RESEARCH REPORT

Monitoring the Performance of an EIFS Retrofit on a 15 Storey Apartment Building, Toronto, Ontario

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FINAL REPORT

Monitoring the Performance of an EIFS Retrofit on a 15 Storey Apartment Building

Toronto, Ontario

Presented to:

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ABSTRACT

This report documents the monitoring of the rehabilitation of a 15-storey, 112-unit apartment complex in Toronto. The rehabilitation involved over cladding the insulated masonry wall with rainscreen EIFS cladding. The EIFS cladding was adhered to the masonry using a trowel-on coating that was intended to function as the air barrier and the drainage plane. Vertical channels located on the interior face of the cladding formed the drainage cavity; these were flashed to the exterior every 5 stories.

The following conclusions were drawn from the project:

- The installation of the EIFS cladding proceeded essentially at normal speed once the gutter and drain block of the rainscreen EIFS were installed.
- The retrofitted wall meets the performance requirements of the National Building Code with respect to environmental separation.
- Monitoring protocols must be designed with a purpose and must include techniques, for example computer sieves, that will efficiently detect anomalous records as the data are collected.
- The potential is limited at present for developing a commercially viable building envelope monitoring protocol for buildings such as were monitored in this project.

DISCLAIMER

This study was conducted for Canada Mortgage and Housing Corporation under Part XI of the National Housing Act. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

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EXECUTIVE SUMMARY

Morrison Hershfield Limited was retained by Canada Mortgage and Housing Corporation to monitor the performance of the rehabilitation of a 15-storey, 112-unit apartment complex located in Toronto. A major phase of the rehabilitation involved installation of exterior insulation and finish system (EIFS) rainscreen cladding over the existing brick masonry walls. The monitoring program included analysis of temperature, moisture content and air pressure measured at five locations over a winter season.

The original wall construction was clay brick masonry with concrete block backup, expanded polystyrene insulation, and plaster interior finish. The EIFS cladding consisted of acrylic stucco lamina installed over expanded polystyrene insulation that was adhered to the brick masonry using a trowel-on, proprietary material. The trowel-on material was intended to function as the air barrier and drainage plane. Vertical channels, which were located on the interior face of the insulation, were intended to drain rainwater that penetrated to the coating through drain blocks located every 5 stories.

The project objectives were.

1. To document the development of a building envelope retrofit strategy for a residential high rise building.
2. To monitor, assess and document the performance of a residential high rise building envelope retrofit.
3. To assess the degree to which the monitoring protocol can be implemented as part of regular operation and maintenance activities for new and existing buildings.
4. To assess the potential for the development of a commercially viable, building envelope performance monitoring protocol.

The objective of the monitoring program was to establish the performance of the retrofit wall with respect to heat, air and moisture control. Instruments were installed at five locations (representing three different elevations and three different orientations) on the building to measure and record temperature, relative humidity, pressure difference and moisture content. Data were recorded from the fall of 1997, the time of the retrofit, to early 1999. Recorded data were evaluated for reliability by comparing measured values with expected norms on both an absolute and a relative basis.

The monitoring program provided the following answers to specific technical questions:

- Since the moisture content under the exterior finish was consistent with an assembly that experiences high local moisture levels, it is postulated that some exterior moisture penetrates the exterior finish and it is speculated that the penetrating moisture is vapour.
- Since the moisture content measured to the interior of the drainage plane was always less than 15%, it is concluded that external water is not penetrating past the drainage plane.
- Since the dew point temperature of the air inside the air barrier was considerably below the air barrier temperature, it is concluded that condensation does not occur on the inside of the air barrier.
- Since the dew point temperature of the air inside the air barrier was below the external temperature most of the time, it is concluded that interior moisture did not condense on the inside of the lamina.
- Since the ratio of the temperature difference across the insulation to the temperature difference across the wall were greater than that calculated from material properties, it is concluded that the full value of the insulation was obtained.
- While it was not possible to determine with certainty the tightest element, it is concluded that either the masonry (the old air barrier) or the trowel-on coating (the new air barrier) was performing the air barrier function.
- Since the masonry temperature remained relatively stable while the exterior temperature varied more than 20°C, it is concluded that the temperature of the masonry element was stabilized.
- No significant differences were evident between the temperature, air pressure and moisture content measured on three elevations and three orientations.

The rehabilitation provided access opportunities similar to those encountered on a new building, especially access to the outside of the building and to interstitial spaces. Details of the rehabilitation were known and a monitoring protocol was designed based on these details even though details of the existing building envelope were sketchy.

Designing a monitoring protocol to measure building envelope performance with respect to heat, air and moisture control requires a fundamental knowledge of building envelope performance, a working knowledge of building envelope construction, and an expert knowledge of sensors, instrumentation and data acquisition. Each sensor should have a purpose such that data from the complete set of sensors will provide an understanding of building envelope performance.

The following conclusions were derived from the project:

- While the rainscreen EIFS was a little slower to install than non-drainage EIFS due to the time spent installing the drain blocks, the installation proceeded essentially at normal speed once these were installed.

- It is concluded, based on the analysis of the monitored data, that the retrofitted walls meet the performance requirements of the National Building Code with respect to environmental separation.

- The building rehabilitation provided an opportunity to design a monitoring protocol to address the building science issues, and it also provided access to the exterior of the building so that the protocol could be implemented.

- Monitoring protocols must include techniques that will efficiently screen the data to detect anomalous records as they are collected. An example is computer sieves, which can include features such as magnitude, gradient, rate of change, and internal consistency to identify anomalous data and raise an alert when found.

- The potential for developing a commercially viable building envelope monitoring protocol is limited at present for buildings of the size and type that was monitored in this project. However, some components of the monitoring system could be adapted to maintenance and capitol repairs planning.

The monitoring program demonstrated that the EIFS retrofit is meeting its performance objectives. The new cladding system maintains the original masonry in a warm and stable environment, and provides effective control of heat transfer, air leakage, vapour diffusion, and rain penetration.

RÉSUMÉ

La Société canadienne d'hypothèques et de logement a confié au laboratoire Morrison Hershfield Limited le mandat de contrôler la performance de la réhabilitation d'un immeuble d'appartements de 15 étages regroupant 112 logements, situé à Toronto. Une étape importante de la réhabilitation comportait la mise en place d'un système d'isolation des façades avec enduit (SIFE) avec écran pare-pluie, par-dessus les murs existants de maçonnerie en brique. Le programme de contrôle comprenait l'analyse de la température, de la teneur en eau et de la pression d'air mesurées à cinq emplacements au cours d'une saison hivernale.

Le mur d'origine comportait un parement de maçonnerie en brique et un mur de fond en blocs de béton, de l'isolant thermique de polystyrène expansé et un revêtement intérieur de finition en plaques de plâtre. Le parement (SIFE) se composait d'un lamifié en stucco acrylique mis en oeuvre par-dessus l'isolant de polystyrène expansé collé à la maçonnerie de brique à l'aide d'un matériau exclusif appliqué à la truelle. Le matériau ainsi appliqué devait remplir la fonction de pare-air et de plan d'évacuation. Des cannelures verticales, pratiquées dans la face intérieure de l'isolant, avaient pour rôle d'évacuer l'eau de pluie qui parviendrait jusqu'au revêtement par les blocs de drainage situés à tous les 5 étages.

La recherche poursuivait les objectifs suivants :

1. Décrire l'élaboration de mesures de rattrapage de l'enveloppe d'une tour d'habitation.
2. Contrôler, évaluer et décrire la performance des mesures de rattrapage de l'enveloppe d'une tour d'habitation.
3. Évaluer dans quelle mesure le protocole de contrôle peut s'appliquer dans le cadre d'activités périodiques d'exploitation et d'entretien aux bâtiments tant neufs qu'existants.
4. Évaluer la possibilité d'élaborer un protocole commercialement viable de contrôle de la performance de l'enveloppe de bâtiments.

L'objectif du programme de contrôle consistait à établir, pour le mur ayant subi des mesures de rattrapage, sa performance en matière de contrôle de la chaleur, de l'air et de l'humidité. Des instruments ont été disposés à cinq endroits (représentant trois différentes élévations et trois différentes orientations) du bâtiment dans le but de mesurer et de consigner la température, l'humidité relative, la différence de pression et la teneur en eau. Les données ont été enregistrées à partir de l'automne de 1997, époque du rattrapage, jusqu'au début de 1999. La fiabilité des données enregistrées a été évaluée en comparant les valeurs mesurées avec les normes attendues tant en termes absolus que relatifs.

Le programme de contrôle a permis d'obtenir les réponses suivantes à des questions techniques précises :

- Étant donné que la teneur en eau derrière le revêtement extérieur de finition correspondait à celle qu'enregistre un ensemble de construction qui subit des niveaux locaux élevés

d'humidité, on présume qu'une certaine quantité d'humidité d'origine extérieure, sous forme de vapeur d'eau, pénètre le revêtement extérieur de finition.
- Vu que la teneur en eau mesurée jusqu'à l'intérieur du plan d'évacuation était toujours inférieure à 15 %, on conclut que l'eau d'origine extérieure ne se rend pas plus loin que le plan d'évacuation.
- Puisque la température du point de rosée de l'air du côté intérieur du pare-air était de beaucoup inférieure à la température du pare-air, on conclut qu'il ne se forme pas de condensation sur la face intérieure du pare-air.
- Étant donné que la température du point de rosée de l'air du côté intérieur du pare-air était, la plupart du temps, inférieure à la température extérieure, on conclut que l'humidité intérieure ne se condensait pas sur la face intérieure du lamifié.
- Vu que le ratio entre la différence de température agissant sur l'isolant thermique et la différence de température agissant sur le mur était supérieur à ce qui avait été calculé à partir des propriétés des matériaux, on conclut que la pleine valeur de résistance thermique de l'isolant a été atteinte.
- Comme il n'a pas été possible de déterminer avec certitude l'élément le plus étanche, on conclut que la maçonnerie (l'ancien pare-air) ou le revêtement appliqué à la truelle (le nouveau pare-air) remplissait la fonction de pare-air.
- Vu que la température de la maçonnerie est demeurée relativement stable alors que la température extérieure variait de plus de 20 °C, on conclut que la température de l'élément en maçonnerie s'était stabilisée.
- Aucune différence appréciable n'était manifeste entre la température, la pression d'air et la teneur en eau mesurées depuis les trois élévations et les trois orientations.

La réhabilitation a fourni un accès ressemblant à celui qu'offre un bâtiment neuf, surtout du côté extérieur du bâtiment et dans les interstices. Les détails de la réhabilitation ont été connus et un protocole de contrôle a été conçu en fonction de ces détails, même si les détails de l'enveloppe du bâtiment existant étaient plutôt sommaires ou incomplets.

Concevoir un protocole de contrôle en vue de mesurer la performance de l'enveloppe d'un bâtiment en ce qui concerne le contrôle de la chaleur, de l'air et de l'humidité requiert la connaissance fondamentale de la performance de l'enveloppe du bâtiment, une connaissance pratique de la construction de l'enveloppe du bâtiment, et une connaissance experte des capteurs, des instruments et de l'acquisition de données. Chaque capteur doit être tel que les données recueillies du jeu complet de capteurs permettent de comprendre la performance de l'enveloppe du bâtiment.

Voici les conclusions suivantes qui découlent de la recherche :

- Bien que le système SIFE avec écran pare-pluie ait pris plus de temps à mettre en oeuvre que le système SIFE sans évacuation en raison du délai occasionné par la pose des blocs d'évacuation, l'installation s'est après coup effectuée à un rythme normal.
- On conclut que, d'après l'analyse des données contrôlées, les murs ayant subi des mesures de rattrapage satisfont les exigences de performance du Code national du bâtiment quant à la séparation de milieux différents.

- La réhabilitation du bâtiment a fourni l'occasion de concevoir un protocole de contrôle pour donner suite à des enjeux de la science du bâtiment, tout en permettant d'accéder au côté extérieur du bâtiment de façon à mettre en application le protocole.
- Les protocoles de contrôle doivent comporter des techniques qui passent au crible les données de manière à déceler toute anomalie dès qu'elles sont recueillies. Prenons l'exemple du « crible » informatique, qui peut compter sur l'ampleur, le gradient, le taux de changement, et l'uniformité interne, pour cerner toute anomalie dans les données et sonner le signal d'alarme, le cas échéant.
- La possibilité d'élaborer un protocole de contrôle commercialement viable de l'enveloppe de bâtiments se limite à l'heure actuelle aux bâtiments de taille et de genre contrôlés dans la présente recherche. Par contre, certains éléments du système de contrôle pourraient être adaptés à la planification d'activités d'entretien et de réparations exigeant des immobilisations.

Le programme de contrôle a démontré que les mesures de rattrapage d'un système SIFE atteint ses objectifs de performance. Le nouveau système de parement conserve la maçonnerie d'origine dans un milieu chaud et stable, et assure un contrôle efficace du transfert de chaleur, des fuites d'air, de la diffusion de vapeur d'eau, et de la pénétration de la pluie.

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1. INTRODUCTION

1.1 Background

Morrison Hershfield Limited was retained by Canada Mortgage and Housing Corporation to monitor the performance of the rehabilitation of an apartment complex located in Toronto. A major phase of the rehabilitation involved installation of exterior insulation and finish system (EIFS) rainscreen cladding over the existing brick masonry walls. The monitoring program included analysis of temperature, moisture content and air pressure measured at five locations over a winter season.

The $6M rehabilitation was completed in 1997 on the 15-storey apartment complex located at 1050 Broadview Avenue in Toronto. The building has approximately 112 residential units and 2 levels of underground parking. The typical wall construction was clay brick masonry with raked face and filled 25 mm collar joint, concrete block backup, 25 mm expanded polystyrene insulation, and an adhered plaster finish (15-20 mm thick) on the interior. The rehabilitation included installation of exterior insulation and finish system (EIFS) rainscreen cladding over the brick masonry.

The EIFS cladding, "Infinity MD" system by Dryvit, consists of an acrylic stucco lamina (base coat, reinforcing mesh and finish coat) installed over 75 mm expanded polystyrene insulation. The insulation is adhered to the brick masonry (substrate) using a trowel-on, proprietary Dryvit material that is applied in two coats – the first to prepare the surface, and the second to adhere the insulation to the prepared surface. The coating is intended to function as the air barrier and drainage plane and may also be intended to function as the vapour barrier. Vertical channels located in the interior face of the insulation are intended to drain rainwater that penetrates to the coating. The channels are flashed to the exterior every 5 stories; they are flashed laterally within the cavity above window heads.

The system has a rainscreen approach to rainwater management. In rainscreen EIFS, the lamina and insulation act as the first line of defence to keep precipitation out of the wall. The second line of defence is the flashed drainage plane located at the substrate. The intent of this configuration is that any water which penetrates past the cladding is intercepted and directed back out by the drainage plane and flashing. The system installed at 1050 Broadview is a fully adhered system in which the substrate is the existing masonry. A section through the assembly is shown in Figure 1.1.

1.2 Objectives

Morrison Hershfield Limited was engaged by the Research Division of Canada Mortgage and Housing Corporation (CMHC) to carry out a research project on the retrofitted wall. The project had the following objectives.

1. To document the development of a building envelope retrofit strategy for a residential high rise building.
2. To monitor, assess and document the performance of a residential high rise building envelope retrofit.
3. To assess the degree to which the monitoring protocol can be implemented as part of regular building operation and maintenance activities for new and existing buildings.
4. To assess the potential for the development of a commercially viable, building envelope performance monitoring protocol.

Objective 1 was documented in an interim report that was presented to CMHC in 1997 and is included as Appendix A[1]. This report documents the remainder of the project.

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[1] Protocol for monitoring the performance of a high rise residential building envelope retrofit. Interim report by Morrison Hershfield Ltd. presented to Canada Mortgage and Housing Corporation, March 1997.

2. METHODOLOGY

2.1 Technical Issues

The objective of the monitoring program is to establish the performance of the retrofit wall with respect to heat, air and moisture control. Specifically, the program addressed the following technical questions, which were identified for investigation and monitoring in the interim report:

1. Does water frequently penetrate the exterior finish? If so, does it dry?
2. Do materials inside the drainage plane remain protected from external water entry?
3. Is there potential for condensation on the inside boundary of the air barrier or materials just inside of it?
4. Is there potential for condensation on the inside boundary of the exterior finish or insulation just inside of it?
5. Is the full value of the installed insulation being obtained? Does moisture collection and retention affect thermal performance?
6. Is the wall reasonably airtight? Is the designed air barrier carrying pressures due to wind and stack forces?
7. Is the temperature of the masonry element stabilized?

2.2 Instrumentation

Instrumentation was installed at various locations on the building to measure and record the data summarized below.

Exterior conditions were measured at the top of the building using a weather station. The exterior conditions recorded were:

- air temperature;
- relative humidity;
- wind speed and direction;
- rainfall on a horizontal surface;
- rain impacting on vertical surfaces.

Interior and interstitial conditions are measured by sensors installed adjacent to Suites 304 and 1204 on the east elevation, Suites 205 and 1205 on the west elevation, and Suite 1207 on the north elevation. Sensors were installed at each suite to measure the following variables (see Figures 2.1 to 2.5 for a typical set of sensors and locations).

- Temperature / relative humidity (ACR logger):
  - ⇒ at interior of suite
  - ⇒ at interface between masonry and air barrier
- Pressure difference (pressure transducers):
  - ⇒ across masonry and interior finish
  - ⇒ across air barrier and masonry/interior finish
  - ⇒ across lamina, air barrier and masonry/interior finish
- Moisture content (Duff gauge):
  - ⇒ on exterior face of masonry to the interior of the air barrier
  - ⇒ on exterior face of insulation to the interior of the lamina

A number of thermocouples were installed at each suite to measure temperature (see Table 2.2). The thermocouples at Suites 205 and 1205 were monitored continuously, while those at the other suites were monitored on a rotating basis.

Table 2.2. Thermocouples installed at each suite.

Location	**Suite**				
	205	304	1204	1205	1207
Air barrier	√	√	√	√	√
Lamina	√	√	√	√	√
Slab edge		√	√	√	
Slab edge below drain block		√			
Drain block	√	√	√	√	√
Above drain block	√	√	√	√	√
Shear wall		√	√		√
Window jamb			√		√

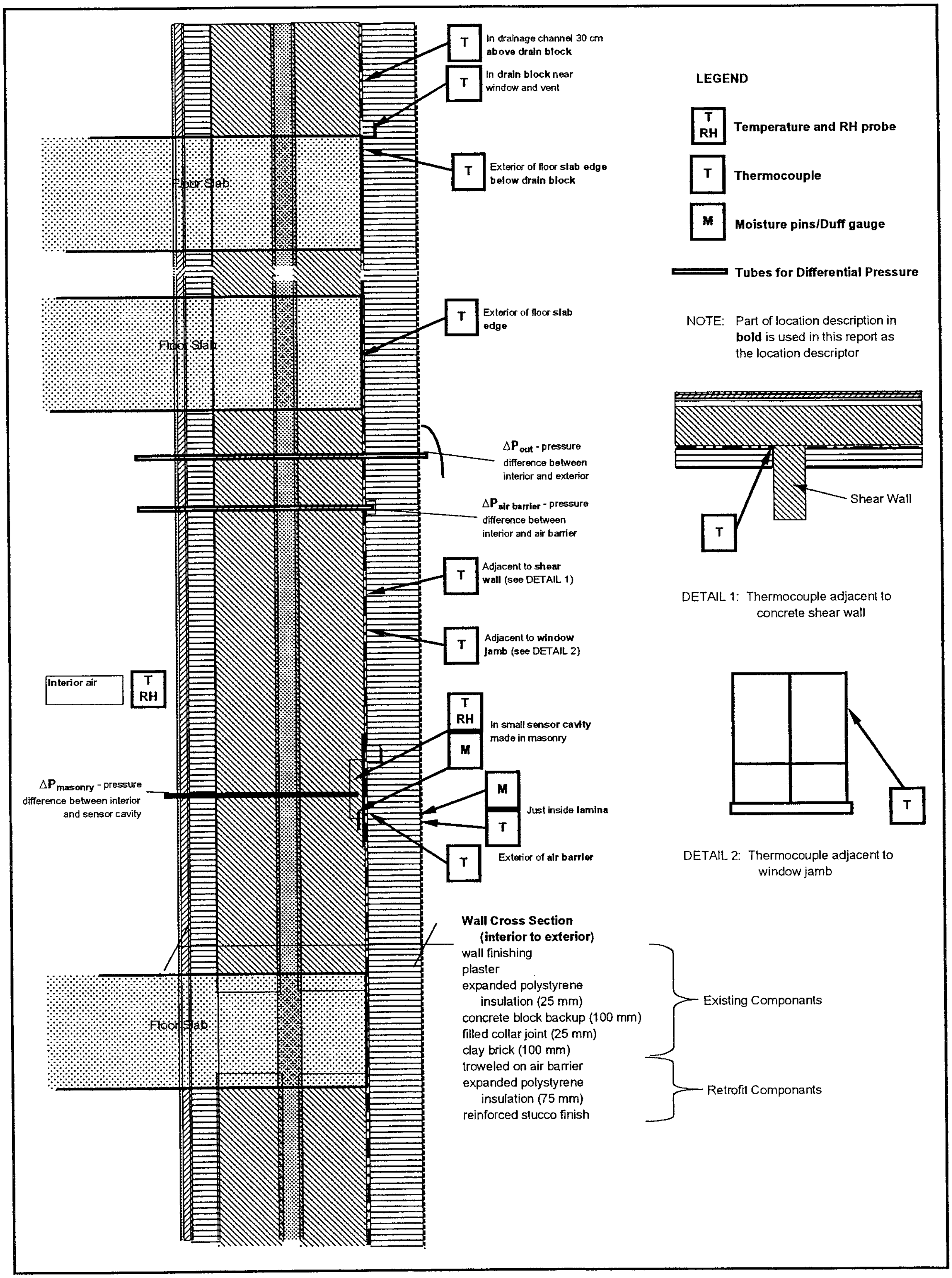


Figure 4.1: Sensor Location Plan

Figure 2.2: Drawing No. 1: Typical Floor Plan - Sensor Locations

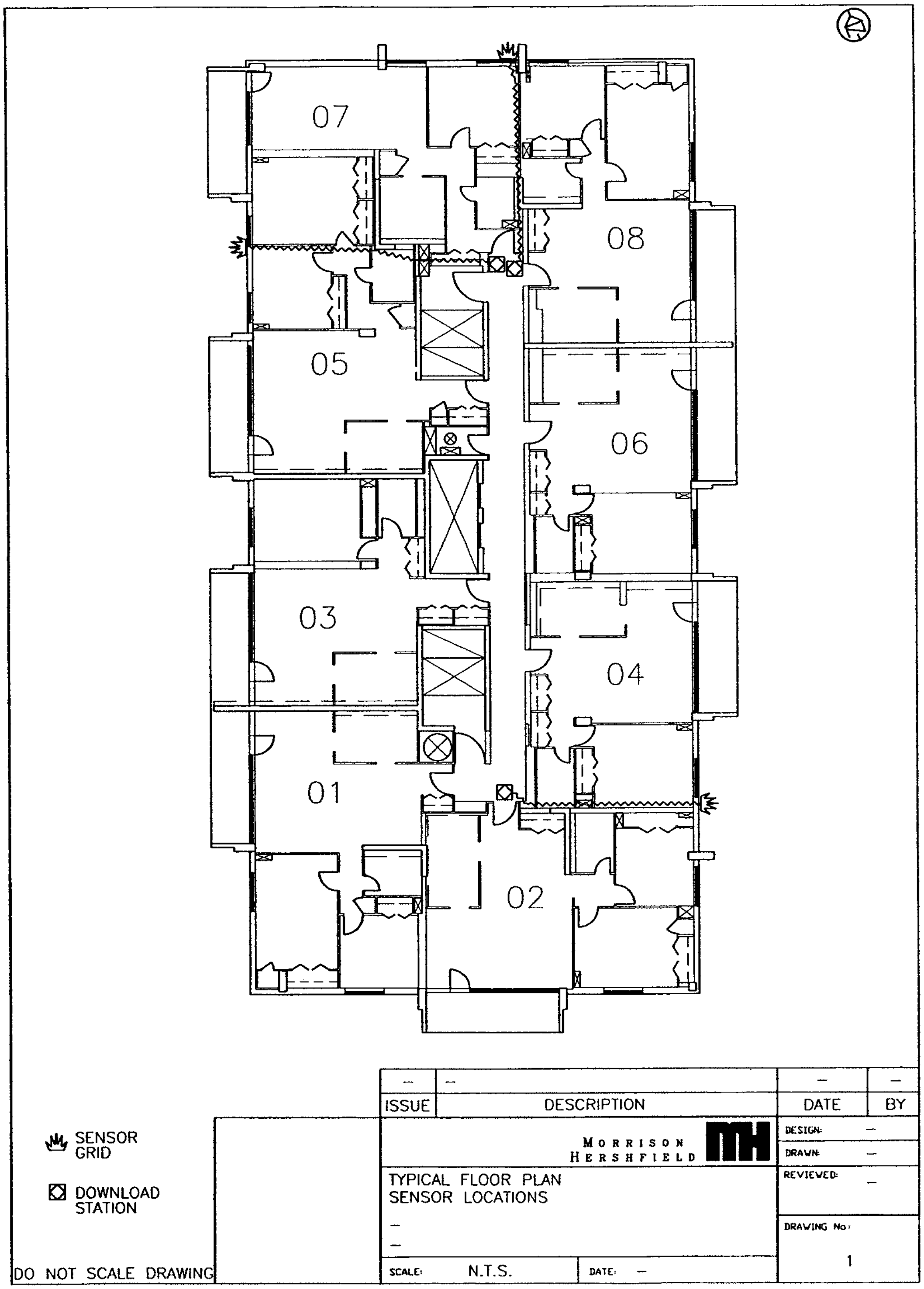


Figure 2.3: Drawing No. 2: Partial East Elevation – Suite 1204 Sensors

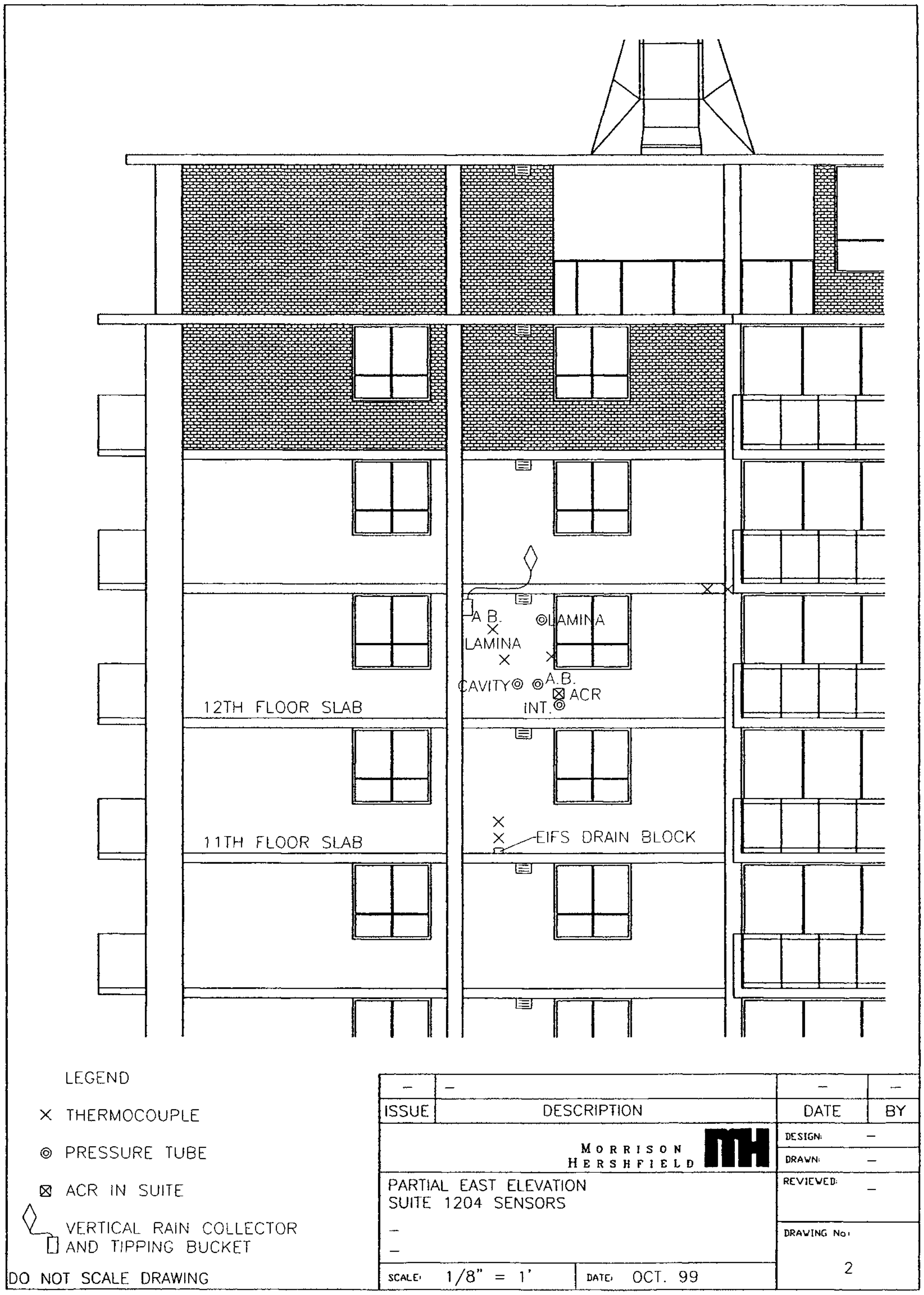
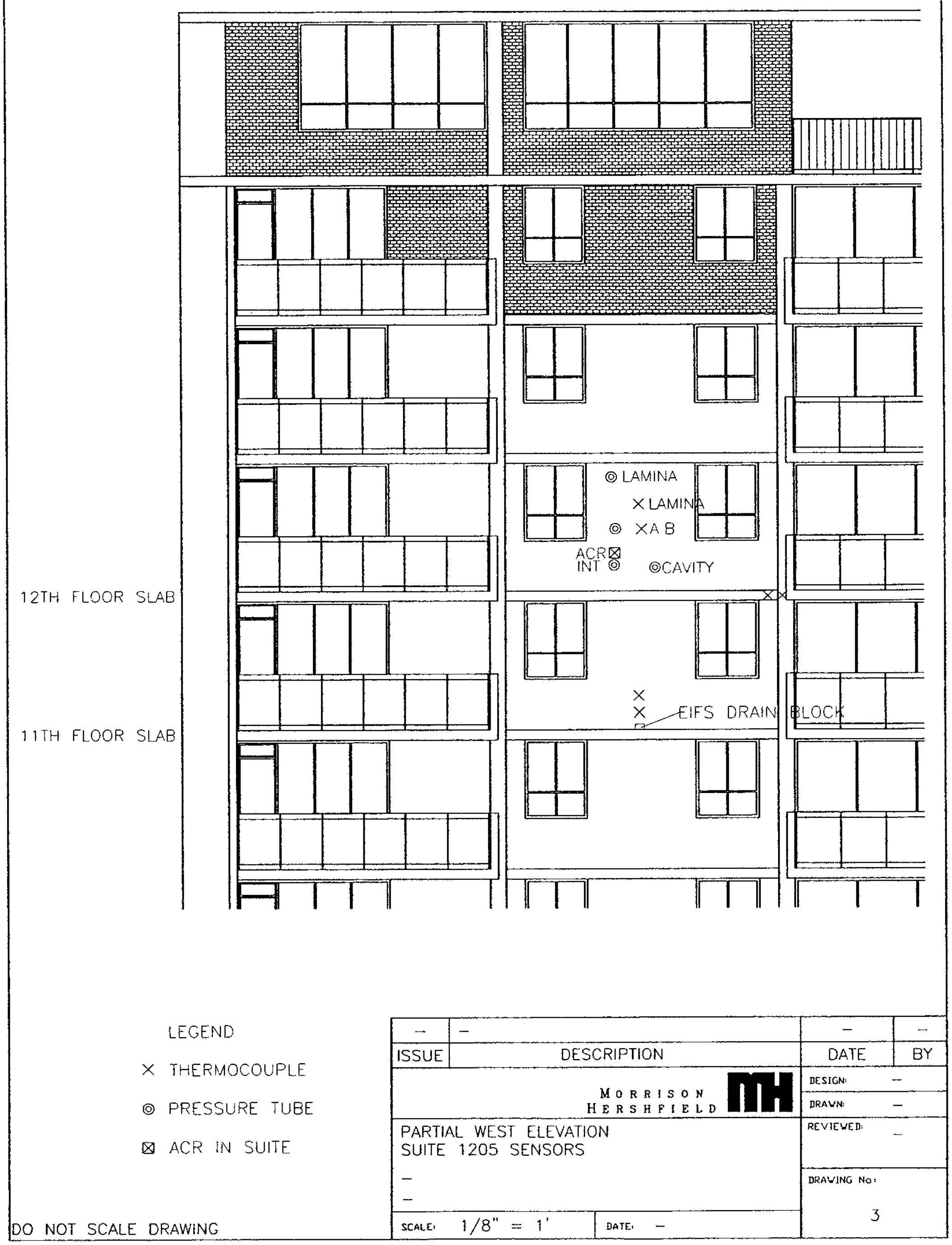


Figure 2.4: Drawing No. 3: Partial West Elevation – Suite 1205 Sensors



ISSUE	DESCRIPTION	DATE	BY
–	–	–	–

MORRISON HERSHFIELD

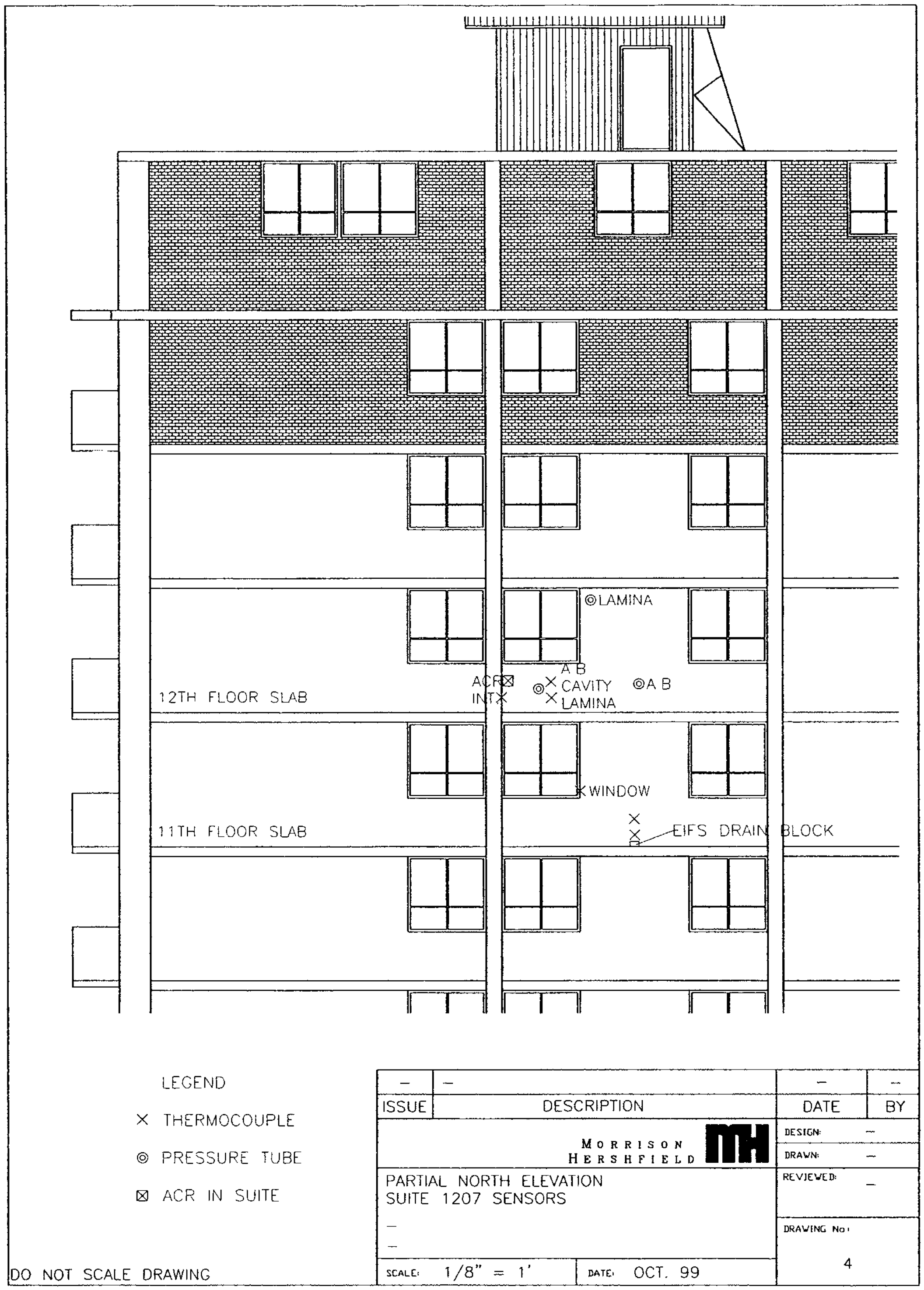
DESIGN: –
DRAWN: –
REVIEWED: –

PARTIAL WEST ELEVATION
SUITE 1205 SENSORS
–
–

SCALE: 1/8" = 1' DATE: –

DRAWING No: 3

Figure 2.5: Drawing No. 4: Partial North Elevation – Suite 1207 Sensors



2.3 Data Analysis

Data were downloaded from the data loggers and transferred to Excel files for processing and analysis following the schedule shown in Table 2.5. Analysis techniques drew on the Canada Mortgage and Housing Corporation document supplied with the RFP[2] and the Morrison Hershfield paper included with our proposal[3]. These techniques were adapted to address the specific technical issues listed in Section 2.1.

Data were recorded from the fall of 1997, the time of the retrofit, to early 1999. All data were transcribed to a CD, which is attached to this report.

Recorded data were evaluated for reliability by comparing measured values with expected norms on both an absolute and a relative basis. For example, temperatures should normally be between the internal and external temperatures, although lamina temperature could be outside this range due to solar or night sky radiation. Pressure difference across the wall should be less than 25 Pa (maximum 23 Pa stack effect at the top floor under winter design conditions) unless affected by wind or mechanical systems.

Data sets were generated to specifically address the technical issues listed in Section 2.1. The data set of moisture content consisted of all values recorded during the monitoring period. Temperature and pressure difference data sets were generated from data recorded from January 1, 1998 to March 31, 1998. This period was chosen because it contained data from the five measurement locations and the weather was cold enough to generate measurable temperature gradients.

The weather recorded for the period from January 1 to March 31, 1998 is presented graphically in Appendix B. The external temperature was below the internal temperature until the latter part of March, although there was no period when it was close to the January 2-1/2% design temperature of –20°C. A number of wind and rain events were recorded during this period, with one exceptional day in February that combined high wind and rain.

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[2] IDEAS Challenge: Exterior wall monitoring protocol. Quirouette Building Specialists Ltd. March 1995.
[3] Lawton, M.D. Diagnosing envelope problems by field performance monitoring. Thermal Performance of the Exterior Envelopes of Buildings V. Clearwater Beach, FL. December 1992.

Table 2.5. Schedule of monitoring at each suite. Note that Suites 205 and 1205 were monitored continuously.

Date	Suite				
	205	304	1204	1205	1207
12-Sep-97	X		X	X	
07-Nov-97	X	X		X	
02-Dec-97	X	X		X	
15-Dec-97	X	X		X	
21-Jan-98	X	X		X	
05-Mar-98	X		X	X	
09-Apr-98	X			X	X
12-Jun-98	X			X	X
24-Jul-98	X	X		X	
11-Sep-98	X	X		X	
23-Oct-98	X	X		X	
05-Nov-98	X			X	X
23-Dec-98	X			X	X
04-Feb-99	X			X	X

3. PERFORMANCE OF THE RETROFIT

The results and observations on the performance of the retrofit are presented as answers to paraphrased versions of the technical questions posed in **2.1 Technical Issues**. In addition, comments are provided on the effect of elevation and orientation.

3.1 Does water frequently penetrate the exterior finish?

It was an expectation of the EIFS cladding design that 'the finish lamina provide the primary weather barrier' (Interim Report Section 3.1). In other words, water was not normally expected to penetrate the exterior finish and, if it did, it would be expected to dry relatively quickly.

A vertical rain gauge was installed near Suite 1204. It was designed to record the horizontal component of rain that impinged on the gauge; it was not designed to record rainwater that ran off the wall. While the data record is continuous, rain was recorded on the vertical surface only five (5) times during the 1998 calendar year - March 20, May 8, May 13, July 8 and December 12. Environment Canada described 1998 as "drought" conditions with water table and Great Lake water surface levels dropping substantially over the period.

Duff gauges were installed at each monitored suite to detect moisture in the lamina. They were mounted in shallow depressions in the exterior face of the polystyrene insulation and embedded in the lamina. The output of Duff gauges is representative of their moisture content and is expected to be less than 15% in a 'natural' environment.

Moisture content data from the monitored locations is presented graphically in Appendix C. The moisture content record is discrete, not continuous, because the installed sensors were read by hand when staff members were on site to download data from the data loggers (see Table 2.5). Only one set of readings was recorded in the summer; data were not recorded on two visits because of equipment malfunction. No readings were taken immediately after a significant rain event; for example, the first set of readings after the wind/rain storm of February was on March 5.

As seen in Figure C1, the moisture content measured under the exterior finish at each suite is generally higher than 15%, although it is noted that the only summer reading is lower than 15%. These results are consistent with an assembly that is experiencing high local moisture levels, and it is postulated that some exterior moisture penetrates the exterior finish. None of the rain gauge events correlated to a change in the moisture content from the duff gauges, although this may be in part due to the time interval between the rain pulse and the duff gauge reading. It is speculated that the penetrating moisture is vapour since Duff gauges fail after exposure to liquid water.

Given the limited amount data, it is not possible to determine with any certainty the source of the exterior moisture (e.g., rainwater, relative humidity), the transport mechanism (e.g., capillary suction, vapour diffusion), or the frequency. It is also impossible to say whether the durability of the system will be compromised since the performance of the system under these conditions is unknown.

3.2 Does the drainage plane protect materials from external water?

An objective of installing the EIFS cladding was to protect the original wall (masonry, etc.) from external water. To achieve this, the EIFS cladding must minimize passage of external water to the drainage plane, and the drainage plane must resist penetration of external water that passes through the EIFS cladding.

Duff gauges were installed at each monitored suite to detect moisture to the interior of the drainage plane. They were installed in cavities that were formed in the exterior face of the masonry.

In contrast to the measurements under the exterior finish (Figure C1), the moisture content measured under the drainage plane is always less than 15% (Figure C2). It is concluded that external water is not penetrating past the drainage plane at the monitored locations and, by extension, at other similar locations.

3.3 Does condensation occur on the inside of the air barrier?

Condensation will occur on the inside of the air barrier if the dew point temperature of the air immediately inside the air barrier is higher than the air barrier temperature. The coating that was applied over the masonry to act as the drainage plane is also intended to be the plane of air tightness of the air barrier system. The air barrier will tend to be warm because the insulation installed over the coating is the main insulation in the retrofitted wall. Condensation will occur if the coating is unusually cold, as might occur if the drainage channels are at outdoor temperature, or if the indoor relative humidity is unusually high, as might occur with a low ventilation (air exchange) rate in the occupied space.

To determine whether condensation could or did occur on the inside of the air barrier, the temperature of the air barrier is compared to the coincident dew point temperature of the air inside the air barrier. Air barrier temperature was measured with the thermocouples installed on the air barrier. Dew point temperature was calculated using equations in the ASHRAE Handbook of Fundamentals and air temperature and relative humidity measured by a temperature/relative humidity sensor installed in the masonry cavity located inside the air barrier.

Temperature data from the five monitored locations are presented graphically in Appendix D. 'External' temperature is common to all three figures; 'Cavity Dew Point' temperature is calculated for each location. It is noteworthy that the air barrier and masonry cavity temperatures, which are nominally from the same plane of the wall, are similar but not exactly the same. There are two possible explanations for this. The first is the accuracy of the sensors and data loggers - the air barrier sensor is a thermocouple mounted on a surface; the masonry cavity sensor is a thermistor mounted in air. Both are estimated to have accuracy no better than ±1°C. The second is the spatial separation of the sensors - they are physically located as much as a metre apart from each other (Figures 2.3 to 2.5). Hence, for a combination of both reasons, the measured air barrier and cavity temperatures are similar but not exactly the same.

As can be seen in Appendix D, the dew point temperature of the air inside the air barrier is considerably below the air barrier temperature. Recall also that the Duff gauges installed in the masonry cavity did not register a high moisture level (Section 3.2). From this, it is concluded that condensation does not occur on the inside of the air barrier.

3.4 Does condensation occur on the inside of the exterior finish?

Condensation will occur on the inside of the exterior finish (lamina) if the dew point temperature of the air inside the lamina is higher than the lamina temperature (note that condensation of exterior moisture on a sub-cooled lamina is not considered here). The dew point temperature will be raised above ambient conditions by moisture from the occupied space. Such moisture will be transported by vapour diffusion, air leakage or both, and the rate of transport will be controlled various low air and vapour permeable assemblies in the wall (including the air barrier and vapour barrier).

Comparing the lamina temperature and the coincident dew point temperature of the adjacent air will determine whether condensation will occur on the inside of the lamina. However, there are problems with both parameters - the measured lamina temperature exhibits short-term changes due to radiation, and the dew point temperature of the adjacent air was not measured – and an indirect comparison is required. The external temperature is used in place of the lamina temperature since it does not exhibit the short-term changes and will be lower than the lamina temperature. The masonry cavity dew point temperature is used in place of the adjacent dew point temperature since it will always be greater than or equal to the adjacent dew point temperature. Since both substitutions are conservative, a negative result with these parameters signifies a negative answer for the actual question.

As can be seen in Appendix D, the masonry cavity dew point temperature is below the external temperature most of the time. It is concluded that condensation of interior moisture does not occur on the inside of the exterior finish.

3.5 Is the full value of the installed insulation being obtained?

It was an expectation of the EIFS cladding design that the full thermal resistance value of the installed insulation would be added to the wall. The insulation is 75 mm of expanded polystyrene, approximately RSI-2.13 (R-12), that is adhered to the wall without the use of fasteners. Since the nominal thermal resistance of the original wall is estimated to be RSI-1.17 (R-7), the nominal thermal resistance of the refurbished wall is estimated to be RSI-3.30 (R-19) (see Table 3.5).

An estimate of the value of thermal resistance added by the installed insulation can be determined by calculating the ratio of the temperature difference across the insulation to the temperature difference across the wall. Note that this ratio is the same as the temperature index for the air barrier for this application. Hence, for the values of thermal resistance listed in Table 3.5, an in-service temperature index greater than 0.6 (2.13/3.30) would indicate that the full value of the installed insulation is being obtained.

Table 3.5. Estimated thermal resistance values for the retrofitted wall elements.

Element	Thermal Resistance $m^2 \cdot K/W$
Indoor Film*	0.12
Plaster*	0.01
EPS*	0.71
Concrete Block*	0.13
Mortar Cavity*	0.03
Brick*	0.14
Air Barrier	0.00
EPS + Lamina	2.13
Outside film*	0.03
Total Resistance	3.30

* Elements of original wall; thermal resistance of original wall = 1.17.

Note that the analysis above assumes steady state thermal conditions. Under the dynamic thermal regime experienced by a wall subjected to weather, the calculated temperature index will fluctuate because of the thermal mass of the wall. The mean value can be taken as the best estimate under these conditions. Temperature index will be affected by solar radiation and will be inaccurate if there is insufficient temperature difference across the wall. Temperature index will also respond to air leakage, especially under windy conditions, if the air barrier system is ineffective.

Temperature index data for the air barrier and the slab edge from the five monitored locations are presented graphically in Appendix E. These values are calculated for nighttime hours, to avoid solar radiation, when the external temperature is lower than 10°C, to ensure there is sufficient temperature difference for the calculation.

It is not possible to judge whether the temperature index is affected by air leakage since insufficient data with large pressure difference were recorded. However, note that the 'Above Drain Block' temperature is occasionally depressed by a high wind condition, e.g., Figure D2, Suite 1207, without a corresponding depression in the 'Air Barrier' or 'Cavity' temperatures. From this, it appears that there is no air leakage through the cavity since the depression manifests itself as a local effect at the drain block that does not extend through the drainage cavity.

Values of temperature index were determined to be greater than 0.6 for all locations (see Appendix E). Values considerably greater than 0.6 may be an indication that the R-value of the original wall is lower than the estimate since the R-value of the added insulation is known with some certainty. It is concluded that the full value of the installed insulation is being obtained.

3.6 Is the designed air barrier performing its intended function?

The intended function of the air barrier system is to minimize air leakage through the wall. In the field of the wall, a proprietary, trowel-on coating was applied over the existing masonry to form the airtight element of the 'designed' air barrier system. Note that if the existing masonry was an effective airtight element before the coating was installed, then it will continue to perform that function after the coating is installed. Continuity to the windows was achieved by returning the trowel-on coating and peel-and-stick membrane into the rough window opening and injecting spray urethane foam between the window frame and the rough opening.

Because the air barrier system minimizes air leakage through the wall, it is the tightest element in the wall. As a consequence, the pressure difference across the wall will be across the air barrier system under static conditions. Pressure taps, referenced to the interior, were installed at each suite to measure the pressure difference across three 'natural' layers of flow resistance in the wall. These layers are the brick/interior finish (the 'masonry'), the air barrier plus brick/interior finish (the 'air barrier'), and the lamina plus air barrier and brick/interior finish (the 'lamina'). The difference between the 'air barrier' tap and the 'masonry' tap is the pressure difference across the air barrier layer, and the difference between the 'lamina' tap and the 'air barrier' tap is the pressure difference across the lamina layer. Note that the 'lamina' tap measures the pressure difference across the entire wall.

The pressure difference measured across the wall is typically less than ±20 Pa (see Appendix F) and, given the precision of the measurements, it is not possible to determine with certainty the element that is the tightest. It is observed, however, that the 'masonry' and 'air barrier' pressure differences track very closely, indicating that the tightest element is either the 'masonry' or the 'air barrier'. It is concluded that, for the most part, either the masonry (the old air barrier) or the trowel-on coating (the new air barrier) is effectively performing the air barrier function.

Note that the lamina experiences roughly half the pressure difference across the wall during high winds (e.g., see Figure D2, Suite 1204). During gust conditions the lamina pressure difference is higher than that at the interior layers because damping reduces the amplitude and time of response at the interior layers. The dynamic response must be considered when generating statistical results from monitored data.

3.7 Is the temperature of the masonry element stabilized?

An objective of installing the EIFS cladding was to stabilize the temperature of the masonry close to interior conditions. This would be achieved by isolating the masonry from the exterior conditions by controlling heat transfer (adding insulation) and controlling air leakage (adding an air barrier system).

The temperature of the masonry element was measured in two places at each monitored location. A combination temperature / relative humidity sensor was mounted in a cavity in the exterior face of the masonry, and a thermocouple was mounted on the air barrier, which is a coating applied over the masonry.

Measured masonry cavity temperature, air barrier temperature and exterior air temperature are plotted in Appendix D. For the three-month period covered by these plots, the cavity temperature remains relatively stable while the exterior temperature varies more than 20°C. Observe the temperatures at Suite 1204 in mid-February when a significant wind event produced a drop in Above Drain Block temperature that was not reflected in the Air Barrier or Cavity temperatures. Observe also the temperatures at Suite 205 in early March when a significant drop in External temperature was not reflected in the Air Barrier or Cavity temperatures. It is concluded that the temperature of the masonry element is stabilized.

3.8 Is there an elevation or orientation effect?

An objective of the instrumentation design was to measure whether elevation or orientation had an effect on the retrofitted walls. Elevation and orientation will obviously effect wind and temperature, and that might produce a corresponding effect on the retrofitted walls. As noted previously, weather data were measured at the top of the building, and temperature, air pressure and moisture content were measured on three elevations (2nd, 3rd and 12th floors) and three orientations (north, east and west). A comparison of these data provides a sense of the effect of elevation and orientation.

Weather data (temperature, wind and rain) are presented in Appendix B for the period from Jan/98 to Mar/98. Temperature data are presented in Appendix D and pressure data are presented in Appendix F for the five monitored locations and for the same period. Coincidental events can be compared between the appendices because the time scales are the same on all graphs. Graphs for different suites are data from different elevations (e.g., Suite 205 is on the 2nd floor, Suite 1205 is on the 12th floor) and different orientations (e.g., Suite 1204 faces east, Suite 1205 faces west). Moisture content data are presented in Appendix C for the entire monitoring period (Sept/97 to Apr/99).

No significant differences are evident between the different locations.

4. MONITORING PROTOCOL

Two of the project objectives were specific to assessing the monitoring protocol.

3. To assess the degree to which the monitoring protocol can be implemented as part of regular building operation and maintenance activities for new and existing buildings.
4. To assess the potential for the development of a commercially viable, building envelope performance monitoring protocol.

4.1 Implementation

Implementation of the monitoring protocol as part of a regular building operation and maintenance activities is not a trivial matter.

In new buildings, the as-built details, at least the designed ones, tend to be known and the locations that are to be monitored tend to be accessible. Hence the monitoring protocol can be designed with a good understanding of the intended building envelope design, and the building will be accessible through the construction stages. Indeed, with the cooperation of the contractor it is possible to install sensors exactly where they should be. Our experience is that most contractors are more than willing to cooperate as long as the request is presented with an appreciation of the time and resource constraints that they face.

In existing buildings, the as-built details are frequently not well known and the locations that are to be monitored are normally not easily accessible. Hence the monitoring protocol must usually be designed with less-than-complete information. Installation of interstitial sensors can be particularly problematic because of the difficulty of installing sensors without changing elements that control performance. For example, installing pressure taps to measure pressure difference across layers in a wall requires that the layers, e.g., air barriers, be penetrated, an action that potentially compromises their function. The installation of a sensor to measure external surface temperature can be particularly difficult if the location is high on a building and not close to an entry point. Finally, it is frequently necessary to install sensors in locations that are occupied by tenants/owners. Our experience has been that many people are unwilling to have sensors installed anywhere close to their space.

Rehabilitation of an existing building, as undertaken in this project, provides access opportunities similar to those encountered when implementing a monitoring protocol on a new building. Such access would not have been available as part of regular building operation and maintenance activities. While details of the existing building envelope were sketchy, details of the rehabilitation were known and a monitoring protocol was designed based on the known details. Also, access to the outside of the building was available through the contractor, and the rehabilitation project made tenants more open to having sensors installed close to their space.

4.2 Design Issues

Developing a monitoring protocol to measure building envelope performance requires a fundamental knowledge of building envelope performance and a working knowledge of building envelope construction. The former defines the important parameters to be measured, while the latter is necessary to an understanding of the scale of the parameters and of the application of the protocol. Building envelope performance issues to be addressed are heat, air and moisture control. The monitoring protocol has to be designed to measure the boundary conditions and the response of the envelope to these boundary conditions. Hence, it is necessary to be able to measure temperature, air pressure, and relative humidity, and these measurements should be conducted both in the indoor and outdoor environment and in the interstitial spaces.

The protocol must be designed with an expert knowledge of sensors, instrumentation and data acquisition if it is to produce reliable data. Temperature sensors should be accurate and sensitive enough to measure thermal gradients across the layers, and appropriate to measuring surface temperature. Pressure transducers should have range and sensitivity capable of discriminating stack pressure gradients while measuring gust pressures. Moisture sensors should be available to cover the range of construction materials, especially moisture sensitive ones. All sensors, especially relative humidity sensors, should be rugged enough to maintain calibration under unattended conditions. At the same time, the protocol must include secondary calibration procedures in order to ensure the accuracy of the measurements.

A commercially viable monitoring protocol must be able to adapt to a range of applications while being focused enough to provide the specific data required. The number of sensors and frequency of reading should be adjustable to the task, and the system should be able to download easily or have sufficient capacity to store data until download can be performed. The data should be checked for accuracy when downloaded. In large buildings, monitoring would typically be done on more than one orientation and at more than one elevation in order to capture orientation and height effects. The monitoring protocol should accommodate this requirement.

A well-defined objective is necessary before any monitoring is undertaken. Each sensor should have a purpose such that data from the complete set of sensors would provide a measure of the building envelope performance. It is pointless to attach a number of sensors on and in a building envelope with the 'hope' that some understanding can be gleaned from the data. The volume of data becomes impossible to manage without a predetermined purpose for each sensor. At the same time, it is recognized that many problems in buildings occur at the details. If the objective of the monitoring were to provide an early warning of failure, then many 'alarm' sensors would likely have to be installed. However, given current knowledge, it is uncertain whether a system could confidently be designed to give the warning required.

5. CONCLUSIONS AND DISCUSSION

5.1 General

The rainscreen EIFS was a little slower to install due to the time required to install the gutter and drain block. Non drained edges and a non-drained top were also installed to act as a joint and drain block opening. The number of drain blocks was minimized for this reason. Once these were installed, the installation proceeded essentially at normal speed.

It is interesting to consider the performance of the refurbished building in the context of the environmental separation requirements of the National Building Code. For the above grade portion of a building, Part 5 - Environmental Separation of the NBC requires that the building envelope control Heat Transfer (5.3), Air Leakage (5.4), Vapour Diffusion (5.5) and Precipitation (5.6). Based on the analysis of the monitored data, it is concluded that the retrofitted wall meets the performance requirements of the National Building Code with respect to environmental separation.

5.2 Monitoring Protocol

The building rehabilitation provided an opportunity to design a monitoring protocol to address the building science issues. It also provided access to the exterior of the building so that the protocol could be implemented.

An important conclusion of the study is that monitoring protocols must include techniques that will efficiently screen the data in order to detect anomalous records as they are collected. Our screening technique involved plotting the data and scanning the plots for 'interesting' occurrences while assessing whether the data were 'rational'. However, we underestimated the amount of time and especially the level of expertise required to effectively screen the data using this approach. There were a number of reasons for this, including the quantity of data and the subtlety of relationships between data points. Some questionable, inaccurate and missing records were identified in the data set when the appropriate effort and skill were ultimately employed. This reinforces the necessity of developing alternative approaches, for example computer sieves, to screen the data. Computer sieves could use features such as magnitude, gradient, rate of change, and internal consistency to identify anomalous data and raise an alert when found. The data could then be examined more closely to judge what action should be taken.

In a building of the size and type that was monitored in this project, it is the authors' opinion that the potential for developing a commercially viable building envelope monitoring protocol is limited at present. The owners, operators, and maintainers of this type of building would not make significant practical use of the data gathered from such a system. However, some components of the monitoring system could be adapted to maintenance and capitol repairs planning. For example, a new building comprised of brick cavity walls could be constructed with water collectors inside the drainage cavities to track the amount of water passing within the cavity over time. A rapid trend upwards at some point in the future could provide advanced warning of upcoming brick deterioration, water penetration, sealant failures, etc.

5.3 Overall Assessment

The monitoring program has demonstrated that the EIFS retrofit at 1050 Broadview Avenue, Toronto is meeting its performance objectives. The new cladding system is providing effective control of heat transfer, air leakage, vapour diffusion, and rain penetration, and is maintaining the original masonry in a warm and stable environment. The retrofit reduced/eliminated condensation on cold exterior wall surfaces and corresponding mold growth, allowing for reliable HVAC operation due to reduced air leakage, etc.

Morrison Hershfield Limited

William C. Brown, M.Sc., P.Eng.

Steve Murray, P.Eng.

APPENDIX A

Protocol for monitoring the performance of a high rise residential building envelope retrofit. Interim report by Morrison Hershfield Limited presented to Canada Mortgage and Housing Corporation, March 1997.

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INTERIM REPORT

Protocol for Monitoring the Performance of a High Rise Residential Building Envelope Retrofit

Presented to:

Duncan Hill, P.Eng
Technical Policy and Research Division
Canada Mortgage and Housing Division
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Report No. 2962056/1 March 19, 1997

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Project Overview and Objectives

Morrison Hershfield was engaged by CMHC's Technical Policy and Research Division to carry out a research project with the following stated objectives.

1. To document the development of a building envelope retrofit strategy for a residential high-rise building.

2. To monitor, assess and document the performance of a residential high rise building retrofit.

3. To assess the degree to which the monitoring protocol can be implemented as part of regular building operation and maintenance activities for new and existing buildings.

4. To assess the potential for the development of a commercially viable, building envelope performance monitoring protocol.

2. TEST BUILDING

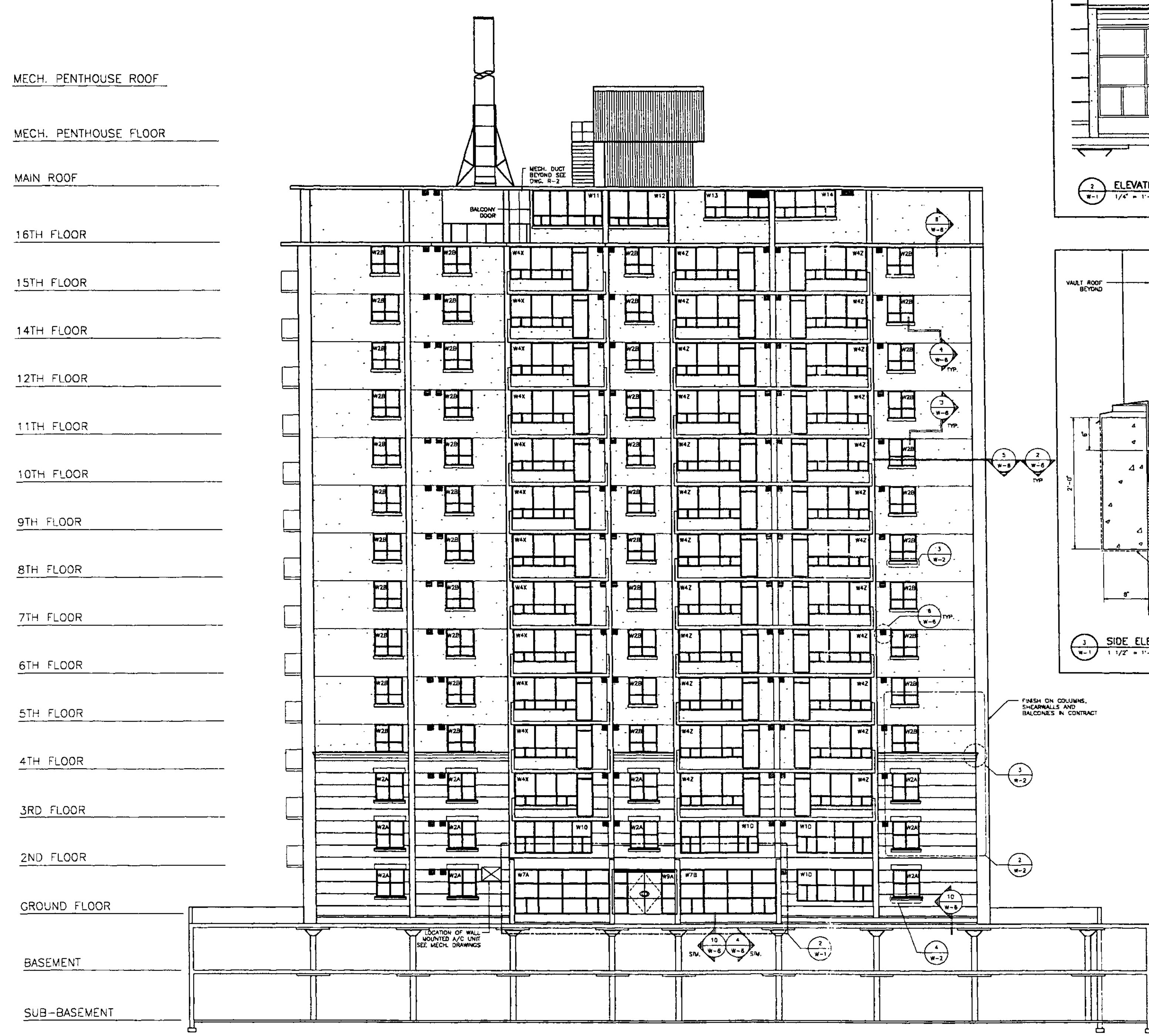
2.1 Description of 1050 Broadview Avenue - Toronto

1050 Broadview Avenue is a 15-storey apartment constructed about 30 years ago, with approximately 112 residential units and 2 levels of underground parking. The building is currently undergoing a $6M rehabilitation self-funded, but supported by an MOH loan guarantee program. This renovation program is taking place while the building remains occupied. Located in the Borough of East York, near the intersection of Broadview Avenue and Danforth/Bloor Avenue, the site is at the top eastern edge of The Don River Valley. Figures W-1 through W-4 show elevation drawings of the building and figures A1.3 through A1.5 show floor plans for the first, typical and penthouse floors.

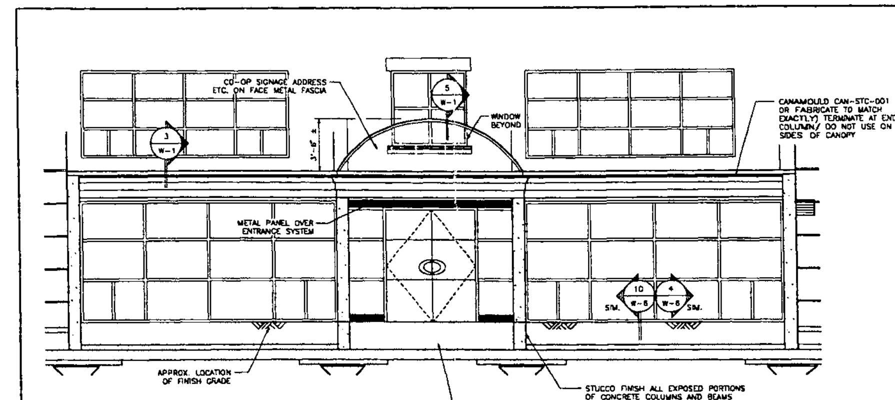
The renovation program includes all mechanical and electrical equipment, fire and life safety systems, elevators, parking garage, landscaping, partial interior renovation, roof replacement, window replacement and exterior wall overcladding.

Windows are combination units of fixed and horizontal sliders, all single-glazed and in unfinished aluminum frames and sashes. Exterior walls are solid masonry, infill within the reinforced concrete structural frame. The concrete floor slabs are exposed at the face. Selected columns and shearwalls project out from the wall as a decorative feature. Projecting concrete balconies are provided on the east, south and west elevations. Also, the roof slab and the floor slab below project out past the walls to form decorative concrete canopies.

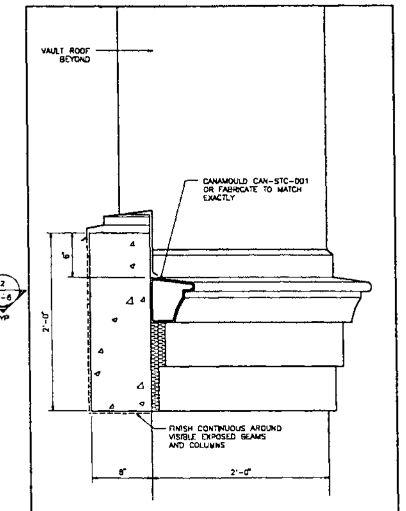
The typical wall construction is: clay brick with raked face; filled 25 mm collar joint; concrete block backup; 25 mm thick expanded polystyrene foam insulation; and an adhered plaster finish (approximately 12 mm thick) on the inside.



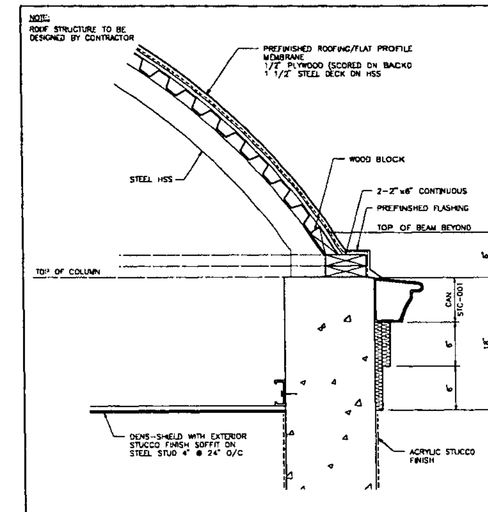
1/W-1 EAST ELEVATION 1/8" = 1'-0"



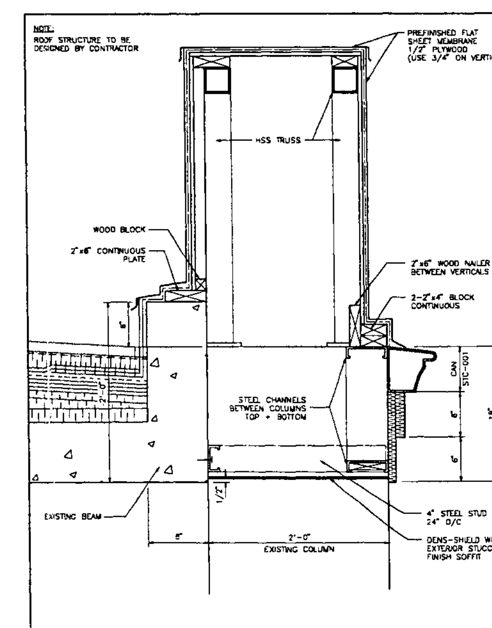
2/W-1 ELEVATION AT MAIN ENTRANCE 1/4" = 1'-0"



3/W-1 SIDE ELEVATION CANOPY MARQUEE 1 1/2" = 1'-0"



4/W-1 LONGITUDINAL SECTION MAIN CANOPY MARQUEE 1 1/2" = 1'-0"



5/W-1 CROSS SECTION CANOPY MARQUEE 1 1/2" = 1'-0"

NOTES:

1. GUARDS (BY OTHERS) NOT SHOWN FOR CLARITY.
2. E/FS NOT REQ'D BELOW BALCONY DOOR THRESHOLDS.
3. WALL BOX LOCATIONS APPROXIMATE AND ARE REPRESENTATIONS ONLY. REFER TO MECHANICAL DRAWINGS FOR ACTUAL NUMBER, SIZE AND LOCATION.
4. WHERE EVER EXISTING TERAZZO STOOLS BECOME DAMAGED OR CANNOT BE RE-USED, INCLUDING WHERE NEW WINDOW OPENINGS ARE CREATED - CREATE NEW STOOLS IN MATCHING DIMENSIONS FROM SOLID NEW STOCK AND P-LAM SURFACING. COLOUR AND PATTERN AS ACCEPTED BY THE CONSULTANT. REFER TO ARCHITECTURAL DRAWINGS AND INTREIOR FINISH SPECIFICATIONS FOR SPECIFIC REQUIREMENTS.
5. E/FS ACRYLIC STUCCO FINISH, WITHOUT AIR BARRIER OR INSULATION, IS TO BE APPLIED ALL EXPOSED COLUMNS AND SHEARWALLS, AND TO THE VERTICAL FACES OF ALL CONCRETE BALCONY SLABS AND BALUSTERS AND THE TOP SURFACE OF THE BALUSTERS. BALCONY SOFFITS TO BE PAINTED.
6. ALL E/FS FEATURE DETAILS TO BE PRE-FABRICATED. SPECIFICALLY REFERENCED PROFILES BY "CANMOULD" CAN BE SHOP FABRICATED BUT MUST REPLICATE PROFILES EXACTLY.

Revision/Issue	Date		Initial
1	08/04/96	ISSUED FOR TENDER AND PERMIT APPLICATION	PWC

This drawing is to be used for the following purposes: | Not to be used for construction unless signed by the architect

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construction north

LICENSED PROFESSIONAL ENGINEER
P.W. CREIGHTON
PROVINCE OF ONTARIO

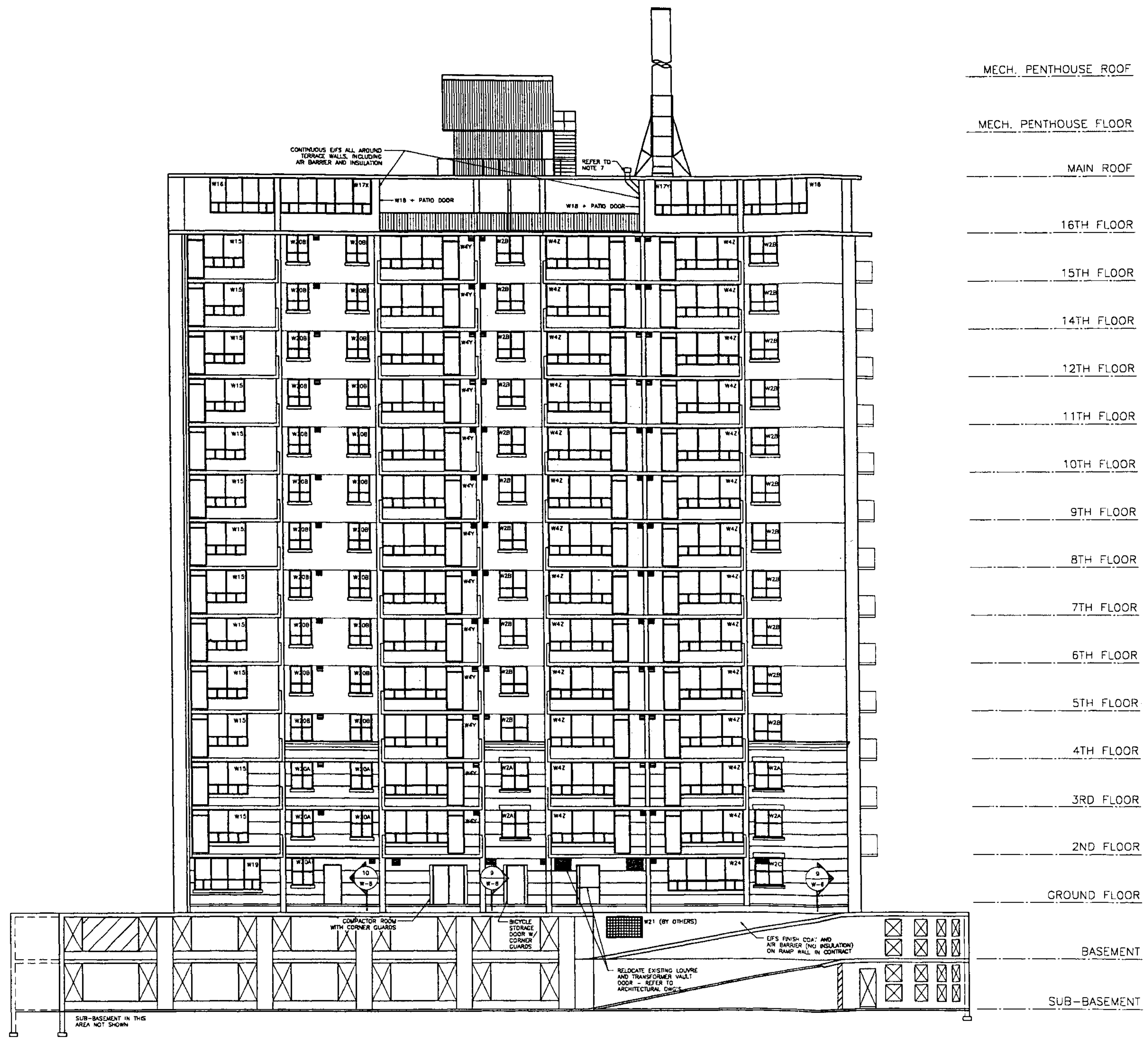
Client: Broadview Avenue Co-op

Project: BROADVIEW AVENUE CO-OP RENOVATIONS
1050 Broadview Avenue
Toronto Ontario

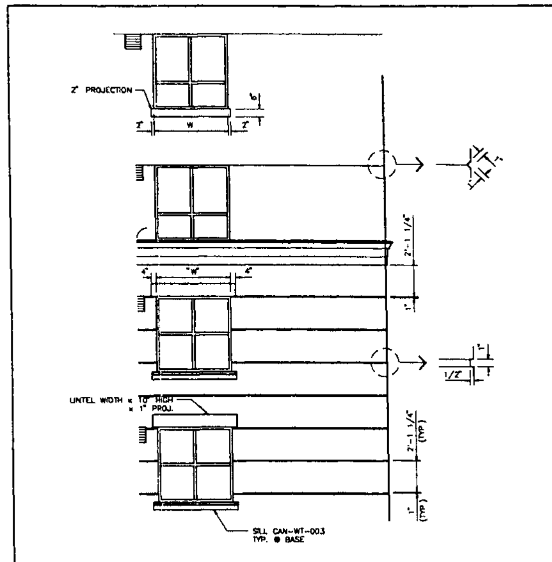
Date	Drawn	Checked
MAR., 1996	C.S.	P.W.C.

Drawing Title: EAST ELEVATION

Scale	Drawing No	Revision
AS NOTED	W-1	0
Project No: 195-2241.00		



1 W-2 WEST ELEVATION 1/8" = 1'-0"



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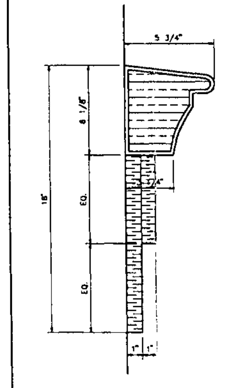

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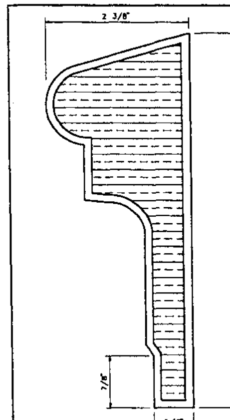

4 W-2 CAN-WT-003 N.T.S.

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6. ALL EIFS FEATURE DETAILS TO BE PRE-FABRICATED SPECIFICALLY REFERENCED PROFILES BY "CANMOULD" CAN BE SHOP FABRICATED BUT MUST REPLICATE PROFILES EXACTLY.
7. KEEP EIFS SYSTEM CLEAR OF TERRACE METAL FIREPLACE CHIMNEY MINIMUM 1'-0". INSTALL PREFINISHED METAL FLASHING AROUND CHIMNEY AND SEAL EIFS AND CHIMNEY. INSTALL SILL WITH DROP (AS PER DETAILS ON W-6) ON TOP OF EIFS BELOW CHIMNEY.

Revision/Issue	Date		Initial
1	08/04/96	ISSUED FOR TENDER AND PERMIT APPLICATION	P.W.C.

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construction north

LICENSED PROFESSIONAL ENGINEER P.B. CREIGHTON PROVINCE OF ONTARIO

Client: Broadview Avenue Co-op

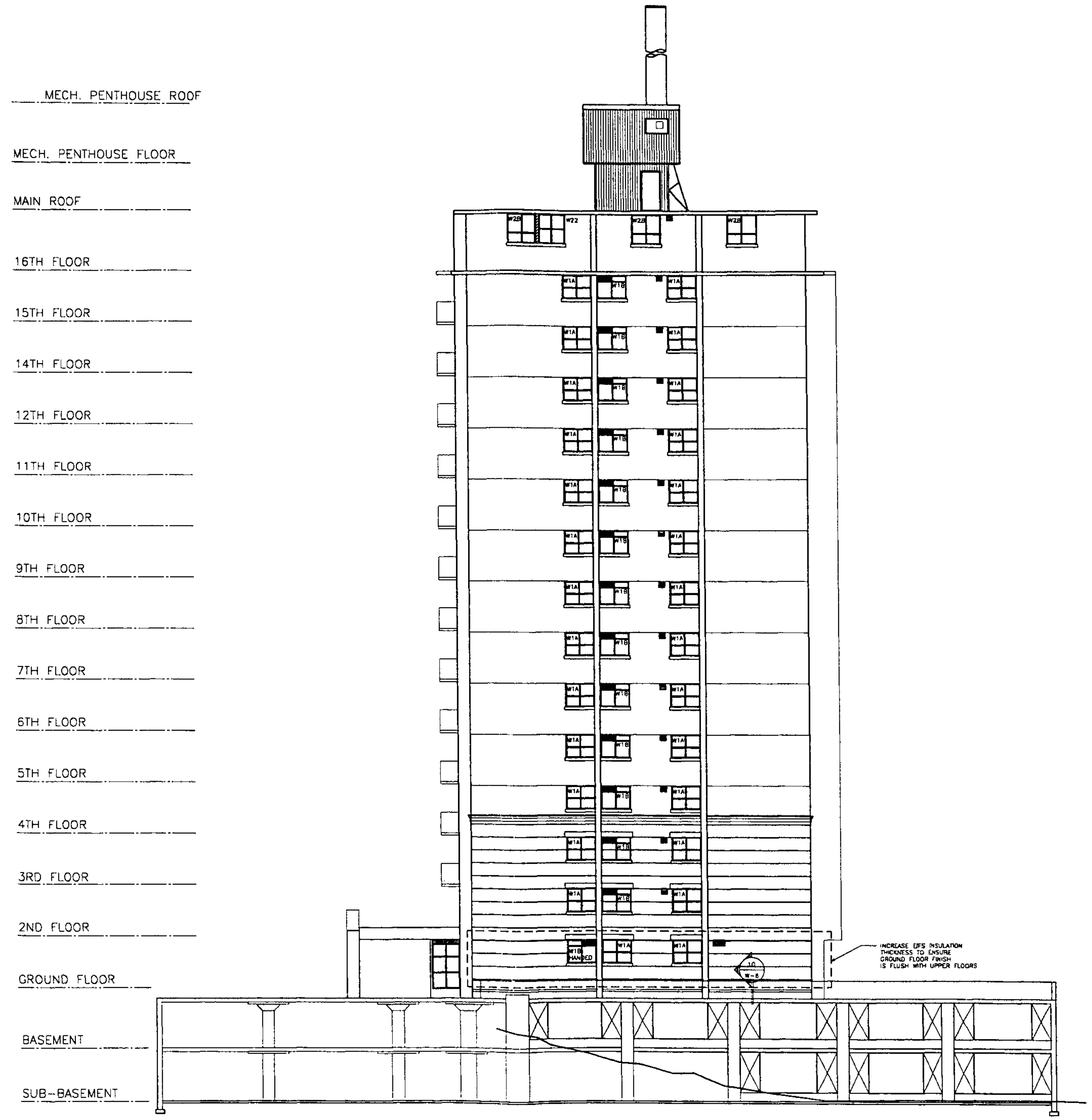
Project: BROADVIEW AVENUE CO-OP RENOVATIONS 1050 Broadview Avenue Toronto Ontario

Date	Drawn	Checked
FEB. 1996	M.B.	P.W.C./W.K.

Drawing Title: WEST ELEVATION

Scale: AS NOTED
Project No: 195-2241.00
Drawing No: W-2
Revision: 0

File name: K:\BLDGENG\1952241\WINDOWS\DRAWINGS\W-3
Last update: June 6, 1996
Plot scale: 1=96 (I)



1 / W-3 NORTH ELEVATION
1/8" = 1'-0"

NOTES:

1. GUARDS (BY OTHERS) NOT SHOWN FOR CLARITY.
2. EIFS NOT REQ'D BELOW BALCONY DOOR THRESHOLDS.
3. WALL BOX LOCATIONS APPROXIMATE AND ARE REPRESENTATIONS ONLY. REFER TO MECHANICAL DRAWINGS FOR ACTUAL NUMBER, SIZE AND LOCATION.
4. WHERE EVER EXISTING TERAZZO STOOLS BECOME DAMAGED OR CANNOT BE RE-USED, INCLUDING WHERE NEW WINDOW OPENINGS ARE CREATED - CREATE NEW STOOLS IN MATCHING DIMENSIONS FROM SOLID NEW STOCK AND P-LAM SURFACING, COLOUR AND PATTERN AS ACCEPTED BY THE CONSULTANT. REFER TO ARCHITECTURAL DRAWINGS AND INTREIOR FINISH SPECIFICATIONS FOR SPECIFIC REQUIREMENTS.
5. EIFS ACRYLIC STUCCO FINISH, WITHOUT AIR BARRIER OR INSULATION, IS TO BE APPLIED ALL EXPOSED COLUMNS AND SHEARWALLS, AND TO THE VERTICAL FACES OF ALL CONCRETE BALCONY SLABS AND BALUSTERS AND THE TOP SURFACE OF THE BALUSTERS. BALCONY SOFFITS TO BE PAINTED.
6. ALL EIFS FEATURE DETAILS TO BE PRE-FABRICATED. SPECIFICALLY REFERENCED PROFILES BY "CANMOULD" CAN BE SHOP FABRICATED BUT MUST REPLICATE PROFILES EXACTLY.

Revision/Issue	Date		Initial
1	06/04/96	ISSUED FOR TENDER AND PERMIT APPLICATION	P.W.C.

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construction north

LICENSED PROFESSIONAL ENGINEER
P.W. CREIGHTON
PROVINCE OF ONTARIO

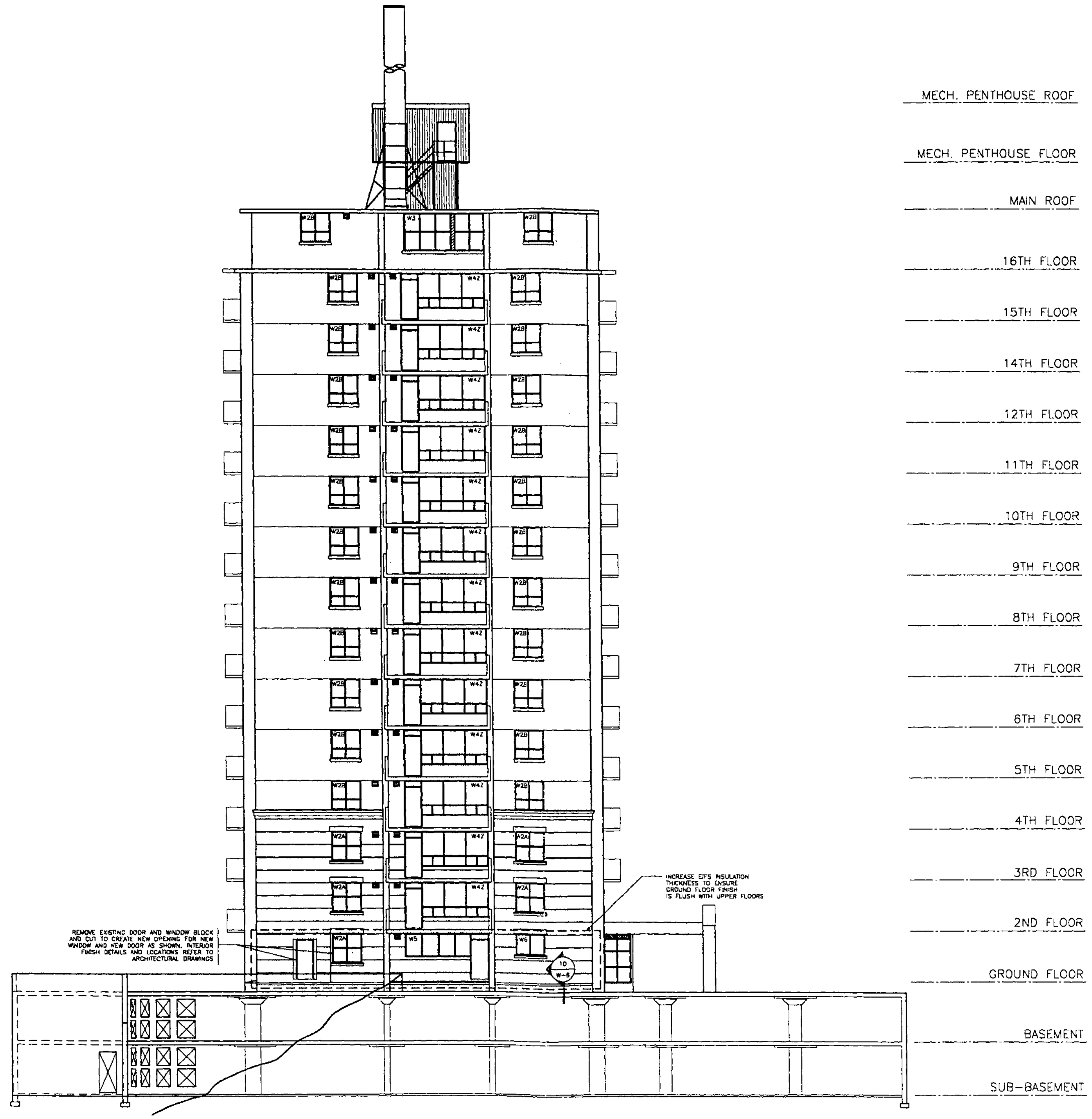
Client: Broadview Avenue Co-op

Project:
BROADVIEW AVENUE CO-OP RENOVATIONS
1050 Broadview Avenue
Toronto, Ontario

Date	Drawn	Checked
MAR., 1996	C.S.	P.W.C.

Drawing Title: NORTH ELEVATION

Scale	Drawing No.	Revision
AS NOTED	W-3	0
Project No. 195-2241.00		



1 / W-4 SOUTH ELEVATION
1/8" = 1'-0"

NOTES:

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2. EIFS NOT REQ'D BELOW BALCONY DOOR THRESHOLDS.
3. WALL BOX LOCATIONS APPROXIMATE AND ARE REPRESENTATIONS ONLY. REFER TO MECHANICAL DRAWINGS FOR ACTUAL NUMBER, SIZE AND LOCATION.
4. WHERE EVER EXISTING TERAZZO STOOLS BECOME DAMAGED OR CANNOT BE RE-USED, INCLUDING WHERE NEW WINDOW OPENINGS ARE CREATED - CREATE NEW STOOLS IN MATCHING DIMENSIONS FROM SOLID NEW STOCK AND P-LAM SURFACING. COLOUR AND PATTERN AS ACCEPTED BY THE CONSULTANT. REFER TO ARCHITECTURAL DRAWINGS AND INTREIOR FINISH SPECIFICATIONS FOR SPECIFIC REQUIREMENTS.
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Revision/Issue	Date		Initial
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construction north

LICENSED PROFESSIONAL ENGINEER P.W. CREIGHTON PROVINCE OF ONTARIO

Client: Broadview Avenue Co-op

Project:
BROADVIEW AVENUE
CO-OP RENOVATIONS
1050 Broadview Avenue
Toronto Ontario

Date	Drawn	Checked
MAR., 1996	C.S.	P.W.C.

Drawing Title: SOUTH ELEVATION

Scale	Drawing No	Revision
AS NOTED	W-4	0
Project No: 195-2241.00		

TYPICAL SUITE UPGRADES

THE FOLLOWING SUITE UPGRADES ARE TYPICAL THROUGHOUT THE BUILDING UNLESS NOTED OTHERWISE IN THE CONTRACT DOCUMENTS.

1. REMOVE AND DISPOSE OF EXISTING KITCHEN CABINETS (UPPERS AND LOWERS). REPAIR DAMAGED WALLS TO ACCOMMODATE INSTALLATION OF NEW CABINETS TO LAYOUT INDICATED ON THE FLOOR PLAN AND DRAWING A3.1 CO-ORDINATED PLUMBING WORK MECHANICAL SUBTRADE.
2. REMOVE AND DISPOSE OF EXISTING BATHROOM VANITY, SINK, FIXTURES, AND WALL-MOUNTED MEDICINE CABINETS. REPAIR DAMAGED WALLS TO ACCOMMODATE INSTALLATION OF NEW BATHROOM VANITIES AND METAL WALL-MOUNTED MEDICINE CABINETS ABOVE VANITY. ALLOW RECOMMENDED CLEARANCE BETWEEN VANITY AND NEW MEDICINE CABINET. EXISTING BATHROOM MIRRORS ARE TO REMAIN, HOWEVER, IF CONFLICT EXISTS BETWEEN MEDICINE CABINET MOUNTING HEIGHT AND BOTTOM OF MIRROR, REMOVE MIRROR AND CUT MIRROR TO FIT. CO-ORDINATE ALL INSTALLATIONS WITH AFFECTED MECHANICAL SUBTRADES.
3. EXISTING BATHTUBS ARE TO BE REMOVED AND REPLACED WITH NEW BY THE MECHANICAL SUBTRADES.
4. REPAIR ALL AREAS AROUND NEW BATH TUB INSTALLATIONS TO ALLOW THE INSTALLATION OF VINYL WALL PANELS ON THREE SIDES OF NEW BATH TUBS. NEW BATH TUB SURROUNDS ARE SPECIFIED IN THE MECHANICAL SPECIFICATIONS.
5. AFTER COMPLETION OF NEW BATHROOM EXHAUST FAN AND DUCT INSTALLATION, REPAIR EXISTING CEILING TO ACCEPT FINAL PAINT.
6. REPAIR EXISTING PLASTER WALLS IN THE BATHROOM TO ACCEPT FINAL PAINT.
7. EXISTING FLOOR TILES TO REMAIN IN BATHROOMS. (PROTECT FROM DAMAGE.)
8. CONSTRUCT NEW GYPSUM BOARD BULKHEADS AND REPAIR EXISTING PLASTER BULKHEADS AFTER MECHANICAL DUCTWORK HAS BEEN COMPLETED TO AREAS SHOWN ON DRAWINGS.
9. REMOVE AND DISPOSE OF EXISTING VINYL FLOOR TILES IN THE KITCHEN AND AT SUITE ENTRANCES. CLEAN EXCESS FLUE FROM AREAS OF TILE REMOVAL AND PREP. FLOOR TO ACCEPT INSTALLATION OF NEW VINYL COMPOSITE TILE SPECIFIED. (DO NOT GRIND OR REMOVE EXISTING TILE IN FRAGMENTS. REMOVE IN AS LARGE SECTIONS AS POSSIBLE.)
10. REMOVE AND DISPOSE OF ALL CLOSET METAL BI-FOLD DOORS, SHELVES, AND RODS. REPAIR DAMAGED SURFACES AND ADJUST OPENINGS. SUPPLY AND INSTALL NEW SLIDING CLOSET DOORS, SHELVES, AND CLOTHES RODS. REMOVE AND REPLACE EXISTING LINEN CLOSET SHELVES.
11. EXISTING EXTERIOR WINDOWS ARE TO BE REMOVED AND REPLACED AS PER "W" SERIES DRAWINGS. EXISTING PRECAST TERRAZZO WINDOW SILLS ARE TO REMAIN. PROTECT FROM DAMAGE DURING WINDOW REPLACEMENT. AFTER WINDOW REPLACEMENT REPAIR ALL DAMAGE TO WINDOW JAMBS/RETURNS TO ACCEPT FINAL FINISH.
12. REPAIR ALL DAMAGED WALLS AND CEILINGS THROUGHOUT THE SUITE (IE. HOLES, CRACKS, BULGES, SCRAPES, SPALLING PLASTER, PEELING PAINT, ETC.) TO LEVEL SATISFACTORY TO ACCEPT FINISH PAINT.
13. THROUGHOUT THE SUITE, REMOVE DAMAGED WOOD FLOORING (IE. LOOSE, WATER-DAMAGED, ETC.). REPLACE WITH NEW WOOD PARQUET FLOORING AND FINISH TO MATCH AREAS OF WOOD FLOORING TO REMAIN.
14. ALL EXISTING UNDAMAGED INTERIOR DOORS AND FRAMES TO REMAIN. PREP. DOORS AND REPAINT TO MATCH ADJACENT SURFACES. REPAIR HARDWARE AS REQUIRED TO ALLOW PROPER OPERATION. REMOVE AND REPLACE DAMAGED OR MISSING DOORS AS REQUIRED AND PAINT TO MATCH ADJACENT SURFACES.
15. REFER TO DOOR SCHEDULE ON DRAWING A5.1 FOR SUITE ENTRY DOORS.
16. REVIEW LOUVRE DOORS AT ENTRANCES TO KITCHENS. IF BROKEN OR MISSING SUPPLY AND INSTALL NEW WOOD LOUVRE DOORS TO MATCH EXISTING. ENSURE ALL LOUVRE DOORS ARE OPERATIONAL.

TYPICAL CORRIDOR UPGRADES

1. REMOVE AND DISPOSE OF EXISTING CARPET AND TRANSITION STRIPS. SUPPLY AND INSTALL NEW CARPETING AS SPECIFIED.
2. EXISTING WOOD BASEBOARDS TO REMAIN. REPAIR AS REQUIRED TO ACCEPT FINAL PAINT. REPLACE ANY MISSING SECTIONS OF BASEBOARD TO MATCH EXISTING.
3. EXISTING TILE AT ELEVATOR LOBBY TO REMAIN. REPAIR AND REPLACE MISSING TILES USING SALVAGED CERAMIC TILES FROM GROUND FLOOR EXISTING VESTIBULE WALL.
4. EXISTING MILK BOXES ADJACENT TO SUITE ENTRANCES ARE TO REMAIN. PERMANENTLY SECURE MILK BOX DOORS IN THE CLOSED POSITION WITH TAMPERPROOF SCREWS AND PREPARE DOORS TO ACCEPT FINISH PAINT. THIS WORK TO BE CARRIED OUT AT ALL SUITE LOCATIONS INCLUDING THE GROUND FLOOR.
5. CORRIDOR WALLS TO HAVE PLASTER SKIM COAT APPLIED OVER EXISTING STIPPLE TEXTURE FOR THEIR FULL LENGTH AND EXPOSED HEIGHT. WALLS TO BE FINISHED TO A LEVEL ACCEPTABLE TO ALLOW PROPER INSTALLATION OF NEW VINYL WALLCOVERING.
6. CO-ORDINATE WORK WITH THAT OF MECHANICAL AND ELECTRICAL TRADES.
7. REFER TO DOOR SCHEDULE FOR UPGRADES TO DOOR HARDWARE.

TYPICAL STAIR UPGRADES

1. REMOVE & DISPOSE OF EXISTING WALL MOUNTED HANDRAILS. SUPPLY AND INSTALL NEW WALL MOUNTED RAILS AS NOTED ON DETAIL 4/A4.1. PAINT EXPOSED METAL AREAS.
2. EXISTING GUARDS AND BALUSTRADES TO REMAIN. UPGRADE TO MEET CURRENT ONTARIO BUILDING CODE STANDARDS BY RETRO FITTING WITH INFILL PANELS AS AS SHOWN DETAIL 4/A4.1 PAINT ALL RAILS, POSTS, INFILL PANELS ETC.
3. SUPPLY AND INSTALL NON-SLIP INSERTS AT ALL STAIR TREADS AS SHOWN ON DETAIL 4/A4.1
4. REMOVE AND DISPOSE OF EXIST. WOOD BASEBOARDS. SUPPLY AND INSTALL NEW WOOD BASEBOARDS 4" HIGH TO PROFILE SIMILAR TO SUB-BASEMENT CORRIDOR BASE SHOWN ON DETAIL 7/A4.1
5. PATCH AND REPAIR PLASTER WALL AND CEILINGS (IE. HOLES, CRACKS, SPALLING AREAS ETC.) TO A LEVEL ACCEPTABLE TO ALLOW PAINT FINISH TO INDUSTRY STANDARDS. REMOVE ALL LOOSE AND SPALLING PLASTER PRIOR TO PATCH WORK.
6. AT THE 7TH AND 9TH FLOOR STAIR LEVELS, GRIND FLOOR IN THE AREA OF THE DOOR TO ALLOW THE EXISTING DOORS TO SWING FREELY WITHOUT BINDING ON THE FLOOR.
7. PREPARE FLOORS (IE. LANDINGS, TREADS, RISERS ETC.) TO ACCEPT FINAL PAINT FINISH.
8. AFTER COMPLETION OF ALL WORK IN EXISTING STAIRWELLS SUPPLY AND INSTALL SIGNS (RAISED NUMERALS) AT LANDING LEVEL TO INDICATE THE SPECIFIC FLOORS REQUIREMENTS:
   a. MOUNT PERMANENTLY ON STAIR SIDE OF WALL AT LATCH SIDE OF DOORS.
   b. NOT LESS THAN 1½" HIGH AND RAISED APPROX. 1/32" ABOVE THE SURFACE.
   c. LOCATE 5'-0" ABOVE FINISH FLOOR AND NOT MORE THAN 8" FROM THE DOOR.
   d. BLACK ARABIC NUMERALS AS FOLLOWS:

   SB, BK, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, PH.

(2 / A1.3) NOTES
N/A

GENERAL NOTES

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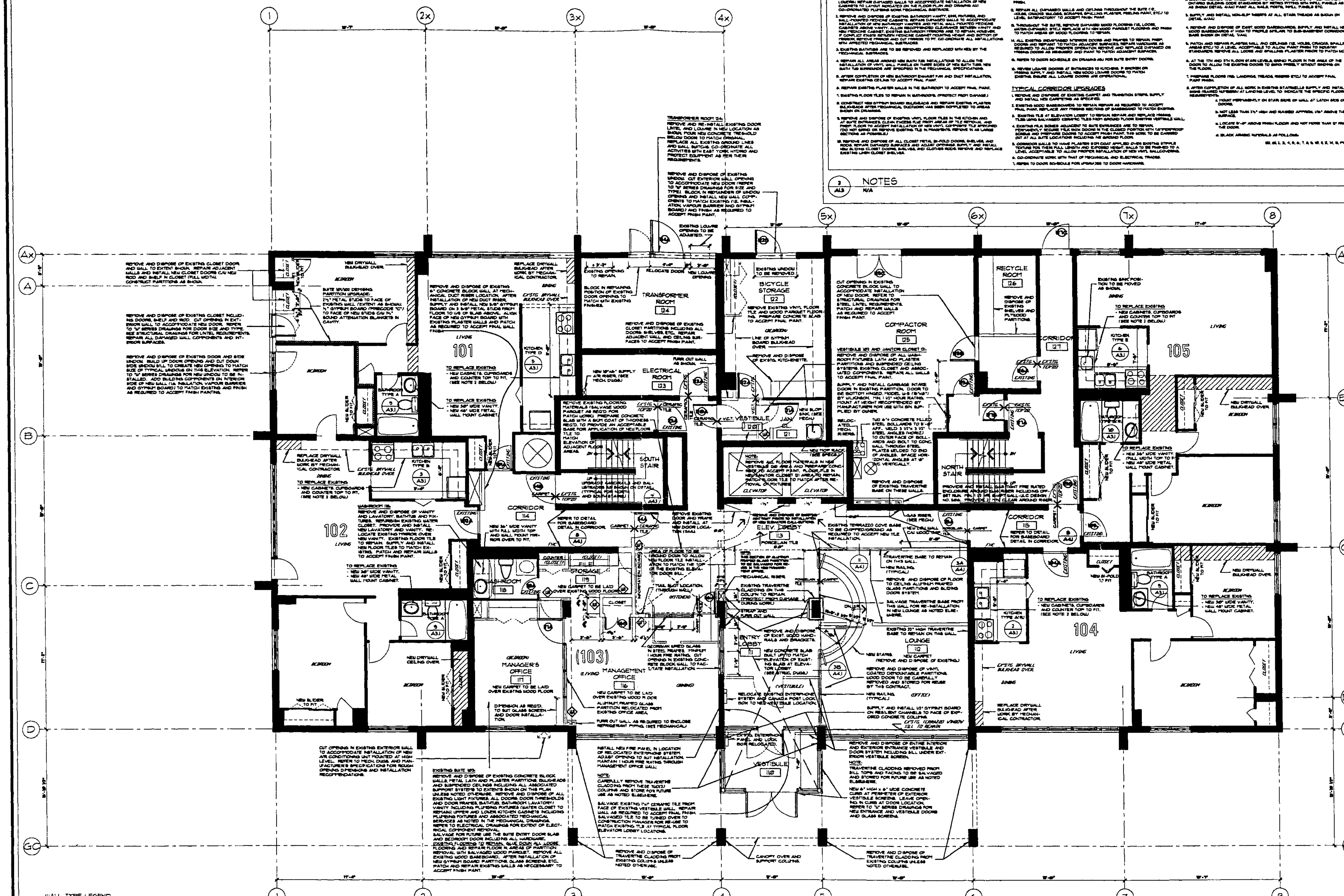
2. VERIFY ALL DIMENSIONS.
3. DO NOT SCALE DRAWINGS.
4. CHECK DRAWINGS AGAINST SPECIFICATIONS.
5. USE THE LATEST REVISED DRAWINGS ONLY.
6. REPORT ANY DISCREPANCIES, DISCOVERED ERRORS OR OMISSIONS TO THE ARCHITECT BEFORE PROCEEDING.
7. DRAWINGS AND SPECIFICATIONS ARE THE PROPERTY OF THE ARCHITECT, AND MUST BE RETURNED UPON COMPLETION OF WORK.

LEGEND

(solid heavy line)	EXISTING STRUCTURE, WALL OR PARTITION TO REMAIN.
(dashed double line)	EXISTING WALL OR PARTITION TO BE REMOVED.
(double line)	NEW WALL OR PARTITION.
BEDROOM	SLANTED TEXT REFERS TO EXISTING ITEMS TO REMAIN.
(BEDROOM)	SLANTED TEXT IN BRACKETS REFERS TO EXISTING ITEMS TO BE REMOVED.
NEW WORK	NEW ITEMS OR WORK INDICATED BY STANDARD UPRIGHT TEXT.



NOTE 1:
THIS DRAWING PRODUCED FROM BASE INFORMATION PROVIDED BY:
MORRISON HERSHFIELD LIMITED
CONSULTING ENGINEERS
(CAD FILE: GROUND.DWG 10-26-95)

NOTE 2:
KITCHEN DIMENSIONS INDICATED ARE APPROXIMATE AVERAGES ONLY. CONTRACTOR RESPONSIBLE FOR MEASURING EACH KITCHEN PRIOR TO FABRICATION OF CABINETRY TO ENSURE PROPER FIT.

(1 / A1.3) GROUND FLOOR PLAN
1/4"=1'-0"

Revision/Issue	Date		Initial
0	JUNE 4, '96	ISSUED FOR TENDER AND PERMIT	T.K.

This drawing is to be used for the following purposes: | Not to be used for construction unless signed by the architect

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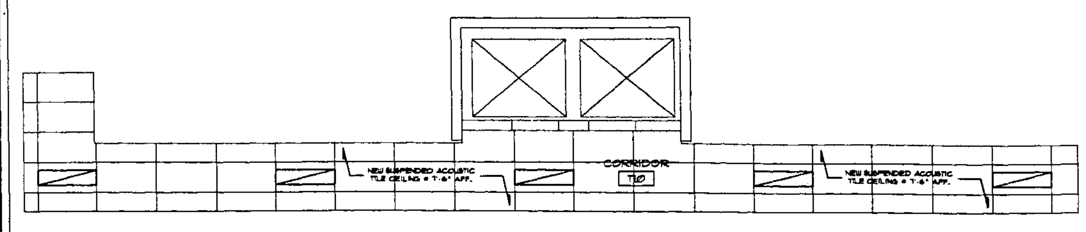
Client: Broadview Avenue Co-op

Project: BROADVIEW AVENUE CO-OP RENOVATIONS
1050 Broadview Avenue
Toronto, Ontario

Date	Drawn	Checked
JUNE, 1996	CC/RW/MK	T.K.

Drawing Title: GROUND FLOOR PLAN

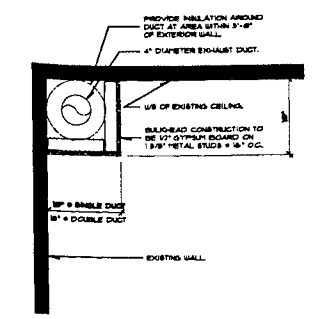
Scale	Drawing No.	Revision
AS INDICATED	A1.3	0
Project No. 95055	BR-A103A	



NOTE:

1. FOR FLOORS 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13 & 14: INSTALL NEW ACOUSTIC TILE CEILING UNDER EXISTING LATH & PLASTER CEILINGS AFTER ELECTRICAL & MECHANICAL INSTALLATIONS. EXISTING CEILINGS ARE AT 8'-0" AFF.
2. FOR FLOORS 6 & 8: REMOVE & DISPOSE OF EXISTING LATH & PLASTER CEILINGS AND INSTALL ACOUSTIC TILE CEILING AFTER ELECTRICAL & MECHANICAL INSTALLATIONS. EXISTING CEILINGS ARE AT 7'-6" AFF.
3. PRIOR TO FINAL INSTALLATION OF CORRIDOR CEILINGS SEAL ALL PENETRATIONS TO MAINTAIN REQUIRED 1 HOUR FIRE SEPERATION.

2 / A1.4 — TYPICAL FLOOR CORRIDOR REFLECTED CEILING PLAN — 1/4"=1'-0"



3 / A1.4 — TYPICAL BULKHEAD DETAIL — 1 1/2"=1'-0"

4 / A1.4 — NOTES — N/A

TYPICAL SUITE UPGRADES

TYPICAL CORRIDOR UPGRADES

TYPICAL STAIR UPGRADES

GENERAL NOTES

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LEGEND

(solid heavy line)	EXISTING STRUCTURE, WALL OR PARTITION TO REMAIN.
(double line)	EXISTING WALL OR PARTITION TO BE REMOVED.
(double line)	NEW WALL OR PARTITION.
BEDROOM	SLANTED TEXT REFERS TO EXISTING ITEMS TO REMAIN.
(BEDROOM)	SLANTED TEXT IN BRACKETS REFERS TO EXISTING ITEMS TO BE REMOVED.
NEW WORK	NEW ITEMS OR WORK INDICATED BY STANDARD UPRIGHT TEXT.

Revision/Issue	Date		Initial
		ISSUED FOR TENDER & PERMIT	

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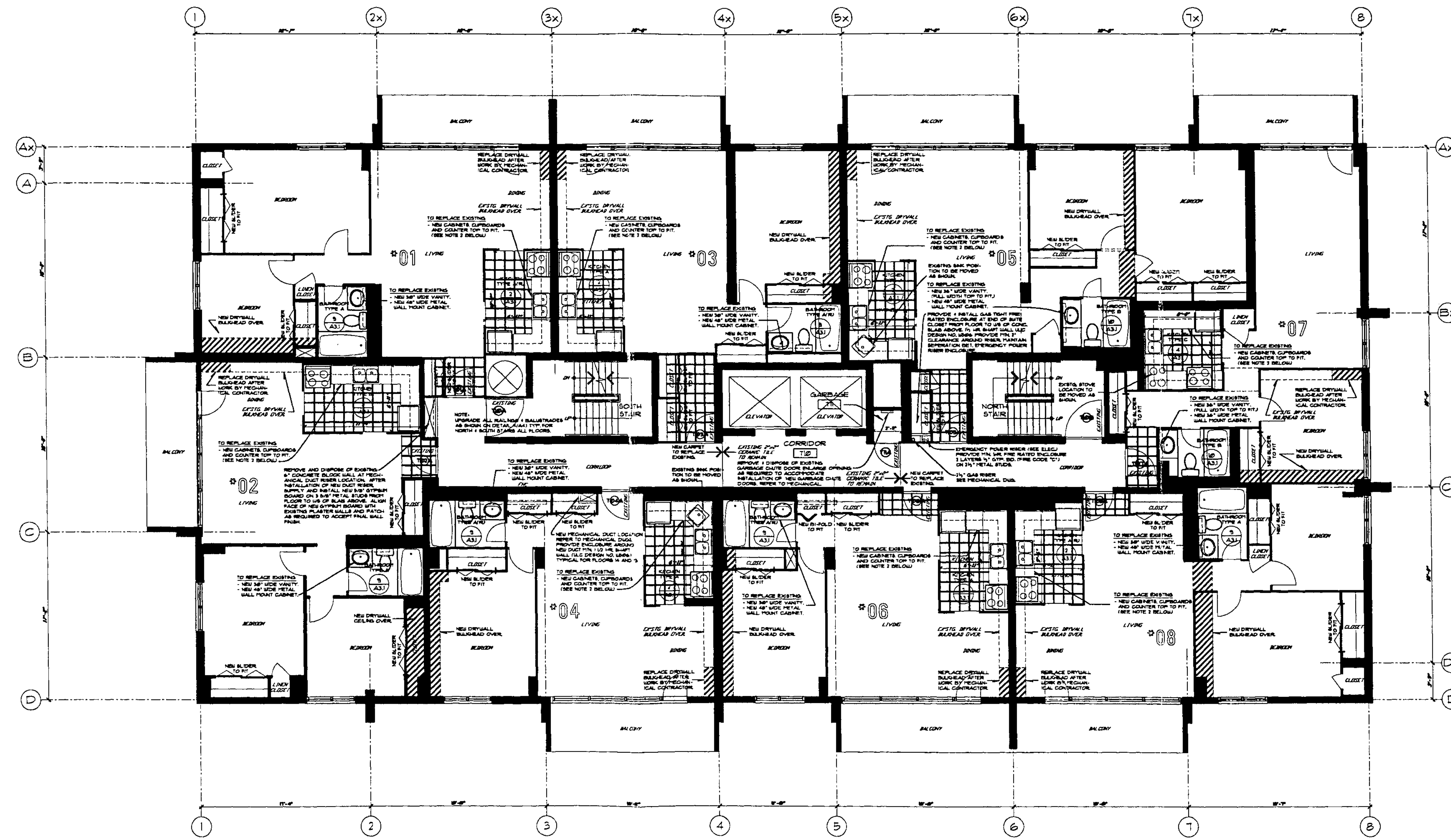

NOTE 1: THIS DRAWING PRODUCED FROM BASE INFORMATION PROVIDED BY: MORRISON HERSHFIELD LIMITED CONSULTING ENGINEERS (CAD FILE: TYPICAL.DWG 95-05-30)

NOTE 2: KITCHEN DIMENSIONS INDICATED ARE APPROXIMATE AVERAGES ONLY. CONTRACTOR RESPONSIBLE FOR MEASURING EACH KITCHEN PRIOR TO FABRICATION OF CABINETRY TO ENSURE PROPER FIT.

1 / A1.4 — TYPICAL FLOOR PLAN — 1/4"=1'-0"

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JBM LANDSCAPE ARCHITECT
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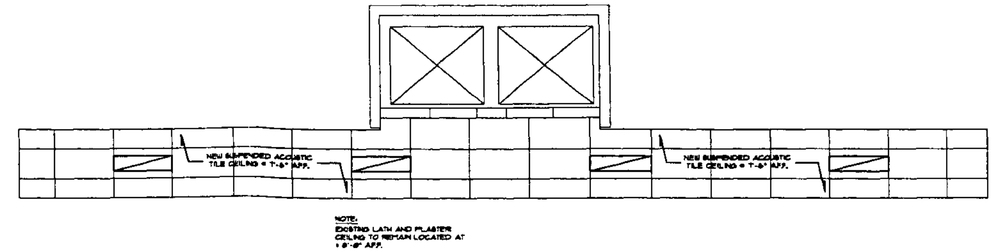
Client: Broadview Avenue Co-op

Project: BROADVIEW AVENUE CO-OP RENOVATIONS, 1050 Broadview Avenue, Toronto, Ontario

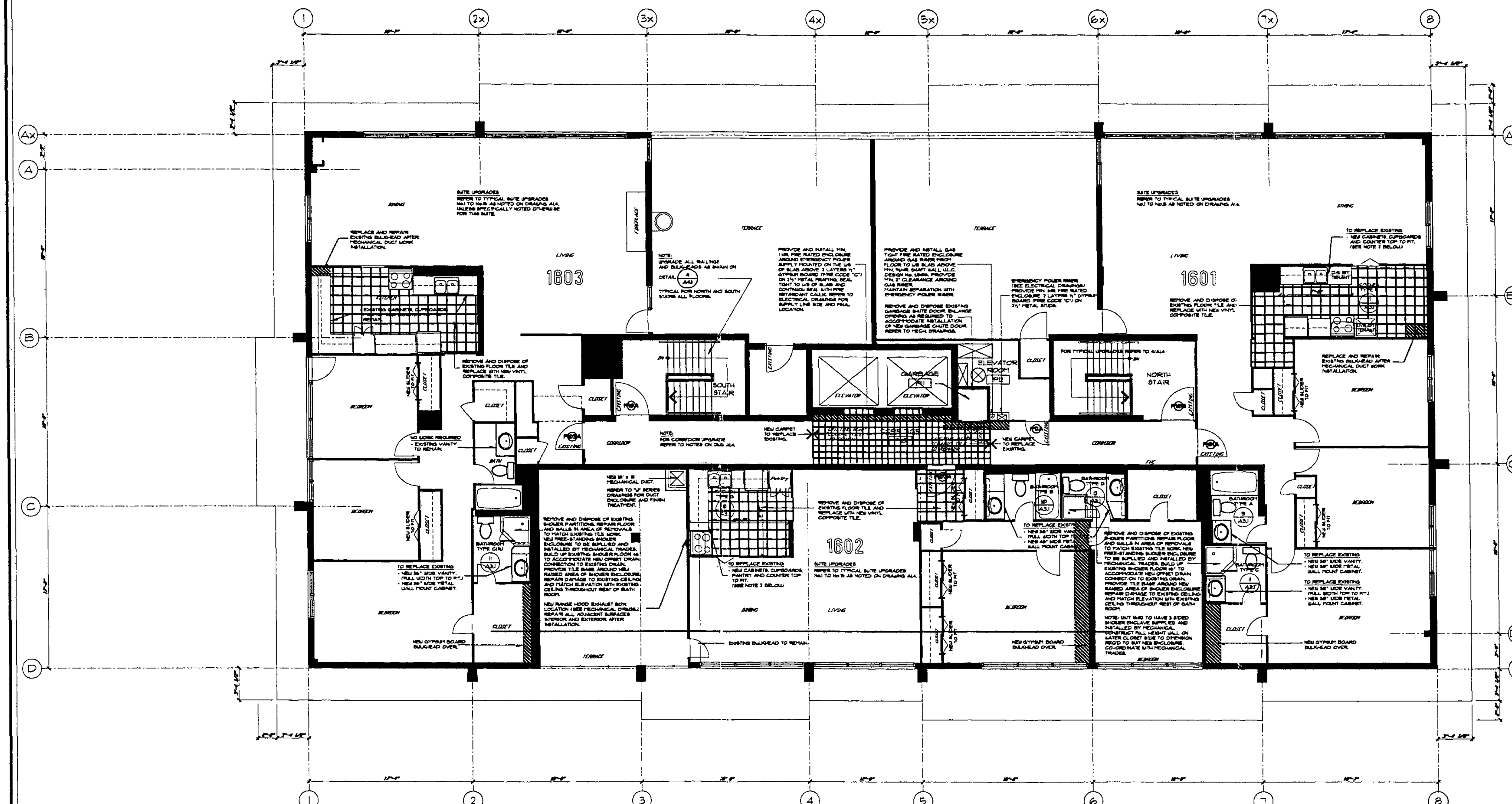
Date	Drawn	Checked
MAY 31, 19/96	C.C.	T.K.

Drawing Title: TYPICAL FLOOR PLAN

Scale	Drawing No	Revision
AS INDICATED	A1.4	0
Project No: 95055	BR-A104A	



2 / A1.5 PENTHOUSE FLOOR CORRIDOR REFLECTED CEILING PLAN
1/4"=1'-0"



1 / A1.5 PENTHOUSE FLOOR PLAN
1/4"=1'-0"

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LEGEND

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(double line)	NEW WALL OR PARTITION.
BEDROOM	SLANTED TEXT REFERS TO EXISTING ITEMS TO REMAIN.
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Revision/Issue	Date		Initials
0	JUNE 4, '96	ISSUED FOR TENDER AND PERMIT	T.K.

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Client: Broadview Avenue Co-op

Project: BROADVIEW AVENUE CO-OP RENOVATIONS
1050 Broadview Avenue
Toronto Ontario

Date	Drawn	Checked
FEB. 1996	RWMK - Cadd	T.K.

Drawing Title: PENTHOUSE FLOOR PLAN

Scale	Drawing No	Revision
1/4" = 1'-0"	A1.5	0
Project No: 95056	BR-A105A	

2.2 Reasons for Retrofit of Exterior Walls

The need for rehabilitation arose from the poor condition of the facility and the desires of the recently formed Co-operative Board of Directors. This Board commissioned a Rehabilitation Plan, which was completed by Enerplan Inc. and submitted on March 1995. The study presented prioritized recommendations for repair, and rough budget estimates. The criteria for repair included issues of: health and safety, compliance to current codes and Ministry of Housing mandatory guidelines; reduction of long-term maintenance costs; structural integrity, etc.

The west face of the building is exposed to wind from the Don Valley and complaints of air and water leakage are particularly prevalent in suites on this side of the building. Among many recommendations, this study recommended replacement of the existing windows and doors, and installation of an exterior insulation system (including an air barrier) on the masonry walls. Justification for these particular recommendations was based on a) bringing the building into a compliance with MOH requirements, and b) a cost-benefit analysis which calculated an annual heating cost reduction of $6,456.20 attributable to the application of RSI 3.27 thermal resistance to the walls alone.

2.3 Description and Rationale of Retrofit Plans

The complete exterior of the building will be overclad, the windows will be replaced, the balcony slabs will be repaired and the railings replaced. The project is being sequentially tendered to minimize occupant disruption with the parking garage repairs, the fire code retrofit and the balcony repairs proceeding in the initial tender packages.

The original intent of the exterior cladding retrofit was to comply with the MOH guideline requirement of RSI 3.27. Of the specified alternatives, an External Insulation Finish System (EIFS), manufactured by Dryvit Systems Canada Inc. was the successful bid. For budget reasons, the projecting concrete slabs (at roof and penthouse levels) and the projecting concrete wing walks (on all elevations) will not be insulated - therefore these areas and the concrete balcony slabs will continue to act as thermal bridges and detract from the envelope's thermal performance. On the positive side, the entire masonry wall and floor slab edges will be brought within the insulation envelope, significantly reducing thermal bridges (and fewer reports of "cold floor"); water penetration, and air leakage.

The EIFS system being applied comprises an acrylic stucco finish with reinforcing mesh; 75 mm thick expanded polystyrene insulation; adhesively applied to a water-resistant air barrier, which is trowelled-on to the face of the brick wall. Intersections of the trowelled-on air barrier and other elements will be sealed with self-adhering rubber modified bitumen sheet membrane tape and/or sealant (where necessary).

Dryvit's' "Infinity MD" system is being used which features a more elastic, upgraded finish, but more importantly includes a means of draining moisture from within the applied EIFS overcladding. Vertical drainage channels are cut into the face of the insulation panels, which allows drainage of any penetrating moisture from the plane between the (cold side) of the insulation and the face of the air barrier. This moisture is vented to the exterior face at regular intervals. Though not promoted as a pressure-equalized rainscreen system, the venting of these channels to the atmosphere will also provide some localized pressure-equalization of the EIFS system.

The EIFS overcladding within the balconies (i.e. immediately below and beside the balcony windows) is not moisture drained. This decision was made for cost saving, and in recognition that the overhanging balcony slabs provides some additional protection from exposure to the weather.

As previously mentioned, projecting concrete thermal bridges are not to be covered. These areas aside, the nominal thermal resistance of the typical overclad wall will be RSI 3, when the existing insulation is included. This falls just short of the MHO guideline, but is the maximum that can be attained within the budget limitations.

Site conditions have already dictated a change in the detailing of the EIFS system from the original design documents. The interface between the new retrofit windows and the applied EIFS system has been a focus of concern since it has been established that these junctures are particularly sensitive, and the cause of wide spread problems in North America. The existing single glazed units are being replaces with thicker frames, and these frames are being set in at different depths: for example balcony units are being set back from the face of the brickwork face approximately 75 mm to better fit the balcony door threshold and other factors, whereas the punched units are set in only 25 mm (to provide a better seal and more interior stool space).

At the time of this writing these details are still being finalized. The current proposal has solid wood blocking the length of the window sill, membrane flashing tape adhered on the face of the brickwork and lapping over onto the blocking. The prefabricated sheetmetal sill is secured on top of this. Membrane tape is also applied to the wall opening all around the punched window opening, and the gap between the frame and the tape filled with injected urethane foam, and the intersection of the window frame and the EIFS lamina is to be caulked at the exterior face.

Since the trowel applied air barrier of the EIFS system cannot adhere to the membrane tape, the EIFS installers will trowel up to and abut the membrane installed with the windows. Once the liquid applied material is dry, a second band of membrane tape will be installed to overlap this butt joint.

2.4 Current Status of Retrofit Work

The overall rehabilitation program is being undertaken under several separate contracts. Substantial repairs to the parking garage have been completed, as well as modifications to the elevators. Rooftop safety tieback anchors, required for suspended stage work, were installed before the balcony repairs were begun. Repairs to all of the other elements, excluding roofing and the application of the EIFS overcladding, are now underway.

Major delays have occurred in repairs to the exposed concrete, primarily balcony slabs but also including exposed floor slab edges and projecting wing walls and slab projections. Causes for the delay are primarily: the amount of deterioration is much greater (more than twice) beyond predictions, and difficulties with the contractor in charge of this work. Half of the balconies have been repaired, and complete concrete repair is forecast for July of 1997. The guards (handrails) will be delivered to site by April, and should be installed by August of 1997.

Window replacement began in suites in March 1997. The windows are being installed in each suite at the same time as that suite's interior finishes, cabinetry and fixtures are being upgraded.

EIFS application is scheduled to begin on June 30, 1997 and continue for 18 weeks. The proposed order of attack is: 3 weeks on the South Elevation; 6 weeks on the West; 3 weeks North; and 6 weeks East.

3. MONITORING PROTOCOL

3.1 Research Issues

Moisture draining or rainscreen EIFS systems are a relatively new concept. The primary air, weather and vapour barrier is inside the insulation and finish lamina. With this approach, the penetration of some water past the exterior finish is accepted because provision is made for draining it down and out of the wall system.

The system that is being installed at 1050 Broadview is a fully adhered system with the substrate being the existing masonry. The air, weather and vapour barrier is a Dryvit proprietary, trowel on material that is applied to the masonry (after any voids are parged). An alternate approach is to create a new surface to apply the membrane to by installing a new substrate on whatever furring is required to provide an even surface. Some would argue that creating a complete plane of air tightness is more reliably achieved with a new substrate. Others argue that the direct application of a mastic is better because it eliminates a lateral air flow path.

The specific technical issues which warrant investigation and monitoring include the following questions.

1. Does water frequently penetrate the exterior finish? If so does it dry?
2. Do materials inside the air barrier remain protected from external water entry?
3. Is there potential for condensation on the inside boundary of the air barrier or materials just inside of it?
4. Is there potential for condensation on the inside boundary of the exterior finish or insulation just inside of it?
5. Is the full value of the installed insulation being obtained? Does moisture collection and retention affect thermal performance?
6. Is the wall reasonably air tight?. Is the designed air barrier carrying pressures due to wind and stack forces?
7. Is the temperature of the masonry element stabilized?

3.2 Overview of Monitoring Plans

The intent of the monitoring program is to collect data to establish the performance of the retrofit wall system with respect to heat, air and moisture flow. More specifically, the following data will be collected.

Outdoor environment including;

- air temperature,
- relative humidity,
- wind speed and direction,
- rainfall on a horizontal surface,
- rain impacting on vertical surfaces.

Monitoring sites have been chosen, considering access and construction sequence, to obtain information from different levels on two facades on the building. At each site the following information will be collected.

Indoor environment at each site including;

- indoor air temperature,
- relative humidity at each wall monitoring site.

Temperature through the retrofit wall system including;

- interior surface,
- inside of masonry,
- between masonry and new air barrier
- between new insulation and exterior finish lamina

Pressure difference carried by elements of the wall including;

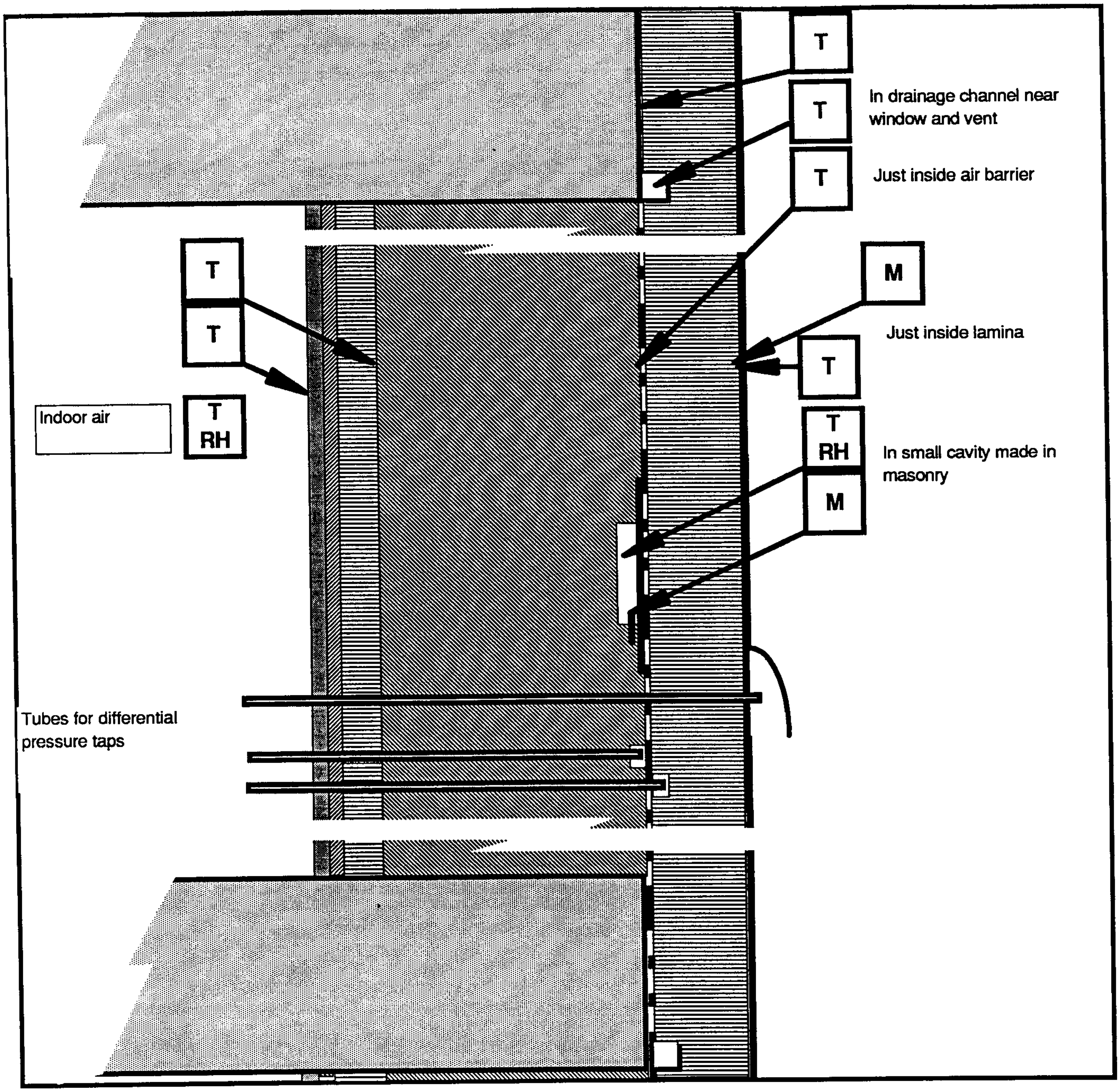
- across existing masonry wall and interior finishes,
- across new air barrier,
- across total wall system.

Relative humidity at the interface of the masonry and new air barrier.

Moisture content at key locations including;

- between masonry and new air barrier,
- between new insulation and exterior finish lamina.

Figure 3.1 Sensor Location Plan



T RH	**Temperature and RH probe for ACR**
T	**Thermocouple**
M	**Moisture pins/Duff gauge**

3.3 Monitoring Locations

We propose to install two data collection packages for the full monitoring period; one at the 14th floor, west exposure and an other at the second floor, west exposure. A third data acquisition packages will be provided and these will be moved between three other monitoring stations to obtain representative seasonal data. The location proposed for these three locations are the 14th floor east exposure, the 14th north east exposure and 2nd floor east exposure.

The sensors for all stations will be installed at the time of construction.

3.4 Instrumentation

The primary data collection method is the use of ACR data loggers. These are self contained devices capable of recording various types of data at preprogrammed intervals between 8 seconds to once a week. Site visits will be made at regular intervals in order to download the data to a computer. The loggers which will be used on this project are;

- SR-002 loggers which read one temperature and relative humidity and, with an EH-020 remote probe, will read a second temperature and RH,
- SR-007 loggers which are capable of reading voltage and/or current outputs from devices such as pressure transducers,
- SR-006+ loggers which have an internal thermistor and provision for up to seven thermocouples.
- SR-009 loggers which will record switch closures from the tipping type rain collector bucket which will be located on the exterior wall.

3.4.1 Wall Stations

Figure 3.1 is sketch showing the proposed placement of sensors in relation to the wall and floor construction. The wall data collection packages consist of:

- ACR SR-006+ to read and record up to seven remote thermocouples.
- Power supply and three Enercorp WGT-420-010B pressure transducers. These instruments are 4 to 20mA devices with a range of ± 1"WG (±250Pa).
- ACR-SR-007 to read voltage output of the three pressure transducers
- ACR -SR-002 to read indoor temperature and RH and remote temperature and RH in wall.
- ACR EH-020 remote probe to measure temperature and RH at the interface of the masonry and new air barrier. This will connected to the SR-002 logger.
- Each of the permanent wall stations will also include rainfall sensors mounted on the exterior wall. Texas Electronics TR-525C tipping bucket sensors have been modified to measure water collected in custom manufactured collector to be mounted vertically on the wall. Water entering the vertical orifice of the collector will trigger the tipping bucket mechanism which will cause the closure of a magnetic switch which will be recorded as a pulse on the SR-009 data logger.

One prototype package has been for testing assembled. The ACR units will be set to read and record all data on 10 minute intervals.

Duff Gauges or moisture pins will be placed in critical materials for manual reading of moisture content during site visits.

One temperature sensor at each monitoring station will be located inside the exterior insulation plane near a drain. Our experience has shown that the Temperature Index/Pressure Difference analysis is most sensitive if the sensor is located on the air leakage path. One can actually use the data to estimate air leakage rate.

3.4.2 Weather Station

A Davis *Weather Monitor II* weather station with optional rain gauge has been purchased for the project and will be mounted on the roof. This collects and stores weather data internally for later down load to a computer by direct connection or modem. This instrument will measure interior and exterior temperatures, interior and exterior humidity, wind speed and direction, rainfall on a horizontal surface and barometric pressure. The interval between storage events can be set to periods between 1 minute and 2 hours but since onboard storage capacity is limited short intervals require frequent down loads. We are proposing to store on hourly intervals which will provide 60 days of storage capacity. The hourly data record contains the following information.

- Date
- Time
- Average *Inside Temperature* during the interval
- Average *Outside Temperature* during the interval
- Highest *Outside Temperature* during the interval
- Lowest *Outside Temperature* during the interval
- Barometric Pressure at time of save
- *Inside Humidity* at time of save
- *Outside Humidity* at time of save
- Average *Wind Speed* during the interval
- Highest *Wind Speed* during the interval
- Dominant Wind Direction during the interval
- *Rainfall* during the interval

The average values are based on readings taken every 30 seconds during the one hour save interval.

3.5 Site Visit Activities and Schedule

Site visits on approximately monthly intervals are planned. During these, data will be down loaded, visual inspections of the building and instruments will be carried out and the calibration of sensors checked. Moisture readings will be taken and instrument packages slated for relocation will be moved. The ACR recorded data will be transferred to EXCEL files and processed to provide analyzed data after each site visit. In this way data anomalies can be identified and followed up on.

3.6 Data Analysis Methods

Analysis techniques will be based on the QBS document supplied with the RFP and the paper in Appendix B. In general, it will be based examining all sequential data and detailed analysis of 2-3 week segments of typical seasonal data. Performance will be compared to expected results from an ideal wall system and design expectations. The evaluation will be based on responding to the questions and issues identified in the Section 3.1.

4. SCHEDULE

Installation of the EIFS system is dependent on the completion of balcony repairs and window installations. Balcony and exterior concrete repairs have been completed on the east and south elevations and window installation are now in progress. EIFS installation is scheduled to start on June 30th, 1997. Work will begin on the south and west elevations of the building and proceed to the other faces when balcony repairs are completed. All EIFS installation work is expected to be completed by November, 1997. Installation of sensors in the walls will be coordinated with EIFS installations. The two continuous monitoring locations are on the west side which is exposed to winds from the Don Valley. We expect that these installations will be completed by August. The other, "periodic", monitoring sites are on the north and east exposure which will be completed after the west face.

Monitoring will commence by November and continue for 12 months under the terms of this contract.

Mark D. Lawton, P.Eng.
Principal

MORRISON HERSHFIELD

APPENDIX B

Weather data for January-March'98.

Appendix B. Weather data for January-March'98.

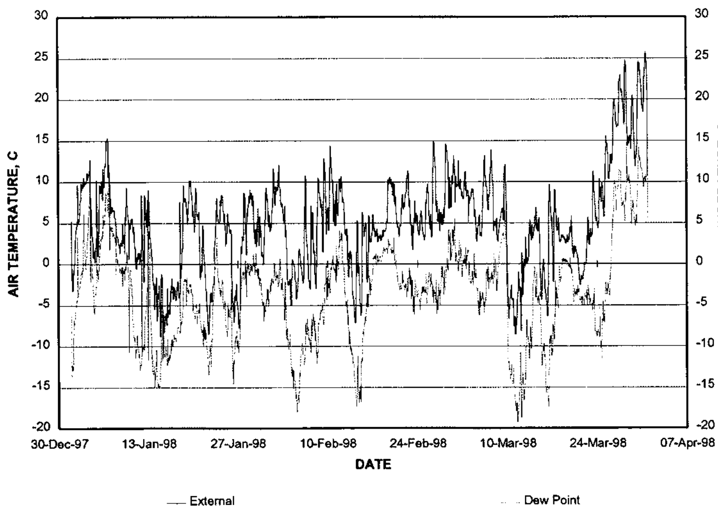


Figure B1. External air and dew point temperatures.

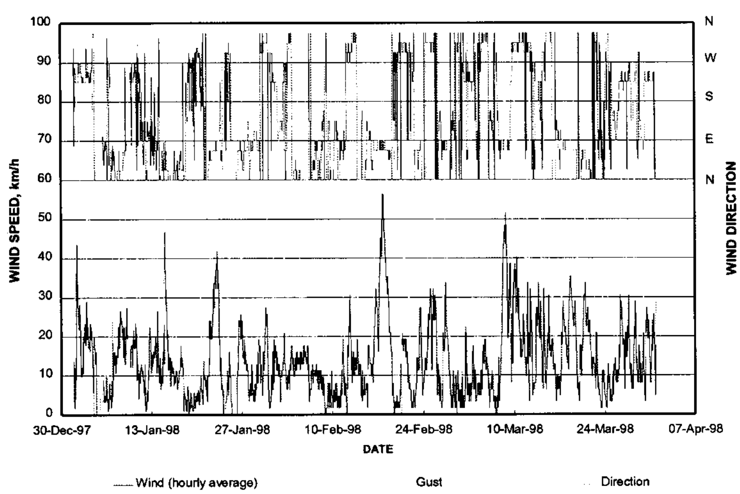


Figure B2. Wind speed, peak gust and direction.

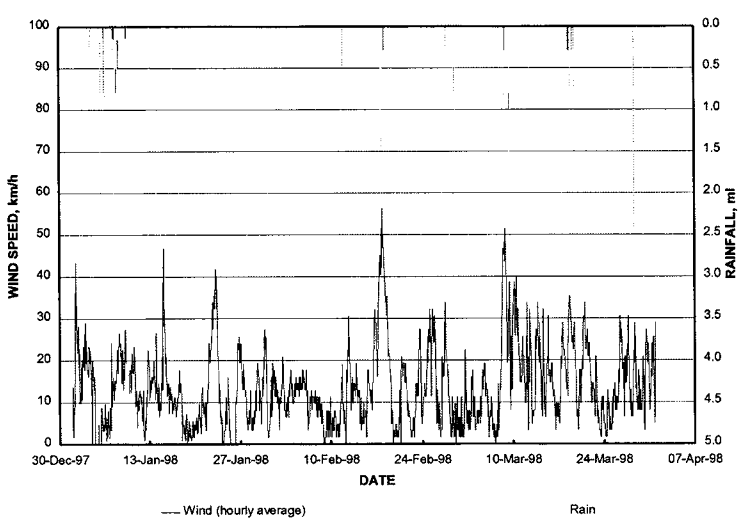


Figure B3. Rain fall and wind speed.

APPENDIX C

Measured moisture content for all suites.

Appendix C. Measured moisture content for all suites.

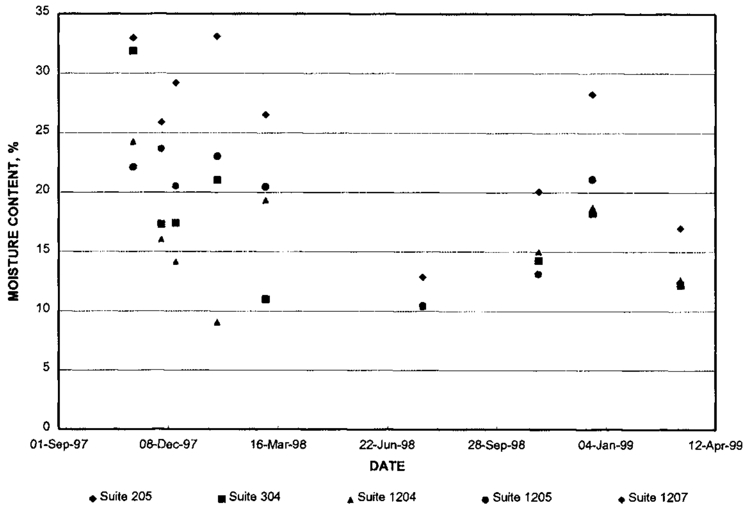


Figure C1. Moisture content measured by Duff gauges to the interior of the lamina for all suites.

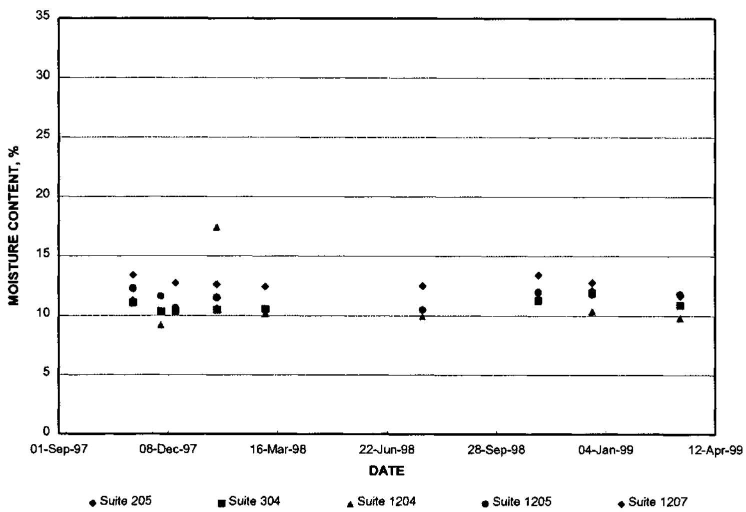


Figure C2. Moisture content measured by Duff gauges to the interior of the drainage plane for all suites.

APPENDIX D

Measured surface temperatures and calculated cavity dew point temperatures.

Appendix D. Measured surface temperatures and calculated cavity dew point temperatures.

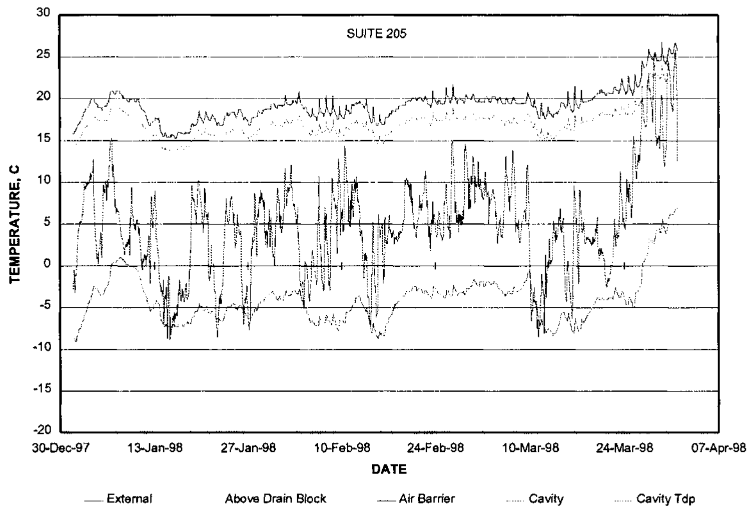


Figure D1. Measured surface temperatures and calculated cavity dew point temperature at Suite 205.

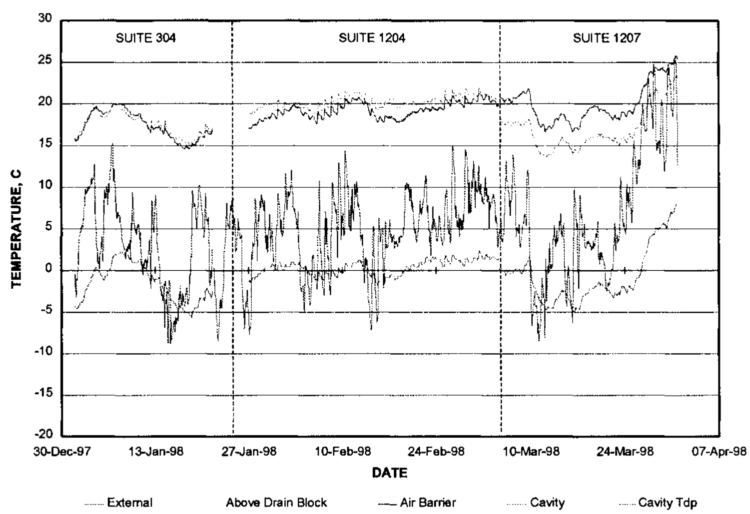


Figure D2. Measured surface temperatures and calculated cavity dew point temperature at Suites 304, 1204 and 1207. Note the large wind-induced dip in 'Above Drain Block' temperature at Suite 1204 in mid-February.

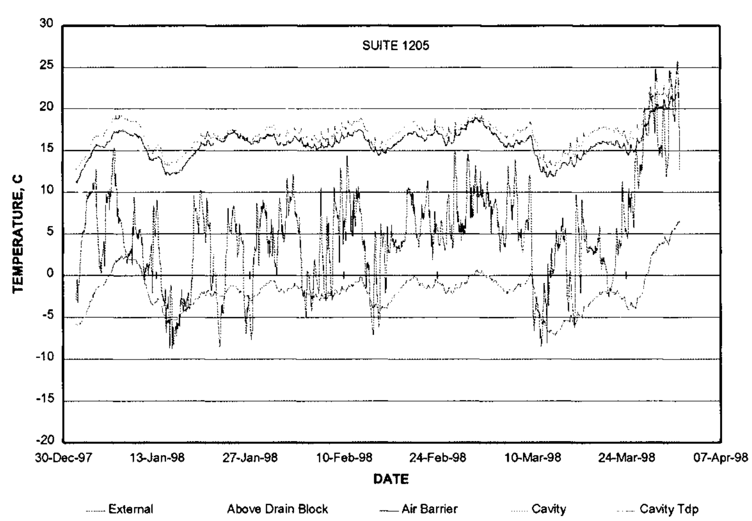


Figure D3. Measured surface temperatures and calculated cavity dew point temperature at Suite 1205.

APPENDIX E

Temperature index calculated for air barrier at various suites.

Appendix E. Temperature index calculated for air barrier at various suites.

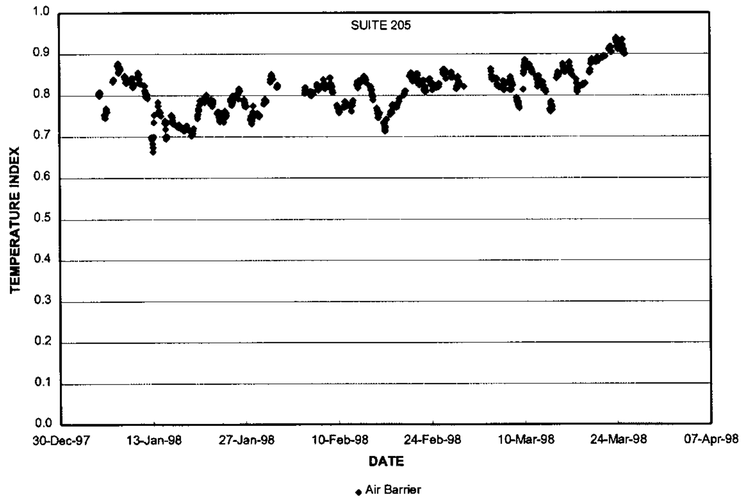


Figure E1. Temperature index calculated for air barrier at Suite 205.

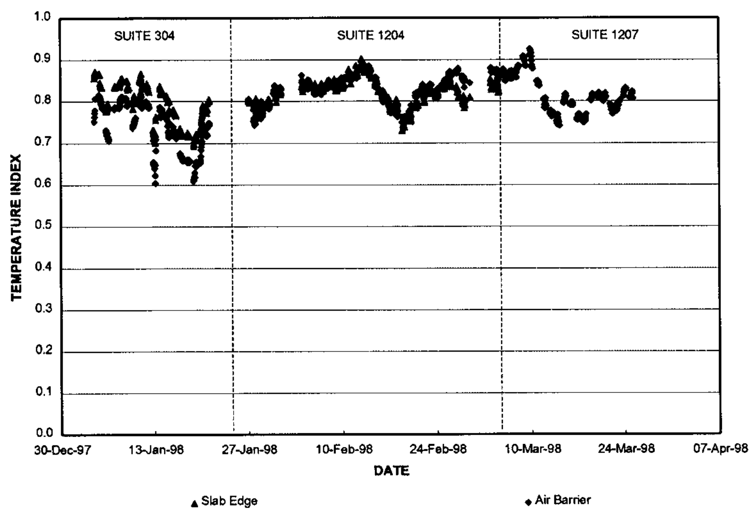


Figure E2. Temperature index calculated for air barriers at Suites 304, 1204 and 1207.

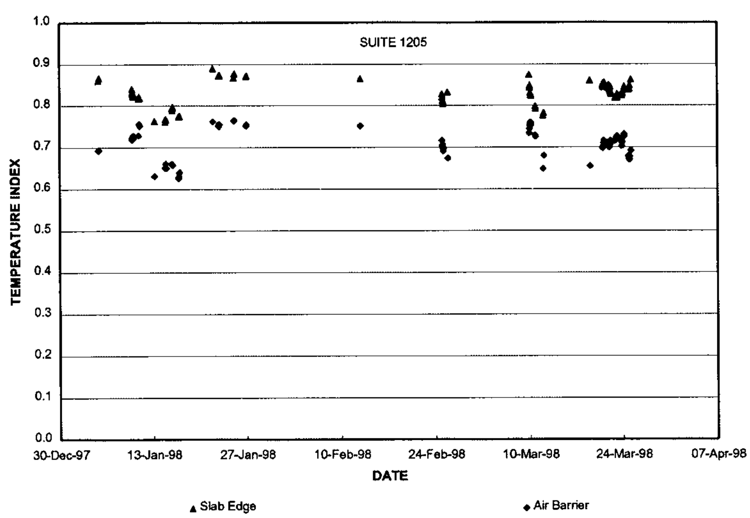


Figure E3. Temperature index calculated for air barrier at Suite 1205.

APPENDIX F

Pressure difference measured at various suites

Appendix F. Pressure difference measured at various suites.

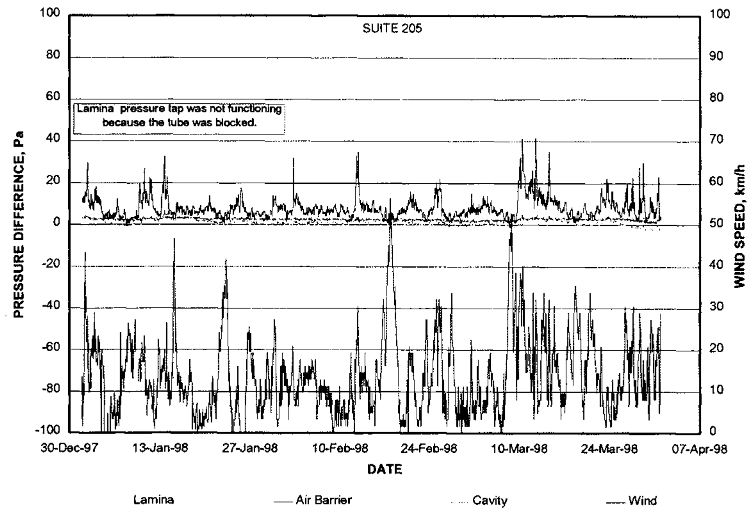


Figure F1. Pressure difference measured at Suite 205 (positive pressure difference is an infiltration condition). Note that the 'lamina' pressure tap was not functioning.

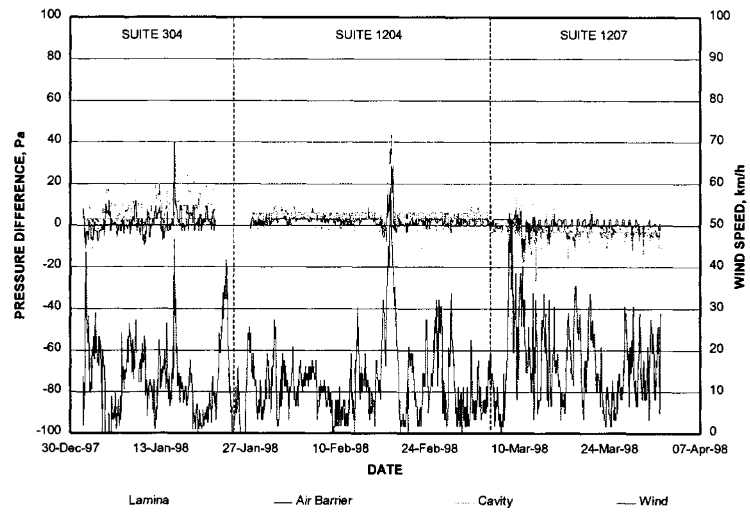


Figure F2. Pressure difference measured at Suites 304, 1204 and 1207 (positive pressure difference is an infiltration condition).

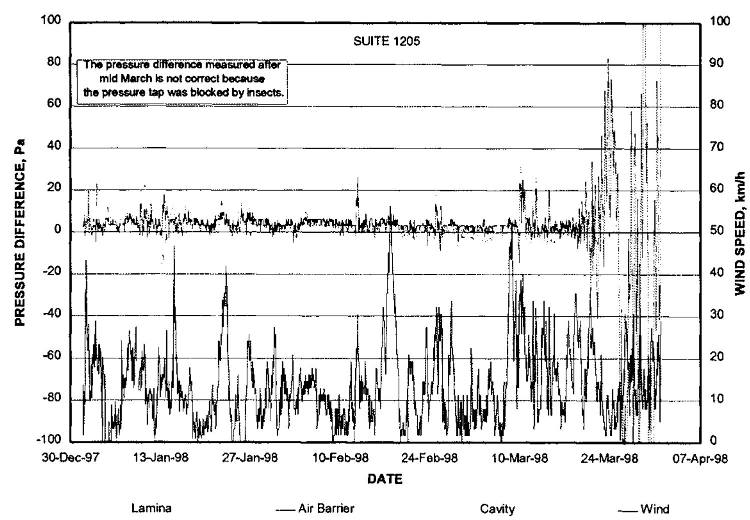


Figure F3. Pressure difference measured at Suite 1205 (positive pressure difference is an infiltration condition). Note that all pressure taps ceased to function accurately around the middle of March.