just under a half-billion dollar demand shock to the economy.

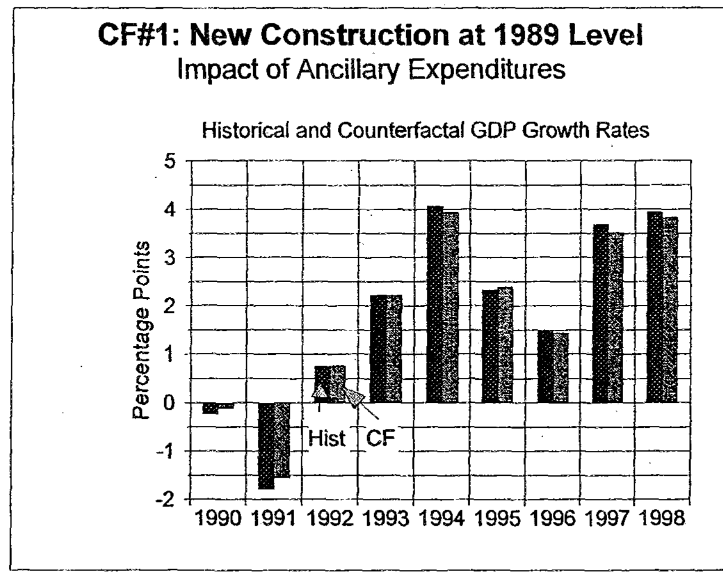
The fourth counterfactual considers what the economy would have looked like if resales had been constant at their 1989-98 average through that period and the resulting change in ancillary expenditures had impacted the economy. As can be seen in the last column, panel B, of Table 5.1, this would have meant changes of between plus and minus $6 billion in resales through this time span. Results of the counterfactual simulations are shown in Tables 5.2 - 5.5 and Charts 5.1 - 5.4. The tables show detailed *impacts* of the assumed changes in ancillary expenditures from the particular counterfactual and so are quite similar to the detailed tables shown in Section 4. The charts show how history "would have looked" under the counterfactuals and compare this with what actually happened for the key indicators of GDP and GDP growth.

Counterfactual Nr. 1: New Construction at 1989 Levels

The first panel of Chart 5.1 shows what happens to the GDP annual growth rate under the counterfactual (the figures appear in line 3 of Table 5.2). The chart, and table, show that under the counterfactual the GDP growth rate would have been increased by just over .1 in percentage points in 1990 and just over .2 points in 1991. The counterfactual would also have reduced the GDP

Chart 5.1 CounterFactual #1: New Construction at 1989 Levels
Impact of Ancillary Expenditures





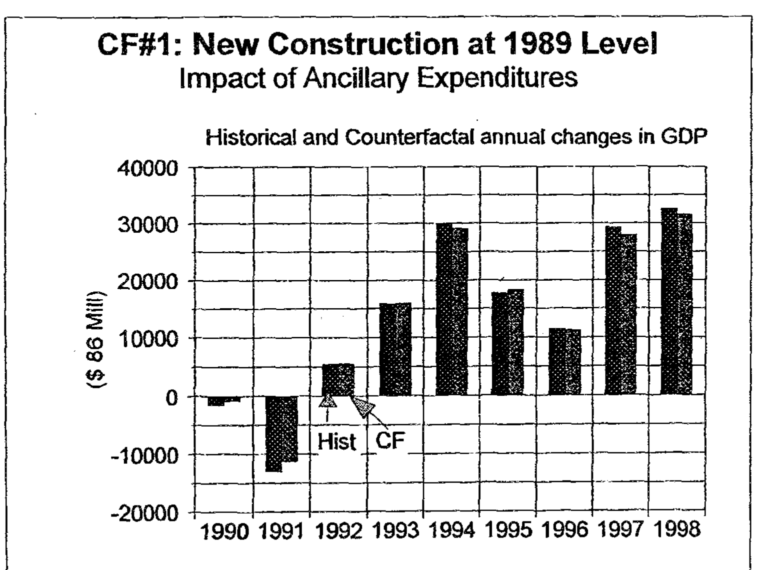


Table 5.2

Counterfactual Experiment: Housing Contruction at 1989 Level Through 1998
Impacts of Ancillary Expenditure Changes
(Interest Rate Target for Monetary Policy)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	Sum 1990-98	Average 1990-98
Real GDP (Change in $96 Million)	773	2399	2492	2483	1650	2134	1838	488	-512	13745	1527
Real GDP (Change in $86 Million)	600	1864	1936	1929	1282	1658	1428	379	-398	10678	1186
GDP Growth Rate (Change in % Pts)	0.11	0.23	0.01	-0.01	-0.13	0.06	-0.04	-0.18	-0.12		-0.01
Real Gross Domestic Product (% Change)	0.11	0.34	0.35	0.34	0.22	0.27	0.23	0.06	-0.06		0.21
Consumer Price Index (% Change)	0	0.02	0.08	0.14	0.22	0.29	0.39	0.48	0.56		0.24
CPI - Inflation Rate (Change in % Pts)	0	0.02	0.06	0.06	0.09	0.07	0.1	0.1	0.07		0.06
Unemployment Rate (Change in % Pts)	-0.06	-0.17	-0.2	-0.22	-0.16	-0.18	-0.14	-0.06	0		-0.13
Employment (% Change)	0.08	0.27	0.32	0.35	0.27	0.3	0.25	0.14	0.04		0.22
Employment (Change in '000)	10.8	34.4	41.3	45.7	36.3	40.9	34.8	19.2	6	269.4	29.9
Fed Balance (Surp(+),Def(-)) (Ch in $ Mill)	218	795	996	1114	1080	1290	1260	1025	855	8633	959
Prov Balance (Surp(+),Def(-)) (Ch in $ Mill)	114	382	390	408	345	418	449	301	190	2997	333

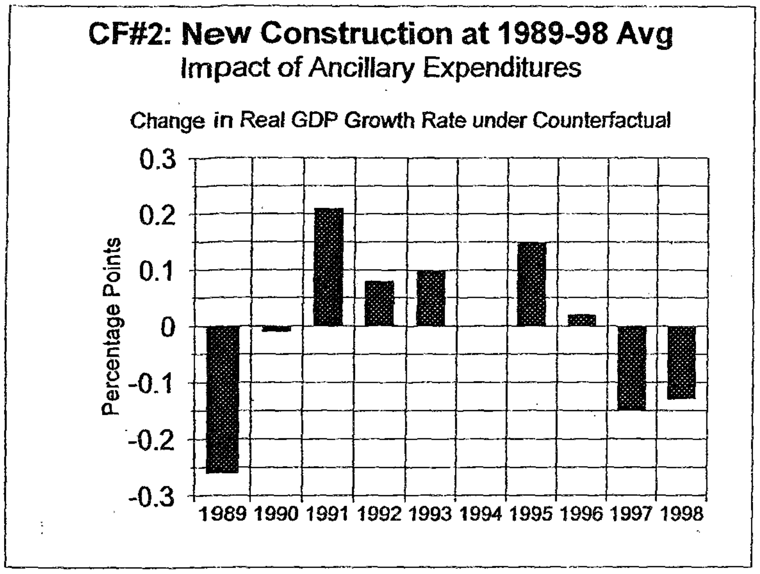
growth rate by almost .2 points in 1997 and by just over .1 in 1998. A priori, the countercyclical effect is at least in the right direction, because GDP growth was in fact quite weak in 1990-91 (the most recent recession) and strong in the economic recovery of 1997-98.

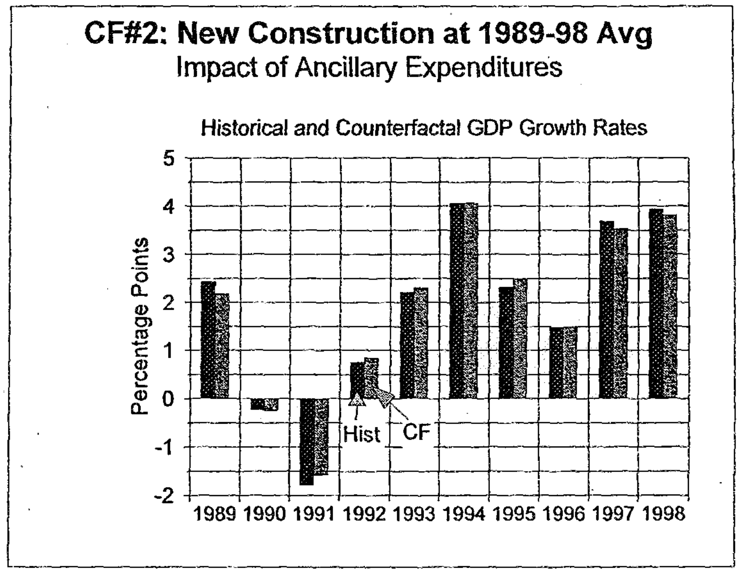
The second panel of Chart 5.1 shows the historical GDP growth rate and the GDP growth rate that occurs under the counterfactual. As can be seen, the counterfactuals effects are indeed in the right direction: boosting growth (making it less negative) in 1990-91 and reducing the high growth rates in 1997-98, and also in the boom year of 1994. However, it can also be seen that the impacts on the GDP growth rate are not huge, and certainly insufficient to undo or reverse the pattern of bust and boom. Nonetheless, this should not be surprising: No component of GDP (except perhaps massive changes in consumption) can move the aggregate around by large amounts, and all that is being altered here is the *ancillary* expenditure related to housing construction, not housing construction itself. As we noted just above, a $1 billion (86 dollar) increase in new construction, generates directly and indirectly $181 million of initial demand on GDP (from which there are both leakages and multiplier effects, as seen in Section 4). Therefore, even the large changes in construction assumed in the counterfactual cannot be expected to have major effects on the pattern of GDP growth. The important point to note is that, were new housing construction to have been maintained at 1989 levels through the 1990s, an important rebalancing of GDP growth patterns would have occurred.
The third panel of Chart 5.2 shows annual changes in real GDP in $86 millions both in history and under the counterfactual. The image and message is the same as for panel 2.

Counterfactual Nr. 2: New Construction at 1989-98 Average

The first panel of Chart 5.2 shows how the GDP growth rate would have changed under this counterfactual. Real GDP growth would have been over .25 percentage points lower in 1989 (a year when the Bank of Canada considered the economy was getting overheated) and important extra growth would have occurred in the weak-growth years of 1991 and 1995. 1997 and 1998 would have had their relatively strong growth cooled by something over .1 percentage points. Again, the counter-cyclical effects are certainly in the right direction. Once again, however, as panels 2 and 3

Chart 5.2 CounterFactual #2: New Construction at 1989-98 Average
Impact of Ancillary Expenditures





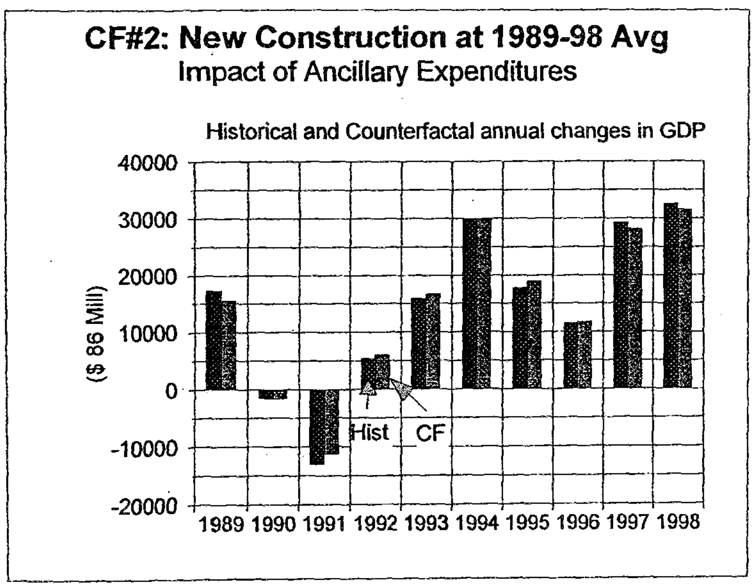


Table 5.3

Counterfactual Experiment: Housing Contruction at 1989-98 Level Through 1998
Impacts of Ancillary Expenditure Changes
(Interest Rate Target for Monetary Policy)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Sum 1989-98	Average 1989-98
Real GDP (Change in $96 Million)	-1833	-1731	-157	383	1144	1158	2350	2548	1470	487	5819	582
Real GDP (Change in $86 Million)	-1425	-1345	-122	297	889	900	1826	1980	1142	379	4521	452
GDP Growth Rate (Change in % Pts)	-0.26	0.01	0.21	0.08	0.1	0	0.15	0.02	-0.15	-0.13		0
Real Gross Domestic Product (% Change)	-0.25	-0.24	-0.02	0.05	0.16	0.15	0.3	0.32	0.18	0.06		0
Consumer Price Index (% Change)	0	-0.06	-0.14	-0.18	-0.2	-0.21	-0.2	-0.13	-0.05	0.04		-0
CPI - Inflation Rate (Change in % Pts)	0	-0.06	-0.08	-0.04	-0.03	0	0.01	0.06	0.09	0.08		0
Unemployment Rate (Change in % Pts)	0.13	0.13	0.03	0	-0.08	-0.09	-0.17	-0.18	-0.13	-0.07		-0
Employment (% Change)	-0.19	-0.2	-0.07	-0.01	0.1	0.13	0.25	0.28	0.2	0.12		0
Employment (Change in '000)	-24.6	-26.6	-8.5	-1.7	13.1	16.8	34.1	37.7	28.1	17.4	85.8	9
Fed Balance (Surp(+),Def(-)) (Ch in $ Mill)	-452	-625	-299	-110	175	260	635	779	639	473	1475	148
Prov Balance (Surp(+),Def(-)) (Ch in $ Mill)	-257	-284	-37	61	156	133	331	372	223	91	789	79

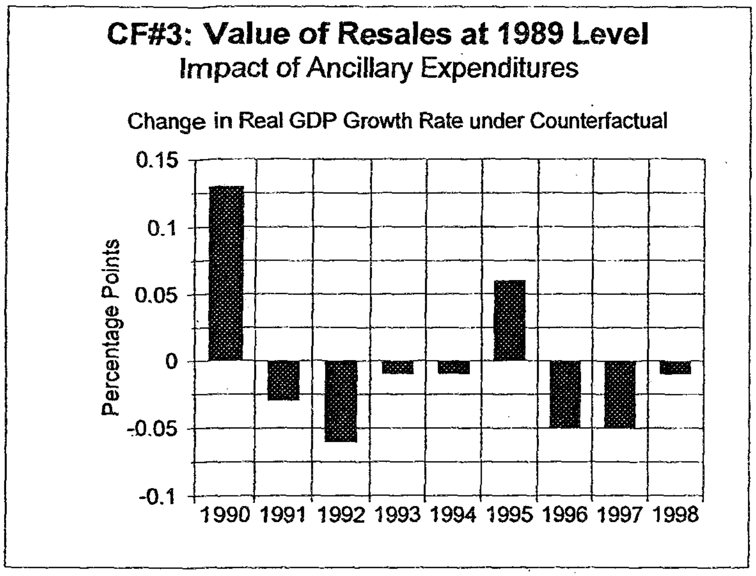
on Chart 5.2 show, the total impact on the overall growth rate or growth in $86 millions of GDP is relatively small - again not surprisingly, considering that it is all of GDP that is being compared to, and that only ancillary expenditures, and not total construction expenditures, that is being altered in the counterfactual. Still, the charts show that, could housing construction demand have been smoothed through the last decade, an important concomitant smoothing of the pattern of GDP growth would also have occurred.

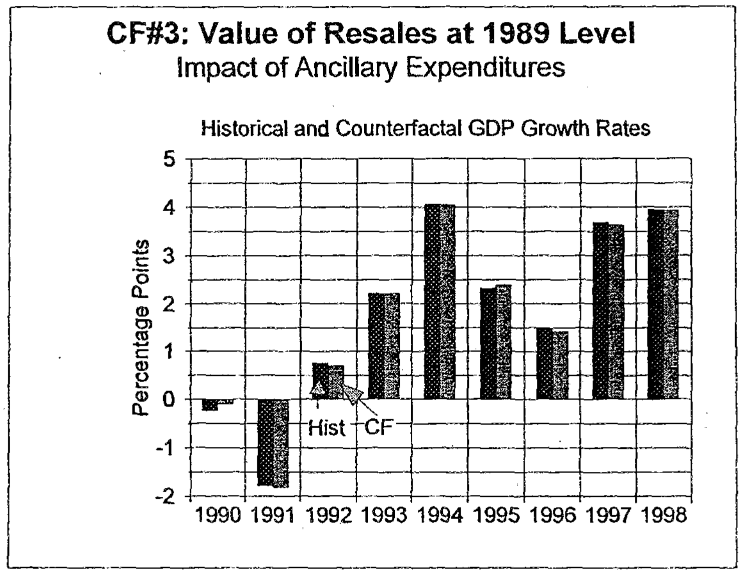
Counterfactual Nr. 3: Value of Resales at 1989 Levels

The third counterfactual holds the value of resales constant at the (high) 1989 level, and examines the impact of this through its effects on ancillary expenditures related to resales. As can be seen in the first panel of Chart 5.3, the counterfactual would have generated an extra .13 percentage points of economic growth in 1990 but would actually have reduced growth slightly in 1991 (also a recession year) and in 1992 (a year of very low growth). Growth would also have been boosted somewhat in 1995 and weakened in 1996 (a low-growth year) and 1997 (a stronger-growth year). Panels 2 and 3 of the chart show actual and counterfactual GDP growth rates and annual changes in GDP in $86 millions.

On the whole, the counterfactual shows that keeping ancillary expenditures from resales at 1989 levels would have been somewhat less effective at countercyclical smoothing of the economy through the 1990s than keeping ancillary expenditures from new construction at 1989 levels. There are two main reasons for this: The first is that the pattern of resales is less closely tied to the overall cyclical pattern of GDP growth than is the pattern of new construction - for example, resales had almost reached their 1989 levels again in 1992, while construction and the economy were still both quite weak. The second reason is that there is less ancillary expenditure associated with a billion dollars of resales ($46 million) than with a billion dollars of new construction ($181 million). Despite the overall larger value of resales and greater dollar changes from peak to trough, the economic impact from ancillary expenditures turns out to be lower.

Chart 5.3 CounterFactual #3: Value of Resales at 1989 Levels
Impact of Ancillary Expenditures





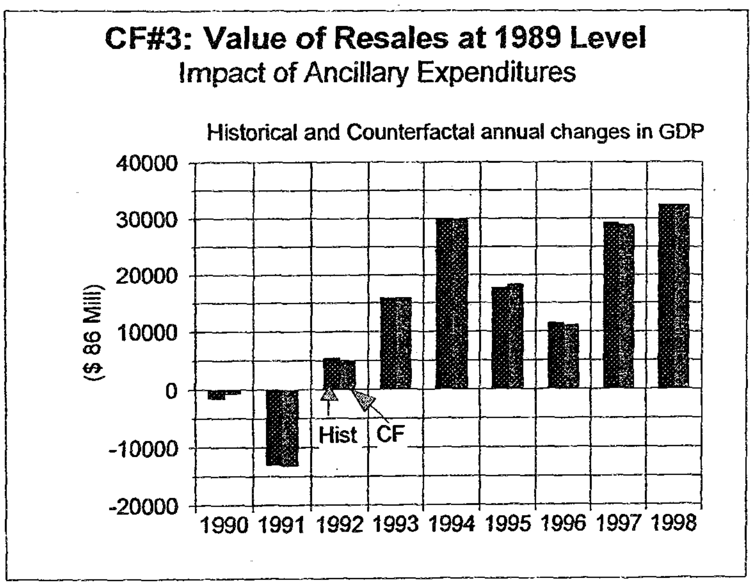


Table 5.4

Counterfactual Experiment: Housing ReSales at 1989 Level Through 1998

Impacts of Ancillary Expenditure Changes

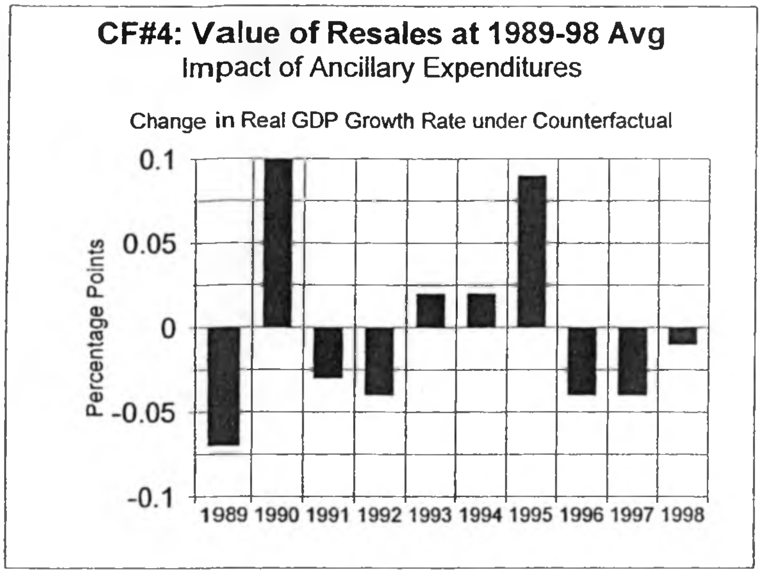
(Interest Rate Target for Monetary Policy)

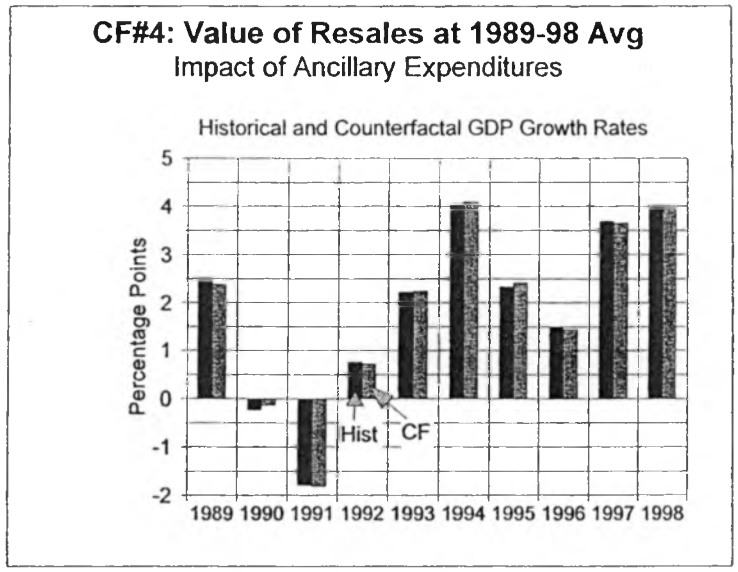
	1990	1991	1992	1993	1994	1995	1996	1997	1998	Sum 1990-98	Average 1990-98
Real GDP (Change in $96 Million)	921	700	306	264	218	722	310	-68	-187	3186	354
Real GDP (Change in $86 Million)	715	544	238	205	170	561	241	-53	-145	2476	275
GDP Growth Rate (Change in % Pts)	0.13	-0.03	-0.06	-0.01	-0.01	0.06	-0.05	-0.05	-0.01		-0.00
Real Gross Domestic Product (% Change)	0.13	0.10	0.04	0.04	0.03	0.09	0.04	-0.01	-0.02		0.05
Consumer Price Index (% Change)	0	0.03	0.05	0.06	0.08	0.09	0.11	0.13	0.14		0.08
CPI - Inflation Rate (Change in % Pts)	0	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.01		0.02
Unemployment Rate (Change in % Pts)	-0.06	-0.05	-0.03	-0.03	-0.02	-0.04	-0.02	0	0.01		-0.03
Employment (% Change)	0.09	0.08	0.05	0.05	0.04	0.07	0.04	0.01	-0.01		0.05
Employment (Change in '000)	11.7	10.3	6.7	6.7	4.9	9.9	5.3	1.7	-1	56.2	6.2
Fed Balance (Surp(+),Def(-)) (Ch in $ Mill)	256	275	190	188	186	330	260	200	166	2051	228
Prov Balance (Surp(+),Def(-)) (Ch in $ Mill)	296	196	95	142	176	365	221	156	185	1832	204

Counterfactual Nr. 4: Value of Resales at 1989-98 Average

Finally, we consider the counterfactual in which resales are held at their 1989-98 average for the span 1989-98. As panel 1 of Chart 5.4 shows, the biggest impacts of the counterfactual are to reduce growth in 1989 and to boost it in 1990 and 1995. These three largest effects are all the right direction, in that growth (according at least to the Bank of Canada) was too high in 1989 and was certainly low in 1990 and 1995. However, again the overall counter-cyclical effect, while certainly present, is not as large nor as consistent as with ancillary expenditures for new construction.

Chart 5.4 CounterFactual #4: Value of Resales at 1989-98 Average
Impact of Ancillary Expenditures





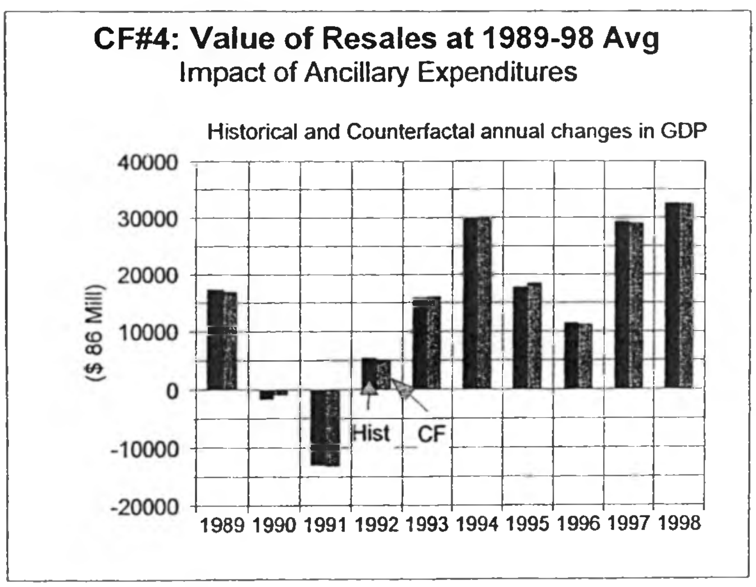


Table 5.5

Counterfactual Experiment: Housing ReSales at 1989-98 Level Through 1998
Impacts of Ancillary Expenditure Changes
(Interest Rate Target for Monetary Policy)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Sum 1989-98	Average 1989-98
Real GDP (Change in $96 Million)	-480	270	35	-234	-101	52	726	428	129	50	875	88
Real GDP (Change in $86 Million)	-373	210	27	-182	-78	41	564	333	100	39	681	68
GDP Growth Rate (Change in % Pts)	-0.07	0.1	-0.03	-0.04	0.02	0.02	0.09	-0.04	-0.04	-0.01		-0
Real Gross Domestic Product (% Change)	-0.07	0.04	0	-0.03	-0.01	0.01	0.09	0.05	0.02	0.01		0
Consumer Price Index (% Change)	0	-0.01	-0.01	-0.01	-0.02	-0.03	-0.04	-0.02	-0.01	0		-0
CPI - Inflation Rate (Change in % Pts)	0	-0.02	0	0	-0.01	-0.01	-0.01	0.01	0.02	0.01		-0
Unemployment Rate (Change in % Pts)	0.03	-0.01	0	0.01	0.01	0	-0.04	-0.03	-0.02	-0.01		-0
Employment (% Change)	-0.05	0.02	0	-0.02	-0.01	0	0.06	0.04	0.03	0.02		0
Employment (Change in '000)	-6.5	2.2	-0.6	-2.8	-1.5	-0.2	8	5.6	3.5	2.7	10.4	1
Fed Balance (Surp(+),Def(-)) (Ch in $ Mill)	-121	36	-10	-83	-51	-28	152	125	87	67	174	17
Prov Balance (Surp(+),Def(-)) (Ch in $ Mill)	-142	110	-4	-89	-33	2	211	60	-11	8	112	11

6. Conclusions

As with the earlier CMHC study of temporary increases in new housing construction or alterations, the simulations have shown that a temporary increase in new housing construction activity can have important induced effects on the economy through the ancillary expenditures that accompany it, and that stimulus of this sort could be considered as a weapon of countercyclical fiscal policy during a slump or recession. Ancillary expenditures related to sales of new or existing dwellings were found to have a much smaller effect and would be correspondingly weaker as counter-cyclical tools. We have also found that, when the stimulus is of significant size, it will have an effect beyond the temporary period when it is directly in effect. For countercyclical policy, therefore, it is important that a housing stimulus be introduced *early* or, as much as possible, in anticipation of the downturn. If the housing stimulus is introduced well after the downturn has begun, the lags in its operation could perhaps overheat a recovery.

Counterfactual simulation tests over the 1990s confirm these basic conclusions and show that, especially, ancillary expenditure associated with new housing construction, would have played a small, but significant and consistent, counter-cyclical role through the decade if new housing construction itself could have been smoothed or kept at late-1980s levels.

We have also found that a temporary stimulus of this kind develops its *own* contractionary aftershock within 3 to 4 years (or somewhat longer under the interest-rate target). If the object of countercyclical policy is to soften recessions and also to suppress booms in recovery, then a temporary housing stimulus works on *both*, since the shock creates first positive and then negative stimulus to GDP and employment.

Naturally, the simulations have shown that the state of the underlying economy matters for the impacts of a temporary housing shock. The higher the base level of the unemployment rate, the less inflationary impact there will be, and the smaller will be the later contractionary impact. However, for the ancillary expenditures we have examined, the inflationary impacts have all been found to be very small.

Finally, the simulations show that the impacts of a temporary spending shock associated with ancillary spending from housing activity cannot be considered in a policy vacuum: the impacts can vary significantly with the policy stance of the Bank of Canada. The more the Bank is prepared to accept additional stimulus, and the inflation it can bring, the larger the impacts will be.

LOG WALLS FIELD TESTS

LOG WALLS FIELD TESTS

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LOG WALLS FIELD TESTS

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DISCLAIMER

This project was funded by the Canada Mortage and Housing Corporation, but the views expressed are the personal views of the authors and the Corporation accepts no responsibility for them.

LOG WALLS FIELD TESTS

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES — Page No.

LOG WALLS FIELD TESTS
EXECUTIVE SUMMARY

The effective RSI values of carefully selected sections of solid log wall houses were measured using a guarded calorimeter test apparatus commonly known as a "mimic box".

The five log houses that were included in the study consisted of the following:

i) three of standard round pine log wall construction
ii) one of square cedar log-chinked wall construction
iii) one of modified round pine log wall construction

All round log houses were less than three years old. The cedar log house was eight years old.

The effective RSI value of a wall section from a house of standard wood-frame construction (eight years old) was also measured to produce a baseline against which the performance of the log wall sections could be interpreted.

Testing was restricted to north facing walls only. Infrared thermography was used to ensure that the selected wall sections were representative of typical log wall construction practice (i.e. the wall sections were chosen so that no voids or discontinuities in the joints were present to bias the results).

The instrumentation package designed for this monitoring project was comprised of:

i) A mimic box complete with a 150W heating cable, controller, thermopile junction and high temperature safety cut-out.

ii) An electronic data acquisition system interfaced to a microcomputer.

iii) An array of thermocouples to measure various temperatures within the mimic box and ambient indoor and outdoor temperatures, all of which were interfaced to the data acquisition system.

iv) A pulse initiating kilowatt-hour meter interfaced to the data acquisition system.

Data was collected approximately every thirty seconds and stored on floppy disk in cumulative hourly functions.

Testing of each log wall section lasted a minimum of three weeks. All testing was performed during mid-winter to early spring, 1986. The test period chosen for analysis was carefully selected so as to minimize the effects of stored energy within the log walls.

The results revealed that the effective thermal resistance of the log walls sections included in the study ranged from a minimum of 1.87 $m^2 \cdot C/W$ (10.6 $hr.ft.^2 \cdot F/Btu$) to a maximum of 2.52 $m^2 \cdot C/W$ (14.3 $hr.ft.^2 \cdot F/Btu$). The effective thermal resistance of the wood frame wall section was found to be 2.41 $m^2 \cdot C/W$ (13.7 $hr.ft.^2 \cdot F/Btu$).

The effective resistivities of the log wall sections tested were found to range from 0.0063 $m^2 \cdot C/W$ per mm (.91 $hr.ft.^2 \cdot F/Btu$ per inch) to 0.0071 $m^2 \cdot C/W$ per mm (1.02 $hr.ft.^2 \cdot F/Btu$ per inch) for the round pine logs. The square cedar log wall section was found to have an effective resistivity of 0.0083 $m^2 \cdot C/W$ per mm (1.2 $hr.ft.^2 \cdot F/Btu$ per inch). These values are below the current value recognized by CMHC for log walls, which is 0.0087 $m^2 \cdot C/W$ per mm (1.25 $hr.ft.^2 \cdot F/Btu$ per inch) for pine logs and 0.0092 $m^2 \cdot C/W$ per mm (1.33 $hr.ft.^2 \cdot F/Btu$ per inch) for cedar logs.

Thermal bridging at the joints appears to be the major weak link in the log wall systems.

LOG WALLS FIELD TESTS

1.0 INTRODUCTION

For several years, the thermal resistance of solid log walls has been a subject of controversy between log home builders and CMHC since the thermal resistance calculated using standard reference data is less than the values CMHC requires in many parts of the country for housing financed under the National Housing Act. The issue remains unresolved partly due to the lack of adequate field data available to CMHC officials on the actual in-place thermal resistance of solid log walls.

Scanada Consultants was contracted to measure the effective RSI values of several solid log walls by measuring energy consumption through carefully selected sections of these walls using guarded calorimeters. The results obtained from this monitoring project are intended to provide sound field data which can be compared to theoretical RSI values.

Log home builders have argued that the actual net heat loss through log walls is less than would be calculated using simple heat conduction formulae because of the benefits of solar energy storage in the logs' mass. However, this aspect is best addressed through analytic studies rather than through short term field tests since the results of the latter would be affected in an unpredictable manner by the particular pattern of solar energy availability that occurred during the test period. Therefore, the tests described herein were limited to north walls only so as to limit the effect of stored solar energy. Thus the results do not include any solar storage benefits that might accrue from the massive nature of log walls.

2.0 OBJECTIVES

The field testing of the thermal resistance of log wall systems has three main objectives. These are -

1) To measure, for known inside/outside temperature conditions, the actual heat loss through several types of log walls and thence to determine their effective thermal resistance.

2) To compare the theoretical and actual thermal resistance values of log walls and, based on this comparison, recommend any required modifications to the present RSI values assigned to log wall construction.

3) To conduct similar measurements and comparisons for walls of standard frame construction in order to produce a baseline against which the performance of the log walls can be interpreted.

3.0 THE "MIMIC BOX" GUARDED CALORIMETER

3.1 General Principle

The "mimic box" is an insulated box Hm high by Wm wide by Dm deep with one of its HxW sides open. The open side is sealed against the wall to be tested. An electric heating element inside the box is controlled by an electronic device which senses any temperature difference between the interior of the box and the ambient room air and turns the element on to eliminate any such difference. Thus the temperature in the box "mimics" that in the room. Since the box is highly insulated and the difference between the air temperature in the box and the room is kept very small, essentially any heat loss from the box, which must be made up by the heating element, must be through the test wall. Thus the measured energy supplied to the heating element, is a proxy for energy flowing out through the test wall. The energy supplied to the heating element is measured using a kilowatt-hour meter.

The energy balance of the mimic box system can be expressed by the following equation which is an expression of the principle of conservation of energy[1]:

$$E_m = \frac{(T_{in} - T_{out})_{mean} \bullet A \bullet t}{RSI} + \Delta Q_s \qquad (1)$$

where -

E_m is the cumulative energy consumed by the heating element (Wh).

---

1 This equation is a simplification of the more general one-dimensional heat conduction equation. Ref. Heat Transfer, J.P. Holman, McGraw-Hill Company, Fifth Edition, 1981, pp. 4.

$(T_{in} - T_{out})_{mean}$ is the average temperature difference between the interior and exterior air films of the metered wall section over the selected test period (°C). Note: T_{in} is the average temperature of the air in the mimic box (°C). T_{out} is the average outdoor temperature near the exterior wall (°C).

A is the area of wall under test (i.e. the area under the mimic box) (m^2).

t is the length of the test period (hours).

RSI is the effective thermal resistance of the portion of the wall under the mimic box, including the effect of heat loss at the log joints (or studs in the case of the wood frame wall). Since the temperature sensors are located outside the air films, the effective resistance also includes air films ($m^2 °C/W$).

ΔQ_s is the difference in the internal energy of the wall at the beginning of the test and at the end of the test (i.e. the net energy stored) (Wh)

Equation 1 can be re-arranged to solve for the resistance term as shown in Equation 2.

$$RSI = \frac{(T_{in} - T_{out})_{mean} \bullet A \bullet t}{E_m - \Delta Q_s} \qquad (2)$$

Equation 2 has two unknowns, RSI and ΔQ_s. Thus, in order to solve for RSI, test conditions must be chosen which will result in ΔQ_s being at or close to zero.

3.2 Minimizing the Effect of Stored Energy

The thermal resistance derived from Equation 2 was shown to be a function of ΔQ_S. One way to minimize the effect of this term is to select a period for analysis such that the final temperature of the log wall is the same as its initial temperature. In theory this would ensure that the difference in energy stored in the wall is zero. However, this criterion is difficult to satisfy in practice because it would require precise measurement of the average temperature of the logs themselves. A possible proxy for temperatures of the log wall might be the average of the inside and outside air temperatures. However, even this method is not likely to accurately assure that the internal energy within the log structure at the end of the test is the same as at the beginning of the test. As a result, using this method alone, although it reduces the effects of ΔQ_S, may still yield a result which is biased by the storage effects, either positively or negatively.

An examination of Equation 2 indicates that the significance of the stored energy is reduced if the heat loss through the wall is large (i.e. ΔQ_S is small in comparison to the overall heat loss through the wall). This can be achieved in two ways -

1) choosing test periods where the temperature differential across the wall section is maximized, or
2) utilizing the longest test period possible, since the quantity on heat loss increases with time and the amount of energy stored is independent of time.

Clearly the optimum monitoring strategy is to combine all the criteria discussed above; i.e. the best results will be obtained if one chooses a test period:

a) for which the inside and outside temperatures are the same at the beginning and end of the test;

b) during which the temperature differential across the wall is high;

c) which is quite long.

These criteria have been followed in choosing the test periods for analysis.

4.0 DESCRIPTION OF HOUSES

Testing was carried out in the following houses:

a) five log wall houses
b) one conventional wood frame house

The field testing was restricted to north facing walls so as to minimize the effects of solar energy stored in the walls. An infrared thermographic scan was performed on each wall section to ensure that there were no thermal anomalies (i.e. voids in the joints) in the test section that might bias the analysis.

The log wall houses can be further sub-divided into the following types of construction -

i) three of standard round log wall construction
ii) one of square log-chinked wall construction
iii) one of modified round log wall construction

All of the houses are two storey homes with a full basement. Only the first floor walls are made of logs. The second floor is conventional wood frame construction.

Each of these wall construction types is discussed briefly below.

<u>Standard Round Log Wall Construction</u>

The first three log houses tested in this project can be classified under this type of construction. These are referred to as Log House No. 1, Log House No. 2 and Log House No. 3 in the balance of the report. Each of these log houses is less than three years old.

The construction of the log walls in these three houses is based on a Scandinavian technique in which a longitudinal round groove is hewn into the bottom of each log. Each log is hand scribed so that the groove matches the contour of the log on which it is to be placed. A thin piece of mineral wool is placed in the groove to help fill voids between the logs. The corner detail in all houses is a double groove type.

The wall section that was tested in Log House No. 1 was comprised of alternating white and red pine logs ranging in diameter from 230 mm to 350 mm with an average diameter of 270 mm (based on on-site measurements of the ends of the logs used in the test section). The joints have an average depth (measured across the wall) of about 145 mm.

The joints of Log House No. 1 differ from the other two houses in that the interior and exterior surface of the joints were caulked using a rubber based caulking compound.

Log House No. 2 uses white pine exclusively in the log walls. The logs in the wall section that was tested in this house range in diameter from 250 mm to 400 mm with an average diameter of 310 mm. The average depth of the joints was 190 mm.

Log House No. 3 also uses white pine exclusively in the log walls. The logs in the wall section that was tested in this house range in diameter from 280 mm to 440 mm with an average diameter of 350 mm. The average depth of the joints was 210 mm.

<u>Square Log-Chinked Wall Construction</u>

This log house, referred to as Log House No. 4 in the balance of the report is about eight years old. The log walls of this house are comprised of 250 mm by 250 mm squared cedar logs tied together by steel bolts. The dovetail corner detail separates the logs

5.0 INSTRUMENTATION

5.1 Mimic Box

The basic principle of the mimic box was discussed earlier. The mimic boxes used were supplied by the Institute for Research in Construction of the National Research Council. These mimic boxes are comprised of the following:

1) The basic five sided guarded calorimeter (mimic box) with one open side which is sealed to the test wall. The dimensions of the box are 1960 mm high by 1210 mm wide by about 200 mm deep. The section of wall under test thus has an area of 2.37 m^2.

2) A 150 W electrical heating cable looped within the mimic box so as to provide even distribution of heating.

3) A thermopile junction to measure the temperature difference between the air in the box and that in the room.

4) A controller to turn the 150 W heater cable on and off to maintain a negligible temperature difference across the mimic box walls.

5) A high temperature safety cut-out to shut off the heaters if the controller fails and temperatures inside the box exceed a preset upper limit.

6) A pulse initiating kilowatt-hour meter to measure the energy consumed by the heater cable.

5.2 Data Acquisition System

The data acquisition system was made up of the following components -

- Sciemetrics Instruments Model 8082A Electronic Measuring System capable of measuring 64 analog channels and 16 digital channels.

- Compaq portable MS-DOS computer with 256 K RAM, two floppy disk drives and a real time clock card.

- J type thermocouples capable of measuring temperatures in the range of -210°C to 760°C with an accuracy of 2.2°C.

- Pulse counter card to provide the interface between the pulse initiating kilowatt-hour meter and the Sciemetrics system.

The temperature sensors and the pulse initiating meter were connected to the Sciemetrics system. The Sciemetrics system was then connected to the microcomputer via a custom interface card. A compiled PASCAL program developed by Sciemetrics for this type of application was used to control the data acquisition system. The program continually reads each of the selected channels sequentially and stores the value in a cumulative average (thermocouples) or cumulative total (kilowatt-hour meter) function. These functions are stored on disk each hour.

In addition, the kilowatt-hour meter reading was recorded manually at the beginning and end of each test period to provide a suitable backup in case of a malfunction of the energy measuring component of the data acquisition system.

5.3 Sensor Placement Strategy

Figure 2 shows the placement of the temperature sensors used in the monitoring project. The placement of the sensors was designed to fully describe the thermal behaviour of the particular wall section. A degree of redundancy was introduced to provide back-up in case of failure of some sensors. The locations of the sensors are summarized in Table 2.

Also shown in Figure 2 are the locations of additional sensors designed to track the box/room temperature difference, ambient indoor and outdoor air temperatures, and temperatures on a wall section adjacent to the mimic box. These measurements are not essential to the determination of heat loss or RSI-value but do provide supplemental information that helps validate the operation of the mimic box and the experiment as a whole.

<u>Attachment of the Mimic Box to the Wall.</u>

The unevenness of the round log walls provided an additional challenge since it was imperative that an airtight seal between the mimic box and the log wall be achieved. The following describes the method used:

1) A square wooden frame 1.21 m by 1.96 m was fabricated using 12 mm by 25 mm wood framing.

2) The frame was attached to the selected wall section with duct tape. The frame was appropriately positioned such that the top and bottom portion of the frame could be attached to a log (i.e. the top and bottom portion of the frame were not placed directly opposite joints).

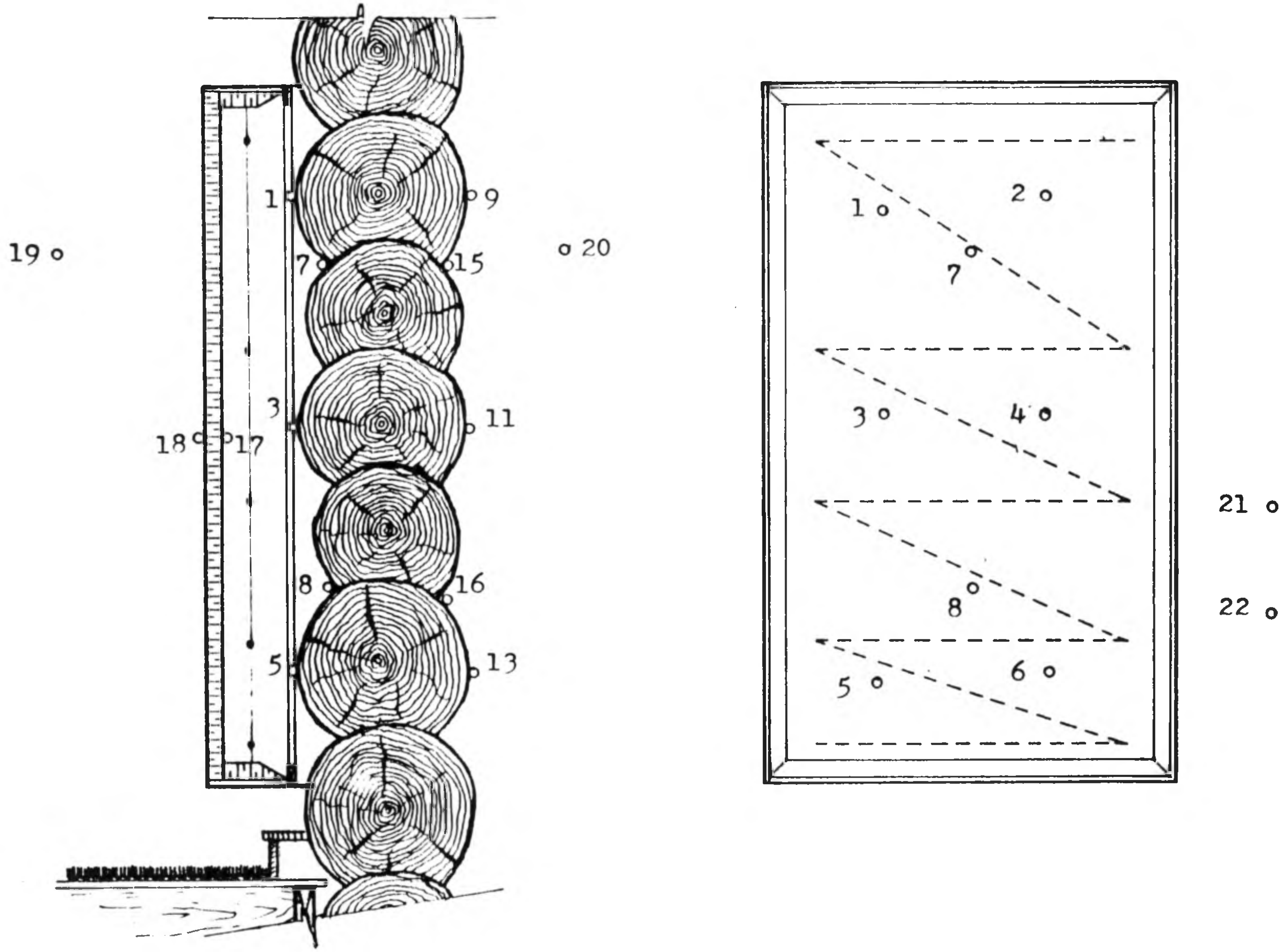
3) Semi-rigid fiberglass insulation was cut to fill in the voids between the log and the vertical framing members caused by the contours of the logs. All joints were sealed with duct tape.

4) The mimic box was braced against the wall with wooden framing members and all seams sealed with duct tape.

TABLE 2:DESCRIPTION OF SENSOR LOCATIONS USED IN MONITORING PROJECT

SENSOR NO.	DESCRIPTION/LOCATION
1	MIMIC BOX AIR TEMPERATURE #1
2	MIMIC BOX AIR TEMPERATURE #2
3	MIMIC BOX AIR TEMPERATURE #3
4	MIMIC BOX AIR TEMPERATURE #4
5	MIMIC BOX AIR TEMPERATURE #5
6	MIMIC BOX AIR TEMPERATURE #6
7	JOINT TEMPERATURE #1 (INSIDE MIMIC BOX)
8	JOINT TEMPERATURE #2 (INSIDE MIMIC BOX)
9	EXTERIOR TEMPERTURE #1 NEAR LOG
10	EXTERIOR TEMPERTURE #2 NEAR LOG
11	EXTERIOR TEMPERTURE #3 NEAR LOG
12	EXTERIOR TEMPERTURE #4 NEAR LOG
13	EXTERIOR TEMPERTURE #5 NEAR LOG
14	EXTERIOR TEMPERTURE #6 NEAR LOG
15	EXTERIOR JOINT TEMPERATURE #1
16	EXTERIOR JOINT TEMPERATURE #2
17	TEMPERATURE ON MIMIC BOX WALL(INSIDE MIMIC BOX)
18	TEMPERATURE ON MIMIC BOX WALL(ROOM SIDE)
19	ROOM AIR TEMPERTURE
20	OUTDOOR AIR TEMPERTURE
21	INDOOR AIR TEMPERATURE NEAR LOG(OUTSIDE MIMIC BOX)
22	INDOOR AIR TEMPERATURE NEAR JOINT(OUTSIDE MIMIC BOX)
23	EXTERIOR AIR TEMPERATURE NEAR LOG(OUTSIDE MIMIC BOX)
24	EXTERIOR AIR TEMPERATURE NEAR JOINT(OUTSIDE MIMIC BOX)

Figure 2: Location of Temperature Sensors



6.0 RESULTS

As pointed out under "Instrumentation", hourly temperature and power consumption data was stored to disk every hour.

A review of the data indicated that in four of the six houses, energy consumption recorded by the data acquisition system was between six to seven percent less than that recorded manually. All equipment was calibrated prior to monitoring. In these four cases, hourly energy consumption recorded by the datalogger was corrected by the discrepancy to bring the power consumption as recorded by the data acquisition system in line with that recorded manually.

In two of the cases, the energy consumption data recorded by the data acquisition system was clearly inconsistent with that recorded manually. In these two houses, the same monitoring equipment was used and hence the error is attributed to either the meter or the pulse reading board. However, since the final RSI value depends only on the total power consumption, the manual meter readings can still be used in lieu of data from the data acquisition system to yield the RSI for these two walls.

Hourly energy data provides an opportunity to measure the effects of stored energy on the final result. Calculation of the RSI value for a number of increasing time intervals from the beginning of a test highlights the error caused by neglecting stored energy in equation (2). This error is larger at the shorter intervals, and diminishes as the intervals get longer. The error will be positive or negative at any one time depending on whether the wall is cooler or warmer than at the start of the test.

For these cases where hourly energy data is available, the RSI value can be calculated for each hour of the test period. For each hourly calculation, the time interval is the duration of the time since the beginning of the test or analysis period and similarly the temperatures are the average temperatures over that same time interval. The average temperature inside the mimic box is based on the six temperature sensors located near the logs. A check of this average temperature against the room temperature for each of the set-ups confirmed that these six sensors were sufficiently far enough away from the wall to be outside the air film. Therefore, the thermal resistance of the interior air film should be considered to be included in the measured RSI value of the wall. Similarly, the outside wall temperature measurement was based on six sensors located near the exterior wall and directly opposite an interior wall sensor. Again, these sensors were far enough away from the wall that exterior air films were considered to be included in the measured RSI value.

Two temperature sensors located near two joints in each of the log wall systems were used to measure the degree of heat loss at the joint. The average value of these joint sensors was compared to the interior and exterior temperatures and a measure of the difference between temperatures near the log and near the joint was used to evaluate the degree of heat loss.

The performance of the control system of the mimic box was evaluated by measuring the box/room temperature differential (i.e. the temperature differential across the back side of the mimic box). The control system was considered to be operating satisfactorily if this temperature differential averaged less than 1°C.

A brief overview of the results for each house is presented in the following sections. The results for each house are summarized in Table 3 which follows this overview.

LOG HOUSE NO. 1

Testing in this house was conducted from 22:00 January 21, 1986 to 10:00 February 15, 1986, a duration of 589 hours. A review of the data indicated that a period from 08:00 January 23, 1986 to 07:00 February 15, 1986, a duration of 552 hours best satisfied the previously established criteria for minimizing the effects of stored energy.

The average outdoor temperature over this period was -13.7°C with a range from -27.2°C to 2.7°C. The average temperature of the room was 20.2°C with a range from 13.8°C to 25.9°C.

The mimic box/room temperature differential was tracked. The results show that the average temperature differential was -0.8°C over the test period, indicating that the box control system was working as intended.

The average air temperature inside the mimic box over the selected period was 19.9°C with a range from 14.1°C to 24.3°C. An examination of the data indicates that the difference between the average temperature measured near the joints and the average air temperature measured near the logs was about 1°C. The difference is small for this house compared to other log wall systems, as will be seen later. This may be attributed to the caulking the occupant performed on the joints which essentially eliminated air leakage through the joints.

Exterior temperatures near the logs over the selected period averaged -12.1°C with a range from -25.7°C to 3.2°C. No perceptible difference was observed between temperatures measured near the logs and temperatures measured near the joints. The temperature profiles for the wall section tested in this house is shown in Figure 3.

In Section 3, three methods of reducing the effects of stored energy in the logs were identified. These were -

a) ending the analysis period at a point having the same inside and outside temperature as at the beginning of the test;

b) maximizing the temperature differential across the wall;

c) utilizing the longest possible period that met a) and b).

Figure 4 shows the hourly RSI-value (using equation (2))for the wall section tested in this house for the period 08:00 January 23, 1986 to 07:00 February 15, 1986. The flattening out of the curves after about 300 hours indicates that the effects of stored energy have become sufficiently small compared to the cumulative conductive heat loss through the wall section. The horizontal line is the final result of 1.87 $m^2 {}^\circ C/W$ (10.6 hr. ft.$^2 {}^\circ F$/Btu) at 552 hours.

It is interesting to note that if the RSI calculation had been performed using the data over the full monitoring period, the RSI value would be have been 1.88 $m^2 {}^\circ C/W$ (10.7 hr.ft.$^2 {}^\circ F$/Btu). This value is almost the same as that calculated above. Thus, if the test period is sufficiently long, the importance of ending the analysis period at a point when the temperature is the same as at the start becomes smaller and smaller.

The advantage of using the full monitoring period is that the final result can be based on the total energy consumption derived from manual meter readings.

Thus, the effective RSI value for wall section tested in Log House No. 1, based on the monitored period 08:00 January 21, 1986 to 07:00 February 15, 1986 was found to be 1.87 $m^2 {}^\circ C/W$ (10.6 hr.ft.$^2 {}^\circ F$/Btu).

Figure 3

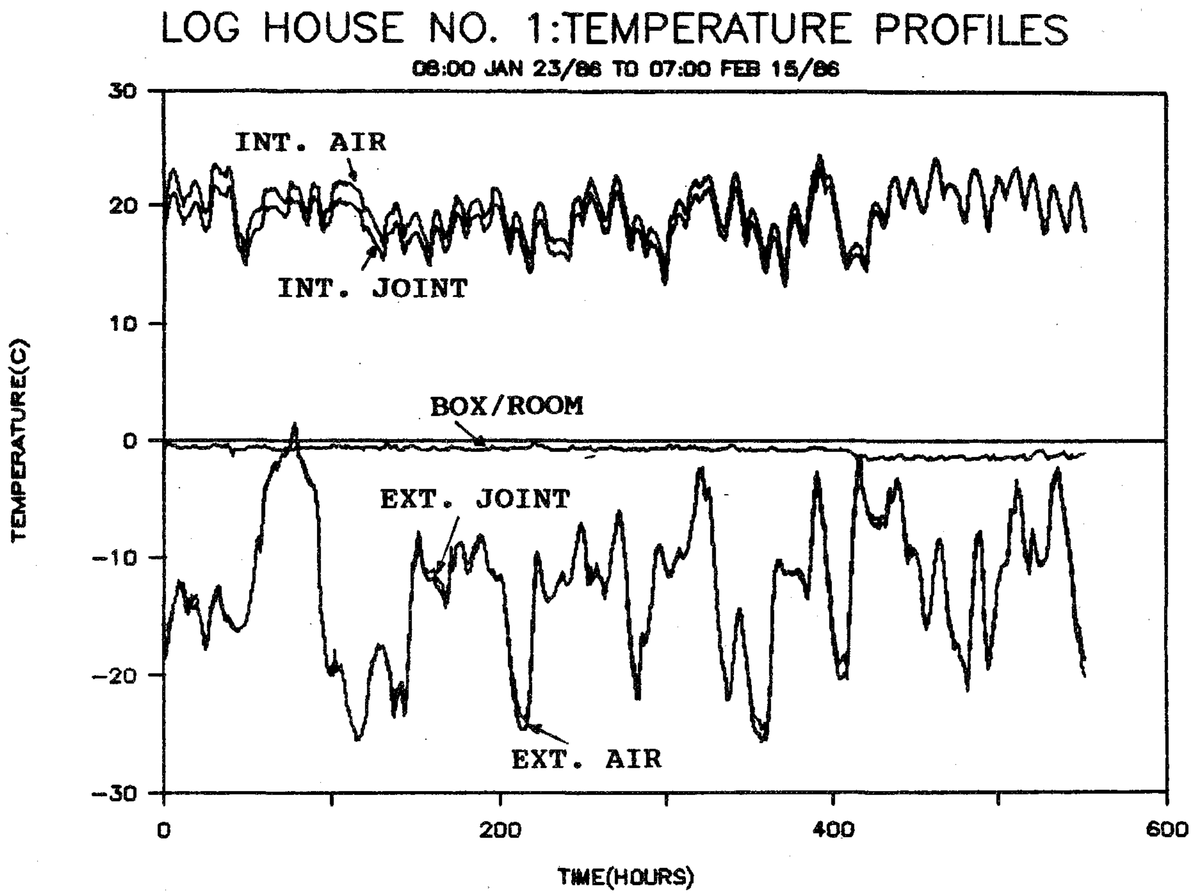
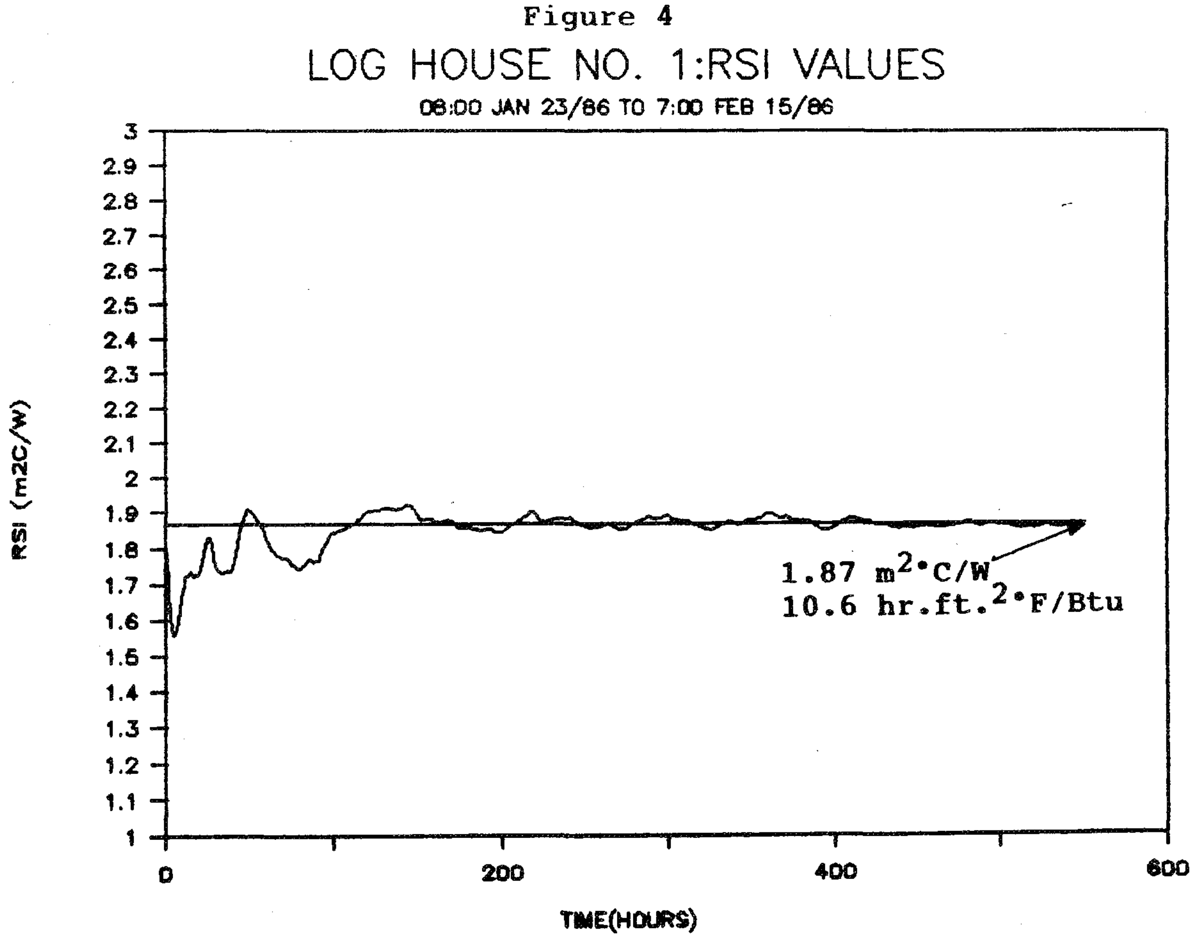


Figure 4



LOG HOUSE NO. 2

Testing in this house was conducted from 22:00 January 27, 1986 to 19:00 March 3, 1986, a duration of 838 hours.

During the monitoring period, the top of the mimic box pulled away from the log wall (i.e. the seal broke). This was first observed at 19:00 January 19, 1986, which was the scheduled termination date for this test. An examination of the mimic box indicated that the gap was small, less than 1 cm and restricted almost exclusively to the top left portion of the box. (The break was not apparent to an observer unless viewed from the top of the box.) Since the actual time that the box broke away from the log wall could not be determined on site, the box was resealed, braced against the opposite wall and the monitoring period extended a further 12 days to 19:00 March 3, 1986.

A review of the box/room temperature differential appears to indicate that the mimic box broke away from the wall sometime on February 17, 1986 since on that day the temperature differential changed from about 0.3°C to 2°C.

As a result of this break in the seal of the mimic box, two independent periods were selected for analysis. The first was from 03:00 January 30, 1986 to 02:00 February 17, 1986 (prior to when the box apparently broke its seal), a duration of 432 hours. The second period was from 00:00 February 20, 1986 (following the repair of the seal) to 19:00 March 3, 1986, a duration of 283 hours.

Test Period 1: 03:00 January 30, 1986 to 03:00 February 17, 1986

The data for this period shows the average outdoor temperature over the period was -11°C with a range from -24.7 to -1.3°C. The average temperature of the room was 24.5°C ranging from 23.1°C to 26.7°C.

The average box/room temperature differential over this selected period was 0.0°C.

The average air temperature in the mimic box was 24.1°C with a range from 22.4°C to 26.0°C. From the data it can be seen that the difference between the average air temperature in the box and that near the joints is about 2°C. This is larger than that observed in Log House No. 1 which had both its interior and exterior joints caulked, whereas Log House No. 2 had only its exterior joints caulked.

Exterior air temperatures near the logs averaged about -9.5°C with a range from -22.8°C to 0.6°C. The exterior air temperatures near the joints were observed to be about 1.7°C warmer. The temperature profiles for the wall section of this house for the first period are shown in Figure 5.

Figure 6 shows a plot of the hourly RSI value for the wall section tested in this house for this first test period. The curve shows that after 300 hours the effect of stored energy has become sufficiently small compared to the cumulative conductive heat loss through the wall section. This is indicated by the flattening out of the curve. Thus, based on the monitored data, the final result at 431 hours is the best result.

Thus, the effective RSI value for the test wall section of Log House No. 2, based on the monitored period 03:00 January 30, 1986 to 03:00 February 17, 1986 was found to be 2.19 $m^2{\cdot}C/W$ (12.4 $hr.ft.^2{\cdot}F/Btu$).

Test period 2: 00:000 February 20, 1986 to 19:00 March 3, 1986

The data for this period shows the average outdoor temperature over the period was -8.1°C with a range from -21.1°C to 2.1°C. The average temperature of the room was 24.8°C with a range from 22.4°C to 27.2°C.

The average box/room temperature differential was 0.6°C over this period.

The average air temperature in the mimic box was 24.3°C with a range from 21.7°C to 26.8°C. From the data it can be seen that the air temperature measured near the joints was about 1.7°C cooler than the average air temperature in the mimic box. This difference is similar to observations made in the first test period.

Exterior air temperatures near the logs averaged about -6.7°C with a range from 5.6°C to 20.4°C. The average exterior air temperatures near the joints were observed to be about 1.2°C warmer than corresponding temperatures near the logs. The temperature profiles for this wall section for the second test period are shown in Figure 7.

Figure 8 shows a plot of the hourly RSI value for the wall section tested in the house during the second test period. An examination of the plot indicates that although the variations appear to have reduced, it is difficult to interpret if this final result is the best result. A longer period would have been preferred in order to fully verify if the final result has actually minimized the effects of stored energy. However, based on this data after 283 hours, the best RSI value for this second period was found to be 2.42 m^2°C/W (13.7 hr.ft.^{2}°F/Btu) after 283 hours.

The two test periods yield a difference in RSI value of about 10%. The lowest value was derived from a period in which the box integrity may be considered suspect (even though the data suggests that the seal broke sometime later). However, assuming that the seal was not perfect, the first test period would result in a higher heat loss from the box and hence bias the RSI value low. Conversely, the second test period probably represents the higher limit that can be expected for this wall section. Although the seal integrity was assured in this test period, the confidence in this result is limited by the shorter duration and lower energy consumption over the period. As discussed earlier, the effects of stored energy would bias the final RSI result unpredictably. It is probably appropriate to present a range of RSI value for this house based on the data collected.

Thus, the effective RSI value for this particular wall section can be estimated to be somewhere between 2.19 $m^2 \cdot C/W$ (12.4 $hr.ft.^2 \cdot F/Btu$) and 2.42 $m^2 \cdot C/W$ (13.7 $hr.ft.^2 \cdot F/Btu$).

Figure 5

LOG HOUSE NO. 2:TEMPERATURE PROFILES

03:00 JAN 30/86 TO 03:00 FEB 17/86

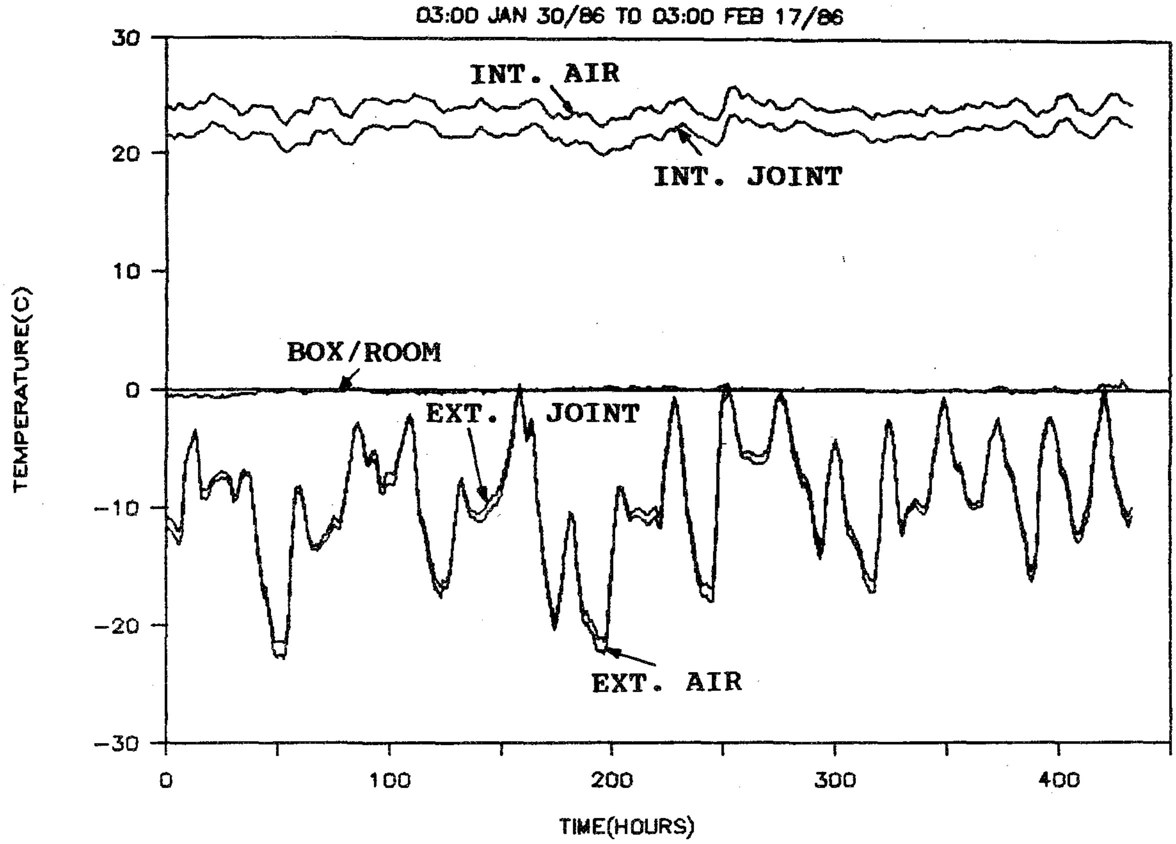


Figure 6

LOG HOUSE NO. 2:RSI VALUE

03:00 JAN 30/86 TO 03:00 FEB 17/86

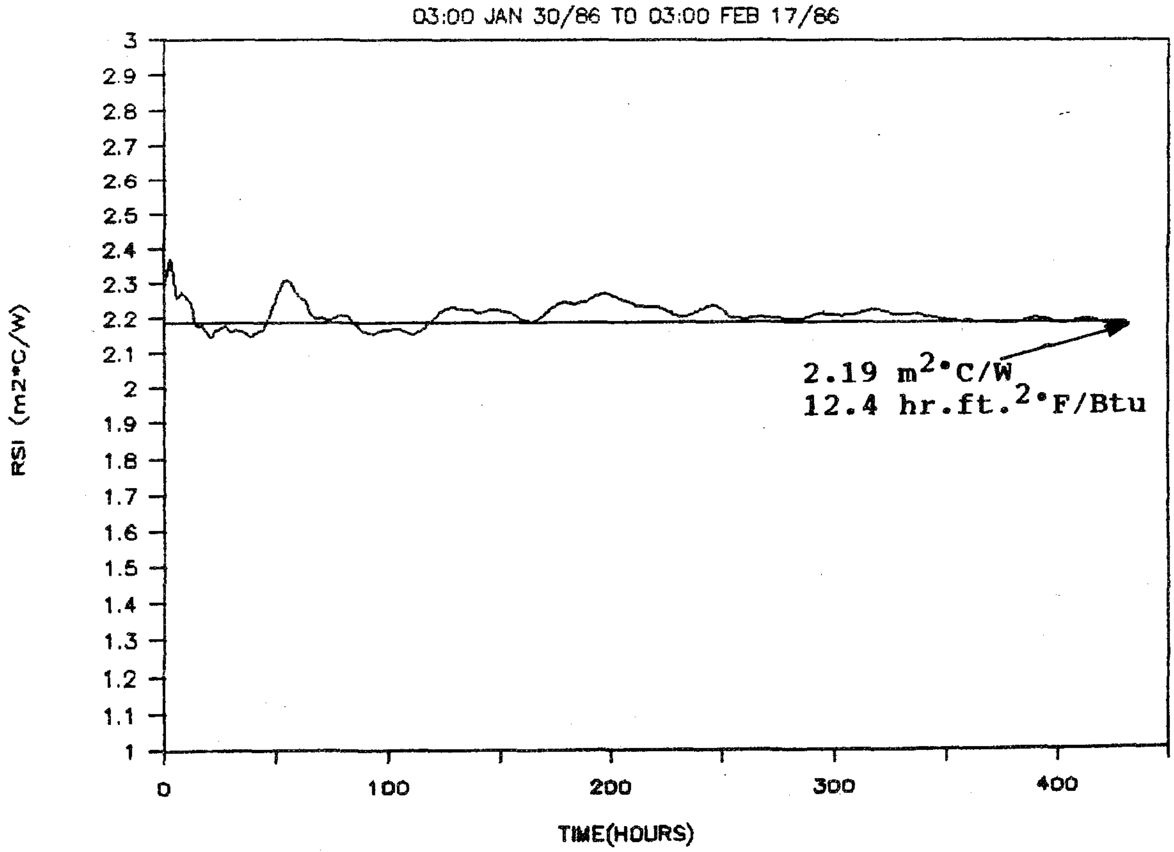


Figure 7

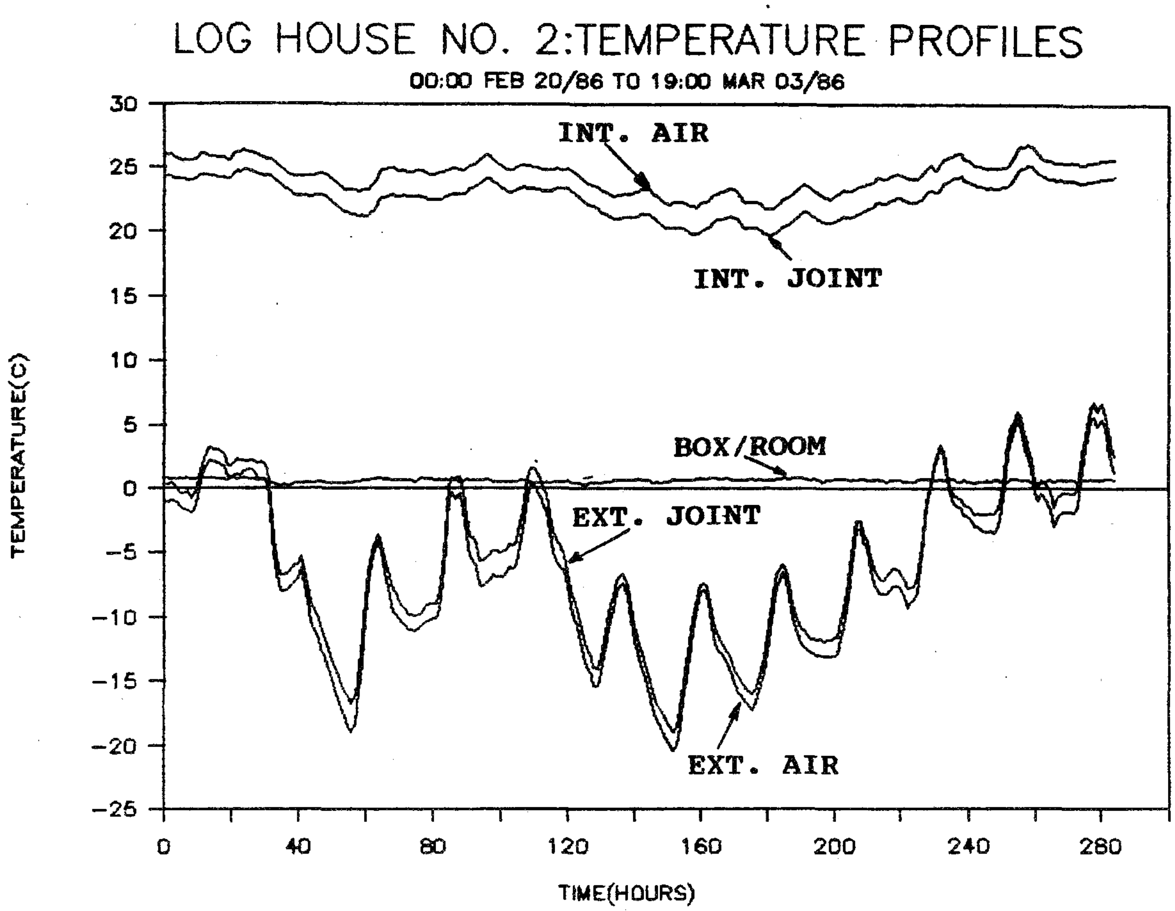
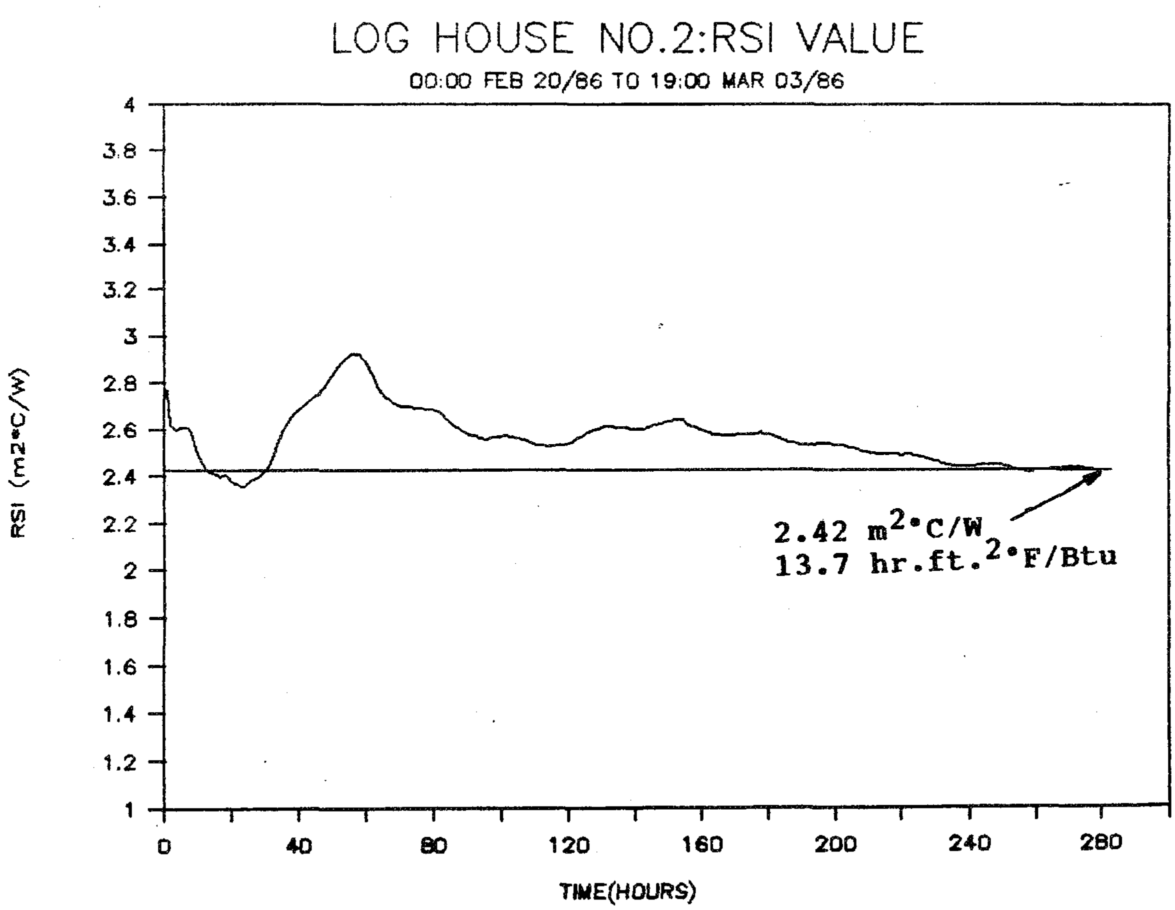


Figure 8



LOG HOUSE NO. 3

Testing in this house was conducted from 19:00 February 7, 1986 to 24:00 February 25, 1986, a duration of 396 hours.

A review of the data indicates that the criteria to minimize the effects of stored energy are satisfied by using the full monitoring period for analysis.

The data shows the average outdoor temperature over the period was -8.7°C with a range from -19.4°C to -0.2°C. The average temperature of the room was 17.3°C with a range from 15.1°C to 19.1°C.

The average box/room temperature differential was 0.1°C.

The average air temperature in the mimic box was 16.3°C with a range from 14.6°C to 17.9°C. The temperatures measured near the joints were about 2°C cooler than the average. Again, neither interior nor exterior joints were caulked in this house.

Exterior air temperatures averaged about -7.3°C with a range from -18.2°C to 2.1°C. The average exterior air temperature near the joints was found to be -5.7°C, slightly less than 2°C warmer than temperatures measured near the logs. Temperature profiles for the wall tested in this house are shown in Figure 9.

The monitoring period for this house was marred by an apparently defective component in the power measuring system. Thus, the plot of RSI vs. time is not available for the wall section of this house. However, as pointed out earlier, the final result relies only on the total power consumption over the analysis period, which in all cases can be derived directly from the manual readings of the kilowatt-hour meter. Since the plot of RSI vs. time is not available for this wall, the reduction of the effect of stored energy cannot be checked graphically. However, as the test period was as long as that used in Log House No. 1, it can be assumed with reasonable confidence that the effect of stored energy has been minimized.

Thus, the effective RSI value for the test wall section of Log House No. 3, based on the monitoring period 19:00 February 7, 1986 to 24:00 February 25, 1986, a duration of 396 hours, was found to be 2.18 $m^2 \cdot C/W$ (12.4 $hr.ft.^2 \cdot F/Btu$).

Figure 9

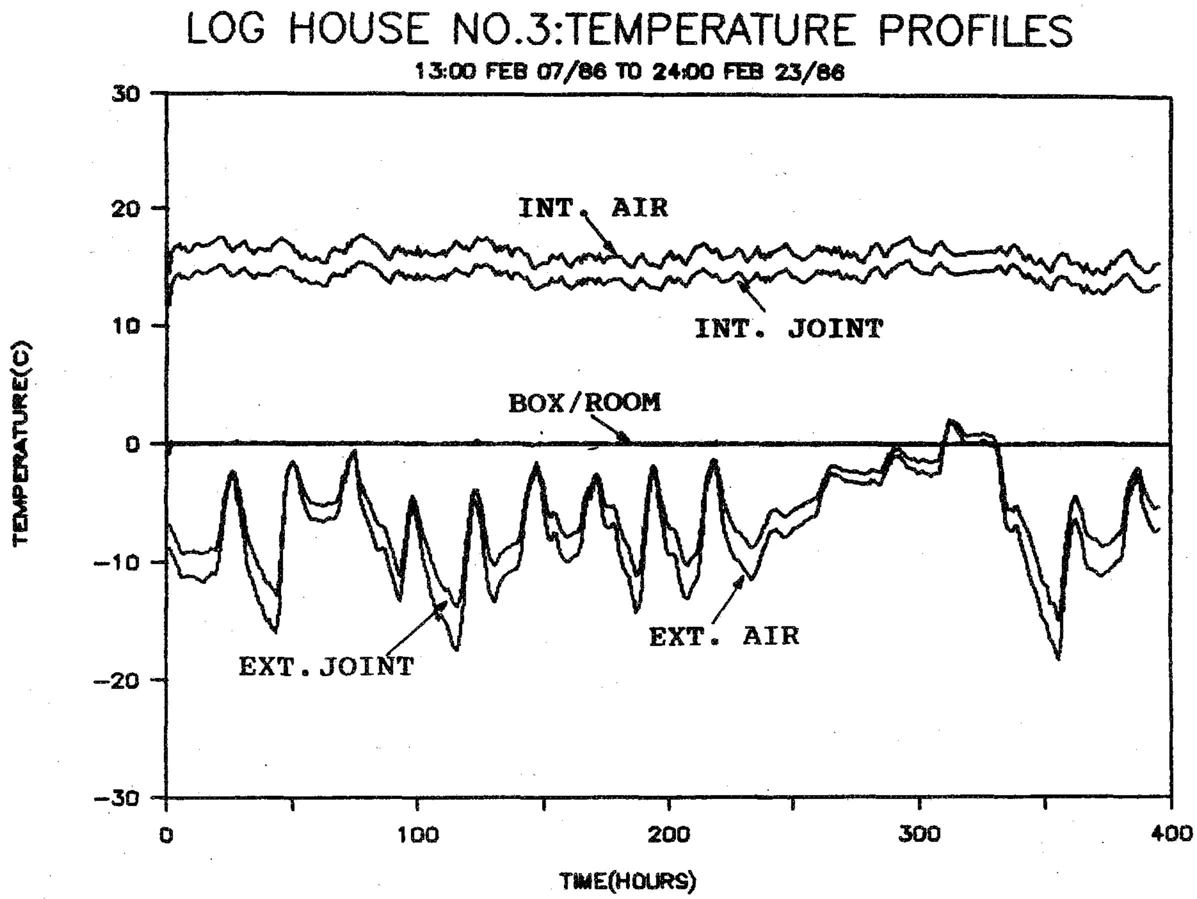
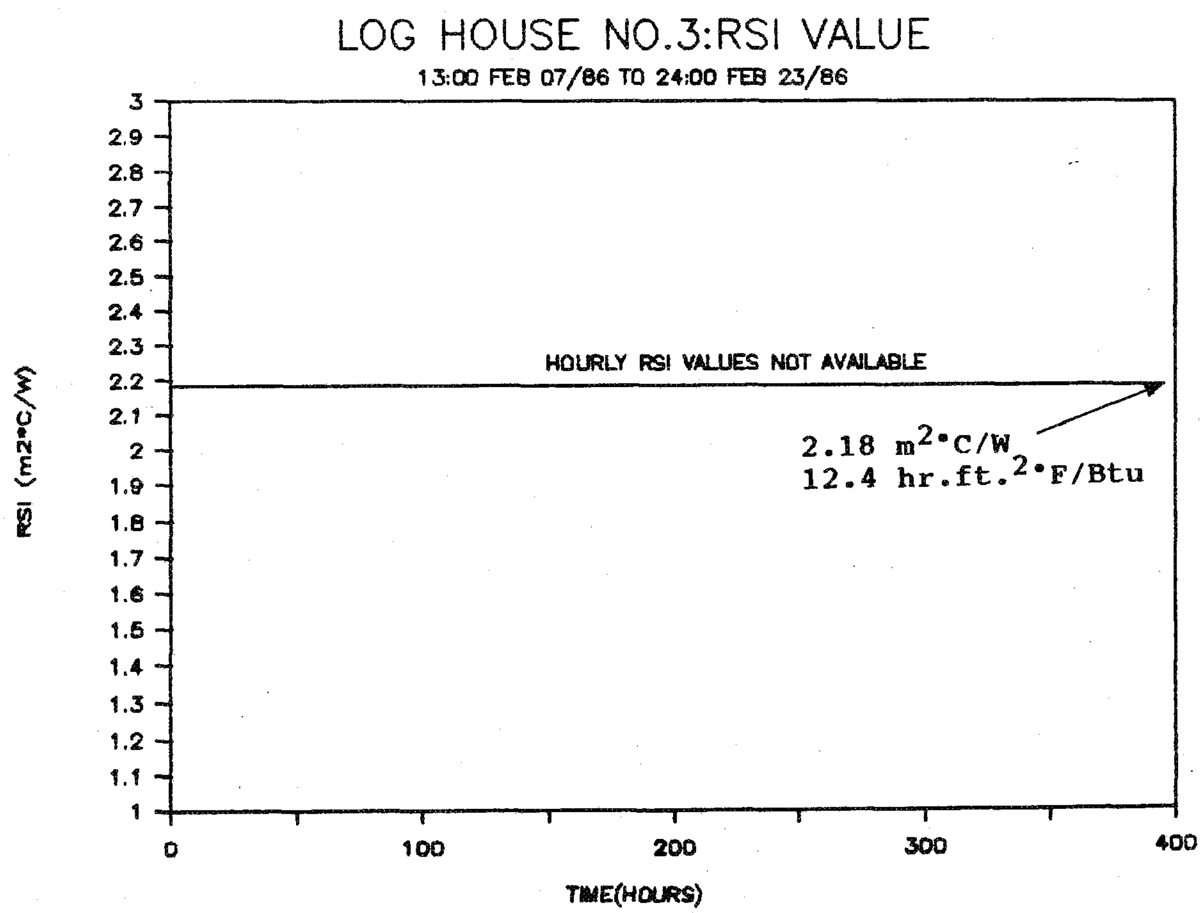


Figure 10



LOG HOUSE NO. 4

Testing in this house was conducted from 16:00 February 19, 1986 to 10:00 March 12, 1986, a duration of 499 hours.

Again, the data indicates that the full monitoring period adequately satisfied the criteria to minimize the effects of stored energy.

The data shows the average outdoor temperature over the period was -6.4°C with a range from -16.7°C to 2.8°C. The average temperature of the room was 17.1°C with a range from 9.4°C to 23.4°C.

The room temperatures varied significantly between day and night. This is attributed to the occupants' practice of setting the thermostat back to a very low temperature at night. Despite this variation the mimic box was able to track the house temperatures within 0.7°C.

The average air temperature in the mimic box was 15.3°C with a range from 8.8°C to 20.4°C. No perceptible difference was observed between the temperature measured near the joints and the average temperature in the box.

Exterior air temperatures averaged about -4.3°C with a range from -13.5°C to 3.5°C. Again, as with the interior joints, no perceptible difference was observed between the exterior air temperature near the joints and the exterior air temperature measured near the logs. This is interesting since the joints were parged, essentially eliminating the effects of lateral or through air leakage. The relative difference between box and joint temperatures is similar to that observed in Log House No. 1 which had its joints caulked. The temperature profiles for the wall section of this house are shown in Figure 11.

Plots of RSI vs. time for this wall section are shown in Figure 12. The curves clearly indicate that after 300 hours the effects of stored energy are sufficiently small compared to the cumulative conductive heat loss through the wall section that the final result at 499 hours is the best result.

Thus, the effective RSI value for the test wall section of Log House No. 4, based on the monitored period 16:00 February 19, 1986 to 10:00 March 12, 1986 was found to be 2.22 $m^2 \cdot C/W$ (12.6 $hr.ft.^2 \cdot F/Btu$).

Figure 11

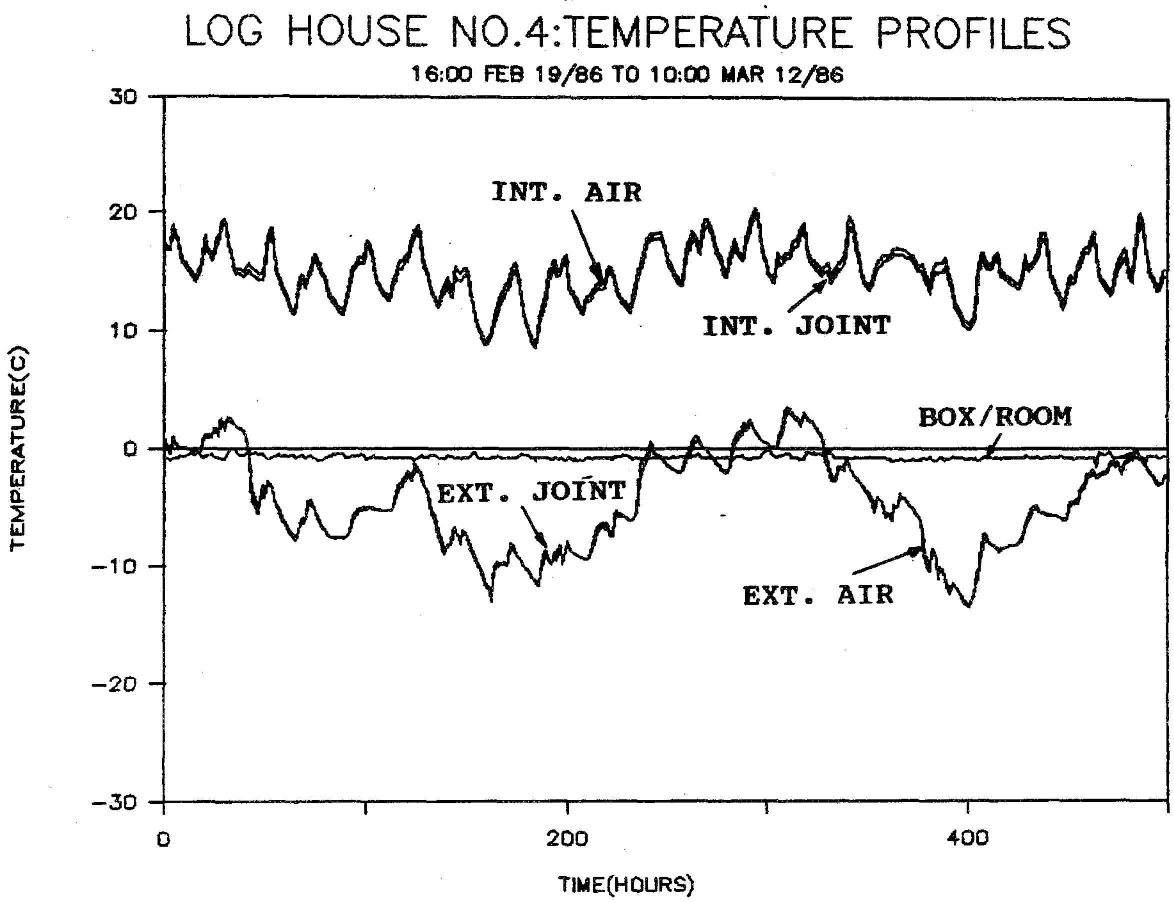
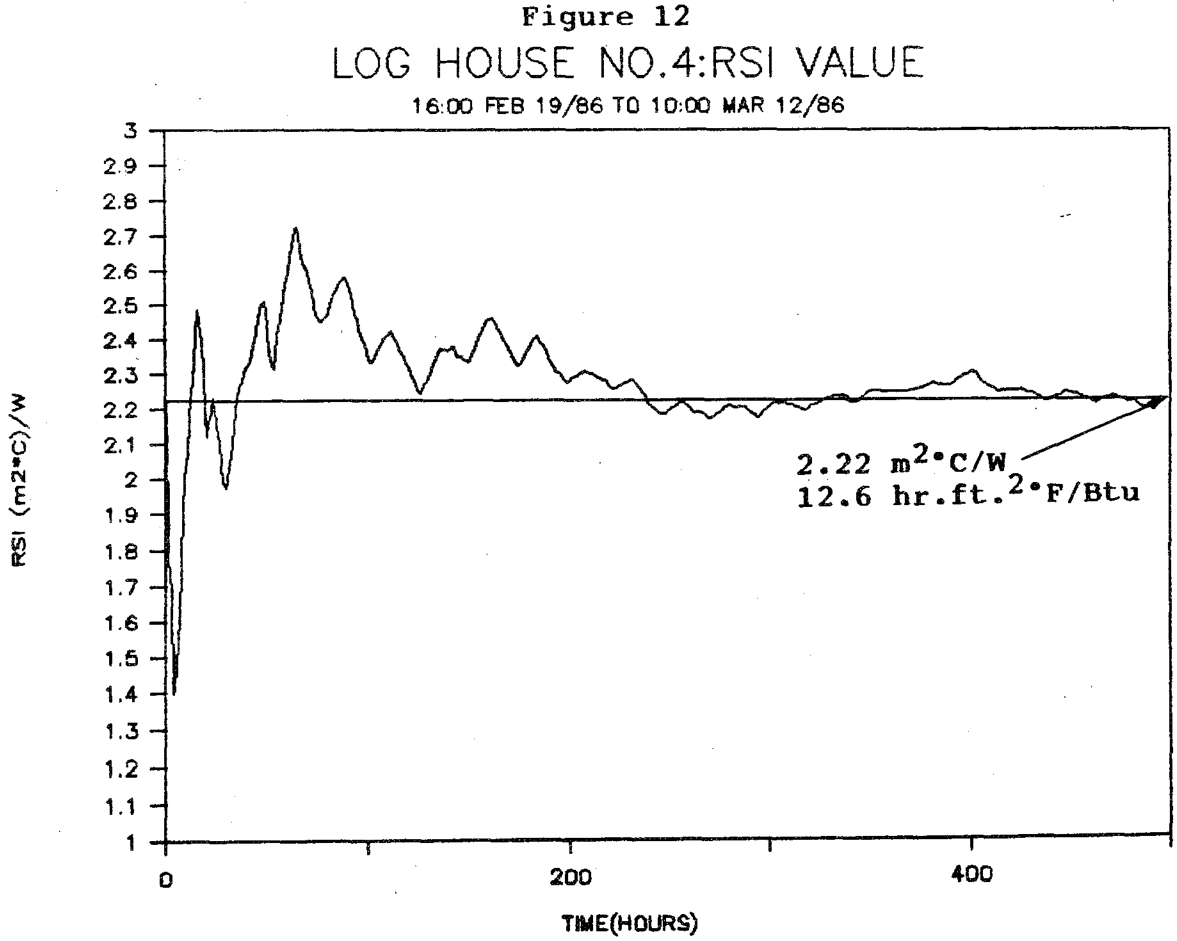


Figure 12



LOG HOUSE NO. 5

Testing in this house was conducted from 19:00 March 3, 1986 to 10:00 March 25, 1986, a duration of 509 hours.

The full monitoring period was found to satisfy the criteria to minimize the effects of stored energy.

Average outdoor temperature over the monitoring period was 0.4°C with a range from -9.9°C to 6.8°C. The average temperature of the room was 19.9°C with a range of 13.8°C to 24.9°C.

The average box/room temperature differential was 0.5°C for this period.

The average air temperature in the mimic box was 19.4°C with a range from 15.7°C to 23.3°C. Average temperature measured near the joints was found to be 18.1°C which is about 1.3°C cooler than the average air temperature in the box.

Average exterior air temperature for the monitoring period was 0.1°C with a range from -6.1°C to 6.8°C. Exterior air temperatures measured near the joints were about 0.5°C warmer than the temperatures measured near the logs. Both the interior and exterior joints of this house were sealed. Temperature profiles for the wall section of this house are shown in Figure 13.

The monitoring equipment used on Log House No. 3 was also used in this log house. As a result, hourly measurements of energy are unavailable for this house and hourly calculations of RSI are thus not possible. However, as in Log House No. 3, the final RSI result can still be calculated using the manual kilowatt-hour meter readings.

As with Log House No. 3 it is assumed that the duration of analysis for this house, 509 hours, is sufficiently long that any difference in stored energy is much smaller than the conductive heat loss through the wall section.

Thus, the effective RSI value for the test wall section of Log House No. 5, based on the monitored period 19:00 March 3, 1986 to 10:00 March 25, 1986, a duration of 509 hours, was found to be 2.52 $m^2 \cdot C/W$ (14.3 $hr.ft.^2 \cdot F/Btu$).

Figure 13

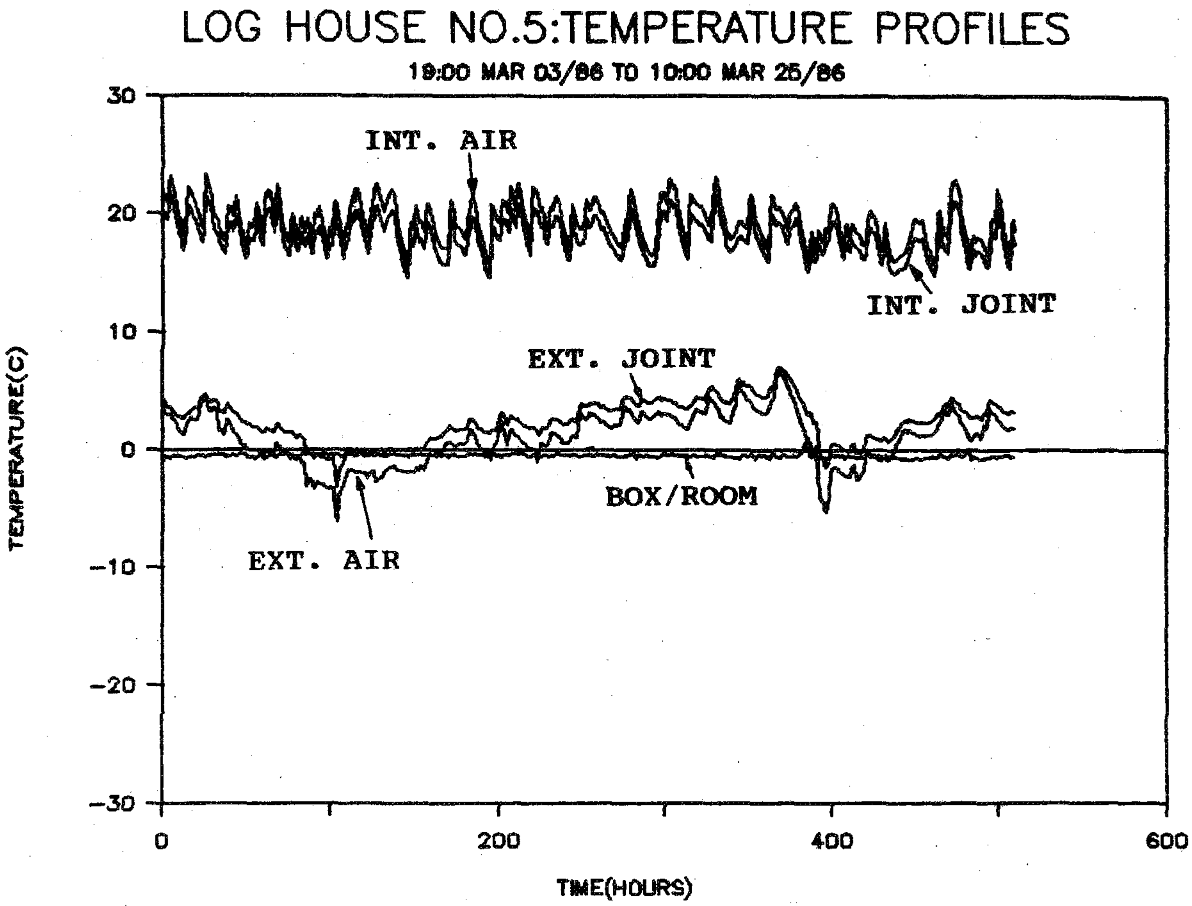
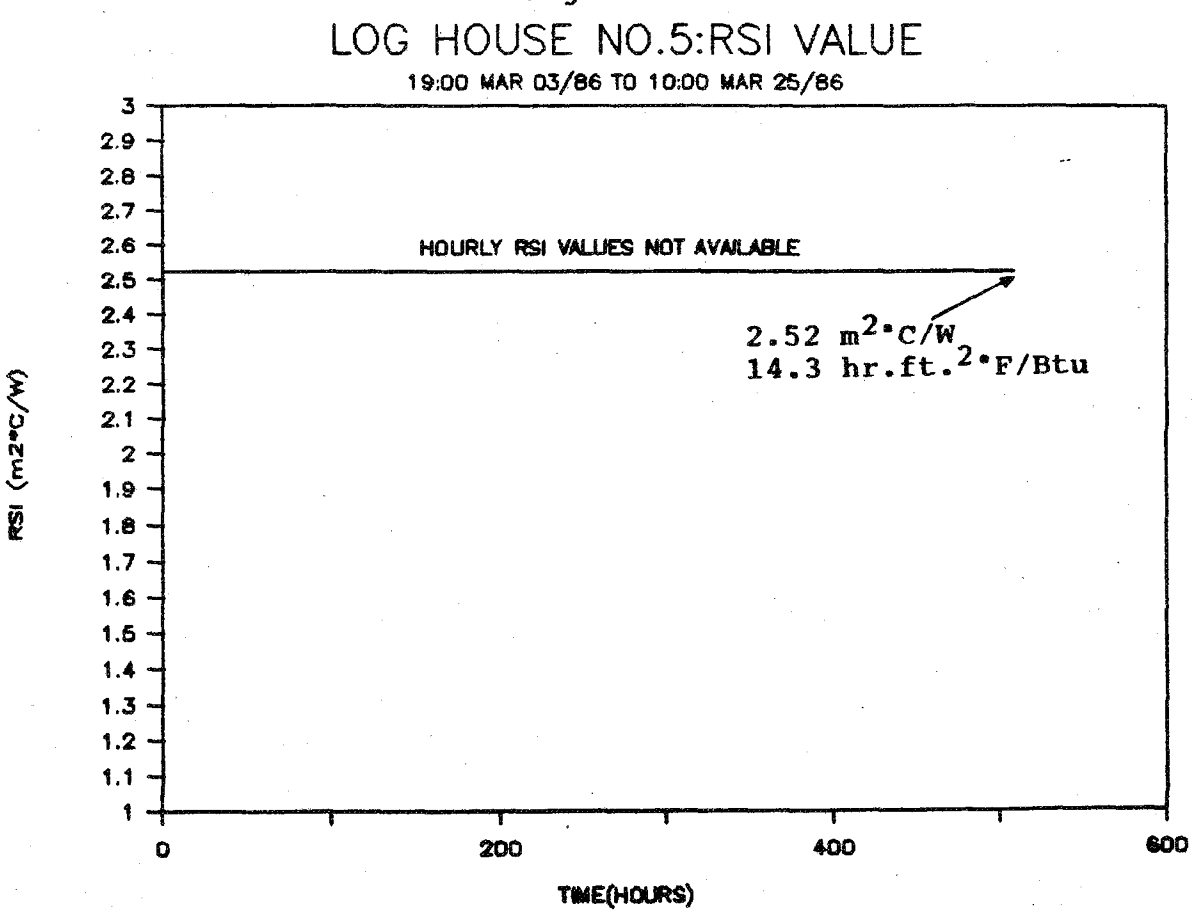


Figure 14



CONTROL HOUSE

Testing of the control house was conducted from 10:00 March 11, 1986 to 13:00 March 25, 1986, a duration of 321 hours.

Because of delays in the start of the monitoring project, the testing of the control house could not begin until March. Unfortunately, several periods of unseasonably mild weather occurred during this period resulting in extreme ranges between daytime and nighttime temperatures. In addition, the only wall with sufficient area on which to place the mimic box was oriented in a northwesterly direction. As a result, some degree of solar exposure resulted adding to the large temperature rises both inside and out.

Because of the large variation between day and night temperatures, it was decided to restrict the analysis periods to nighttime periods so as to net out any potential effects of stored energy. However, it should be noted at this point that since the temperature sensors were located close to the wall, their values are essentially what the wall "sees". As long as the criteria to minimize stored energy are adhered to, the effective RSI value will be essentially the same as that calculated for the night periods. The only limitation to this is if the exterior temperature exceeds the interior temperature. In this case the analytical basis for the mimic box is not applicable during these periods since the conductive heat loss becomes negative.

The net result is an analysis period limited from 22:00 to 08:00 hours over the period from March 11, 1986 to March 25, 1986, a duration of 136 hours.

The average outdoor temperature during these night periods was -2.1°C with a range of -17.3°C to 4.8°C. Indoor temperatures averaged 22.7°C with a range from 19.1°C to 23.7°C. Average temperature in the mimic box was 20.3°C with a range from 17.8°C to 23.5°C. Exterior air temperatures near the wall ranged from -16.5°C to 5.3°C with an average of -2.0°C

Average box/room temperature differential was 0.0°C.

Thus the effective RSI value for this control wall for the selected night periods from 22:00 March 11, 1986 to 00:00 March 25, 1986 was found to be 2.41 $m^2 \cdot C/W$ (13.7 $hr.ft.^2 \cdot F/Btu$).

The temperature profiles and RSI value for this wall section are shown in Figure 15 and 16 respectively.

Figure 15

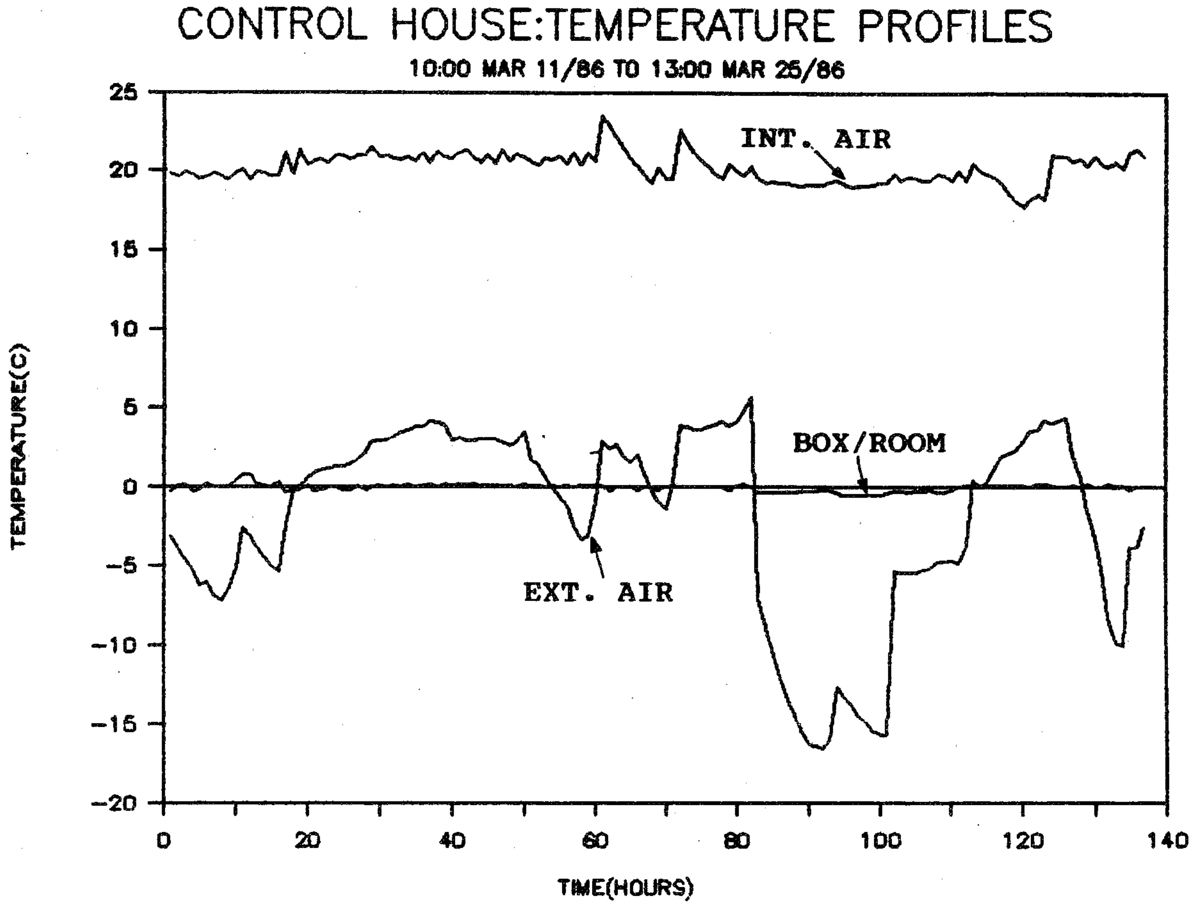


Figure 16

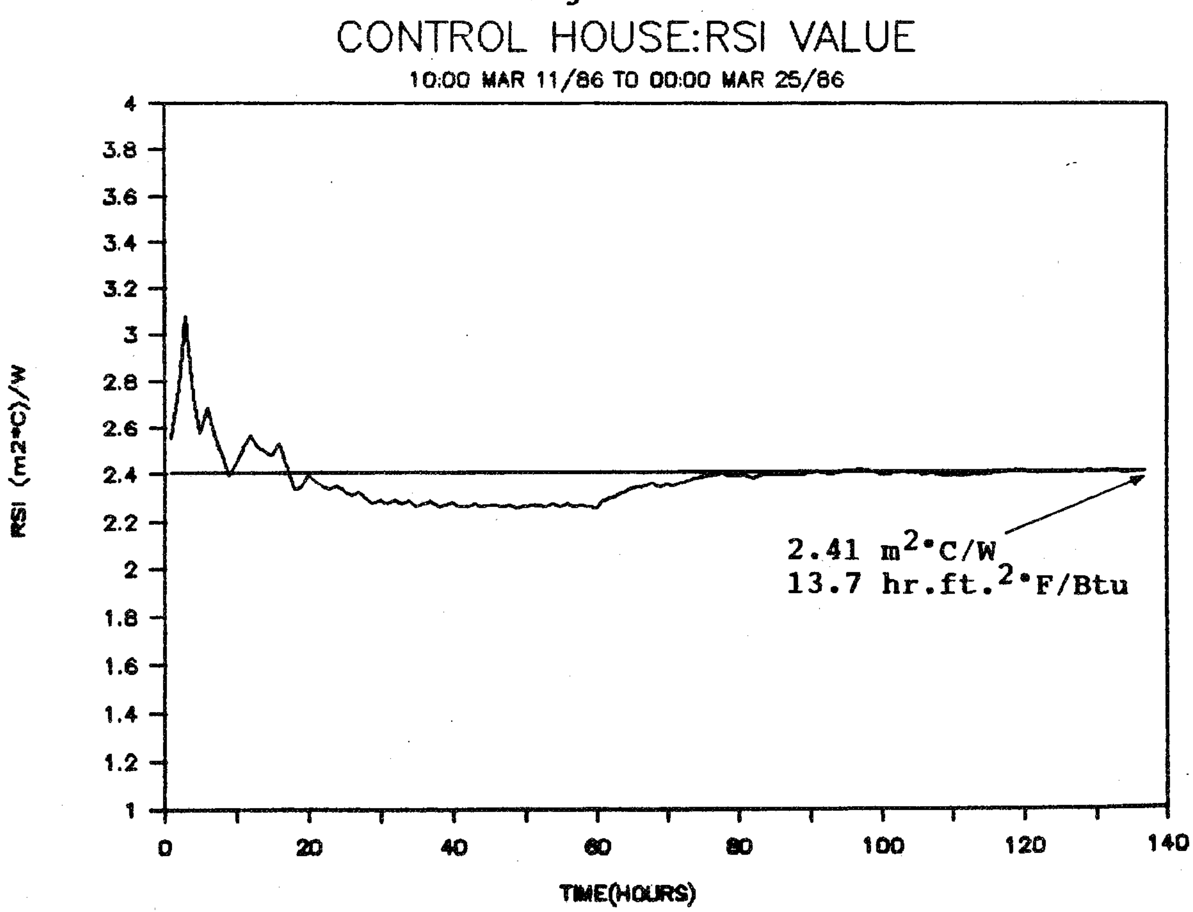


TABLE 3:SUMMARY OF RESULTS FOR THE ANALYSIS PERIODS SELECTED FOR EACH HOUSE.

TEMPERATURE AND ENERGY DATA FOR LOG HOUSE NO. 1-08:00 JANUARY 23/86 TO 07:00 FEBRUARY 15/86

	BOX AVERAGE DEGC	JOINT AVERAGE DEGC	BOX MIMICING DEGC	ROOM AVERAGE DEGC	EXTERIOR AVERAGE DEGC	EX. JOINT AVERAGE DEGC	OUTDOOR AVERAGE DEGC	TOTAL ENERGY CONSUMPTION WH
AVERAGE	19.94	18.95	-0.77	20.17	-12.56	-12.20	-13.65	
MAXIMUM	24.27	24.05	-0.10	25.90	1.33	1.50	0.30	22766.75
MINIMUM	14.12	13.25	-1.60	13.80	-25.65	-25.50	-27.20	

TEMPERATURE AND ENERGY DATA FOR LOG HOUSE NO. 2-03:00 JANUARY 30/86 TO 03:00 FEBRUARY 17/86

	BOX AVERAGE DEGC	JOINT AVERAGE DEGC	BOX MIMICING DEGC	ROOM AVERAGE DEGC	EXTERIOR AVERAGE DEGC	EX. JOINT AVERAGE DEGC	OUTDOOR AVERAGE DEGC	TOTAL ENERGY CONSUMPTION WH
AVERAGE	24.09	21.91	0.01	24.69	-9.53	-8.13	-10.96	
MAXIMUM	25.95	23.55	1.00	26.70	0.62	0.75	-1.30	15749.51
MINIMUM	22.42	20.00	-0.60	23.10	-22.83	-19.90	-24.70	

TEMPERATURE AND ENERGY DATA FOR LOG HOUSE NO. 2-00:00 FEBRUARY 20/86 TO 19:00 MARCH 03/86

	BOX AVERAGE DEGC	JOINT AVERAGE DEGC	BOX MIMICING DEGC	ROOM AVERAGE DEGC	EXTERIOR AVERAGE DEGC	EX. JOINT AVERAGE DEGC	OUTDOOR AVERAGE DEGC	TOTAL ENERGY CONSUMPTION WH
AVERAGE	24.33	22.56	0.59	24.88	-6.71	-5.52	-8.12	
MAXIMUM	21.73	19.75	0.20	22.40	-20.47	-19.00	-21.10	8605.10
MINIMUM	26.75	25.05	0.90	27.20	5.60	6.75	2.90	

TEMPERATURE AND ENERGY DATA FOR LOG HOUSE NO. 3-13:00 FEBRUARY 07/86 TO 24:00 FEBRUARY 23/86

	BOX AVERAGE DEGC	JOINT AVERAGE DEGC	BOX MIMICING DEGC	ROOM AVERAGE DEGC	EXTERIOR AVERAGE DEGC	EX. JOINT AVERAGE DEGC	OUTDOOR AVERAGE DEGC	TOTAL ENERGY CONSUMPTION WH
AVERAGE	16.31	14.33	0.09	17.31	-7.34	-5.67	-8.72	
MAXIMUM	17.85	15.80	0.40	19.10	2.12	2.15	-0.20	10170.00
MINIMUM	14.55	11.90	-0.80	15.10	-18.22	-14.95	-19.40	

TABLE 3(CONT):SUMMARY OF RESULTS FOR THE ANALYSIS PERIODS SELECTED FOR EACH HOUSE.

TEMPERATURE AND ENERGY DATA FOR LOG HOUSE NO. 4-16:00 FEBRUARY 19,1986 TO 10:00 MARCH 12,1986

	BOX AVERAGE DEGC	JOINT AVERAGE DEGC	BOX MIMICING DEGC	ROOM AVERAGE DEGC	EXTERIOR AVERAGE DEGC	EX. JOINT AVERAGE DEGC	OUTDOOR AVERAGE DEGC	TOTAL ENERGY CONSUMPTION WH
AVERAGE	15.29	14.82	-0.70	17.14	-4.34	-4.39	-6.37	
MAXIMUM	20.38	19.80	0.00	23.40	3.52	3.00	2.80	10440.00
MINIMUM	8.80	8.55	-1.60	9.40	-13.48	-13.35	-16.70	

TEMPERATURE AND ENERGY DATA FOR LOG HOUSE NO. 5-19:00 MARCH 03,1986 TO 10:00 MARCH 25,1986

	BOX AVERAGE DEGC	JOINT AVERAGE DEGC	BOX MIMICING DEGC	ROOM AVERAGE DEGC	EXTERIOR AVERAGE DEGC	EX. JOINT AVERAGE DEGC	OUTDOOR AVERAGE DEGC	TOTAL ENERGY CONSUMPTION WH
AVERAGE	19.42	18.07	-0.45	19.94	1.02	1.41	-0.35	
MAXIMUM	23.27	21.60	1.10	24.90	6.80	6.70	6.80	8800.00
MINIMUM	15.73	14.65	-0.90	13.80	-6.12	-6.10	-9.90	

TEMPERATURE AND ENERGY DATA FOR CONTROL HOUSE-11:00 MARCH 11,1986 TO 13:00 MARCH 25,1986

	BOX AVERAGE DEGC	BOX MIMICING DEGC	ROOM AVERAGE DEGC	EXTERIOR AVERAGE DEGC	OUTDOOR AVERAGE DEGC	TOTAL ENERGY CONSUMPTION WH
AVERAGE	20.31	0.00	22.74	-2.02	-2.12	
MAXIMUM	23.47	0.80	32.70	5.43	4.80	3017.30
MINIMUM	17.82	-0.50	19.10	-16.48	-17.30	

NOTE:BOX AVERAGE IS THE AVERAGE OF THE SIX SENSORS LOCATED IN THE MIMIC BOX OPPOSITE A LOG
NOTE:JOINT AVERAGE IS THE AVERAGE OF TWO SENSORS LOCATED OPPOSITE LOG JOINTS
NOTE:MIMICING REFERS TO THE BOX/ROOM TEMPERATURE DIFFERENTIAL
NOTE:ONLY PERIODS FROM 22:00 TO 08:00 WERE SELECTED FOR THE CONTROL HOUSE.

7.0 DISCUSSION

The RSI values determined in this monitoring project for each of the log wall sections tested are summarized in Table 4. The results show that the wall section tested in the modified round log house, Log House No. 5, has the highest effective RSI value (2.52 $m^2 \cdot C/W$ - 14.3 $hr.ft.^2 \cdot F/Btu$) while the wall section tested in the standard round log house, Log House No. 1, has the lowest effective RSI value (1.87 $m^2 \cdot C/W$ - 10.6 $hr.ft.^2 \cdot F/Btu$). The remainder of the log wall sections tested in the study all fit within this range. Note that the lower limit derived for the wall section tested in Log House No. 2 (i.e 2.19 $m^2 \cdot C/W$ - 12.43 $hr.ft.^2 \cdot F/Btu$) is almost identical to the result derived for the wall section of Log House No. 3 (i.e. 2.18 $m^2 \cdot C/W$ - 12.37 $hr.ft.^2 \cdot F/Btu$). This is interesting since both of these houses used the same construction technique, had similar size logs and similar degrees of heat loss as measured by temperatures near the joints. This provides further confidence that the lower limit of 2.19 $m^2 \cdot C/W$ (12.37 $hr.ft.^2 \cdot F/Btu$) that was derived for the wall section of Log House No. 2 is probably closer to the best result for this house. Consequently, this value will be used in the balance of the report.

The wall tested in the control house has an effective RSI value of 2.41 $m^2 \cdot C/W$ (13.7 $hr.ft.^2 \cdot F/Btu$). This result can be compared with the calculated value of 2.24 $m^2 \cdot C/W$ (12.7 $hr.ft.^2 \cdot F/Btu$) (calculation includes effect of thermal bridging through studs based on actual stud area within the test wall area) based on standard reference data, which yields a theoretical RSI value of 2.24 $m^2 \cdot C/W$ (12.7 $hr.ft.^2 \cdot F/Btu$). Thus the field result is within 7% of the theoretical value.

The effective RSI value for each of the log walls is plotted in Figure 17. To provide some perspective on these values the results determined from the monitoring project can be compared to the value prescribed by CMHC according to the 1978 Measures for Energy Conservation in New Buildings. This document defines the minimum effective RSI value for new housing for various degree day (DD) climates. These range from 2.5 $m^2 \cdot C/W$ (14.2 $hr.ft.^2 \cdot F/Btu$) for up to 3500 DD to 3.7 $m^2 \cdot C/W$ (21.0 $hr.ft.^2 \cdot F/Btu$) for 8000 DD and up. Interpolation is permitted. This standard however does not take into account the effects of thermal bridging between framing members. Thus, if these results are to be compared to the Measures, the RSI value recommended in the Measures should be corrected to take into account the reduction in RSI value due to thermal bridging in a normal frame wall. A typical 2 x 6, R-20-batt-insulated wood-frame wall that satisfies the Measures up to a climate of about 7000 DD would be reduced by a factor of about 11% due to the effects of thermal bridging at the framing members. Applying this factor to each of the minimum values in the Measures yields "adjusted minimum" values to which the results for each of the log walls can be compared. These adjusted minimum values are represented by the horizontal lines in Figure 17.

The results show that the measured RSI values of the walls of Log Houses Nos. 2, 3 and 4, (about 2.2 $m^2 \cdot C/W$ - 12.5 $hr.ft.^2 \cdot F/Btu$) satisfy the adjusted minimum value for a degree day climate up to about 3500 DD.

The measured RSI value of the wall of Log House No. 1 (1.87 $m^2 \cdot C/W$ - 10.6 $hr.ft.^2 \cdot F/Btu$), however, would only be recommended for a climate up to about 3000 DD. The value for the wall of Log House No. 5 and the control house, 2.52 $m^2 \cdot C/W$ (14.3 $hr.ft.^2 \cdot F/Btu$) and 2.41 $m^2 \cdot C/W$ (13.7 $hr.ft.^2 F/Btu$) respectively, satisfy the adjusted minimum value for up to about 4500 DD.

7.1 Comparison of Field Results to Calculated RSI

The measured RSI value determined in this project can also be compared to calculated RSI values for the log walls that were tested. The calculated values are based on the resistivity for softwood lumber.[2] The value recognized by CMHC for pine is 0.0087 $m^2 \cdot C/W$ per mm thickness (1.25 $hr.ft.^2 \cdot F/Btu$ per inch of thickness). For cedar logs this value is 0.0092 $m^2 \cdot C/W$ per mm thickness (1.33 $hr.ft.^2 \cdot F/Btu$ per inch of thickness). This resistivity is multiplied by an appropriate depth of wall, and values for indoor and outdoor air films are added. It should be noted here that the accuracy of this method is affected by the accuracy in the assumed R-value of the air films. For the purposes of this discussion, a value of 0.12 $m^2 \cdot C/W$ (0.68 $hr.ft.^2 \cdot F/Btu$) was used for the interior air film and a value of 0.03 $m^2 \cdot C/W$ (0.17 $hr.ft.^2 \cdot F/Btu$) was used for the exterior air film.

The depth of wall was calculated by first determining the volume of logs in the test section and converting this volume into an equivalent rectangular volume with the same height as the test area and with a depth 'd'. The steps to determine this depth are described below.

1) The face area of each log within the test section was calculated. The area was based on an on-site measurement of the diameter at the end of the logs. The distance of this measurement was generally less than two meters from the section that was tested so the diameter is probably representative of the area at the test section. All logs were assumed to be circular prior to

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2 Derived from several sources including ASHRAE Handbook of Fundamentals and Testing by National Research Council.

hewing, and the total volume of a 1m length of log was calculated.

2) The volumes of the hewn portions cut out of the logs were then calculated to find the net volume of each log.

3) A total volume of logs within the test height was then calculated. The equivalent depth of a rectangular cross section of width one mēter was then calculated by dividing this total volume by the height.

Once the equivalent depth was determined for each of the log walls, it was multiplied by the resistivity of wood used by CMHC for log walls and the appropriate air films added. The resultant RSI value was then compared to the measured results for each wall system. These results are also shown in Table 4 and Figure 17.

In all cases the measured RSI values are below the calculated RSI values. For the round pine logs, the measured RSI values were, on average, about 20% below the calculated RSI values. The cedar wall section was found to be only about 9% below the RSI value determined using the CMHC rating of 0.0092 $m^2 \cdot C/W$ per mm thickness (1.33 $hr.ft.^2 \cdot F/Btu$ per inch of thickness).

The equivalent depth calculated for each of the log wall systems can also be used to deduce the apparent resistivity of the wood in each wall system, to compare with the standard values used by CMHC. Again the accuracy of the measured (field-derived) resistivity is limited to the accuracy in the assumed interior and exterior air film RSI values, since these values must first be subtracted from the field results.

The results are also shown in Table 4. Figure 18 plots the apparent resistivity for each of the wall systems. These were calculated by dividing the measured RSI values (after subtracting the air films) by the equivalent depth of each of the wall systems.

From the results of this project it appears that the current CMHC rating for log walls is generous. Based on the results of this project, the RSI/mm value for the white pine round log systems ranged from 0.0063 $m^2 \cdot C/W$ per mm thichness (0.91 $hr.ft.^2 \cdot F/Btu$ per inch of thickness) to 0.0071 $m^2 \cdot C/W$ per mm thickness(1.02 $hr.ft.^2 \cdot F/Btu$ per inch of thickness) with an average for the round log systems of 0.0068 $m^2 \cdot C/W$ per mm thickness (0.98 $hr.ft.^2 \cdot F/Btu$ per inch of thickness). The results indicate that the squared cedar log system had an apparent resistivity of 0.0083 $m^2 \cdot C/W$ per mm thickness (1.2 $hr.ft.^2 \cdot F/Btu$ per inch of thickness). The reduction in the insulating value of the wood is apparently linked to increased heat loss at the joints. It is not clear how this should be taken into account when using the CMHC-recognized resistivity values.

There appears to be a correlation between the apparent resistivity of each of these log wall systems and the degree of heat loss observed near the joints. The walls of Log Houses Nos. 1, No. 4 and No. 5, all of which had their interior and exterior joints sealed, have the best apparent resistivity. The walls of Log House No. 2 (exterior joints caulked only) and Log House No. 3 (joints not caulked) had the highest degree of heat loss through the joints and had the lowest apparent resistivity. Caulking of the exterior joints may be the major reason why Log House No. 2 has an apparently higher resistivity compared to the wall of Log House No. 3 even though the overall RSI values for these two walls are almost identical.

The issue of air leakage may only be important in those wall sections where the joints were not caulked i.e. Log House No. 3 and to a lesser extent Log House No. 2. However, over time as the logs shrink and shift, the caulked joints may deteriorate making air leakage a much greater concern. This was already observed in Log House No. 1. It should be pointed out that the effects of through air leakage is virtually eliminated by the presence of the mimic box apparatus. Some air leakage may occur either through convective loops within the mimic box exacerbated by varying wind pressures or lateral air movement along the joints. The total heat loss, however, for those wall sections susceptible to air leakage, will thus be somewhat lower than without the mimic box, biasing the measured RSI values slightly high (but still lower than a perfectly sealed wall section).

(In addition to confirming the extra losses at log-to-log joints, the thermographic scans also pointed to some extra heat loss effects at wall corners. The extra losses there appear to be independent, or largely independent, of the degree of airtightness. The properties of the wood itself are apparently in full play: wood resistivity along the grain (i.e. along the log) is less than half the resistivity across the grain. Hence the losses at or near corners must be largely a matter of heat flow along the grain from indoors to outdoors. Perhaps the resulting reduction in indoor surface temperatures in the corners is significant in terms of dust marking or even condensation and mould potentials, especially since corners tend to have stagnation (poor heat distribution) in any case. More thermographic analysis might prove useful.)

Although the sample size was small and the number of types tested in the study was limited, it is believed that these systems are representative of good log wall construction practice since many of the houses were built by a reputable contractor.

As pointed out in the Introduction, log wall builders have argued that the actual net heat loss through log walls is less than would be calculated using simple heat conduction formulae mass in the logs' walls. This present project was designed to provide sound field data on the effective RSI values of typical log wall systems, exclusive of any mass effect. The results provide a foundation upon which the mass effect can now be evaluated.

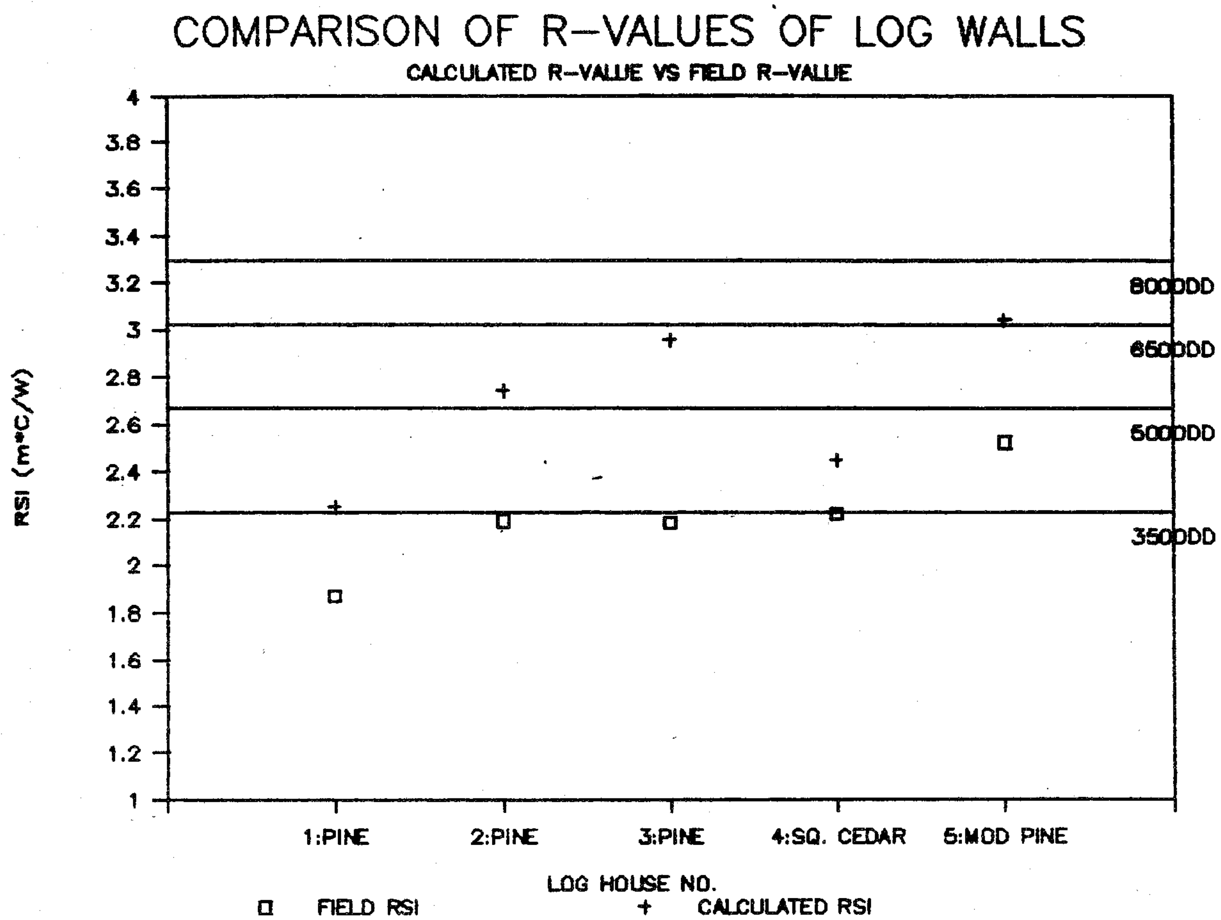
TABLE 4:SUMMARY OF RESULTS:FIELD VS. STANDARD VALUES

HOUSE NO -	DESCRIPTION - -	DIAMETER cm	EQUIVALENT DEPTH cm	FIELD RSI m2C/W	CALCULATED RSI m2C/W	DIFFERENCE %	THEORETICAL VALUE/mm m2C/Wmm	FIELD RSI PER mm m2C/Wmm
1	ROUND PINE	27	24.1	1.87	2.25	16.8%	0.0087	0.0071
2	ROUND PINE	32	29.8	2.19	2.74	20.1%	0.0087	0.0068
3	ROUND PINE	35	32.3	2.18	2.96	26.4%	0.0087	0.0063
4	SQUARE CEDAR	25	25	2.22	2.45	9.4%	0.0092	0.0083
5	MOD RND PINE	39	33.3	2.52	3.05	17.3%	0.0087	0.0071
6	CONTROL	12	12	2.41	2.24	-7.6%	-	-

NOTES:
CALCULATED VALUE IS BASED ON THEORETICAL RSI/mm MULTIPLIED BY EQUIVALENT DEPTH.
THE RSI VALUE OF AIR FILMS ARE THEN ADDED TO THIS VALUE TO GIVE THE CALCULATED VALUE

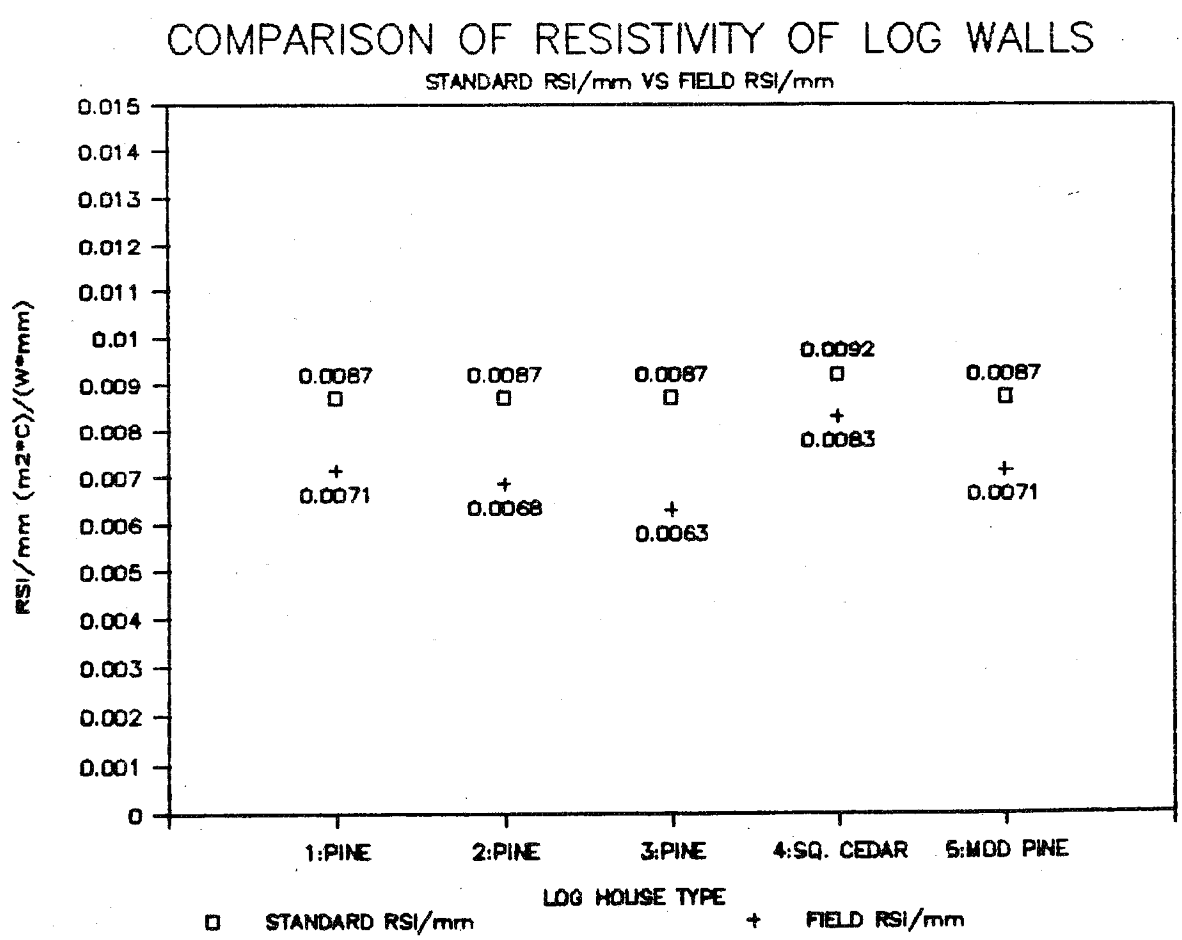
FIELD RSI/mm IS THE RSI VALUE DETERMINED IN THE FIELD MINUS RSI FOR AIR FILMS
AND DIVIDED BY EQUIVALENT DEPTH

Figure 17



*DD=Degree Days

Figure 18



8.0 CONCLUSION

The heat loss through selected north wall sections of five log houses and one conventional wood frame house was monitored using a guarded calorimeter (mimic box) interfaced to a data acquisition system.

The results indicate a range of effective RSI values of the log walls from a minimum of 1.87 $m^2 \cdot C/W$ (10.6 $hr.ft.^2 \cdot F/Btu$) to a maximum of 2.52 $m^2 \cdot C/W$ (14.3 $hr.ft.^2 \cdot F/Btu$). The conventional wood frame house was found to have an effective RSI value of 2.41 $m^2 \cdot C/W$ (13.7 $hr.ft.^2 \cdot F/Btu$).

The highest RSI value measured would satisfy CMHC requirements for walls located in areas with up to 4500 DD. The lowest, RSI value measured would not satisfy the minimum CMHC requirement for areas with up to 3500 DD.

The results were also used to derive apparent resistivity values for the logs which were compared to the current resistivity value recognized by CMHC for logs, which is 0.0087 $m^2 \cdot C/W$ per mm thickness (1.25 $hr.ft.^2 \cdot F/Btu$ per inch of thickness) for pine logs and 0.0092 $m^2 \cdot C/W$ per mm thickness (1.33 $hr.ft.^2 \cdot F/Btu$ per inch of thickness) for cedar logs. All apparent resistivity values were found to be below the recognized values. The round pine logs were found to have an apparent resistivity in the range of 0.0063 $m^2 \cdot C/W$ per mm thickness (0.91 $hr.ft.^2 \cdot F/Btu$ per inch of thickness) to 0.0071 $m^2 \cdot C/W$ per mm thickness (1.02 $hr.ft.^2 \cdot F/Btu$ per inch of thickness) with an average of 0.0068 $m^2 \cdot C/W$ per mm thickness (0.98 $hr.ft.^2 \cdot F/Btu$ per inch of thickness). The square cedar logs were found to have an apparent resistivity of 0.0083 $m^2 \cdot C/W$ per mm thickness (1.2 $hr.ft.^2 \cdot F/Btu$ per inch of thickness).

Heat loss at the joints appears to be a major weak link in the log wall systems and efforts to seal these joints seemed to have a major influence on the insulating value of the wall system.

The effect of thermal mass was identified by all the occupants as a major contributor to the thermal comfort of these homes. However, this effect was not addressed in this project. Further study of this effect is recommended.

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vertically from each other creating a space about 50 mm high. This space is filled with mineral wool insulation. These insulated joints are then covered both inside and out with expanded metal lath and parged with concrete.

Modified Round Log Wall Construction

This house is about two years old and is referred to as Log House No. 5 in the balance of the report. The house was built using a construction technique similar to the squared log house discussed above but instead round logs were used. In this type of construction, the top and bottom of each log is flattened to create a flat face of about 250 mm. The logs are placed one on top of another separated by about 40 mm of semi-rigid fiberglass insulation. The logs are tied about every one meter by 30 mm round hardwood dowels. Corner detailing uses the "Butt and Pass" method. All joints are sealed on the interior and exterior surfaces with re-enforced plastic cement. The logs range in diameter from 350 mm to 450 mm with an average diameter of 390 mm.

Conventional Wood Frame Construction

A single wood frame house was also included in the study to produce a baseline for comparison to the log wall measurements. This house, referred to as the "Control" house in the balance of the report is a conventional wood framed house about eight years old. The interior is finished with 13 mm drywall covering an 89 mm wood stud/insulation cavity. The cavity is insulated with 2.1 RSI (R 12) batt insulation. The exterior finish is 16 mm plywood panelling over building paper.

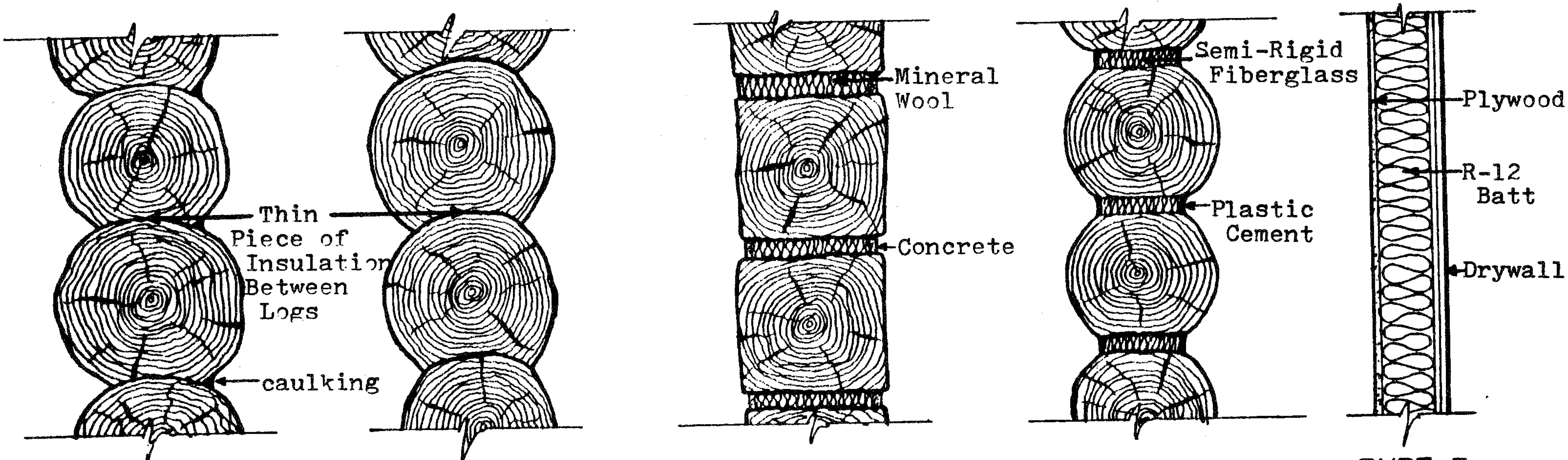
The wood studs are 400 mm o.c. Three wood studs were included in the test section.

Table 1 summarizes the dimensional features of each of the log wall sections tested in the study. Figure 1 shows cross-sections of each of the different types of log walls tested in the study.

Table 1: Summary of Dimensional Features of Log Houses Included in the Study

Log House No.	Age yrs	Log Size (mm) Max	Min	Avg	Joint Size (mm) Max	Min	Avg	Test Location	Test Period
1	3	350	230	270	180	100	145	Bathroom	22:00 Jan.21/86 - 10:00 Feb.15/86
2	3	400	250	310	220	180	180	Closet	21:00 Jan.27/86 - 19:00 Mar.03/86
3	2	440	280	350	260	180	210	Bedroom	13:00 Feb.07/86 - 24:00 Feb.23/86
4	8	250	250	250	250	250	250	Living Room	16:00 Feb.19/86 - 10:00 Mar.12/86
5	2	450	350	390	270	210	240	Living Room	19:00 Mar.03/86 - 10:00 Mar.25/86

Figure 1: Various Log Wall Construction Techniques Examined in the Study



TYPE 1 (LOG HOUSE NO.1)

TYPE 2 (LOG HOUSE NO. 2 and 3)

TYPE 3 (LOG HOUSE NO. 4)

TYPE 4 (LOG HOUSE NO. 5)

TYPE 5 (CONTROL HOUSE)