RESEARCH REPORT

Comparative Analysis of Residential Construction in Seattle, WA and Vancouver, B.C.

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January 27, 1999

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EXECUTIVE SUMMARY

The purpose of this study was to compare wood frame residential buildings located in Vancouver B.C. and Seattle, WA and identify potential causal factors of building envelope problems. The comparative analysis will highlight any differences in construction materials, methods or codes/regulations which dictate specific techniques or building characteristics. The basic objective was to pinpoint any obvious differences that can be concluded as avoiding the typical causal factors leading to building envelope failure.

Four buildings were studied and compared; two "problem" buildings (one in each of Vancouver and Seattle) which had experienced problems, and two "control" buildings which had not experienced problems. The building attributes used as selection criteria for the sampling were: three to four storey wood-frame, stucco clad, built in last ten year as market (Strata or Condominium title) residential buildings.

The results of the study found some legislative (insurance) and contracting (bonding) differences, has created a more heavily regulated building industry in Seattle. This allied with the slower economic activity in Seattle may be a factor in improving the quality of residential construction, but there are as yet no available statistics (a current survey anticipates results in April 1999), which can provide comparable data of envelope performance problems or percentage of incidence to number of residential units.

The comparison of construction materials and envelope assemblies found some differences in sheathing material (gypsum board) and variability in the application of a vapour retarder. However, these differences did not appear to be significant in creating different causal factors leading to moisture related building envelope failures. The problem buildings in fact exhibited the same problematic features with respect to water management principles and failed to effectively balance moisture ingress, drainage and drying mechanisms. The prime failure mechanism in both locales is water bypassing the weather barrier and lack of protection of the sheathing from wetting (from an exterior source not interior moisture source).

The conclusions from the study indicate that face sealed design strategies are very sensitive to climatic/exposure and construction variables and therefore the reliance on concealed barrier systems is unlikely to achieve acceptable performance. Rainscreen wall assemblies offer the best opportunity to achieve acceptable performance.

RÉSUMÉ

Cette étude avait pour but de comparer des immeubles résidentiels à ossature de bois situés à Vancouver, en Colombie-Britannique, et à Seattle, dans l'État de Washington, afin de déterminer quels facteurs pouvaient être à l'origine des problèmes d'enveloppe des bâtiments. Cette analyse comparative devait faire ressortir toute différence au chapitre des matériaux et des méthodes de construction ou des codes et des règlements qui exigent des techniques de construction ou des caractéristiques particulières pour les bâtiments. On cherchait plus précisément à trouver toute différence évidente susceptible d'éviter les facteurs causant habituellement la défaillance des enveloppes.

Les chercheurs ont étudié et comparé quatre immeubles, soit deux immeubles « à problèmes » (un à Vancouver et l'autre à Seattle), qui avaient effectivement présenté des vices, et deux immeubles « de référence » qui n'avaient jamais présenté de problèmes. Les caractéristiques des bâtiments utilisées comme critères de sélection pour l'échantillon étaient les suivants : immeubles résidentiels en copropriété de trois ou quatre étages à ossature de bois, revêtus de stucco, et construits au cours des 10 dernières années par le secteur privé.

L'étude a permis de constater que le secteur de la construction de Seattle était plus rigoureusement réglementé sur les plans législatif (assurances) et contractuel (cautionnement). Cette situation, doublée d'une activité économique plus lente à Seattle, pourrait avoir favorisé la réalisation de bâtiments résidentiels de meilleure qualité, mais on ne dispose encore d'aucune statistique (une enquête en cours devrait donner des résultats en avril 1999) susceptible de fournir des données comparables sur les problèmes de performance des enveloppes des bâtiments ou des pourcentages d'incidence pouvant permettre de connaître le nombre de logements touchés.

En comparant les matériaux de construction et les types d'assemblage des enveloppes, on a remarqué certaines différences pour ce qui est des matériaux utilisés comme revêtement intermédiaire (plaques de plâtre) et une variabilité dans l'application du pare-vapeur. Toutefois, ces différences n'ont pas semblé être suffisantes pour entraîner les défaillances reliées aux problèmes d'humidité. En fait, les immeubles à problèmes possédaient les mêmes caractéristiques problématiques en matière de gestion de l'eau et n'arrivaient pas à atteindre un équilibre entre les mécanismes d'infiltration d'humidité, d'évacuation de l'eau et de séchage. Le principal mécanisme à l'origine des défaillances, dans les deux villes, est l'infiltration d'eau à travers l'étanchéité aux intempéries et le peu de protection accordée au revêtement intermédiaire contre l'humidité provenant d'une source extérieure et non intérieure.

L'étude conclut que les complexes étanches externes sont très sensibles aux intempéries et aux variables de construction et que, par conséquent, il est peu probable que les complexe étanches internes puissent offrir une performance acceptable. Les murs à écran pare-pluie sont plus prometteurs pour atteindre une performance acceptable.

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TERMINOLOGY

This report compares construction differences and practice in the exterior walls of wood-frame multi-unit residential buildings located in Seattle, WA. and Vancouver, B.C. A number of terms are used in the report which have specific meanings in this context and may be unfamiliar to readers who are not experienced in this field. Some of these terms are defined below:

Balcony refers to a horizontal surface exposed to the outdoors, but projected from the building so that it is not located over a living space.

Building paper refers to a breather-type asphaltic sheathing paper which is rated in minutes (15, 30 and 60 minutes); based on preventing water flow through it for number of minutes in accordance with a standard test.

Capillary break refers to the gap between parallel layers of material sufficient to break the surface tension of water, which is typically a minimum of 3/8".

Cladding refers to a material or assembly which forms the exterior skin of the wall and is exposed to the full force of the environment. Cladding types included are stucco, wood siding, and vinyl siding.

Concealed barrier refers to a strategy for rain penetration control that relies on the elimination of holes through a combination of the cladding as well as a secondary plane further into the assembly.

Deck refers to a horizontal surface exposed to the outdoors, located over a living space, and intended for moderate use but not for access to other areas of the building.

Drained Cavity (also rain-screen) refers to a design strategy whereby a positive drainage plane is created immediately behind the exterior cladding material, sufficient in width to break the surface tension of water and allowing incidental water entering the wall system to drain by gravity with the aid of flashings and membranes.

In general, the difference between a "drain-screen" and "rain-screen" design strategy is that the former uses a sealed polyethylene (SPA) or air-tight drywall approach (ADA) in achieving an air barrier (with building paper as the weather barrier), as opposed to an exterior air barrier located on the outer face of the sheathing

Efflorescence refers to the dissolved salts in the material (such as concrete or brick) being transported by water, and redeposited after evaporation and drying.

EIFS refers to Exterior Insulated Finish System and generally consists of layers of rigid insulation adhered or fastened to the substrate, and finished with thin coats (lamina) of reinforced cementitious material and a finish coat of acrylic stucco.

Envelope refers to those parts of the building which separate inside conditioned space from unconditioned or outside space, and includes windows, doors, walls, roofs, and foundations.

Face-seal refers to a building envelope strategy where the performance of the wall is dependent on the ability of the exterior surface of the cladding / windows and associated sealant to shed water and prevent any water infiltration. This system can not easily accommodate water which penetrates past the exterior face since no positive drainage path or additional continuous barrier to water are provided.

Fishmouth refers to a deficiency in the installation of waterproofing membranes (roofing, self-adhering membranes etc.) which results in a fold in the edge of the membrane, through which water can penetrate.

Flashing refers to sheet metal or other material used in roof or wall construction and designed to shed water (typically sloped outwards and with a drip edge to shed water). Used in conjunction with:

- **Cap (or parapet) flashing:** top of wall (at roof), pier, column or chimney
- **Saddle flashing:** an upturn, transition piece between a horizontal and vertical plane, i.e. balcony cap and wall intersection.
- **Head/sill flashing:** at head or sill of window opening or other penetration
- **Base flashing:** at bottom edge of wall surface

- **Through-wall flashing:** a flashing which sheds water from the weather barrier plane to the exterior wall plane (at floor level)

Gum lip refers to a method of sealing a metal flashing to a wall surface whereby the top edge of the metal flashing is bent outwards to form a caulk-filled cavity (typically at the termination of a waterproofing membrane).

Housewrap refers to a sheet plastic material which is used as a sheathing paper, generally between the wall sheathing material and the exterior cladding. Although recognized as a proprietary term, in this report housewrap is used to represent a generic group of materials. One common type of housewrap consists of Spun-Bonded Polyolefin (SBPO), another is made of perforated polyethylene. Their resistance to liquid water is high, but resistance to water vapour is lower than many common "vapour barrier" materials.

Maintenance refers to a regular process of inspection of envelope elements and exterior systems such as roof, walls, windows, gutters, downspouts and drains, cleaning of those items as required on a regular basis (such as leaves from gutters and drains in the fall, and cleaning lint from dryer vents), and reinstating failed elements such as areas of cracked caulking or peeling paint.

Movement Joint refers to a joint in the building envelope which allows differential movement of portions of the building structure (expansion joint), or prevents or localizes cracking of brittle materials such as stucco, where movement needs to be controlled (control joint).

Operation of the building or envelope refers to normal occupancy of the building where the envelope is affected by interior space conditioning, changes to light fixtures, signs, vegetation and planters, and accidental damage or vandalism.

Penetration refers to a hole passing through the building envelope in which ducts, electrical wires, pipes, and fasteners are run between inside and outside.

Problems: Buildings and walls which have a "symptom report" are called "problem buildings" and "problem walls".

Punch window refers to the architectural style of the window being expressed as a single "punched" opening surrounded by the cladding material, as opposed to being arranged in vertical or horizontal strips of several window units.

Saddle refers to the transition of small horizontal surfaces, such as the top of a balcony guardrail or parapet wall, with a vertical surface, such as a wall.

Scupper refers to a metal pipe or trough section creating a drainage overflow from a roof or balcony to a downpipe or to a surface below.

Sheathing refers to a material (OSB [Oriented Strand Board] or plywood) used to provide structural stiffness to the wall framing and to provide structural backing for the cladding and sheathing paper.

Sheathing Paper refers to a material or combination of materials in an exterior wall whose purpose is to retard penetration of incidental water further into the wall structure once past the cladding. Commonly-used materials are building paper and housewrap.

Strapping refers to the use of wood or metal strapping material (typically ¾" nominal thickness) to form a drainage cavity and act as a capillary break behind the cladding material.

Symptoms refers to visual evidence such as staining and wetting of surfaces, loss of strength, delamination or cracking of materials, peeling paint and debonded coatings, etc.; which suggests a performance problem within the exterior envelope of a building.

UV refers to ultra violet radiation (from the sun), which has a degrading effect on membrane materials (asphaltic based) unless protected by an appropriate shielding layer.

Walkway: Refers to a corridor exposed to outdoors which provides access between suites and stairwells or elevators.

Weather Barrier: This refers to a material or combination of materials in an exterior wall whose purpose is to prevent further penetration of water into the structure. Commonly-used materials are building paper (also called sheathing paper) and housewrap.

1. INTRODUCTION

1.1. Background

This report and comparative analysis between construction practices in Seattle, WA and Vancouver, B.C. takes as a starting point the survey data collected for the previous report entitled "Survey of Building Envelope Failures in the Coastal Climate of British Columbia".

Over the past ten years there has been a residential building boom in the Lower Mainland of British Columbia. The construction types have included single family residential, high rise non-combustible construction, and low rise multi-unit wood frame construction. While some envelope performance problems have been experienced within all of these types of construction, these problems have been more prevalent, more severe, and have appeared earlier in low rise multi-unit wood frame construction. The problems have included water penetration, damage to cladding systems, and rotting and decay of wood components (siding, framing members and sheathing). The extent and severity of these performance problems has been well publicized through the media.

In buildings of four stories or less (i.e. predominantly of wood frame construction) the following CMHC housing data of Residential completions in BC between 1983 and 1997 can be summarized:

Apt. <5 Stories: 28,613 **Condo <5 Stories:** 69,372

Source: CMHC, Urban Centres. Appendix 3 of The Barrett Commission Report.

The Barrett Report further concludes that residential structures built between 1983-1987 have fewer structures at risk than during the last decade, because of different design features and slower economic activity. The wood frame structures built between 1988 and 1997 are therefore assumed to be at higher risk and have been estimated at 75% of the units built have leakage problems. Further analysis has estimated the per unit repair costs to be $15,000 per unit for wood frame structures. (Appendix 3 of The Barrett Commission Report.)

Comparable statistics were not available for Washington or for the Seattle area, although a survey is being currently conducted by the Seattle Design, Construction and Land Use Department on behalf of the Construction Codes Advisory Board to provide statistics on the prevalence of newer buildings with moisture damage problems (the survey results are expected in April 1999).

This current study is not intended to provide a statistical representation. Thus conclusions generated from the review of sample buildings should not be extended to apply to the entire population of low-rise multi-unit buildings in the Lower Mainland and Seattle area of Washington.

1.2 Objectives

The primary objective of the study is to identify any obvious differences between the respective residential building industries to draw any conclusions from the causal factors which have led to an envelope failure. The study will highlight any differences in construction materials, methods or codes/regulations which dictate specific techniques or building characteristics. This will identify the key aspects of the design, construction, operations and maintenance processes leading to the problems, which can then be presented as a comparative analysis. Specific questions addressed include:

- Do differences in codes/regulations impact the wall assembly construction?
- Are differences in Contract provisions, such as bonding, insurance and warranties causing differences in quality control issues?
- Do the mechanisms by which water gets into exterior wall assemblies vary?
- Do stucco cladding systems reflect similar problems, or are different problems prevalent?
- Are similar weather barriers and vapour barriers being used and how effectively?
- Are different sheathing materials being used, and do they perform differently?
- Are other detail elements of the wall a factor - i.e. windows, doors, vents, etc.?

- Is the envelope water protection concept used for each wall system appropriate for the Lower Mainland and Seattle Washington climate zone ?
- What aspects of the building envelope failures in the Lower mainland of B.C. can be corrected by similar repair strategies in Seattle, WA.

1.3 Project Team

The project team was led by Morrison Hershfield Limited (MH). Other contributors included North-West Wall and Ceiling Bureau (NWBC); Olympia Associates and The Soltner Group Architects. The latter two firms are Seattle based Architectural / Engineering companies. All team members contributed background information to the study and participated in the review of the data and conclusions.

Review and input was also received from the City of Seattle, Department of Design, Construction and Land Use: Code Development Analysis Branch.

2. METHODOLOGY

2.1 Study Design

The purpose of the study and proposed methodology consists of the following steps:

- establish initially that a similar problem (building envelope failures) exists in Washington state
- determine if a poly vapour barrier is commonly used, or if other vapour retarders are prevalent
- compare a typical 3 to 4 storey, wood framed residential development in the respective cities of Vancouver and Seattle (problematic and successful building in each location)
- determine potential causal factors with the building envelope problems which the buildings may be experiencing
- highlight any differences in construction materials, methods or codes/regulations which dictate specific techniques or building characteristics
- Write a final report which presents the results of the study as a comparative analysis.

2.2 Criteria for Sample Buildings

Some of the specific attributes of the buildings included in the study are described as follows:

- Three and four-storey woodframe, residential buildings located in the Coastal area of B.C. and in the locale of Seattle, Washington. Only market (Strata or Condominium title) buildings have been included in the study.

- Age of no more than ten years. The purpose of this is to restrict the study to the perceived problem population of recent buildings which have experienced rapid deterioration.

- Cladding types were restricted to stucco (excluding EIFS systems). EIFS systems were excluded because they are the subject of a separate study, not because buildings with EIFS cladding are considered problem-free.

- Buildings which appear to be performing well and exhibit no outward signs of moisture problems within their walls; were selected as "control" buildings. The criteria for eligibility of these buildings in the study was defined to be as above, with a further requirement that they be completed no later than 1991; this provides a minimum five year time period during which no problems have become evident.

2.3 Building Sample Characteristics

The choice of buildings in Seattle, WA was limited by the confidentiality of several selected projects with envelope failures which were undergoing insurance claims. This has a major impact on the reliability of the conclusions drawn from analysis of the buildings and their problems. The primary criteria for selection of buildings was to ensure that the selected projects are representative of the population of buildings, i.e. wood-frame residential buildings located in the coastal climate region of B.C. and Seattle, Washington and built in the last 10 years.

One aspect of the major objective of this project is to provide an indication of whether there are specific differences in materials, design, construction, or maintenance between buildings which have problems and buildings which do not. The sample of buildings is divided into two major types, "problem" buildings and "control" buildings.

"Problem" buildings are defined as those in which a moisture problem within the walls, decks, or exterior framing has resulted in damage requiring $10,000 or more to repair (this may include expenses of repairs which did not solve the problem). "Control" buildings are those buildings which, over a period of at least five years, have not experienced such moisture problems.

2.4 Data Input Form and Guide

A copy of the final Data Input Form, and a Guide to the completion of the Data Input Form, are included in Appendix A. The Guide contains definitions of a number of the building details, materials, and condition assessments used in the form, and in this report

2.5 Data Collection

Existing data for the two Lower Mainland B.C. located projects was obtained from MH's files from the previous Study. The two Seattle, WA located properties were obtained from local consulting firm's files and site observations were carried out on a visit to each building site on July 21, 1998.

3.0 FIELD OBSERVATIONS

3.1 Legislative and Contracting Practices

A number of different construction practices are prevalent in Washington state which may be a factor in regulating the quality of construction especially in an economic climate unlike that which the lower mainland of B.C. experienced in the last decade.

A common practice of Washington-based Condominium Boards was to take out an insurance policy which provided protection against water damage, repairs and in some cases rehabilitation of the structure.. This protection loophole was available until recently when due to the number of claims, several insurance companies introduced different eligibility for collapse coverage.

In addition Seattle's heavily regulated building industry has reduced the proliferation of "fly-by-night" contractors by the instigation of bonding. All Washington contractors must register with the State and post a $6,000 bond for their work, and sub-contractor's must post a $4,000 bond. Contractor's in Washington are also required to carry $120,000 of liability insurance.

A combination of these building industry regulations and the reduced pace of economic expansion (compared to the lower mainland of B.C.), have been cited as reasons for a generally better quality of residential construction in Washington. Conversely, the sub-standard quality of residential construction particularly in the major urban centres of B.C. has been identified as one of the contributing factors to premature building envelope failures in the Barrett Report:

" The building process has been undertaken in a largely unregulated, residential construction industry, driven to the lowest common denominator by ruthless, unstructured competition."

The following findings are based on a comparative analysis of the one problem building and one control buildings from each area (Seattle and Lower Mainland). The ages of the problem and control buildings are similar both being approximately 8 years old. The buildings are three and four-storey; and all are wood frame over a single level concrete framed parking garage.

3.2 Wall Construction

The typical exterior wall assemblies differed between the Seattle and Lower Mainland locations as follows (as described on the architectural drawings):

Lower Mainland (problem & control bdlg)	**Seattle Washington (problem building)**
Wall assembly:	**Wall assembly:**
3 coat Stucco and lathe	3/4" Stucco and lathe
Building paper	1 layer15# Building paper
1/2" exterior OSB sheathing	1/2" gypsum sheathing
2x6 wood studs @ max. 16" o.c.	2x6 wood studs @ max. 16" o.c.
Batt insulation	R19 Batt insulation
polyethylene vapour barrier	
5/8" gypsum board	5/8" type 'X' gypsum board

The primary differences between the wall assemblies is the use of gypsum board sheathing instead of wood (OSB) sheathing; and the omission of the "poly" vapour barrier at the Seattle, WA building location. One of the factors responsible for the sheathing difference is that the Uniform Building Code (UBC) in the U.S. requires exterior walls to be rated for one hour fire resistance. However, it is more common for the wall assembly to achieve the one hour fire resistance through application of the gypsum board over a wood sheathing layer.

The absence of a "poly" vapour barrier could not be confirmed as an "as-built" condition since the local consultant's report consisted of no test openings through the wall assembly. There were no drawings available for the "control" building in Seattle, so comparison with the wall assembly components could not be ascertained. However, the industry practice of incorporating a vapour barrier has varied in the U.S. as a result of changes in the Energy Code (see 3.6.5 Vapour barriers). In Seattle, vapour barriers have been required since the 1974 code (see Appendix B for History of Vapour Retarders in Seattle codes).

The buildings were typically equipped with windows having aluminum frames without thermal break and with nailing flanges for attachment. These windows do typically have a drained frame design; however, the frame joints are often reported to be unsealed, as are the joints between the frame and the cladding; and the placement is close to flush with the exterior face of the cladding. All of these factors tend to increase the volume of water passing over and around the window, and the potential for water to enter the window opening.

3.3 Features of Problem Buildings

The Seattle "problem" building exhibited the following contributors to water entry (as summarized from the consultant's report and visually confirmed on the site visit):

- Improper roof venting: vents located on fascia above gutters allowing moisture into enclosed soffit overhang (this was a deviation from the design drawings which showed standard soffit vent strips)
- No flashing over window heads; and improper flashing tie-in at top floor windows where soffit overhangs terminate directly above window head
- Window frame to stucco joint at window heads sealed with sealant
- Improper control joint locations in stucco cladding leading to movement cracks: panels exceed 150 square feet and control joints are not located at penetrating elements
- Improper horizontal to vertical control joint relationship: the horizontal joint abuts the vertical joint which dams the water flow
- Improper louvered bathroom and dryer vents: louvers no longer close or are missing
- Improper metal cap flashings at corner ledge projections: vertical dimension of metal flashing is inadequate to protect stucco below and counterflashing to stucco above caps
- Improper stucco to horizontal trim (shiplap wood boards) at 2nd floor: metal flashing lacks adequate vertical dimension to protect stucco below and drainage from stucco panels above is not provided.

The distinctive elements of wall construction are the cladding, the weather barrier, the sheathing, the framing thickness, and the presence of insulation. Walls that are completely exposed to exterior conditions (parapets, balcony dividers, and solid guardrails) are not insulated.

The specific construction studied consists of stucco cladding, building paper, OSB or gypsum sheathing, 89 mm. wood frame with glass fibre insulation, interior vapour barrier (if present) and drywall. However, the treatment of these details is highly variable in quality. All flat roof parapets and most window and door heads are flashed, and most of these flashings and details are rated acceptable. Note that window sills are considered to be an outward projection from the plane of the wall, not simply the bottom of a window.

3.4 Problem Elements

There are some specific details that are involved in a high proportion of problems. The first category of problems relate to windows. One major cause of window problems is poor sealing of mitre joints, a product assembly characteristic.

The next two categories relate to waterproof membranes on decks, balconies, and exterior walkways. It is rarely the application of the membrane on the substrate that causes problems; it is usually the lack of appropriate design or construction of its joints with penetrations and walls.

The largest category of problem occurs at the saddle joints of balcony/walkway guardrails with surrounding walls. These, combined with the defects on balcony rail cap flashings and the problems with waterproof membranes, make the balconies, decks, and walkways a key problem generator identified.

A key observation is that nearly all the problem categories relate to details such as windows, decks, and penetrations found on walls rather than to the basic construction of the wall assembly.

3.5 Features of "Control" Building

The primary elements that were observed in the "control" or successful residential buildings were as follows:

- Substantial overhangs at roof level providing wall protection from rain (the overhangs also had continuous well-dimensioned soffit vents)
- Good slopes to flat roof and well-detailed scuppers and collection hoppers to rain water leaders
- Vinyl extruded window frames with drainage weepers and well-detailed head and sill flashings
- Well placed vertical control joint locations at window openings to avoid stucco cracks
- Balcony waterproofing with durable wearing-surface and well detailed balustrade post attachments at balcony floor level
- Generally clean and simple architectural forms, and where decorative detailing occurs such as raised feature bands, detailed to provide water-shedding surfaces

3.6 Discussion of Differences in Wall Components

3.6.1 Sheathing

The use of gypsum sheathing instead of wood sheathing in the Seattle problem building (presumably to achieve a one hour fire resistance rating), is a significant factor influencing moisture deterioration. Both during construction and once moisture ingress has come into contact with the gypsum board, it will absorb moisture readily and a more rapid deterioration of the structural capabilities of the sheathing is likely to occur. Once saturated, the paper surface on the interior side provides a medium for mold and mildew growth. Exterior gypsum board has organic components in both the paper-facing and the gypsum core which supports organic organisms which once wetted cause loss of structural strength.

In addition, the attachment of the stucco wire lathing must be done only at stud locations since gypsum board strength will be greatly reduced at fasteners. Once the gypsum paper is deteriorated, the ability for the fasteners to hold the system together under wind loads will be seriously reduced and the original strength will not be restored even if the building is sealed and the walls dried out. In addition, with the saturation of gypsum board, strength of the material is reduced to the point where the ability of the fasteners to secure the sheathing to the studs is compromised.

3.6.2 Weather Barriers

The use of building paper as the weather barrier over the sheathing without the use of waterproof membranes at critical openings (windows), junctions and penetrations are a common failure factor between problem buildings in both locales studied. Once water has penetrated to the building paper, it meets a sheet material made of organic fibres saturated in an asphalt emulsion. Typical paper is rated to prevent water flow through it for 15, 30 or 60 minutes in accordance with a standard test. In reality, water exposure of the paper is usually in the order of days rather than minutes. In a face-sealed building once the water has found its way through the stucco to the building paper, it is severely limited in terms of drainage and drying, and therefore tends to stay there for long periods of time. Any holes, tears, poor laps, or other defects in the building paper such as might be caused by nailing wire lath fasteners through it or wind damage during construction may result in the water penetrating to the inside of the building paper in larger volumes, thus exposing the sheathing layer.

It was reported by the local consultants in Seattle that where a concealed barrier strategy is employed either in the original construction or in a rehabilitation project, a typical design consists of a double layer of 30 minute building paper (supplemented with membranes at critical locations). The stucco industry has generally advocated this to be an improvement since it is believed this provides added protection by creating a drainage plane between the layers of paper. However, it has not been demonstrated to be a successful improvement. The positive creation of a drainage cavity with furring strips was not a repair strategy yet adopted by the Seattle based retrofit consultants.

3.6.3 Orientation of Wall

It is a generally held opinion, backed by substantial data on storms and wind-driven rain frequency, that in the lower mainland of B.C. the east-facing walls are significantly more exposed to wetting and therefore deteriorate faster. Seattle, on the other hand, has a predominance of wind-driven rain coming from the south and south-west, which similarly has caused the most moisture-impacted walls to occur on those elevations. The Seattle consultant's report on the "problem" building was limited to the south wall of the building, presumably because this represented the worst deterioration of the building elevations. Problems related to decks, balconies, and walkways are also typically more problematic on these exposed elevations. This indicates that wind-driven rain is important in forcing water penetration through any flashing or waterproofing defects on horizontal surfaces.

3.6.4 Insulation

Some practitioners believe that the increase in insulation levels in wood frame walls in recent years has provided less heat to wet exterior materials to promote drying. All the walls in the Study that separate living space from the exterior are insulated with glass fibre batts; therefore there are no apparent differences that can be highlighted. The nature of glass fibre batts allows a good capacity for drying since they have an ability to wick water away.

3.6.5 Vapour Barrier

The purpose of a vapour barrier is to separate interior/exterior environments and avoid interior moisture laden air, particularly in winter months from reaching cold materials in the wall cavity and condensing. However, the amount of moisture migration through diffusion is typically measured in nanograms as opposed to litres (for moisture ingress from exterior sources), and the diffusion rate is a much slower process.

The changes in practice in the U.S. in the use of different types of vapour barrier, may be the result of Codes which are generally more prescriptive than the performance based Canadian codes dealing with moisture control. The 1986 Seattle Energy Code permitted the use of inset Kraft-backed insulation batts (provided gaps did not exceed 1/16 of an inch). However, the inset stapling of batts tended to compress the insulation, reducing insulation value and creating a space in the wall cavity where air leakage could occur. The 1991 Energy Code therefore revised the method of fastening to face stapled (Kraft-paper flaps stapled onto the stud face to maintain the continuity of the vapour barrier) to overcome this reduction in thermal performance. However, due to installation difficulties (staples sticking out from surface of stud caused difficulties in attaching gypsum board evenly) contractors are likely to have changed to using unfaced batts (such as continuous polyethylene or vapour retarder paints) to provide the vapour retarder. The more common practice in use over the last few years is to paint a 1 perm PVA primer to seal the surface layer of gypsum board. The 1 perm rating is typically verified by a UL test rating by the paint manufacturer. Polyethylene vapour retarders are reportedly less prevalent.

Some practitioners have suggested that drying to the interior benefits a wall assembly that has suffered water penetration from the exterior. However, this premise is flawed since it presupposes acceptance of the primary failure mechanism which is water by-passing the weatherbarrier through poor detailing. An incidental benefit of the polyethylene vapour barrier is protection of the interior face of the gypsum board from moisture build-up and mold growth.

3.6.6 Drying of Wall Assemblies

Moisture problems result from a sequence of events that occur when water is brought into contact with a wall. First, the water must penetrate the cladding and possibly the weather barrier. Secondly, the water must be absorbed into or remain in contact with the water-sensitive components of the wall (sheathing, framing, insulation, subfloor, interior finishes) long enough to weaken them, either by chemically dissolving materials or by initiating rot. Over time, and given conducive conditions, liquid water will evaporate and leave the wall cavity, or drain out at the bottom. The balance between the rate at which water enters the wall from the outside and leaves via drainage and evaporation determines whether the wall provides durable performance or not.

There are essentially four ways that water can leave wall cavities: drainage, capillary action, via movement of humid air, and via diffusion. Drainage occurs as bulk water runs down passages under the influence of gravity or air pressure. Water moves through small passages in porous materials via capillary action and evaporate at the surface. Bulk air movement can only occur if there are significant air passages through the wall, and some force moves air through those passages. Diffusion relies on movement of water vapour molecules through materials.

In terms of the volume of water that can be removed per unit time, gravity drainage through large passages is by far the highest-capacity. Next is capillarity, if water can evaporate at an exposed surface. Bulk air movement has about the same capacity if the air is not already close to saturated. Vapour diffusion is typically a much slower process through common building materials used in walls.

If we consider a typical Lower Mainland or Seattle locale wall clad in stucco without drainage provisions, it is evident that if water penetrates the cladding, its main way of drying out is via capillary action and evaporation at the outer surface of the stucco. The weather barrier, if it is intact and complete, should restrict movement of water inwards. There are generally no air passages within this part of the wall to allow for air movement. In the Lower Mainland and North Washington climate, the outer surface will be wet a substantial part of the time during the winter due to the quantity of rainfall, high air humidity and resulting poor air drying potential. The stucco remains wet, and is in contact with the weather barrier. If the weather barrier is building paper, it relies on impregnated chemicals for water repellence. These chemicals are slowly dissolved and expose the paper, an organic material susceptible to loss of structure and rot. Once the paper disintegrates, the outer surface of the sheathing is exposed. Now the stucco can dry fairly easily by transferring its moisture to the sheathing, but as the sheathing is exposed to constant high moisture levels it begins to swell and rot.

Current research by MH on behalf of NRC and CMHC, is being conducted on a number of stucco wall panels to examine the relative drying capabilities of these wall assemblies. Preliminary results in these experiments have demonstrated that:

- the drying rates of stucco clad walls via vapour diffusion is a slow process, regardless of the air space provisions behind the cladding
- drying of high moisture contents occurred over a period of several months; those with a MC over 30% did not dry to below 20% under a period of 2 months
- water accumulation causing staining on the sheathing is predominantly at the base of the panels, within 6" of the bottom plate

How might we expect choice of sheathing to affect drying performance of walls in the Lower Mainland and Seattle locale? There is little difference between plywood and OSB in terms of vapour transmission and water absorption. Structurally, they are both affected by long-term water exposure; both will swell and rot, although plywood will generally be less affected than OSB. The data on buildings using plywood sheathing does not show substantial performance differences from those using OSB. The durability of gypsum board as indicated previously is related to its initial absorption of moisture and its subsequent loss of structural strength.

In summary, the study information indicates that the defects that allow water to penetrate into walls are widespread and appear on many wall systems, both performing and non-performing. It is water bypassing the weatherbarrier which is the prime failure mechanism and protection of the sheathing from wetting will determine whether a wall can provide acceptable performance.

3.7 Differences between "Control" and "Problem" Buildings

Many of the obvious differences between the "control" building group and the "problem" building group have already been presented in the preceding discussion. The following summarizes those differences:

- The wind exposure of the "control" buildings is on average lower than that of the "problem" buildings. This indicates that the local environment around many new buildings has some correlation with the problems experienced.

- Roof overhangs are significantly larger on the control buildings than on the problem buildings. Also, the control buildings have fewer flat roofs with parapets over the exterior walls than the problem buildings.

- In general, there are fewer architectural features and details on the control building walls, and a greater percentage of the details are flashed on the control walls. Although the frequency of penetrations in the two groups are similar, they are flashed in a much higher percentage of the cases on the control walls.

- An evaluation of quality of design, construction, and materials indicates that there are certain details that are often poorly-designed on the control buildings as well as the problem buildings. For example, the majority of saddle details were rated poor design on both groups of buildings; the main reason is that no detail was provided for saddle joints in the plans, so that this troublesome detail was left up to the contractor and his tradesmen to figure out on-site. The same situation was found with penetrations through the walls; there are typically no details on the building plans showing how these are to be made, flashed, and terminated. The difference between a performing detail and one which causes problems is the contractor's knowledge and experience of what might work in each situation, and the sensitivity of the assembly performance to a particular detail.

4.0 DISCUSSION AND CONCLUSIONS

4.1 General

It should be emphasized that conclusions drawn from this study are not necessarily representative of the general population of buildings constructed in the Lower Mainland or in the locale of Seattle, Washington over the past ten years. The buildings chosen for the study represent a random sample of "problem" buildings which experienced envelope performance problems and which had been investigated previously by the study team.

However, due to the nature of the investigative process, very little information is available to the team to establish why the design evolved the way it did, why the as-constructed details are as they were found during our investigation or what the maintenance and operations history is. We are usually faced with the symptoms of a problem for which the technical cause can be determined along with the development of an appropriate remedial work strategy. Thus, it is beyond the scope of the current study to examine the question of why the design, construction, operations and maintenance activities were undertaken as they were.

4.2 Specific Conclusions

Several common issues have been established through comparison of the field observations at the Seattle locations with the data collection files of the Lower Mainland locations. These conclusions are necessarily interrelated, however, independently they represent opportunities for improvement in performance:

1. Exterior water is the moisture source for the majority of the performance problems. Neither construction moisture nor interior moisture sources were found to be significant.

2. The vast majority of the problems are related to interface details between wall components or at penetrations. Water enters the wall assembly where details bypass the weather barrier and is held against the sheathing/framing long enough to initiate rot of wood components.

3. Exterior moisture penetration through or around windows is a significant contributor to moisture problems. Water penetrates through the window frame joints and through the interface details between the windows and adjacent wall assemblies.

4. Exterior moisture penetration at perimeters of decks, balconies, stairways and walkways are significant contributors to moisture problems.

5. The presence or contribution of the vapour barrier is a benefit to the performance of the wall assembly and does not adversely affect the drying capability of the wall cavities.

6. Buildings with walls protected from rain by roof overhangs perform significantly better.

7. In general, buildings with simple details or those which contain fewer of the details which are associated with problems (exterior walkways, saddle connections) performed better.

4.3 Related Issues and Conclusions

While the study focused on moisture sources and paths, the performance of many of the components, details and assemblies is clearly also very sensitive to the drainage and to a lesser extent the drying potential of the wall assemblies. The ability of a wall to perform effectively is a balance of water management principles associated with the control of moisture ingress, drying potential, and drainage.

The impact of the Lower Mainland's similarity in climate to the Seattle area of Washington needs to be reviewed in the context of these three water management principles. There is a difference between the two locales with respect to primary wind-driven rain direction: easterly in Vancouver and south or south-westerly in Seattle. Exposure conditions on the corresponding elevation appears to correlate to areas of worst deterioration or moisture damage. It is clear that the ability of wall assemblies to perform must take into account these climatic conditions in establishing water management strategies.

The problem walls in this study failed to utilize face-sealed or concealed barrier strategies effectively. Our review of the design documentation and the as-constructed details indicates that there were inconsistencies in the application of the strategies. Regardless of whether a face seal or concealed barrier assembly was intended, the results of the study clearly indicate that sealing of the surface of the cladding could not be achieved effectively. In addition, the potential for excessive collection of moisture within the assemblies was emphasized by the unique climatic conditions in Lower Mainland and Seattle area environment which tend to encourage wetting and limit the drying potential of the assemblies.

In general therefore, it can be concluded that face seal and concealed barrier systems are very sensitive to design and construction variables which lead to ingress of water through the cladding, and that in the environment of the Lower Mainland and North Washington it may not be possible to achieve acceptable performance with such systems. The use of concealed barrier systems are also very sensitive to water ingress both through the face seal and secondary weather barrier. In order for these systems to perform adequately significant improvement is required in the design and construction of interface details.

Rainscreen and/or drainscreen systems provide the best opportunity to achieve acceptable performance due the more forgiving nature of the assemblies in the application of basic water management principles.

For some of these claddings, changes of this nature must be accompanied by systematic confirmation of the performance of the new wall assemblies. In particular, the development of rainscreen stucco systems and details need to be supported through testing and monitoring programs as currently in progress.

APPENDIX A: DATA INPUT FORMS AND GUIDE

GENERAL BUILDING INFORMATION

General Information: This information apllies to the entire building and is not unique to one wall assembly or performance problem

Collecting Agency__________________________
Evaluating Individual________________________
Date of Survey______________________________
Source of Data: Specific Investigation for this study
Historical Info from files

Building Identification Number________________
Building Contact Person______________________ **Telephone No.** _______________________
Building Name______________________________
Building Address____
Postal Code_______________________
Municipality_______________________
Province__________________________

Type of Building: Condo Rental Co-op Social
Year Building Constructed_______________
Number of Storeys______________________

Shielding:

Elevation	N	E	S	W	Guideline:
Minimal					No obstructions or local shielding
Low					Few small or lower obstructions within 2 bldg. hts.
Moderate					Many large obstructions within 2 bldg. hts.
High					Large buildings immediately adjacent

Windows:

Frame Type: Wood
Vinyl
Thermally broken aluminum
Non thermally broken aluminum

Glazing Layers: 1
1 with Storm
2

Design: Face Sealed
Drained
Rainscreen

Sealant at Perimeter: (to adjacent cladding) Yes
No

Placement: Flush
Rebate

WALL ASSEMBLY DESCRIPTION

Wall Assemblies: List wall assembly components starting with 1 at exterior surface
Use one page for each wall type

Wall Type ______

Component	Layer	Thickness
Low permeance paint or stain		na
High permeance paint or stain		na
Horizontal wood siding		
Vertical wood siding		
Wood sheet		
Vinyl siding		na
Horizontal metal siding		na
Metal panel		na
Cement stucco and lath		
Acrylic stucco and lath		
Unit Masonry		
EIFS		
Air space		
Polyolefin housewrap		na
Asphalt impregnated paper		na
Self Adhesive Mod Bit Membrane		
Plywood (untreated)		
Plywood (treated)		
OSB		
Exterior grade gypsum board		
Dens - Glas generic?		
Semi rigid fibreglass sheathing		
Foam sheathing		
89 mm wood frame with fibreglass insul.		
89 mm frame without fibreglass insul.		
140 mm wood frame with fibreglass insul.		
140 mm frame without fibreglass insul.		
Polyethylene sheet		
Foil back interior gypsum		
Interior Gypsum		
Other (specify)______________________		

Percentage of total wall surface? ______________

Layer which is most air tight (air barrier)? ______ (choose number from list above)

Level of air tightness ? Loose
Normal
Tight

Roof overhang width?______________________

Layer farthest in to which water penetration should be acceptable by design? ________
(weather barrier, choose number from list above)

SYMPTOM DESCRIPTION

Performance Problem Information

Use one sheet for each significant perfomance problem

Performance Problem No.__________ (new number for each significant and unique problem)
Which wall type? ________ (choose from types defined)
% of wall type area this problem adversely affects? _______
Predominant orientation of problem area(s):
N E S W Random

Material Deterioration Found

Layer[1]										
Side of Layer Where Damage is Visible[2]										
Symptoms[3]										
Severity[4]										

1 Choose from layer previously defined for this wall type
2 A Inside
B Outside
C Both
4 A Minor
B Moderate
C Severe

3 Choose from:
A Stains, water marks
B Mould or mildew
C Dimensional change
D Decay or rot
E Water saturated (but no rot)
F Not inspected
G No problems found
H Other ________________

Anecdotal Description of Problem

Include general description of cause effect scenario and append photograph of problem if possible.

History of Problem

When did problem likely originate (years after completion of construction)?________
When was problem first noticed?________________
Remedial work undertaken? Currently under way
Completely repaired
Partially repaired
Unsucessfully repaired

FAILURE MECHANISMS

EXTERIOR

Source of Exterior Moisture	%Contrib	%Confid
Direct rain penetration		
Run-off		
Splash back		
Snow Melt		
Indirect (through window)		
Other_______________		

Path Through Cladding	%Contrib	%Confid
Failed material:		
Sealant		
Cladding		
Other_______________		
At penetration:		
Vent hood (Dryer, etc.)		
Railing attachment		
Electrical connection		
Scupper		
Other_______________		
Poor flashing details:		
Roof parapet		
Roof drain		
Perimeter gutter		
Saddle		
Roof / wall connection		
Window/Door sill		
Window/door head		
Window/door jamb		
Window vent		
Balcony/walkway ext. edge		
Base flashing		
Inherent pores or joints		
Other_______________		

Path Through Weather Barrier	%Contrib	%Confid
No weather barrier		
Discontinuities		
Material degradation		
At flashing		
At penetration		
Other_______________		

INTERIOR

Source of Interior Moisture	%Contrib	%Confid
None identified		
Wet Basement		
Open sump		
Interior clothes drying		
Abnormal occupancy uses		
Vents venting into wall		
Other_______________		

Wall Condensing Surface	Layer No.
Primary	
Secondary	

Window Condensation	Y or N
Glass	
Frames	
None	
Don't know	

CONSTRUCTION

Source of Construction Moisture	%Contrib	%Confid
Wet materials used		
Exposure to weather		
Installation uses water		
Other_______________		

Cause of Moisture Problem	%Contrib	%Confid
Design		
Construction		
Maintenance		
Operation		
Other_______________		

APPENDIX B: HISTORY OF VAPOUR RETARDER AND AIR LEAKAGE REQUIREMENTS IN SEATTLE CODES

HISTORY OF VAPOR RETARDER AND AIR LEAKAGE REQUIREMENTS IN SEATTLE CODES

(23 September 1998)

Overview

Seattle has had requirements for vapor retarders at least since 1974. Requirements for limiting air leakage have been in Seattle codes at least since 1977.

Detailed Summary

This section contains a summary of the effective dates for vapor retarder and air leakage requirements in versions of the Seattle Energy Code (SEC), the Washington State Energy Code (WSEC), and the Seattle Building Code (SBC).

1974 amendment to the SEATTLE BUILDING CODE
(Ordinance 103985 - effective 14 December 1974)
Summary: Applies to "hotels, motels, apartment houses, lodging houses, dwellings, and other residential buildings". First building envelope standards.

Section 1718, Table 17-B, footnote 3: "Ceiling and wall insulation shall include a vapor barrier."

1977 SEATTLE BUILDING CODE - amended 1973 Uniform Building Code (UBC)
(Ordinance 106350 - effective 7 May 1977)
Summary: Applies to "Group H and Group I Occupancies four stories or less". Revised building envelope standards.

Section 1718 (g) 1: "Vapor Barriers. A ground cover of 4 mil (0.004") polyethylene or equivalent, lapped one foot at each joint and extended up the foundation wall to at least the outside ground line, is required at crawl spaces. An approved vapor barrier shall be properly installed in roof decks, in enclosed rafter spaces formed where ceilings are applied directly to the underside of roof rafters, and at exterior walls."

Section 1718 (g) 3: "Air Leakage. All doors, windows, skylights, and openings exposed to the exterior or to unheated spaces shall be fully weatherstripped, caulked, gasketed, or otherwise treated to limit infiltration."

1979 SEATTLE BUILDING CODE Supplement - amended 1979 UBC
(Ordinance 108508 - effective 17 October 1979)
Summary: Applies to "Group R occupancy four stories or less". Building envelope standards similar to those in Washington State House Bill 98.

Section 1720 (g) 1: "A ground cover of 4 mil (0.004") polyethylene or equivalent, lapped one foot at each joint, is required in crawl spaces. A vapor barrier shall be properly installed at exterior frame walls and in ceilings formed when a finished surface is applied directly to the underside of the roof rafters."

Section 1720 (g) 3: "Air Leakage. All doors, windows, skylights, and openings enclosing a heated space and exposed to the exterior or to unheated spaces shall be fully weatherstripped, caulked, gasketed, or otherwise treated in accordance with sound building practices."

1980 SEATTLE ENERGY CODE
(Ordinance 108500 - effective 20 February 1980)<)R>
Summary: Applies to all occupancies. First comprehensive energy code for all occupancies.

<u>**Section 601 (f):**</u> "Vapor Barriers. A ground cover of 4 mil (0.004") polyethylene or equivalent, lapped one foot at each joint and extended up the foundation wall to at least the outside ground line, is required at crawl spaces. An approved vapor barrier shall be properly installed in enclosed rafter spaces formed where ceilings are applied directly to the underside of the roof rafters, in enclosed floor sections over unheated spaces, and at exterior walls."

<u>**Section 601 (e):**</u> "Air Leakage.

1. Windows and Doors. All windows and doors shall conform to the air infiltration requirements specified in Section 405. Site built windows shall be constructed to minimize air leakage.

EXCEPTION: Required fire doors with a fire resistance rating over one (1) hour and fire windows are exempt from this section.

2. Exterior joints around windows and door frames, openings between walls and foundations, between walls and roof and between wall panels; openings at penetrations of utility services through walls, floors, and roofs; and all other openings in the building envelope shall be sealed, caulked, gasketed, or weatherstripped to limit air leakage."

1986 SEATTLE ENERGY CODE
(Ordinance 113058 - effective 24 October 1986)
Summary: Applies to all occupancies. Minimum standards for all occupancies revised to comply with Washington State Building Code Council (WSBCC) September 1986 revisions to the April 1986 WSEC. Other minimum standards for other than Group R occupancies revised for consistency with April 1986 WSEC. (Overall code provides equivalent energy savings to the 1986 Model Conservation Standards of the Northwest Power Planning Council.)

<u>**Section 502.2.3:**</u> "Moisture Control.

502.2.3.1 Walls separating conditioned space from unconditioned space shall have a vapor retarder installed when thermal insulation is installed. The vapor retarder shall have a one perm dry cup rating or less. Inset stapled batts with a perm rating less than one may be installed if staples are placed not more than 8 inches on center and gaps between the facing and the framing do not exceed 1/16 of an inch.

502.2.3.2 Roof/ceiling assemblies where the ventilation space above the insulation is less than an average of twelve (12) inches shall be provided with a vapor retarder having a dry cup perm rating of 1.0 or less.

° Vapor retarders shall not be required in roof/ceiling assemblies where the ventilation space above the insulation averages twelve (12) inches or greater.

° Vapor retarders shall not be required where all of the insulation is installed between the roof membrane and the structural roof deck.

° Vapor retarders with a 1.0 or less dry cup perm rating polyethylene or approved equal shall be installed in roof/ceiling assemblies where the insulation is comprised of insulation between the roofing membrane and the structural roof deck and insulation below the structural roof decking.

502.2.3.3 A ground cover of 4 mil (0.004" thick) polyethylene or approved equal shall be laid over the ground within crawl spaces. The ground cover shall be overlapped twelve (12) inches minimum at joints and shall extend the foundation wall."

EXCEPTION: The ground cover may be omitted in unheated crawl spaces if the crawl space has a concrete slab floor with a minimum thickness of 3-1/2 inches."

<u>**Section 502.4:**</u> "Air Leakage for All Buildings.

502.4.1 The requirements of this section shall apply to all buildings and structures, or portions thereof, and apply to those locations separating outdoor ambient conditions from interior spaces that are heated or mechanically cooled and are not applicable to the separation of interior conditioned spaces from each other.

502.4.2 Exterior windows shall be designed to limit air leakage into or from the building envelope. Manufactured windows shall have air infiltration rates not exceeding those shown in Table No. 5-3.

EXCEPTION: Site built windows are exempt from testing but shall be made tight fitting. Fixed lights shall have glass retained by stops with sealant or caulking all around. Operating sash shall have weatherstripping working against overlapping trim, and a closer/latch which will hold the sash closed. The window frame to framing crack shall be made tight with caulking, overlapping membrane, or other approved technique.

502.4.3 Exterior joints around window and door frames; between wall cavities and openings between walls and foundations, between walls and roof/ceilings and between wall panels; openings at penetrations of utility services through walls, floors, and roofs; and all other such openings in the building envelope shall be caulked, gasketed, or weatherstripped to limit air leakage.

502.4.4 All exterior doors or doors serving as an access to an enclosed unheated area shall be weatherstripped to limit air leakage around their perimeter when in a closed position. Doors meeting the infiltration requirements of Table No. 5-3 shall be deemed to comply. Compliance with the criteria for air leakage for all types of doors shall be determined by Standard ASTM E 283-73, Standard Method of Test for Rate of Air Leakage through exterior windows, curtain walls and doors.

502.4.5 Openings required to be protected by fire resistive assemblies are exempt from this section.

502.4.6 Masonry and factory-built fireplaces shall have the following:

° Tightly fitting flue dampers, operated with a readily accessible manual or approved automatic control.

EXCEPTION: Fireplaces with gas logs installed in accordance with Seattle Mechanical Code Section 803 shall be equipped with tightly fitting glass or metal doors.

° An outside source for combustion air. The duct shall be at least six square inches in area, and shall be provided with a readily operable damper.

502.4.7 For all buildings more than three stories, all entrances which are the principal means of access for the public shall be protected with a revolving door or an enclosed vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to be open at the same time. Elevator lobbies do not qualify as vestibules.

EXCEPTION: Minor entrances and service entrances need not comply with this requirement."

1986 SEATTLE ENERGY CODE w/1989 WSEC amendments
(Ordinance 114549 - effective 1 July 1989)
Summary: Applies to all occupancies. Minor amendments. Requires outside combustion air to be ducted directly to woodstoves. Minor adjustments in insulation R-values.

Section 502.2.3: "Moisture Control." (no changes)

Section 502.4: "Air Leakage for All Buildings." (no changes except add a new subsection)

502.4.7 Solid fuel burning appliances shall be provided with combustion air ducted directly to the appliance. Combustion air shall be provided as per manufacturers specifications.

EXCEPTION: Combustion air may be supplied to the room in which the solid fuel burning appliance is located in lieu of direct ducting, in an existing building, provided that:

1. The solid fuel burning appliance is not designed for directly connected outside combustion air or;
2. The existing construction prohibits the introduction of outside combustion air directly to the solid fuel burning appliance.
3. The combustion air source shall be located as close to the solid fuel burning appliance as possible, shall be provided with a backdraft damper, and shall be no less than six inches in diameter.
4. The solid fuel burning appliance is part of a central heating system and is installed in the room designed to house it."

1991 SEATTLE ENERGY CODE
(Ordinance 115641 - effective 1 July 1991)
Summary: Applies to all occupancies. Group R occupancy revised to match 1991 Washington State Energy Code. Other than Group R occupancy similar to ASHRAE/IES Std. 90.1-1989.

Section 502.1.6: "Moisture Control.

502.1.6.1 Vapor retarders shall be installed on the warm side (in winter) of insulation as specified in the following cases.

EXCEPTION: Vapor retarder installed with not more than 1/3 of the nominal R-value between it and the conditioned space.

502.1.6.2 Floors: Floors separating conditioned space from unconditioned space shall have a vapor retarder installed. The vapor retarder shall have a one perm dry cup rating or less (i.e. 4 mil. polyethylene or kraft faced material).

502.1.6.3: Roof/ceiling assemblies where the ventilation space above the insulation is less than an average of twelve (12) inches shall be provided with a vapor retarder. Faced batt insulation where used as a vapor retarder shall be face stapled. Single rafter joist vaulted ceiling cavities shall be of sufficient depth to allow a minimum one inch vented air space above the insulation.

502.1.6.4: Vapor retarders shall not be required in roof/ceiling assemblies where the ventilation space above the insulation averages twelve (12) inches or greater.

502.1.6.5: Vapor retarders shall not be required where all of the insulation is installed between the roof membrane and the structural roof deck.

502.1.6.6 Wall insulation: Walls separating conditioned space from unconditioned space shall have a vapor retarder installed. Faced batt insulation shall be face stapled.

502.1.6.7 A ground cover of 4 mil (0.004" thick) black polyethylene or approved equal shall be laid over the ground within crawl spaces. The ground cover shall be overlapped twelve (12) inches minimum at the joints and shall extend the foundation wall."

EXCEPTION: The ground cover may be omitted in unheated crawl spaces if the crawl space has a concrete slab floor with a minimum thickness of 3-1/2 inches."

Section 502.4: "Air Leakage for All Buildings.

502.4.1 The requirements of this section shall apply to all buildings and structures, or portions thereof, and apply to those locations separating outdoor ambient conditions from interior spaces that are heated or mechanically cooled.

502.4.2 Exterior doors and windows shall be designed to limit air leakage into or from the building envelope. Site constructed doors and windows shall be sealed in accordance with 502.4.3. For Other than Group R Occupancy,

(a) Fenestration shall meet one of the following standards for air leakage:

1. ANSI/AAMA 101-1988 Aluminum Prime Windows.
2. ASTM D 4099-89, Poly (Vinyl Chloride) (PVC) Prime Windows.
3. ANSI/NWWDA I.S. 2-87 Wood Window Units (Improved Performance Rating Only).

(b) Sliding doors shall meet one of the following standards for air leakage:

1. ANSI/AAMA 101-1988 Aluminum Sliding Glass Doors.
2. ANSI/NWWDA I.S. 3-87 Wood Sliding Patio Doors.

(c) Commercial entrance swinging or revolving doors shall limit air leakage to a rate not to exceed 1.25 cfm/ft^2 of door area when tested at standard test conditions in accordance with ASTM E283-84.

502.4.3 Exterior joints around window and door frames; openings between walls and foundations, between walls and roof/ceilings and wall panels; openings at penetrations of utility services through walls, floors, and roofs; and all other openings in the building envelope for all occupancies and all other openings in between units in R-1 occupancy shall be sealed, caulked, gasketed, or weatherstripped to limit air leakage.

All exterior doors or doors serving as an access to an enclosed unheated area shall be weatherstripped to limit air leakage around their perimeter when in a closed position.

Site built windows are exempt from testing but shall be made tight fitting. Fixed lights shall have glass retained by stops with sealant or caulking all around. Operating sash shall have weatherstripping working against overlapping trim, and a closer/latch which will hold the sash closed. The window frame to framing crack shall be made tight with caulking, overlapping membrane, or other approved technique.

Openings required to be protected by fire resistive assemblies are exempt from this section.

502.4.4 Recessed lighting fixtures: When installed in the building envelope, recessed lighting fixtures shall meet one of the following requirements:

1. Type IC rated, manufactured with no penetrations between the inside of the recessed fixture and the ceiling cavity and sealed or gasketed to prevent air leakage into the unconditioned space.
2. Type IC or non-IC rated, installed inside a sealed box constructed from a minimum one-half inch thick gypsum wall board or constructed from a preformed polymeric vapor barrier, or other air tight assembly manufactured for this purpose, while maintaining clearances of not less than one-half inch from combustible material and not less than three inches from insulation material.
3. Type IC rated, certified under ASTM E283 to have no more than 2.0 cfm air movement from the conditioned space to the ceiling cavity. The lighting fixture shall be tested at 75 Pascals or 1.57 lbs/ft^2 pressure difference and have a label attached, showing compliance."

1991 SEATTLE ENERGY CODE w/1992 WSEC amendments
(Ordinance 116159 - effective 1 July 1992)
Summary: Applies to all occupancies. Minor amendments. Allows use of NFRC glazing rating procedure and prohibits non-IC rated lighting fixtures in shell of building.

Section 502.1.6: "Moisture Control." (no changes)

Section 502.4: "Air Leakage for All Buildings." (no changes, except revise 502.4.4 (2))

502.4.4 Recessed lighting fixtures: When installed in the building envelope, recessed lighting fixtures shall meet one of the following requirements:

1. Type IC rated, manufactured with no penetrations between the inside of the recessed fixture and the ceiling cavity and sealed or gasketed to prevent air leakage into the unconditioned space.
2. Type IC rated, installed inside a sealed box constructed from a minimum one-half inch thick gypsum wall board or constructed from a preformed polymeric vapor barrier, or other air tight assembly manufactured for this purpose.
3. Type IC rated, certified under ASTM E283 to have no more than 2.0 cfm air movement from the conditioned space to the ceiling cavity. The lighting fixture shall be tested at 75 Pascals or 1.57 lbs/ft^2 pressure difference and have a label attached, showing compliance."

1994 SEATTLE ENERGY CODE (1994 WSEC w/1994 Seattle amendments)
(Ordinance 117081 - effective 29 April 1994)
Summary: Applies to all occupancies. First Seattle Energy Code to consist of the Washington State Energy Code with Seattle amendments as insert pages. Significant change in format - WSEC subdivides code into Group R occupancy (residential, chapters 1-10) and other than Group R occupancy (nonresidential, chapters 11-20). For WSEC residential: minor changes, nonresidential requirements deleted from Chapters 1-10. For WSEC nonresidential: envelope and HVAC comparable to ASHRAE/IES Std. 90.1-1989, simple systems option for HVAC, lighting power allowances reduced. For SEC amendments: primarily carryover of 1991 SEC requirements.

Section 502.1.6: "Moisture Control." (no changes except 6 mil in 502.1.6.7)

502.1.6.7 Ground Cover: A ground cover of 6 mil (0.006" thick) black polyethylene or approved equal shall be laid over the ground within crawl spaces. The ground cover shall be overlapped twelve (12) inches minimum at the joints and shall extend the foundation wall."

EXCEPTION: The ground cover may be omitted in unheated crawl spaces if the crawl space has a concrete slab floor with a minimum thickness of 3-1/2 inches."

Section 502.4: "Air Leakage for All Buildings." (no changes except to 502.4.2)

502.4.2 Exterior doors and windows shall be designed to limit air leakage into or from the building envelope. Site constructed doors and windows shall be sealed in accordance with 502.4.3."

1997 SEATTLE ENERGY CODE (1997 WSEC w/1997 Seattle amendments)
(Ordinance 119081 - effective 15 August 1998)
Summary: Applies to all occupancies. Minor changes to air leakage.

Section 502.1.6: "Moisture Control." (no changes)

502.1.6.7 Ground Cover: A ground cover of 6 mil (0.006" thick) black polyethylene or approved equal shall be laid over the ground within crawl spaces. The ground cover shall be overlapped twelve (12) inches minimum at the joints and shall extend the foundation wall."
EXCEPTION: The ground cover may be omitted in unheated crawl spaces if the crawl space has a concrete slab floor with a minimum thickness of 3-1/2 inches."

Section 502.4: "Air Leakage for All Buildings." (no changes except to 502.4.3 for housewrap)

502.4.3 Exterior joints around window and door frames; openings between walls and foundations, between walls and roof/ceilings and wall panels; openings at penetrations of utility services through walls, floors, and roofs; and all other openings in the building envelope for all occupancies and all other openings in between units in R-1 occupancy shall be sealed, caulked, gasketed, or weatherstripped to limit air leakage. Other exterior joints and seams shall be similarly treated, or taped, or covered with moisture vapor permeable housewrap.

All exterior doors or doors serving as an access to an enclosed unheated area shall be weatherstripped to limit air leakage around their perimeter when in a closed position.

Site built windows are exempt from testing but shall be made tight fitting. Fixed lights shall have glass retained by stops with sealant or caulking all around. Operating sash shall have weatherstripping working against overlapping trim, and a closer/latch which will hold the sash closed. The window frame to framing crack shall be made tight with caulking, overlapping membrane, or other approved technique.

Openings required to be protected by fire resistive assemblies are exempt from this section."