RESEARCH REPORT

ENVELOPE DRYING RATES ANALYSIS

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Envelope Drying Rates Experiment
Final Report

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Abstract

The design and construction of building envelopes must be based on the assumption that some moisture will accumulate in the wall assembly, during construction and during the life of the building. Construction practices for multi-unit wood frame residential buildings in the coastal area of British Columbia, Canada are changing in response to a large number of envelope failures experienced in the period from 1985 to 1999. The new design approach includes the use of enhanced deflection and a drained cavity. While this approach will manage a large portion of the exterior moisture load, designs may also need to incorporate enhanced drying capabilities. A research program conducted at Forintek Canada Corp.'s western lab in Vancouver, Canada has evaluated the relative drying rates of wall assemblies under controlled laboratory conditions. The research ranks test wall panels in terms of their relative drying capacities, identifies potential wall locations at greater risk of slow drying (thus requiring enhanced material durability) and derives baseline data which can be used to improve parametric models of wall performance.

Results from the first group of 12 wall panels tested indicate that all the panels dried. There was a substantial range in drying rates, with ratios up to 3 times for comparable wall panels with and without a cavity. The major influences on drying rates were:

- The presence of a wide cavity (the 19 mm cavity performed better that either the 10 mm cavity or the 0 mm cavity)
- The choice of venting (top and bottom venting had a marginal improvement over venting at the bottom only).
- The choice of sheathing (plywood sheathed panels dried faster than OSB sheathed panels, partly because the plywood started out at a higher moisture content),

There was no clear indication that the choice of moisture barrier material had a substantial influence on drying.

The results of the test were compared to predictions made by CMHC's WALLDRY model. The WALLDRY parametric model demonstrated good predictive capabilities in terms of overall drying trends.

The first EDRA test has set a "benchmark" drying rate of 1600 ng/Pa.sec.m2 for the effective permeance of the 'best drying' panel in the test group.

Keywords: Walls, Drying, Durability, Parametric models.

Summary

The Envelope Drying Rates Analysis (EDRA) experiment tested the drying rates of 12 wall panels under controlled laboratory conditions. The experiment was set up as part of the program of the Building Envelope Research Consortium (BERC), an industry/government consortium formed by Canada Mortgage and Housing Corporation to solve the leaky condominium problem in British Columbia. In 1998 the BERC produced a Best Practice Guide for Wood Frame Envelopes in the Coastal Climate of British Columbia [1]. The central design thesis of this guide is that walls have to manage moisture by incorporating four features, Deflection, Drainage, Drying and Durability (the 4-D's) [14]. Deflection, drainage and durability have been studied, but relatively little attention has been paid to the effect of wall design on drying rates.

Adoption of the Best Practices Guide by the building industry is expected to result in a near total elimination of moisture ingress in wall cavities. However, small defects or the deterioration of a building's deflection and drainage system can still cause moisture to accumulate if drying does not occur. We need to know to what extent drying can contribute to our overall moisture management plan for wall designs. At present there are no data on the drying rates of various wall assemblies in the BC coastal climate.

Computer models have been developed to predict the hygrothermal performance of walls. These models require adequate lab and field data to verify their predictions. This experiment was designed to produce detailed data on the laboratory drying of test wall panels. These data will assist with developing our understanding of how walls dry and help other researchers validate their computer models.

The experiment set out 8 questions to answer from the data (see below). These involve the overall drying rates of the 12 assemblies, relative differences in drying for different wall component systems, and the effects on drying by varying cavity widths, and venting arrangements. A rating system using effective permeance was created. Finally, simulated solar effects on wall panel drying were also investigated.

Ultimately, designers, building officials and builders want to know from the experiment if walls dry and whether there are any differences in the drying rates among wall designs.

Twelve wall panel designs, including ten stucco-clad and two wood-clad wall panels were tested. Nine of the wall panels used OSB sheathing and three used plywood sheathing. Nine of the wall panels used conventional 30-minute building paper (Haltex 30) and three used Spun Bonded Polyolefin (Tyvek). Three of the panels used conventional stucco cladding applied directly over the sheathing protection membrane to the sheathing. Seven panels used stucco on a variety of strapped cavities. One wood-clad panel used the direct applied method and one wood-clad panel incorporated a vented cavity behind the siding. The wall panels with vented cavities used a variety of venting and cavity size arrangements to examine what differences these would make.

Wood is a highly variable material. In order to ensure that the panels had the same wood wetting and drying characteristics, special consideration was given to the selection of all wood materials. All OSB used was from the same bundle. All plywood used was from the same bundle. All 38 x 89 framing lumber were from the same bundle. Studs were sorted by wetting and drying capabilities and evenly distributed between the panels. All the stucco was mixed and applied by the same tradesmen from the same materials at the same time. All building paper used was supplied by a single manufacturer. One

brand of spun bonded polyolefin was used. The insulation was all of the same brand and thermal resistance value.

Once the test panels were constructed, with instrumentation and cladding applied, they were ready for wetting. The test panels were wetted in a consistent manner by placing the uninsulated panels, studs down, in a shallow tank of water for ten days. The water level was below the sheathing. The studs absorbed water consistently from panel to panel reaching an average moisture content of 30%. The OSB sheathing reached an average 22% moisture content, while the plywood sheathing was higher at 35% moisture content.

Immediately after wetting, the panels were insulated and finished on their interior side. They were then installed in the wall of the test chamber with the exterior cladding facing into the chamber. The interior finish of the test panels faced the lab space.

The interior of the chamber was conditioned to steady state conditions typical of a winter drying day in Vancouver B.C. (70% RH at 5°C). The exterior of the chamber (laboratory space) was conditioned to simulate the interior of a home or apartment (40% RH at 21°C). An air pressure differential of 0 Pa was maintained between the interior of the chamber and the lab. In order to simulate the ambient air conditions on the exterior of a wall, air was blown across the exterior face of the test panels. This resulted in a 1 to 5 Pa pressure differential between the bottom and top of each panel.

The panels went through two phases of testing; Phase 1 without simulated solar radiation for 1500 hours and Phase 2 with simulated solar radiation for 2000 hours. The solar effect was simulated with heat lamps inside the chamber, radiating on the panel cladding. The solar effect was adjusted to simulate the exposure of a north east wall in Vancouver B.C., in the period from January 10th to February 10th.

The wall panels in the EDRA experiment were subjected to steady state temperature and relative humidity laboratory conditions. Readers are cautioned not to extrapolate the lab results beyond the conditions under which the testing took place. This experiment does not simulate drying in the field. The experiment did not attempt to model air leakage (infiltration or exfiltration) normally resulting from stack effect or wind loads on walls in the field, therefore it is not within the scope of this experiment to comment on how this would affect drying performance. The experiment did not model water ingress. The panels in this test were purposely loaded with moisture in excess of 30% moisture content to study their drying. During the test the panels were not re-wetted. This does not simulate wetting in the field. The 30% moisture content level was chosen to ensure uniform wetting. Designing drying capacity in walls does not mean that walls in the field should be designed or constructed to allow them to become wet on the assumption that they could dry to a safe level. According to the National Building Code of Canada, the moisture content of lumber in wood frame construction should not be more than 19% at the time of installation. Correspondingly for wood sheathing, it is usually assumed that the moisture content in service should not exceed 16% to be considered dry. Drying capability should only be used as a mechanism to remove unintended moisture.

The answers to the eight questions posed by the experiment are summarized as follows.

1. When specimen wall panels are wetted to > 25% moisture content, do they ever dry out?

Drying occurred in all panels. The moisture content in the studs at the time of installation averaged 29% and at the time of removal averaged 12%. There were no test panels in which all locations in all components dried to below 19% moisture content by the end of the test, (1500 hrs in Phase 1 and 2000 hrs in Phase 2). The proposition that panels would dry into the chamber was confirmed by the test and some panels had substantial moisture loss. However, the drying was not uniform over all components of the panels and these slower drying areas would be at risk of decay if the test were to continue indefinitely. No decay was found after the 3500 hours of testing.

2. Under test conditions and without re-wetting, how long do they take to dry out?

The framing dried on average to below 19%, in less than 500 hours in both phases. The OSB and the plywood sheathing generally stayed above 19% MC to beyond the end of the test, in both phases.

On closer examination, the 38 mm x 89 mm framing, made up of studs and double plates, can be divided into 2 zones; Zone 1, more than 20 mm from the sheathing and Zone 2, within 20 mm of the sheathing. Zone 1 dried to below 19% within 500 hours. Zone 2 dried slower than Zone 1. In some panels Zone 2 in the upper part of the stud dried to below 19% within 1000 hours. However in the bottom 600 mm of the stud, Zone 2 generally stayed above 19% for over 1500 hours in Phase 1 and over 2000 hours in Phase 2.

Panels with OSB sheathing started Phase 1 with average sheathing MC in the 20% to 29% range and finished the test with average MC in the 18% to 28% range. Most panels had a drop in average sheathing MC of 1% to 3%. (The exceptions were Panel 1, which had an increase of 1% and Panels 2 and 8 , which had a drop in average MC of 8%.) Only the wood-clad panels numbers 8 and 9 had final average moisture contents in their sheathing below 19%. All OSB-sheathed panels had spot MC readings in the sheathing of over 30% in the lower areas of the panels.

The plywood-sheathed panels started Phase 1 with higher average sheathing MC than the OSB sheathed panels. The range was 26% to 37% average MC. The plywood-sheathed panels ended Phase 1 with two panels showing no change in average sheathing MC and one panel having an 8% increase in average sheathing MC.

In Phase 2, the panels with OSB sheathing started at a lower MC in the sheathing than in the framing. The average MC in the OSB sheathing started at 23% and rose during the test to finish at 34%. The plywood-sheathed panels started Phase 2 with an average MC in the sheathing of 37%. The plywood-sheathed panels with vented cavities had a decline in sheathing MC and ended the test with average sheathing MC of 27% and 31%. The plywood-sheathed panel with no cavity had an increase in sheathing MC and ended the test with an average sheathing MC of 42%.

Time of drying is an important consideration in assessing effectiveness of a design. Parts of the panels (especially the surface of the studs) dried to below 19% in under 100 hours. This result allows us to speculate that a panel that can be designed such that it will dry rapidly in all areas and could therefore tolerate repeated minor wetting.

However, the slow drying which occurred in other parts of the panels indicates that the designs as tested would not be effective at preventing decay by drying if allowed to be wetted to the test levels. These wall types have to rely on a more perfect deflection and drainage system as well as proper construction quality management practices to avoid trapping moisture during construction.

3. Are some test wall panels drying faster than others? What is the variation between the test panels?

1) Panels with cavities dried faster than comparable panels without cavities.
2) Panels with plywood sheathing dried faster than comparable panels with OSB sheathing.
3) There was no substantial difference in the drying rates of panels with building paper vs. panels with spun bonded polyolefin.
4) Panels with top and bottom vented cavities dried faster than comparable panels with bottom only vented cavities
5) Panels with wood siding dried faster than comparable panels with stucco cladding in Phase 1 however this trend was reversed in Phase 2 (with solar).

4. Does the drainage cavity width affect drying? By how much?

Three cavity widths (depth from cladding to sheathing protection membrane) were tested, 0 mm 10 mm and 19 mm. Cavity width appears to be a major determinant in affecting drying rates. In both phases panels with large cavity widths dried faster than panels with small cavity widths.

5. Does the vent area affect drying? By how much?

There was no specific test for vent size or shape variations. All vented panels had equivalent vent height, length and shape. The difference between the panels was in the width of the cavity and the presence or absence of top and bottom vents. The width of the cavity affects the vent areas to the extent that the entry area is restricted by the cavity width. Top and bottom venting had a small impact on drying. Panels vented at the top and bottom dried faster than panels vented at the bottom only. The magnitude of the difference was small.

6. What is the correlation between the predicted (by prior runs of CMHC's WALLDRY computer model) moisture movement within the framing lumber and the sheathing and the actual moisture movement?

It was not within the scope of this project to validate computer models. However, we have made some observations on the apparent consistencies and deviations between the predictions of the test using WALLDRY [7] and the data gathered from EDRA . The WALLDRY model was reasonably accurate in its predictions of change in moisture levels in the framing and in the sheathing. The computer model of the outer shell of the stud was consistent with the EDRA data for Zone 1 of the framing (more than 20mm from the sheathing). The model prediction of the inner core of the stud was consistent with the EDRA data for Zone 2 of the framing (within 20mm of the sheathing). The WALLDRY model prediction of the outer layer of the sheathing was consistent with the EDRA data for average sheathing moisture content. The model prediction for the inner layer of the sheathing deviated from the EDRA data. The WALLDRY model predicted lower rates of overall moisture (mass) loss than was found in EDRA over the 1500 hours of the EDRA test (Phase 1).

7. Compare the calculated permeance of the test wall panels to their effective permeance.

The overall drying rates of panels can perhaps, best be summed up by looking at their effective permeance, in ng/Pa·sec·m^2. The effective permeance of the panels was measured for both the non-solar and solar phases. Calculations in this report were based on total moisture loss over the test period. The calculated permeances ranged from 314 ng/Pa·sec·m^2 to 556 ng/Pa·sec·m^2. We expected that the effective permeances would be greater in the case of vented cavity panels. This turned out to be correct. The effective permeances in Phase 2 ranged from 324 ng/Pa·sec·m^2 to 1663 ng/Pa·sec·m^2 or from 1.0 to 3.6

times the calculated permeance. Panel 11, with stucco, on a 19 mm cavity, bottom vented, with building paper, on plywood sheathing had the highest effective permeance at 1663 ng/Pa·sec·m^2. This provides us with a "benchmark" effective permeance to better with future tests.

8. Compare the effect of the solar simulation on wall panels.

The simulated solar condition produced a difference in drying between Phase 1 and Phase 2. The effective permeances were higher with the solar effect. Additionally, there were differences in the final moisture distribution in the sheathing between Phase 1 and Phase 2.

At the end of 1500 hours in Phase 1 both the OSB and plywood sheathing remained close to the same moisture content as at the start of the test. In Phase 2, after 2000 hours, (with the solar effect) the moisture content of the OSB in panels with vented cavities had risen an average of 11% while the moisture content in the plywood-sheathed panels with vented cavities had dropped an average of 7.5%.

Part of the differences between the phases could be attributed to the differential in the start points of the moisture content in the framing and the sheathing. The plywood sheathing had 13% higher moisture content than the OSB sheathing at the start of Phase 2. The faster drying rates of the plywood-sheathed panels with cavities may be partly due to the extra moisture in the sheathing being in the best location to dry to the exterior.

The data suggests that moisture was leaving the framing and migrating into the plywood and OSB sheathing. All panels lost moisture during the test. However, in Phase 2 moisture was not leaving the OSB sheathing at the rate it was entering in either the vented or the unvented panels. In the plywood-sheathed panels with vented cavities, the data suggests that moisture was leaving the plywood sheathing at a greater rate than it was entering. Both of these plywood-sheathed panels ended the test with a lower sheathing moisture content (27% and 31%) than they started the test (39% and 34%). Without replicates these results are not statistically significant. However, the differences do suggest that cavity venting of plywood-sheathed panels (starting at >35%MC) has a substantial effect on drying but that the same venting has less of an effect on drying for OSB-sheathed panels (starting at >25%MC).

Conclusions:

The EDRA experiment was able to demonstrate differences in the drying rates of test panels under experimental conditions depending on their materials, drainage cavity and venting. The arrangement of materials and cavity width matters substantially in drying. Differences in drying rates between comparable cavity and non-cavity panels can be as much as a factor of 3.

The sheathing material was the other major factor affecting drying rates in the 12 panels tested. Plywood-sheathed panels absorbed more moisture initially and dried faster than comparable OSB-sheathed panels. Both OSB and plywood-sheathed panels ended the test with moisture levels above 19% in the sheathing. The portions of the studs within 20 mm of the sheathing were slow in drying and in most cases remained above 20% moisture content at the end of both phases of the experiment.

All panels experienced slower drying in the bottom 200 mm of the panel. This could be a result of the higher mass of wood, combined with the impermeable through-cavity flashing located next to the bottom plate. The test set-up based this flashing location on a common field application. It is noteworthy that this cavity flashing could be located elsewhere in the cavity and this might enhance drying at the base of a wall. Alternatively, the flashing could be made of a high vapour permeance material.

The WALLDRY computer model is a useful tool for predicting overall trends and moisture content levels in drying.

The EDRA experiment has produced a "benchmark" data set for 12 panels and a target effective permeance number of 1663 $ng/Pa \cdot sec \cdot m^2$. These provide us with relevant numbers to measure other systems against.

Recommendations:

- Testing should be done on all other commonly used cladding systems, especially where there is some potential for higher effective permeances being obtained. One such system is vinyl siding with supplementary perforated laps.
- Further effort should be made to correlate the computer models with the lab experience. The other models available might provide a better predictive capability than WALLDRY.
- Large concentrations of lumber in the wall present special challenges to rapid drying. Testing should be done on common construction details such as walls at rim joists and headers. This will be especially valuable where the testing incorporates holes in the sheathing to increase the permeance at these areas.
- Induced air-flow in the cavity is one of the possible mechanisms to accelerate drying. Further testing should be done to evaluate wind effects on cavities.
- The EDRA experiment should be evaluated by the Canadian Construction Materials Centre at NRC-IRC and by the American Society for Testing and Materials for the development of a standard laboratory test method to rate the drying performance of wall systems.
- The results of these tests are too limited to make sweeping changes to the current best practice documents. However, the tests show that drying can be an important component of moisture management. Therefore the Best Practice Guide for Wood Frame Construction in the Coastal Climate of British Columbia should focus its revisions first on:
  - Encouraging drainage cavities of not less than 19mm with top and bottom venting.
  - Top venting could be very small and shielded to prevent water entry.
  - Impermeable membranes around openings should be reduced to the minimum required to maintain an effective drainage plane.
  - Impermeable through-cavity flashings should be located away from high concentrations of framing where possible.

Résumé

La présente étude a porté sur l’analyse des taux d’assèchement de l’enveloppe 12 panneaux muraux mis à l’essai en laboratoire dans des conditions normalisées. Ces expériences faisaient partie d’un programme élaboré par le Consortium de recherche sur l'enveloppe du bâtiment (CREB), un partenariat entre les secteurs public et privé établi par la Société canadienne d'hypothèques et de logement afin de trouver des solutions aux problèmes d’infiltrations d’eau dans des logements en copropriété en Colombie-Britannique. En 1998, le CREB a produit un guide des règles de l’art intitulé *Enveloppe des bâtiments à ossature de bois dans le climat littoral de la Colombie-Britannique*[1]. Dans le guide, on avance comme thèse centrale que les murs extérieurs doivent comporter quatre caractéristiques afin de gérer efficacement l’humidité : la déviation, l’évacuation, l’assèchement et la durabilité [14]. Jusqu’à maintenant, on ne s’est penché que sur trois de ces caractéristiques, soit la déviation, l’évacuation et la durabilité, mais peu d’efforts ont été déployés pour déterminer les effets découlant de la conception du mur sur son taux d’assèchement.

Compte tenu de la mise en pratique des recommandations du Guide des règles de l’art par les gens de l’industrie, on estime que la majorité des problèmes d’infiltration d’eau dans les cavités murales seront presque entièrement éliminés. Toutefois, des défauts mineurs ou une détérioration du système de déviation ou d’évacuation d’un bâtiment pourrait causer une accumulation d’humidité lorsque la cavité ne s’assèche pas. Il est impératif de connaître dans quelle mesure l’assèchement pourrait contribuer à la gestion globale de l’humidité pour les assemblages muraux. À l’heure actuelle, on ne sait rien des taux d’assèchement des différents assemblages de mur dans le climat littoral de la C.-B.

On a mis au point des modèles informatiques qui prévoient la performance hygrométrique des murs. Ces modèles requièrent toutefois des données obtenues en laboratoire et sur le terrain afin de vérifier leurs prévisions. La recherche dont il est question ici a été conçue de manière à fournir des données de laboratoire relatives à l’assèchement de panneaux muraux d’essai. À l’aide de ces données, on comprendra mieux le phénomène de l’assèchement des murs, et d’autres chercheurs pourront les utiliser pour valider leurs modèles informatiques.

Les chercheurs ont formulé huit questions auxquelles les résultats de la recherche devaient aider à répondre (voir ci-dessous). Celles-ci traitent du taux d’assèchement global des douze assemblages muraux, des différences relatives dans l’assèchement des différents composants des murs et des effets sur l’assèchement de la largeur des cavités ainsi que de leur mode de ventilation. Pour attribuer une cote de rendement aux murs, on a eu recours à la perméance effective. Enfin, les effets sur l’assèchement des murs d’un rayonnement solaire simulé ont été étudiés.

En bout de ligne, ce qui intéresse les concepteurs, les constructeurs et les agents du bâtiment c’est de savoir si les murs peuvent s’assécher et s’il existe des différences entre les taux d’assèchement des différents assemblages muraux.

Douze panneaux muraux ont été mis à l’essai, dont dix étaient revêtus d’un parement en stucco et deux d’un parement de bois. Neuf panneaux d’essai comportaient un revêtement intermédiaire d’OSB et trois présentaient un revêtement intermédiaire de contreplaqué. Neuf échantillons étaient revêtus d’un papier de construction de 30 min. (Haltex 30) tandis que les trois autres possédaient une membrane de polyoléfine filée-liée (Tyvek). Sur trois panneaux, on a employé un parement de stucco classique qui a été posé directement sur la membrane de protection déjà installée sur le revêtement intermédiaire. Sept

panneaux comportaient un parement de stucco posé sur des murs dont on faisait varier la largeur de la cavité à l’aide de fourrures. Un panneau était doté d’un parement en bois posé directement sur le papier de revêtement et un autre comportait une cavité ventilée à l’arrière du parement de bois. Les panneaux muraux munis de cavités ventilées affichaient différents concepts de ventilation et des dimensions variées pour permettre aux chercheurs de découvrir tout changement dans la performance résultant de ces modifications.

Le bois est un matériau dont les caractéristiques varient grandement. Afin de s’assurer que les panneaux avaient tous les mêmes caractéristiques relativement au mouillage et à l’assèchement du bois, on a choisi avec soin les matériaux en bois. Les panneaux OSB employés provenaient tous du même ballot. C’était aussi le cas pour le contreplaqué et le bois d’œuvre de 38 x 89 mm. Les poteaux d’ossature ont été classés suivant leur capacité de mouillage et d’assèchement, et répartis uniformément entre les panneaux. Tout le stucco a été malaxé et appliqué par les mêmes ouvriers à partir des mêmes matériaux et en même temps. Tout le papier de construction a été fourni par un seul fabricant, tout comme pour la pellicule d’oléfine filée-liée. Tous les matériaux isolants provenaient d’un seul manufacturier et affichaient une résistance thermique identique.

Une fois les panneaux d’essai construits, dotés d’instruments de mesure et revêtus de leur parement, on les a mouillés d’une manière uniforme. Pour ce faire, on a déposé les panneaux non isolés, côté non revêtu vers le bas, dans un bac peu profond rempli d’eau, et ce, pendant une période de dix jours. Le niveau d’eau n’atteignait pas le revêtement intermédiaire. Les poteaux de tous les panneaux d’essai ont absorbé l’eau uniformément pour atteindre une teneur en eau de 30 %. Le revêtement intermédiaire d’OSB et celui en contreplaqué ont atteint une teneur en eau moyenne de 22 % et de 35 % respectivement.

Aussitôt après avoir été mouillés, les panneaux ont été isolés et revêtus du côté intérieur. Ils ont ensuite été installés dans le cadre de l’enceinte d’essai, le parement extérieur donnant sur l’intérieur de l’enceinte. Le revêtement de finition intérieur des panneaux faisait donc face au laboratoire.

Des conditions uniformes de température et d’humidité relative (HR), typiques d’une journée d’hiver à Vancouver, ont été maintenues à l’intérieur de l’enceinte d’essai (5 ^{o}C et 70 % d’HR). L’extérieur de l’enceinte d’essai (l’aire du laboratoire) a été maintenu à des conditions devant simuler l’intérieur d’une maison ou d’un appartement, soit 21 ^{o}C et 40 % d’HR. Les chercheurs ont maintenu une différence de pression de 0 Pa entre l’intérieur de l’enceinte et le laboratoire. Afin de simuler les conditions ambiantes du côté extérieur des murs, on a soufflé de l’air sur toute la surface extérieure des panneaux d’essai. Cet écoulement d’air a produit une différence de pression qui s’échelonnait de 1 à 5 Pa sur la hauteur de chacun des panneaux.

Les panneaux ont été soumis à deux séries d’essais : ceux de la phase 1, sans rayonnement solaire simulé pendant 1 500 heures et ceux de la phase 2 comportant un rayonnement solaire simulé pendant 2 000 heures. On a simulé l’effet du rayonnement solaire à l’aide de lampes thermiques dirigées sur le parement des panneaux, depuis l’intérieur de l’enceinte d’essai. Les chercheurs ont ajusté l’effet du rayonnement solaire de manière à simuler un mur nord-est, à Vancouver (C.-B.), entre le 10 janvier et le 10 février.

Les panneaux muraux de l’étude des taux d’assèchement de l’enveloppe ont été soumis à des conditions uniformes de température et d’humidité en laboratoire. On ne saurait extrapoler les résultats obtenus en laboratoire au-delà des conditions dans lesquelles les essais ont été effectués. Ces expériences ne constituent pas un reflet fidèle de l’assèchement qui se produit sur le terrain. Les chercheurs n’ont pas tenté de modéliser les fuites d’air (infiltration ou exfiltration) normalement causées par l’effet de tirage ou les charges dues au vent s’exerçant sur le mur. Il ne saurait donc être question ici de commenter l’effet que pourraient avoir ces phénomènes sur le taux d’assèchement des murs. L’étude n’a pas modélisé le phénomène d’infiltration d’eau, puisqu’on a volontairement donné aux panneaux une teneur en eau supérieure à 30 % afin d’étudier leur capacité d’assèchement. Les panneaux n’ont pas été mouillés à nouveau durant les essais, ce qui est loin de reproduire le genre de mouillage qui se produit sur le terrain. On a choisi une teneur en eau de 30% afin que le mouillage soit uniforme d’un panneau à l’autre. Si un mur est conçu avec une certaine capacité d’assèchement, il ne faut pas supposer que cela permette de concevoir ou de construire des murs dans le dessein exprès qu’ils se détrempent, dans l’espoir qu’ils pourront s’assécher suffisamment. En vertu du Code national du bâtiment, la teneur en eau du bois d’œuvre utilisé dans les constructions à ossature de bois ne doit pas dépasser 19 % au moment de sa mise en oeuvre. De ce fait, on suppose que la teneur en eau du revêtement intermédiaire en service ne devrait pas être supérieure à 16 % pour qu’on le considère comme sec. Cette capacité d’assèchement ne devrait être utilisée que pour éliminer l’humidité qui s’est introduite accidentellement.

Les réponses à chacune des huit questions formulées au début de la recherche se résument comme suit :

1. Lorsque les panneaux possèdent une teneur en eau supérieure à 25 %, est-ce qu’ils finissent par s’assécher?

Tous les panneaux se sont asséchés. La teneur en eau des poteaux au début et à la fin des essais était en moyenne de 29 % et de 12 % respectivement. À la fin des essais, aucun panneau ne s’était asséché partout et pour tous ses composants à une teneur en eau inférieure à 19 % (après un délai de 1 500 h dans la phase 1 et de 2 000 h dans la phase 2). L’hypothèse selon laquelle les panneaux s’assécheraient dans l’enceinte d’essai a été confirmée par les essais et par la perte considérable d’humidité dans certains panneaux. L’assèchement n’était, toutefois, pas uniforme sur l’ensemble des composants des panneaux. Les endroits à assèchement plus lent risqueraient donc de pourrir si l’essai se poursuivait indéfiniment. Après 3 500 heures, on n’a découvert aucune trace de pourriture.

2. Dans des conditions d’essais et sans les mouiller à nouveau, combien faut-il de temps aux panneaux pour s’assécher?

Dans les deux phases des essais, l’ossature a atteint une teneur en eau inférieure à 19 % en moins de 500 heures. Les revêtements muraux intermédiaires d’OSB et de contreplaqué se sont maintenus en général au-dessus de 19 % bien au-delà de la fin des deux phases d’essais.

À la suite d’un examen plus attentif, les éléments d’ossature de 38 sur 89 mm composés de poteaux et de lisses doubles peuvent être séparés en deux groupes : soit ceux de la zone 1 et de la zone 2, selon qu’ils se situent à plus de 20 mm ou à moins de 20 mm de distance respectivement du revêtement intermédiaire. Les composants de la zone 1 se sont asséchés à moins de 19 % en moins de 500 heures, alors que les composants de la zone 2 se sont asséchés plus lentement que ceux de la zone 1. Dans certains panneaux, la zone 2, en partie supérieure du poteau, s’est asséchée à moins de 19 % au bout de 1 000 heures. Toutefois, dans les premiers 600 mm des poteaux, la teneur en eau de la zone 2 est demeurée supérieure à 19 % pendant plus de 1 500 heures durant les essais de la phase 1 et pendant plus de 2 000 heures durant la phase 2.

La teneur en eau des panneaux OSB au début des essais de la phase 1 se trouvait dans une fourchette comprise entre 20 % et 29 %, et à la fin des essais dans une fourchette allant de 18 à 28 %. La plupart des panneaux ont affiché une baisse de leur teneur en eau de l'ordre de 1 à 3 %, (sauf pour le panneau 1 qui a subi une hausse de 1 % et les panneaux 2 et 8 qui ont présenté une baisse moyenne de 8 % de leur teneur en eau). Seuls les revêtements intermédiaires des panneaux 8 et 9, revêtus d'un parement en bois, affichaient une teneur en eau inférieure à 19 %. Tous les panneaux dotés d'un revêtement intermédiaire en OSB comportaient des endroits précis dans la partie inférieure des panneaux où la teneur en eau était supérieure à 30 %.

Au début des essais, les panneaux dotés d'un revêtement intermédiaire en contreplaqué affichaient tous une teneur en eau moyenne plus élevée que celle des panneaux revêtus d'OSB. La teneur en eau moyenne variait entre 26 et 37 %. À la fin des essais de la phase 1, deux panneaux revêtus de contreplaqué n'affichaient aucun changement dans la teneur en eau moyenne du revêtement intermédiaire et un panneau présentait une augmentation de 8 % de la teneur en eau moyenne de son revêtement intermédiaire.

Lors des essais de la phase 2, les panneaux revêtus d'OSB ont commencé l'essai avec une teneur en eau plus faible dans l'OSB que dans l'ossature. Au début, la teneur en eau moyenne dans le revêtement intermédiaire d'OSB était de 23 % et a augmenté pendant l'essai pour s'établir à 34 %. Les panneaux revêtus de contreplaqué ont amorcé la phase 2 avec une teneur en eau moyenne de 37 % dans le revêtement intermédiaire. Les panneaux revêtus de contreplaqué et munis d'une cavité ventilée ont subi une baisse de la teneur en eau du revêtement, et ont terminé l'essai avec une teneur en eau moyenne de 27 % et de 31 %. Le panneau revêtu de contreplaqué mais dépourvu de cavité a subi une augmentation de la teneur en eau du revêtement intermédiaire et enregistrait à la fin de l'essai une teneur en eau moyenne de 42 %.

Le temps d'assèchement constitue un important élément au chapitre de l'évaluation de l'efficacité des assemblages. Certaines parties du panneau (particulièrement la surface des poteaux) se sont asséchées à un niveau de teneur en eau inférieur à 19 % en moins de 100 heures. Cette constatation permet de croire qu'on pourrait concevoir un panneau qui puisse s'assécher rapidement partout et résister à un léger mouillage répété.

Toutefois, la lenteur avec laquelle d'autres parties du panneau ont séché indique que l'assèchement des panneaux mis à l'essai ne suffirait pas à prévenir la pourriture si le niveau de mouillage atteint lors des essais se répétait sur le terrain. Dans ce genre de mur, on doit plutôt se fier à ses caractéristiques de déviation et d'évacuation de l'eau, ainsi que sur la mise en œuvre de bonnes pratiques visant à empêcher que l'on emprisonne l'eau dans la cavité durant sa construction.

3. Certains panneaux d'essai s'assèchent-ils plus rapidement que d'autres? Quel est l'éventail des valeurs de teneur en eau dans les différents panneaux d'essai?

    1) Les panneaux dotés de cavités s'assèchent plus rapidement que les panneaux semblables qui en sont dépourvus.
    2) Les panneaux revêtus de contreplaqué s'assèchent plus rapidement que ceux dotés d'un revêtement intermédiaire d'OSB.
    3) On n'a constaté aucune différence notable dans les taux d'assèchement des panneaux, qu'ils soient munis d'un papier de construction ou d'une pellicule de polyoléfine filée-liée.
    4) Les panneaux munis d'une cavité ventilée au sommet et au bas se sont asséchés plus rapidement que les panneaux semblables qui étaient munis d'une cavité ventilée au bas seulement du panneau.

5) Les panneaux comportant un parement en bois se sont asséchés plus rapidement que les panneaux comparables dotés d'un parement extérieur en stucco dans la phase 1. Toutefois, cette tendance s'est renversée dans la phase 2 (effet du rayonnement solaire).

4. La largeur de la cavité d'évacuation influe-t-elle sur l'assèchement? Dans quelle mesure?

Trois largeurs de cavité (depuis l'arrière du parement extérieur jusqu'à la membrane de protection du revêtement intermédiaire) ont été mises à l'essai soit 0, 10 et 19 mm. Il semble que la largeur de la cavité soit un facteur déterminant en matière de taux d'assèchement. Lors des deux phases, les panneaux comportant de grandes cavités se sont asséchés plus rapidement que les panneaux dont les cavités étaient plus petites.

5. L'assèchement est-il tributaire de l'aire de ventilation? À quel point?

Il n'y a pas eu d'essais visant plus particulièrement les variations de dimensions ou de forme des orifices de ventilation. Tous les panneaux ventilés comportaient des orifices de ventilation dont la hauteur, la longueur et la forme s'équivalaient. Les panneaux différaient par la largeur de leur cavité et par la présence ou l'absence d'orifices de ventilation au sommet et au bas des panneaux. La largeur de la cavité influe sur l'aire de ventilation dans la mesure où le point d'entrée est limité par la largeur de la cavité. La ventilation inférieure et supérieure des panneaux influe peu sur l'assèchement. Les panneaux ventilés au sommet et au bas se sont cependant asséchés un peu plus rapidement que les panneaux ventilés au bas seulement.

6. Existe-t-il une corrélation entre la migration prévue de l'humidité (à l'aide du modèle informatique WALLDRY de la SCHL) dans l'ossature et dans le revêtement intermédiaire et la migration réelle de l'humidité?

La recherche n'avait pas pour but de vérifier la simulation informatique. Les chercheurs ont toutefois remarqué une cohérence et des déviations apparentes entre les prévisions du logiciel WALLDRY [7] et les données recueillies pendant les essais. Les prévisions du modèle WALLDRY étaient assez précises en ce qui concerne les variations d'humidité dans l'ossature et dans le revêtement intermédiaire. En ce qui a trait à la partie extérieure des poteaux, les données du modèle informatique étaient conformes aux données de la recherche pour la zone 1 de l'ossature (à plus de 20 mm du revêtement intermédiaire). Les prévisions du modèle en ce qui a trait à l'intérieur des poteaux étaient conformes aux données de la zone 2 des poteaux (zone à moins de 20 mm du revêtement intermédiaire). Quant à la couche extérieure du revêtement intermédiaire, les prévisions du modèle WALLDRY étaient conformes aux données correspondantes de la recherche quant à la teneur en eau moyenne. Les prévisions relatives au côté intérieur du revêtement intermédiaire différaient des données tirées de l'étude. Les taux globaux de perte d'humidité (en poids) prévues par le modèle WALLDRY étaient plus faibles que ceux observés durant les 1 500 heures d'essais de l'étude des taux d'assèchement de l'enveloppe (phase 1).

7. Comparer la perméance calculée des panneaux muraux d'essai à leur perméance effective.

La meilleure façon de décrire le taux d'assèchement global des panneaux consiste probablement à examiner leur perméance effective en ng/Pa•s•m^2. La perméance effective des panneaux a été mesurée tant pour la phase d'exposition au rayonnement solaire que pour la phase de non-exposition. Les calculs présentés dans le rapport dont il est question ici sont fondés sur la perte totale d'humidité survenue durant toute la période. La perméance obtenue par calcul allait de 314 à 556 ng/Pa•s•m^2. On estimait que la perméance effective serait plus grande dans le cas des panneaux munis d'une cavité ventilée, une hypothèse qui s'est confirmée. La perméance effective observée durant les essais de la phase 2 a varié de 324 à 1 663 ng/Pa•s•m^2, soit de 1,0 à 3,6 fois la perméance calculée. Le panneau 11, revêtu de stucco, doté d'une cavité de 19 mm ventilée par le bas et muni d'un revêtement intermédiaire en contreplaqué ainsi que d'un papier de construction affichait la perméance effective la plus élevée, soit 1 663 ng/Pa•s•m^2. On obtient ainsi une valeur de référence pour la perméance effective qu'on pourra tenter d'améliorer lors d'essais ultérieurs.

8. Déterminer les effets d'un rayonnement solaire simulé sur les panneaux.

Le rayonnement solaire simulé a engendré des taux d'assèchement différents entre les phases 1 et 2. Les perméances effectives étaient plus élevées en présence d'un rayonnement solaire simulé. En outre, on a constaté des différences entre les phases 1 et 2 en ce qui concerne le taux d'humidité final du revêtement intermédiaire.

Au bout des 1 500 heures de la phase 1, tant la teneur en eau de l'OSB que celle du contreplaqué sont demeurées presque les mêmes qu'au début de l'essai. À la fin des 2 000 heures de la phase 2 (avec rayonnement solaire simulé), la teneur en eau de l'OSB des panneaux munis de cavités ventilées a augmenté en moyenne de 11 % tandis que la teneur en eau des panneaux dotés d'une cavité ventilée et revêtue de contreplaqué a diminué en moyenne de 7,5 %.

On peut attribuer les différences observées entre les résultats des deux phases en partie au fait que la teneur en eau de départ de l'ossature et du revêtement intermédiaire n'était pas la même. Le revêtement intermédiaire de contreplaqué affichait une teneur en eau qui était supérieure de 13 % à celle affichée par l'OSB au début de la phase 2. Le taux d'assèchement plus rapide des panneaux dotés d'un revêtement intermédiaire en contreplaqué et d'une cavité s'explique peut-être par le fait que le surplus d'eau dans le revêtement était situé dans un endroit propice à son assèchement vers l'extérieur.

Les données indiquent que l'humidité migrait de l'ossature au revêtement intermédiaire de contreplaqué ou d'OSB. Tous les panneaux se sont asséchés durant les essais. Durant les essais de la phase 2 touchant les panneaux ventilés ou non, toutefois, l'humidité ne quittait pas le revêtement d'OSB au même rythme qu'elle y pénétrait. Dans les panneaux revêtus de contreplaqué et dotés de cavités ventilées, les données suggèrent que l'humidité quitte les panneaux à un rythme plus élevé que celui auquel elle y pénétrait. À la fin des essais, les deux panneaux revêtus de contreplaqué avaient une teneur en eau plus faible (27 % et 31 %) qu'au début des essais (39 % et 34 %). En l'absence de résultats similaires répétés, ces résultats ne sont pas significatifs. Ces différences indiquent tout de même que le fait de ventiler la cavité des panneaux revêtus de contreplaqué (à des teneurs en eau supérieures à 35 %) produit un effet considérable sur l'assèchement, mais que la même technique de ventilation produit moins d'effet sur l'assèchement des panneaux revêtus d'OSB (à des teneurs en eau supérieures à 25 %).

Conclusions

Les essais menés dans le cadre de l'étude des taux d'assèchement de l'enveloppe ont montré que le taux d'assèchement des panneaux d'essai présente des différences dans des conditions de laboratoire qui sont fonction des matériaux, des orifices d'évacuation et de la ventilation. La disposition des matériaux et la largeur de la cavité ont un effet considérable sur l'assèchement. Le taux d'assèchement de panneaux comparables, avec et sans cavité, peut varier par un facteur aussi élevé que 3.

Le type de revêtement intermédiaire est l'autre facteur qui influait le plus sur les taux d'assèchement des 12 panneaux mis à l'essai. Les panneaux revêtus de contreplaqué ont absorbé plus d'humidité initialement et se sont asséchés plus rapidement que les panneaux semblables à revêtement intermédiaire d'OSB. À la fin des essais, tant les revêtements intermédiaires d'OSB que les revêtements intermédiaires de contreplaqué avaient une teneur en eau supérieure à 19 %. Les parties des poteaux à moins de 20 mm du revêtement intermédiaire s'asséchaient lentement et, dans la plupart des cas, elles affichaient une teneur en eau supérieure à 20 % à la fin des deux phases des travaux de recherche.

Le bas de tous les panneaux sur une hauteur de 200 mm s'asséchaient plus lentement. Ce résultat est peut-être dû à la plus grande masse de bois, jumelée à la présence d'un solin imperméable traversant la cavité et posé près de la lisse basse. Pour les essais, on a fondé l'emplacement du solin sur les installations courantes sur le terrain. Il est à remarquer que le solin pourrait être posé ailleurs dans la cavité, ce qui pourrait améliorer le taux d'assèchement à la base d'un mur. En revanche, le solin pourrait être composé d'un matériau à perméance élevée.

Le modèle informatique WALLDRY constitue un outil efficace pour prévoir les tendances générales des teneurs en eau lors de l'assèchement.

Les travaux portant sur l'étude des taux d'assèchement de l'enveloppe ont engendré un ensemble de données repères pour les 12 panneaux, ainsi qu'une cible de perméance effective de 1 663 ng/Pa•s•m^2. À l'aide de ces résultats relatifs, on sera en mesure d'évaluer d'autres assemblages.

Recommandations

- Des essais devraient être effectués sur tous les autres parements communément utilisés, particulièrement pour les cas où il serait possible d'atteindre une perméance effective plus élevée, comme les parements en vinyle dotés de perforations supplémentaires.

- On devra s'efforcer d'établir une meilleure corrélation entre le modèle informatique et les résultats de laboratoire. Les autres modèles disponibles pourraient peut-être afficher une capacité prévisionnelle plus grande que celle du programme WALLDRY.

- La présence d'une grande quantité d'éléments en bois dans un mur pose un défi de taille à l'égard de son assèchement rapide. On devrait mettre à l'essai des détails courants de construction comme celui de la rencontre des murs avec les solives de rive et de bordure, ce qui serait particulièrement utile lors d'essais de panneaux comportant un revêtement intermédiaire perforé pour augmenter sa perméance dans ces régions.

- L’une des possibilités consiste à introduire dans la cavité un mouvement d’air induit pour accélérer l’assèchement. Des essais supplémentaires devraient être effectués afin d’évaluer les effets du vent sur les cavités.

- La recherche dont il est question ici devrait faire l’objet d’une évaluation par le Centre canadien des matériaux de construction, à l’Institut de recherches en construction du CNRC, et par l’American Society for Testing and Materials aux fins d’élaboration d’une méthode d’essai en laboratoire normalisée portant sur l’assèchement des murs.

- Les résultats des essais sont trop limités pour justifier des changements importants dans les guides des règles de l’art. Toutefois, ils montrent que l’assèchement peut représenter une composante importante de la gestion de l’humidité. Ainsi, les révisions au guide des règles de l’art intitulé *Enveloppe de bâtiments à ossature de bois dans le climat littoral de la Colombie-Britannique* devraient mettre l’accent sur les éléments suivants :
  - Favoriser la mise en place de cavités à évacuation d’au moins 19 mm dotées d’orifices de ventilation au bas et au sommet.
  - Réduire au minimum la taille des orifices la ventilation au sommet et les protéger contre les infiltrations d’eau.
  - Réduire la taille des membranes imperméables autour des ouvertures à la dimension minimale requise pour maintenir un plan de drainage efficace.
  - Dans la mesure du possible, les solins traversant la cavité devraient être placés dans des endroits éloignés d’une concentration élevée d’éléments d’ossature de bois.

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***Note**: participation on the EDRA Steering Committee does not necessarily imply endorsement of the interpretation of the test results.*

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1 Introduction

The design of walls in wood frame residential buildings in British Columbia's coastal climate region requires high-performance water management systems [18]. The Homeowner Protection Office (a crown corporation of the government of British Columbia), estimates there are 65,000 units in BC in need of major repair due to water damage [30]. Most of these were built in the period from 1984 to 1995.

The climate of Vancouver is mild and wet with average winter lows of 5°C and summer highs of 25°C. Most of the rainfall in Vancouver comes in the period from November to April. Vancouver averages 1100 mm of precipitation per year, but rainfall can reach 2200 mm closer to the mountains. During the winter period the average number of drying days between periods of wetting is 3 days. The ambient solar radiation during that period is at its lowest for the year.

In response to the construction failures, architects in BC have been experimenting with many different variations of vented and drained cavity walls over the period from 1996 to 2000. To improve on industry practice, Canada Mortgage and Housing Corporation (CMHC) with the assistance of the Building Envelope Research Consortium (BERC), published the Best Practice Guide for Wood Frame Envelopes in the Coastal Climate of British Columbia. [1]. The guide recommends that walls should be designed to manage moisture using the appropriate combination of deflection, drainage, drying and durability characteristics. Part of the Best Practice Guide development program was to test out the potential of drying as a moisture management mechanism.

This experiment sets out to collect data on various wall systems to determine their drying characteristics, compare test panels in a relative manner and measure their effective permeances under equivalent drying conditions.

The work was carried out by Forintek Canada Corp. in Vancouver, British Columbia. The project began in March 1998. Testing of 12 wall panels was completed in October 2000.

2 Rationale

There is a large body of empirical and scientific data concerning the deflection, drainage and durability characteristics of wood frame walls [15]. Little scientific data exists which describes the drying characteristics of wood frame walls (especially those with stucco cladding).

Building Science has evolved significantly over the past 20 years, however most testing of wall systems in the Canadian climate has been directed at testing for the continental climate with exterior temperatures ranging from a wintertime low of -30° to a summertime high of +30° [26].

Vapour permeances of various claddings, sheathing protection membranes and sheathing materials have been determined [16]. However, little data has been collected on the combined effect of these materials in a wall system. Given the climatic conditions of coastal BC, deflection and drainage are the primary means of managing exterior moisture. However they will not be perfect, small amounts of moisture will enter the wall putting the structure at risk of decay. Building envelope design must result in effective drying. In the coastal climate with high frequency of rain and short drying periods we must also have the fastest drying walls possible.

Typically we measure the drying rate of walls in terms of their calculated permeance. There is enough information about material properties to be able to sort walls according to their calculated permeances. If this approach was sufficient, this research would not have been necessary. However, this does not take into account that the effective permeance of a wall may be several times greater than the calculated permeance. This is a result of accelerated transfer of moisture through the wall assembly, by mass flow of air through a vented cavity and can result in walls which have an effective permeance substantially greater than their calculated permeance.

The concept of calculated permeance vs effective permeance was explored by Forrest and Walker in 1990 where they studied the drying of wall panels in an outdoor test hut in Alberta [2]. Studies in the Atlantic Region used outdoor test huts in a variety of locations to collect data on the drying of walls [3]. The Ontario Wall Drying project further demonstrated how drying could be studied in outdoor test huts [4]. Similar work done by Stewart looked at the drying regime in an outdoor test chamber with a continental climate [17]. The EDRA experiment differs principally in its use of an indoor, fully regulated test chamber to simulate a controlled climate. A model for the EDRA experiment was conducted by Morrison Hershfield in 1991 with an indoor test chamber in which both summer and winter drying conditions for the climate of Southern Ontario were simulated [27]. Part of the BERC drying rates program was another indoor chamber study by Morrison Hershfield in which 6 stucco-clad panels were tested [28]. All of these studies provided us with insights into the problems of testing wall panels in an indoor chamber. Their methodological weaknesses included such factors as variations in wood from panel to panel, problems with uneven wetting, problems with inconsistent driving forces for drying and problems with mechanical systems and instrumentation breakdowns. All of these combined to make the results of these previous tests difficult to replicate and resulted in performance comparisons between panels lacking validity. Given the scope and cost of the EDRA experiment, it was not possible to have a large number of replicates.

Recognizing the problems experienced by previous studies and drawing upon the experience of the steering committee and outside experts, the experiment was designed to yield valid results with no replicates. Therefore it was important that the test include the least number of variables between test panels and test conditions as possible. Part of the approach was to subject all the wall panels to the same drying forces. This would enable us to quantify the differences in the drying rates between the panels based on their designs, without having to factor out differing drying conditions, seasonal variations, solar orientations, wind effects, etc. Significant additional effort was invested to mitigate the natural variability of wetting and drying of wood used in the panels. The test sought to handicap the panels equally such that the differences in their drying rates could only be attributed to their designs. Also, in this series of tests, all wall panels dried to the exterior only.

The entire question of the drying rates of walls has been elevated in the eyes of the industry of late. In the field, water from exterior moisture sources (rain, snow, ground, etc) penetrates past the moisture barriers and enters the structural wood components of walls at many locations. The wood components inside the wall may store the moisture safely for a period of time. However, if they do not allow the excessive moisture to leave the wood within a limited time (by drainage, capillarity or diffusion), decay occurs and the walls deteriorate.

Before commencing this study we acknowledged there was no possibility that walls could be made to dry at a rate which would equal or exceed the ingress of moisture in a leaky wall typical of recent problems in the BC coastal climate. Building envelopes have to be constructed to deflect and drain the bulk (i.e. 95% to 99%) of the moisture incident on them. In Vancouver this could be over 400 kg/m^2 of wall area per year [13]. Walls must manage rainwater, primarily by deflection and drainage. The test samples in this study were not intended to be indicative of walls which could manage large amounts of water ingress by drying alone. The test wall panels are a selection of possible wall designs in current use. The study was not designed to justify the selection or rejection of various wall assemblies.

The thesis of the current Best Practice Guide [1], is that walls should employ the best possible drying. One of the goals of this study is to determine what differences in drying might be observed between various wall systems in order to either validate the status quo or provide a basis for changes to the Best Practice Guides.

CMHC and the National Research Council Institute for Research in Construction (NRC-IRC) have developed parametric models to predict moisture movement in walls (WALLDRY and HYGIRC). One of the goals of the Envelope Drying Rates Analysis (EDRA) research project was to provide baseline data on the drying rates of wall panels under controlled laboratory conditions to assist in the development of hygrothermal simulation tools. These simulation tools will ultimately model wall designs with the same sort of security and economy that presently exists in the modeling of structural systems. This will contribute to improved design and construction practice, which will reduce the risk of wall failures in coastal British Columbia to an acceptable level. The project is linked to the NRC-IRC Moisture Management in Exterior Wall Systems (MEWS) consortium program, where the results of EDRA will be compared to NRC's parametric model HYGIRC.

3 Objective

The objective of the project was to collect baseline data on the drying capability of wood frame test wall panels in a controlled laboratory environment simulating one condition (5°C 70% R.H.) from the winter climate of Vancouver. Wall panels were selected to provide a comparative range of data on commonly used stucco and wood-clad wall systems incorporating a variety of vent areas, cavity sizes, sheathing materials and moisture barriers. The test wall panels utilized a variety of sheathing protection membranes and sheathing materials.

The experiment was set up to answer the following 8 questions:

1. When specimen wall panels are wetted to > 25% moisture content (MC), do they ever dry out?
2. Under test conditions and without re-wetting, how long do they take to dry out?
3. Are some test wall panels drying faster than others? What is the variation between the test panels?
4. Does the drainage cavity width affect drying? By how much?
5. Does the vent area affect drying? By how much?
6. What is the correlation between the predicted (by prior runs of computer models; NRC's HYGIRC) and CMHC's WALLDRY) moisture movement within the framing lumber and the sheathing and the actual moisture movement?
7. Compare the calculated permeability to the effective permeability.
8. Compare the effect of the solar simulation on test wall panels.

4 Limitations

This study has been designed to gather data under specific test conditions. It does not replicate how walls will perform in the field. The results cannot be used to determine whether walls built to code in the period from 1985 to 1998 were inadequate in their drying capabilities. Some of the variations from field conditions are noted as follows:

- The panels in this study were not wetted to simulate the wetting of walls in the field. The wetting procedure used was intended to distribute the moisture in a controlled manner, to apply the same moisture load to all the panels. Panels were not re-wetted during the phases of the test.

- All the wall panels were exposed to the same environmental conditions. These conditions were steady state, rather than representative of real weather data.

- The panels in this study were not subjected to the kind of random wind and air movement of walls in the field. The air movements in the chamber were consistent from panel to panel.

- The panels in this study were not subjected to solar radiation as experienced in the field. A steady state solar cycle was applied consistently from panel to panel.

- The wall panels in this study, deal only with the field portion of the typical wall. The wall panels did not include any envelope penetrations (windows, vents, etc) in the panel assembly.

- The panels in this study were not built with the same kind of air tightness as those in the field and were not subjected to pressure differentials similar to those in the field. All panels were constructed as laboratory specimens with consistent sealing and tested in steady state conditions with less than 5 Pa pressure differential across them.

- Where data has been gathered using resistance type measurements and converted to an estimate of wood moisture content (MC), the normal ranges of accuracy for these measurements apply. Estimates of moisture content in the framing were corrected for species and temperature. In the range of 15% to 25% MC they are within ± 2%. Estimates of moisture content in the OSB and plywood sheathing are an indicator only.

5 Staff

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6 Method

In brief the test method consisted of the fabrication of test panels, which were then wetted and inserted into openings of an indoor test chamber for up to 3 months to measure their drying. The mechanisms for drying were vapour diffusion driven by the vapour pressure differential between the lab, the panels' interior and the interior of the chamber, the adsorption and desorption effect off the surface of the panels into the chamber and the air flows through the cavities of the vented panels into the chamber. Drying by mass flow from the interior of a building to the exterior is contrary to the air barrier objectives of the Best Practice Guide [1] and the Building Code [29] and was not part of this experiment. Mass flow by air movement through the panels from the lab to the chamber was effectively eliminated from the experiment.

The method chosen for the experiment was based on similar tests of wall panel performance, both in the laboratory with test chambers and in the field using test huts [4,6,17,24,27]. The key consideration in the design of the test method was the lack of replicates. The comparability of results from panel to panel within a test group and from test group to test group would be possible if the variables between the panels were reduced to their design differences. It was not the intention of the experiment to create a standard test. However, the experiment may provide sufficient data for a body such as ASTM or CCMC to develop a standard test for wall panel drying. The major differences between this test and previous tests are:

1) the method for equalizing the response capability of the wood framing .
2) the method for the wetting of the wood framing.

3) the choice of set points for the chamber interior to simulate a steady state winter condition for the British Columbia coastal climate.
4) the extensive instrumentation of the test panels.
5) the capability of the HVAC system and chamber to maintain steady state conditions.

As with other test programs the panel size was set at 1220 mm by 2440 mm. This provided a manageable panel with three stud spaces. Fully loaded panels weighted up to 231 kgs. The centre stud space would provide data from a representative wall section which was effectively buffered by the side stud spaces. In this series of tests the lumber used for framing was 38mm by 89mm studs. Future tests are planned to incorporate 38mm by 150mm studs.

A twelve-panel chamber with exterior dimensions of 2.6m wide by 5.1m high by 15m long was constructed inside the Forintek Wood Engineering Laboratory. The size of the space available in the laboratory as well as the access by overhead crane for panel insertion/removal dictated that the chamber be double sided with 6 panels on each side. The clear height in the lab allowed a chamber height of 5100 mm. One consideration was the reduction of edge effects caused by the floor and ceiling of the chamber. The chamber design accommodated a transom and base of 1200 mm above and below the panels. The interior of the chamber was 2440 mm wide. The overall width was governed by the allowable space in the lab and the desire to keep the volume of air to be conditioned at the minimum. The centre 600 mm of the chamber was taken up by a Unistrut rack holding the HVAC ducting and the heat lamps for the solar simulation (see photographs Appendix 11).

The inside of the chamber was kept at steady state conditions of 5^{o}C and 70% relative humidity. The lab was kept at 20^{o}C and the RH allowed to fluctuate between 30% and 50%.

Air flow was directed at the lower portion of the panel to induce a 1 Pa pressure differential between the top and bottom of the panels. This pressure differential regime was recommended by Dr. J. Straube based on his measurements of air flows over wall panels in the BEG Hut [4].

The decision was made to run the chamber under steady state conditions of temperature and relative humidity for three reasons.

1) to reduce the variables involved in the experiment to facilitate analysis of the results of the data.
2) to facilitate comparison of the data to the WALLDRY model.
3) to facilitate an achievable temperature and humidity regime. The alternative was to choose a variable climatic regime which would be unnecessarily complex, expensive to simulate and not achievable within the project's resources.

The target wetting for the wood framing of the panels was 25% to 30% moisture content (just above fibre saturation). The 25% to 30% MC level in the framing was chosen to provide data on the drying of panels in which there was limited free water in the framing.

The target wetting for the sheathing was 20% to 25% moisture content. This level was chosen for the sheathing to avoid excessive wetting which might cause deformation of the sheathing and cladding.

The panels were tested twice, once without solar for 1500 hours and once with solar for 2000 hours. This would allow for the comparison to predictions made by WALLDRY and the comparison of the effect of no solar with simulated solar on the test panels. The results of the testing by Morrison Hershfield both in

1991 and in 1999 [27,28] as well as the preliminary runs of WALLDRY [7], led to the conclusion that the test duration should be 2 to 3 months.

Data were collected from the panels by both manual measurements before and after the test and automated data acquisition system during the test.

The apparatus and methodology are explained in more detail in the following sections and their related appendices.

6.1 Chamber

The test chamber was constructed according to the plans and specifications of Figures 9 and 10. The Chamber contains a multi-component mechanical system for regulating internal conditions. The set-up allows for the independent control of airflow, temperature and relative humidity within the chamber. The building HVAC system controlled the environmental conditions within the lab in which the chamber was located.

The HVAC system consisted of:

- Air handling unit with fan controlled by a variable speed drive capable of supplying up to 6000 cfm and a direct expansion (DX) cooling coil with thermal expansion (TX) valve.
- Water cooled compressor serving the DX coil, with refrigerant loop capable of continuous operation at full or partial load, which is ensured through compressor unloading and refrigerant gas bypass. The compressor was a 10 hp machine with 109,500 Btu/h nominal capacity.
- Supply air ducts with grills directed at the test panels. Conditioned air was distributed through a series of two 80 mm by 490 mm dual-vane diffusers per panel located 750 mm from the panel face and 500 mm above the bottom of the panel. Each diffuser had individual balancing scoops.
- Return air was collected by a series of ducts located along the top of the chamber 1200 mm below the ceiling.
- Desiccant dehumidifier capable of moisture removal of 9.8 lb/hr at 600 scfm
- An electrode type steam humidifier.
- System control by a separate PLC with PID controller linked to its own sensor array in the chamber.
- Chamber and lab conditions were monitored and recorded every 15 minutes using 19 temperature and 11 RH sensors.

6.1.1 Chamber Conditions Summary

- The interior of the chamber was conditioned to 5^{o} C and 70% RH with a temperature variance of not more than $\pm 1.5^{o}$ C with an RH variance of not more than ±5%.

- The exterior of the chamber (the lab space) was conditioned to 20^{o} C and had an average RH of 40 %. The Wood Engineering Laboratory was monitored for RH and T conditions for 5 years prior to the test. There have been some hourly fluctuations in RH and T as doors are opened and material brought in and out. The daily average for the lab was between 20 and 22 °C and between 30 and 40% RH in the period from January 1, 1999 to March 31, 1999.

- The chamber HVAC directed a continuous air-flow of 1 m/sec at the lower half of the exterior cladding side of the panels. This produced a pressure differential between the top and bottom of the panel of 1 to 5 Pa. See Appendix 5 for the detailed report on the air-flow conditions.

- During Phase 2 in which the solar cycle was employed, the panels were evenly subjected to light sources providing an 8-hour solar cycle. Lights were switched on at 8:00 am and ramped up in power from 0 to 120 watts/m^2 maximum at 11:00 am and staying at 120 watts for 2 hours. From 1:00 pm to 4:00 pm they were dimmed down gradually, returning to 0 watts/m^2. The panels were in darkness for 16 hours. The goal of the solar cycle was to achieve a combined ambient and solair temperature of up to 15^{o}C at the surface of the panel. See Appendix 6 for the detailed report on the solar conditions.

6.2 Panels Description

6.2.1 Panel Design Overview

The original plan for the full EDRA test program was to evaluate as many panels as were necessary to improve the Best Practice Guide for Wood Frame Building Envelopes in the Coastal Climate of British Columbia. Initially up to 40 wall types were contemplated. From these, 12 panels were selected for the first test group. The field of the wall was chosen as the best starting point for evaluation of the entire wall assembly. The field of the wall would represent typical wall areas with no penetrations for windows, doors or other connections to balconies, etc. (It was acknowledged that the detail areas around windows, doors and other penetrations, as well as at rim joists and balcony framing were also important areas for future tests.) Standard 1220 by 2440 (4 foot by 8 foot) panels were chosen for the test. These were chosen because of their manageable size and the use of three standard stud spaces. It was assumed that the centre stud space would provide data, typical of the field of a wall and the two adjacent stud spaces would moderate edge effects. For the first group a series of 10 stucco-clad panels, plus 2 wood-clad panels were selected. One of the stucco-clad panels (Panel 1) and one of the wood panels (Panel 8) would form reference panels for inclusion in future test groups for comparison purposes. Future tests would encompass other cladding systems such as vinyl, concrete board, brick veneer etc.

6.2.2 Panel Assembly

Each test wall panel was 1220 by 2440 in size constructed as per Figure 1. The material for the base panel frame was 38 x 89 (nominal 2 x 4) J grade, lodgepole pine, with 11.5 mm OSB sheathing or 12.5 mm Canadian Softwood Plywood (CSP) sheathing applied horizontally with a 3 mm gap at mid panel. All panels were insulated in the stud space with RSI 2.45 (R14) glass fibre friction fit insulation.

The interior finish was 12.5 mm (CSP) plywood as a substitute for conventional gypsum board. Plywood was chosen as an interior finish to provide a more durable material than gypsum board. The vapour barrier was provided by 6 mil polyethylene film. Since 6 mil polyethylene is a type 1 vapour barrier, the interior environment (lab space) would not add to or remove moisture from the wall panel assembly. The interior plywood faces were painted with grey paint to minimize weight changes during the experiment as hourly RH conditions in the lab fluctuated. The moisture barriers were 2 layers 30 minute HAL Building paper or 1 layer Tyvek Homewrap (SBPO). The cavity was created by using 19mm x 38mm CCA treated plywood furring @ 400 mm o.c., or 10 mm x 38 mm CCA treated plywood furring @ 400 mm o.c. The furring was applied vertically, directly opposite the studs.

All the OSB for the test was drawn from the same bundle of 50 sheets. The material was sourced from the Ainsworth mill in 100 Mile House, British Columbia. All the sheathing plywood for the test was drawn from one bundle, sourced from the Richmond Plywood Corp. mill in Richmond, British Columbia.

The vent area was created by a standard stucco J mold and a base flashing of pre-painted 28 gauge steel. The base flashing rests on a piece of Laminated Veneer Lumber (LVL). The LVL was totally encased in epoxy resin to prevent any water uptake or loss from this portion of the wall panel assembly.

The panel configurations are described in Table 1.

Prior to wetting, the panels were fully clad and instrumented, but left uninsulated and with no interior finish. This allowed the panels to be placed studs (inside face) down, in shallow tanks of water to evenly wet the lumber. (See photographs - Appendix 11.)

6.2.3 Lumber Selection Criteria

Lumber variability was discussed extensively in the Steering Committee meetings. It was decided that the potential for wide variability of the lumber could skew the experiment. If a test panel were constructed of randomly selected lumber, there was a chance that all the lumber in one panel could be fast drying sapwood and all the lumber in another panel could be slow drying heartwood. To offset this, a procedure for selecting the lumber was implemented. J grade was chosen for the test wall framing, because it is the grade with the narrowest range of wood variability. One bundle of lodgepole pine was purchased from a B.C. interior mill.

The selection process started with 251 pieces, these were visually sorted to 195 pieces by eliminating pieces with minor defects. The 195 pieces were then wetted in a pressure retort using the following schedule. They experienced this schedule while fully immersed in the retort.

- 30 minutes initial vacuum 740 mm Hg (28” Hg)
- 1 hour pressure at 1035 kPa (150 psi)
- 30 minute final vacuum at 740 mm Hg (28” Hg)

A record of weight gains was taken for 195 pieces. They were then kiln dried using the following schedule.

Hours	Dry Bulb (°C)	Wet Bulb (°C)	RH (%)	EMC (%)
5.5	60	60	100	24.1
6.0	71	66	77	11.6
9.5	71	60	59	7.9

- EMC was the target EMC for the conditions noted
- Air velocity 750 fpm
- 24 hours cool down at 20^{o} C (70^{o} F)

A record of weight losses was taken for the 195 pieces. From this the 195 were sorted as to maximum wetting and maximum drying. To construct the panels we then chose 100 pieces straddling the median. The 100 pieces were separated into 4 classes or groups:

Group A - maximum wetting (63% sd 5) / maximum drying (30% sd 4)
Group B - maximum wetting (59% sd 7) / minimum drying (19% sd 5)
Group C - minimum wetting (45% sd 5) / maximum drying (20% sd 2)
Group D - minimum wetting (40% sd 5) / minimum drying (12% sd 3)
(sd - standard deviation)

Panels were constructed using a piece from Groups A, B, C, and D for each of the four studs and plates as described in Figure 1:

By this procedure we are able to ensure that the variations in wood wetting and drying capability are equally distributed among the panels. Additionally we instrumented the same class of wood in each panel. Therefore, we believe that data gathered is more comparable from panel to panel because variations in wood characteristics have been reduced as much as possible.

6.2.4 Panel Cladding

There were 12 panels in Group A, with cladding as described in Table 1. In summary, nine panels had OSB sheathing and three had plywood. Nine panels had building paper and three had spun bonded polyolefin (SBPO). Four panels had 0 mm (or no) cavity, two had a 10 mm cavity and six had a 19 mm cavity. Four panels had no venting, four panels had cavity venting at the bottom only and four panels had cavity venting at top and bottom. The vent areas at top and bottom were each 0.8% of the panel area, and consisted of a 19 mm high continuous horizontal slot. Ten panels had stucco cladding and two had wood siding. Stucco cladding was applied according to the specification derived from the BC Wall and Ceiling Association, Stucco Resource Guide. This is the standard 21 mm thick sand cement lime, three coat application procedure as found in the National Building Code (see attached specification – Appendix 4). Wood siding was applied according to the manufacturer's recommendations. The panels with wood siding had an edging strip on both sides, installed with caulking to prevent lateral diffusion of moisture and simulate an infinite length of wall. (See photographs – Appendix 11)

6.2.5 Sacrificial Panels S1, S2, S3, S4

Four additional sacrificial panels were constructed, in order to more fully examine the effects of moisture distribution through the panels after wetting. The sacrificial panels were constructed with the same design as the test panels, to the following specifications:

- Stucco applied in conventional direct-applied system over 2 layers of 30-minute paper.
- For Panels S1 (Wall Panel #13) and S2 (Wall Panel #14): Lath was 50mm x 50mm (2" by 2") self-furring wire mesh.
- For panels S3 (Wall Panel #15), and S4 (Wall Panel #16): Lath was paper backed Tilath 3mm (1/8") flat rib.
- For panels S1 and S3 sheathing was OSB.
- For panels S2 and S4 sheathing was CSP (Canadian Softwood Plywood).
- Nailing was as per the stucco resource guide.

Two sacrificial panels S1 and S2 were wetted prior to the first round of wetting. S3 and S4 were wetted prior to second round of wetting. Their wetting procedure was the same as that used for the test panels. Hand held moisture meter measurements in the lumber and sheathing were taken with a Delmhorst RDM-1 meter set for SPF at 21^{o}C. The sacrificial panels were then cut up to obtain distributions of moisture in the lumber and sheathing by oven drying of samples (see Appendix 8).

6.3 Instrumentation

6.3.1 Panel Instrumentation

All panels were instrumented as per Figure 2, for the 12 test panels of Group A. The full set of measurement locations for each panel are identified in Appendix 2, (see Figures 3 & 4 for locations). Instrumentation varied depending on cladding type. Each panel was connected to the Data Acquisition System (DAS) for on line continuous measurement to: 1 load cell, up to 22 moisture content points, up to 12 temperature points and up to 2 relative humidity points. In addition, pressure measurement data were collected manually and are reported on in Appendix 5.

Wood moisture was measured using the circuit shown in Figure A7.1. Delmhorst pins were embedded at set depths (see Appendix 7, for detailed instrumentation locations) or gold pins were installed at the surface of the framing and the sheathing. Semi-conductor temperature sensors were fixed to the surface at various points. One Honeywell RH & T sensor in a sealed desiccant package tube was placed in the centre of the batt insulation.

6.3.2 Data Acquisition

The data acquisition system utilized FieldPoint, a data management system from National Instruments using LabVIEW graphical programming. Data were collected and recorded from each measurement point every 15 minutes.

The DAS was tested extensively prior to commencing the panel test. The goal of the testing was to ensure that the DAS collects certifiable (based on N.I.S.T. certified instruments) readings on all channels. A summary of the testing is found in Appendix 7.

6.3.3 Stucco Moisture Measurements

To more fully examine the redistribution of moisture in the panels gravimetric sample readings were taken at three points (numbers 21, 22, 23) in the right stud space of Panels 1, 3 and 5 (See Figure 4). The gravimetric data is reported in Table 9.

6.4 Test Procedure

6.4.1 Phase 1 - Panels Drying Without Solar Effect

1. Panels were fully constructed and clad with all instrumentation in place, not including: interior finish plywood, vapour barrier, insulation, RH and T sensor. Dry panel weights were taken.
2. Panels were wetted to achieve 28-30% M.C. by weight in the studs and plates and 15 to 22% MC in the OSB and plywood, by immersing the panels, studs down, in a shallow tank of water. (Panel wetting is described in detail in Appendix 8.) Panels were laid in a horizontal position on dunnage and were allowed to drain off excess water for 1 hour. Panels were weighed suspended from a 340 kg (750 pound) capacity load cell.

3. Final assembly of panels included weighing separately the plywood interior finish, poly vapour barrier, insulation, RH and T sensor. Technicians installed insulation, RH & T sensor in the centre of the insulation, vapour barrier with acoustic sealant on the perimeter of the panel, and plywood interior finish. The instrumentation cables were all routed through an air-tight drywall electrical box. The poly was sealed to the framing and the plywood interior finish was installed. The load cell mounted on the overhead crane was calibrated to known weighs and tare established. Panel weights were taken by the load cell.
4. Dummy panels were removed from the chamber bays just prior to panel insertion and the test panels were inserted into the fully operational chamber. Instrumentation was connected within 1 hour of panel insertion. Panels weights were taken by DAS load cell. Load cell offset was set to cause the DAS to display the correct panel weight as per the crane load cell.
5. Panels were subjected to total darkness (No Solar) and continuous wind effect (to achieve 1 to 5 Pa pressure difference between the top and bottom of the panels. Panels were monitored in the chamber for 1500 hours. During monitoring, their drying was evaluated to determine whether the panel weights had returned to 15% moisture content (M.C.) by weight of the original panel and sheathing. This arrangement allowed the panels to be modeled with the same driving forces as the WALLDRY computer simulation.
6. After 1500 hours, the instrumentation was disconnected from the DAS and panels were removed from the chamber bays. Immediately upon removal each panel was weighed. The plywood interior finish, insulation and poly were then removed. The bare panel was weighed and the interior finish plywood, insulation and poly were weighed. The data from the weights are summarized in Table 3.
7. Experiment phase complete.

6.4.2 Phase 2 - Panels Drying With Solar Effect

Steps 1 through 6 were repeated, except in this phase during step 5 the chamber was operated with the solar effect as follows:

5. Panels were subjected to a cycle of solar radiation as per section 6.1.1 (to simulate winter sun on east elevation in Vancouver) and continuous wind effect (to achieve 1 to 5 Pa pressure difference between the top and bottom of the panels). Panels were monitored in the chamber for 2000 hours.

7 Results and Discussion

The experiment was set up to answer the 8 questions in section 1. Objective.

The data collected on the panels includes 1500 hours of drying for Phase 1 and 2000 hours of drying for Phase 2. There were over 500 separate data measurement points reported on. The DAS points were scanned every 15 minutes and changes recorded. Gravimetric measurements of stucco inserts were recorded manually approximately every 400 hours. Weights and hand held moisture meter readings were taken at the start and finish of each round of testing.

7.1 Question 1 Overall Drying

When specimen wall panels are wetted to > 25% MC (moisture content % by dry weight), do they ever dry out?

Overview of results from both phases:
Based on the average figures of Chart 1, the MC % in the framing started the test in the 25% to 31% MC range for Phase 1 and the 34% to 39% MC range for Phase 2. At the end of the test after 1500 hours in Phase 1, the framing was in the 12% to 16% MC range. In Phase 2, after 2000 hours, the framing was in the 11% to 15% MC range.

The sheathing performance differed from the framing. In Phase 1, the sheathing started the test in the 20% to 30% range for OSB and the 25% to 40% range for plywood. At the end of the test some OSB sheathing had dried slightly to the 15% to 20% range. However, most were at or above their initial MC. The plywood sheathings were all at or above their initial MC.

In Phase 2, the OSB sheathings started in the 20% to 25% MC range and the plywood in the 30% to 40% MC range. After 2000 hours the OSB MC had all risen finishing in the 30% to 35% MC range. The plywood MC rose in the case of the 0 mm cavity panel, finishing in the +40% range but in the vented cavity panels it dropped finishing in the 25% to 32% MC range.

While the framing generally finished the tests in the 10% to 15% range, portions of the framing within 20 mm of the sheathing ended the test at higher MC as recorded by the C3, C6 and C9 data points (refer to Charts A1-1, 2, 3 and A2-1, 2, 3). In particular the C9 point in the centre of the lower 50 mm of the studs next to the sheathing ended Phase 1 in the 20 to 30% range. In Phase 2 this portion of the framing achieved the same MC as in Phase 1 reaching the 20% to 30% range after 1500 hours.

7.1.1 Overall Drying: Phase 1 - Without Solar

The wall panels absorbed an average of 7756 g (17.1 lb) and a median of 7257 g (16.0 lb) of moisture from the dip tanks. The stud lumber started the test averaging 31%. The OSB started the test averaging 24%. The plywood started the test averaging 31% in phase 1. (The distribution of moisture in the panels is reported on in Appendix 8.)

In phase 1 the test wall panels lost between 2857 g and 680 g during their 1500 hours in the chamber. The average loss was 1497 g, with a median loss of 1134 g, (see Table 3). All panels continued to lose moisture up to the end of Phase 1.

The moisture content (MC) in the studs at the time of installation averaged 29% and at the time of removal they averaged 12% (as measured with a Delmhorst RDM-1 meter set for SPF at 21°C, see Table 2).

The MC in the plates at the time of installation averaged 29% and at the time of removal they averaged 15% (as measured with a Delmhorst RDM-1 meter set for SPF at 21°C, see Table 2).

The MC in the OSB sheathing at the time of installation averaged 25% and at the time of removal averaged 22% as measured with a Delmhorst RDM-1 meter set for SPF at 21°C. (The oven-dry tests of

OSB as reported on in Appendix 8 indicate that the correlation between the Delmhorst RDM-1 meter readings and the OSB MC % are within 2% in the range of 12% to 25% MC.)

The MC in the Plywood sheathing at the time of installation averaged 31% and at the time of removal averaged 33% as measured with a Delmhorst RDM-1 meter set for SPF at 21°C.

None of the panels achieved complete drying to original weight levels during the test. There was significant drying of certain components by redistribution, and continued loss of weight throughout the experiment. Table 10B summarizes the results of hand held wood moisture meter reading using the RDM-1 meter. It shows the Average, Maximum and Minimum MC % at the end of the test.

The highest MC at the end of the test was 53% found in the OSB sheathing of Panel 3. The highest average MC was found in the plywood sheathing of panels 10 and 12 at 37%. The highest minimum MC over all panels was found in the plywood sheathing of panel 12 at 32%.

Panel weight gains and losses are described in Table 3. The plywood-sheathed panels gained more weight in the wetting process than comparable OSB-sheathed panels. The plywood sheathing also started at a higher moisture content than the OSB sheathing and remained comparatively high at the end of the experiment. At the end of Phase 1 the plywood-sheathed panels lost the most weight and were the 1st, 2nd and 3rd fastest drying panels by total weight loss.

In all panels the general effect was the same. Moisture was redistributed from the framing to the sheathing. The framing MC was close to the original (before wetting) moisture levels at the top of the panel but still had relatively high MC at the bottom of the panel and for the 20 mm of the framing next to the sheathing. The sheathing MC remained relatively high (>20%) throughout the test.

7.1.2 Overall Drying: Phase 2 - With Solar

The panels absorbed an average of 7756 g (17.1 lb) and a median of 7257 g (16.0 lb) of moisture from the dip tanks. The stud lumber started the test averaging 31%. The OSB started the test averaging 24%. The plywood started the test averaging 37% in Phase 2. (The distribution of moisture in the panels is reported on in Appendix 8.)

In Phase 2 the test panels lost between 4300 g and 1000 g during their 2000 hours in the chamber. The average loss was 2086 g, with a median loss of 1995 g, (see Table 3). All panels continued to lose moisture for the first 1800 hours of the 2000 hour test. Moisture loss was negligible during the final 200 hours in panels 1,2, 7 and 8.

The moisture content (MC) in the studs at the time of installation averaged 37% and at the time of removal averaged 11% (as measured with a Delmhorst RDM-1 meter set for SPF at 21°C, see Table 2).

The MC in the plates at the time of installation averaged 36% and at the time of removal averaged 14% (as measured with a Delmhorst RDM-1 meter set for SPF at 21°C).

The MC in the OSB sheathing at the time of installation averaged 23% and at the time of removal averaged 34% (as measured with a Delmhorst RDM-1 meter set for SPF at 21°C).

The MC in the Plywood sheathing at the time of installation averaged 37% and at the time of removal averaged 33% (as measured with a Delmhorst RDM-1 meter set for SPF at 21°C).

None of the panels achieved complete drying to original weight levels during the test. There was significant drying of certain components by redistribution, and continued loss of weight throughout the experiment. Table 10B summarizes the results of hand held wood moisture meter reading using the RDM-1 meter. It shows the Average, Maximum and Minimum MC % at the end of the test.

The highest MC at the end of the test was 60% found in the OSB sheathing of Panels 4, 5, 8 and 10. The highest average MC was found in the plywood sheathing of panel 10 at 42%. The highest minimum MC over all panels was found in the plywood sheathing of panel 10 at 31%.

Panel weight gains and losses are described in Table 3. Although the plywood-sheathed panels started at a higher moisture content than the OSB and remained comparatively high at the end of the experiment, the plywood-sheathed panels lost the most weight and are the 1st, 2nd and 3rd fastest drying panels by total weight loss.

In all panels the general effect was the same. Moisture was redistributed from the framing to the sheathing. The framing was close to the original (before wetting) moisture levels ±12% at the top of the panel but still had relatively high MC at the bottom of the panel and for the 10 to 20 mm of the framing next to the sheathing. The sheathing MC remained relatively high (>30%) throughout the test. Panel 11 had the best performance with the largest percentage weight loss and the lowest average MC in the sheathing at the end of the test.

7.2 Question 2 Drying Times

Under test conditions and without re-wetting, how long do they take to dry out?

Overview of results from both phases:
The framing components generally dried out to below 19% after 1200 hours depending on wall design and the presence or absence of solar effects. The exception to this occurs in the lower 200 mm of the framing and in the 20 mm zone of the framing next to the sheathing. Here drying was slower and the MC stayed above the 19% mark for the duration of both Phase 1 and Phase 2. The average moisture content of the sheathing stayed above 19% beyond the end of the test period in both Phase 1 and Phase 2.

7.2.1 Drying Times Discussion

There are three phases of drying which we are characterizing and will use to describe the results of this drying experiment. 1. initial drop, 2. redistribution, and 3.final drying.

Initial drop: We expect a material with a high MC to lose free water quickly at the start of the drying period. This water will be removed by gravity, capilarity and suction. The drop may only take a few hours to accomplish and the MC of the material may drop 10%. This is especially prevalent with surface MC readings.

Redistribution: After the initial drop moisture will redistribute within the material and from adjoining materials and air spaces. Drying is still going on. Water is moving by capilarity and vapour diffusion during this stage. We postulate that the MC of the material may slowly rise to a point where the entire panel has reached internal equilibrium redistribution. At this point internal redistribution stops, and the flow of moisture out of the panel through the sheathing governs further redistribution within the panel.

Final drying. Once the wall panel system has reached the state where redistribution stops, it enters the phase where drying predominates and moisture is moving by vapour diffusion. The vapour diffusion rate is governed by the effective permeance of the wall system, principally the sheathing, the sheathing protection membrane and the cladding assembly.

The total drying of the test panel is dependent on all three of these rates. The drying of a wall in the field, where the wall may be subject to re-wetting will be different from a test wall panel in that the frequency of re-wetting may extend the first two phases over many cycles before final drying occurs. In Phase 2, the solar cycle will affect the air movement in the cavity, the moisture capacity of the air in the cavity and the vapour pressure differential between the stud space and the cavity.

7.2.2 Drying Times: Phase 1 Without Solar

After 1500 hours of drying, the test panels had lost an average of 1500 grams of the original average 7800 grams of moisture gained in the wetting process. We know that not all components were dry, however significant redistribution of moisture has occurred. (See Figure 2 and Appendices 2 and 7 for locations of sensors referred to in the following description of results.)

Studs:
We can look at this redistribution by examining the data for the type A stud. These are data points C1 through C9 at locations 11, 12 and 13 of Figure 3. C1, C4 and C7 are on the Surface. C2, C5, and C8 are at the Core. C3, C6 and C9 are Near Sheathing at the stud centre line, 10 mm from the sheathing. For the typical panel #5 (see DAS charts A1-W5-1):

Initial Drop:
- Surface: drops to below 25% within 50 hours – in the lower half of the stud.
- Core: stays below 20% and drops below 14% within 50 hours
- Near Sheathing: starts at 50% and drops to below 45% after 50 hours.

Redistribution:
- Surface: drops to below 20% after 250 hours and below 14% after 400 hours.
- Core: Gains slightly for first 200 hours but stays below 12% for duration of test.
- Near Sheathing: drops to below 30% after 850 hours except at the bottom of the stud where it reaches <30% after 1450 hours.

Final Drying:
- Surface: From 400 hours to 1500 hours drops from 14% to 12%.
- Core: Stays below 12% for last 1300 hours of test.
- Near Sheathing: After 850 hours it is at 30% it then begins to drop down to an average of 21% over the next 1000 hours of slow drying.

The problem area for the studs is at the junction with the sheathing. This area stays above the 20% MC level longer than the other instrumented areas of the stud. In our review of the time for drying to occur we will focus on this area of the stud data.

Plates:

We can look at this redistribution by examining the data for the A and B plates. These are data points D1 through D4 at locations 6, 7 and 8 of Figure 3. D1 is in the centre of the centre stud space on the Surface of the upper or A plate. D2 is below D1 at the Core of the A plate. D3 is below D2 at the Core of the lower or C plate. D4 is at the core of the A plate 50 mm from the end cut in the centre of the right stud space. For the typical panel #5: (see DAS Chart A1-W5-5)

Initial Drop:

Surface: remains at 27% for 250 hours.
Core Upper Plate: drops to below 20% within 100 hours
Core Lower Plate: stays at a low level 12% (note accuracy decreases below 12% due to high resistance values being measured)
Near End Cut: drops to below 25% after 50 hours.

Redistribution:

Surface: stays near 27% for 250 hours then drops quickly to below 15%.
Core Upper Plate: drops from 25% to 20% within the first 100 hours then continues to drop at the same rate to below 15% over next 200 hours.
Core Lower Plate: Stays flat at 12%
Near End Cut: drops to below 25% in the first 50 hours then maintains 22% for next 350 hours before entering into next phase.

Final Drying:

Surface: after 300 hours has dropped to below 15%, then enters slow drying down to final 12% range.
Core Upper Plate: after 300 hours of redistribution has dropped to below 14%, then enters slow drying down to final 12% range.
Core Lower Plate: Stays flat at 12%
Near End Cut: after 400 hours of redistribution has stayed at 22%, then enters steady drying down to final 13% range.

In the centre section of the plate (away from the end cut) rapid drying occurs within the first 300 hours, down to below 16%. The plates core MC drops to below 20% MC within the first 100 hours. The Surface moisture lingers longer, for up to 250 hours. Close to the end cut the plate retains moisture longer through the redistribution phase. It is assumed that it is picking up moisture from the sheathing and the stud space during this phase. As there were no moisture sensors in the plates next to the sheathing it is not possible to say how the distribution of moisture was affected by the sheathing.

Sheathing:

We can look at moisture redistribution in the sheathing by examining the data for locations 1, 2, 3, 4 & 5 of Figure 3. Two MC sensors, A1 and A2 were placed in locations 1 and 2, near the outside surface of the sheathing next to the building paper or SBPO (Cavity Side). Five MC sensors were placed in locations 1 to 5 on the inside surface of the sheathing next to the insulation (Stud Space Side). For the typical panel #5: (see DAS Chart A1-W5-6)

Initial Drop:

Cavity Side: the A1 sensor was not considered reliable. A2 shows a slow steady rise in MC from 8% to 13% over 1500 hours. The first 100 hours show no change.

Stud Space Side: the B Sensors show a rapid decline in surface moisture over the first 24 hours followed by a leveling off period below 16% up to the first 100 hours.

Redistribution:

Cavity Side: the A1 sensor was not considered reliable. A2 shows a slow steady rise in MC from 8% to 13% over 1500 hours. The second 400 hours show no change.

Stud Space Side: the B Sensors show a variety of change in surface moisture over the first 100 hours. B5 at the bottom of the stud space increases rapidly to 27%. B3 at the bottom of the stud space increases gradually to 20%. The three sensors at the mid and top of the panel decline slowly before leveling off and remaining below 15% for the duration of the test for the next 1400 hours.

Final Drying:

Cavity Side: A2 continues to climb for the duration of the test ending over 13% after 1500 hours.

Stud Space Side: The lower sensors remain steady at an MC above 20% for the first 1100 hours at which point B5 begins to decline while B3 continues to climb. They both finish the test around 22% MC.

The Upper and Mid panel sensors stay flat at below 14% and below 10%, showing no long term drying effect beyond this point.

The results indicate that moisture is being redistributed to the OSB sheathing for the first 1100 hours of the test. Some drying starts to occur at the top of the panel but the bottom of the panel remains above the 20% mark for the majority of the 1500 hours and does not dry to its original MC in the end of the test.

7.2.3 Drying Times: Phase 2 With Solar

After 2000 hours of drying the panels had lost an average of 2100 grams of an original 7400 grams of moisture. We know that not all components are dry, however significant redistribution of moisture has occurred. (See Figure 2 and Appendices 2 and 7 for locations of sensors referred to in the following description of results.)

Studs:

We can look at this redistribution by examining the data for the A stud. These are data points C1 through C9 at locations 11, 12 and 13 of Figure 3. C1, C4 and C7 are on the Surface. C2, C5, and C8 are at the Core. C3, C6 and C9 are Near Sheathing at the stud centre line, 10 mm from the sheathing. For the typical panel #5 (See DAS Chart: A2-W5-1):

Initial Drop:

Surface: from initial MC of 28% drops to below 25% within 50 hours.
Core: Starts at 20% stays at 20% and has MC rise at mid stud to 22%
Near Sheathing: Starts at 22% and has MC rise to 23% over first 100 hours

Redistribution:

Surface: drops from 25% to below 15% after 400 hours.
Core: Gains slightly for first 200 hours to 23% then drops slowly for 600 hours to 15%
Near Sheathing: Rises to 23% at 200 hours and remains there for next 1000 hours.

Final Drying:

Surface: Has reached final MC of 12% at 600 hours and stays unchanged for next 1400 hours.
Core: Stays below 14% for last 1300 hours of test.
Near Sheathing: Reaches final MC of 23% after 200 hours and stays unchanged for next 1800 hours.

The high moisture retention area for the studs is at the junction with the sheathing. This area stays above the 20% MC level for the entire test. In our review of the time for drying to occur we will focus on this area of the stud data.

Plates:

We can look at this redistribution by examining the data for the A and B plates. These are data points D1 through D4 at locations 6, 7 and 8 of Figure 3. D1 is in the centre of the centre stud space on the Surface of the upper or A plate. D2 is below D1 at the Core of the A plate. D3 is below D2 at the Core of the lower or C plate. D4 is at the core of the A plate 50 mm from the end cut in the centre of the right stud space. For the typical panel #5: (See DAS Chart: A2-W5-5)

Initial Drop:

Surface: Starts at 28% drops to below 25% within 200 hours.
Core Upper Plate: Starts at 25% and drops to below 21% within 200 hours.
Core Lower Plate: Starts at 25% and drops to below 21% within 200 hours.
Near End Cut: Starts at 30% and drops to below 27% after a 100 hours.

Redistribution:

Surface: Continues to drop for 300 hours to below 12%.
Core Upper Plate: Continues to drop for the first 800 hours to below 12%.
Core Lower Plate: Drops to below 12% after 700 hours
Near End Cut: Rises to 31% after 300 hours. Stays at this >30% level for a further 300 hours.

Final Drying:

Surface: Stays below 12% for final 1500 hours of test.
Core Upper Plate: After 800 hours has dropped to below 12%, MC remains below 12% for duration of test.
Core Lower Plate: Same response as core upper plate.
Near End Cut: after 600 hours of redistribution has stayed risen to 31%, then enters steady drying down to final 14% range.

The plates core MC away from the end cut drops to below 20% MC within the first 200 hours. The Surface moisture MC follows the core trend. Close to the end cut the plate gains moisture through the redistribution phase. It is assumed that it is picking up moisture from the sheathing and the stud space during this phase. As there were no moisture sensors in the plates next to the sheathing it is not possible to say how the distribution of moisture would be affected by the sheathing.

Sheathing:

We can look at this redistribution by examining the data for locations 1, 2, 3, 4 & 5 of Figure 3. Two MC sensors, A1 and A2 were placed in locations 1 and 2, near the outside surface of the sheathing next to the building paper or SBPO (Cavity Side). Five MC sensors were placed in locations 1 to 5 on the inside surface of the sheathing next to the insulation (Stud Space Side). For the typical panel #5 (See DAS Chart A2-W5-6):

Initial Drop:

Cavity Side: the A1 sensor was not considered reliable. A2 shows a slow steady rise in MC from 8% to 16% over 1500 hours. The first 100 hours show no change.

Stud Space Side: the B Sensors show a decline in surface moisture over the first 100 hours with an average MC of 18%.

Redistribution:

Cavity Side: the A1 sensor was not considered reliable. A2 shows a slow steady rise in MC from 8% to 16% over 1500 hours.

Stud Space Side: the B Sensors show a variety of change. B5 and B3 at the bottom of the stud space increase to >20%. The three sensors at the mid and top of the panel decline slowly before leveling off and remaining below 15% for the duration of the test, the next 1900 hours.

Final Drying:

Cavity Side: A2 continues to climb for the duration of the test ending over 15% after 2000 hours.

Stud Space Side: The lower sensors remain steady at a MC above 20% for the final 1800 hours of the test.

The Upper and Mid panel sensors stay flat at below 14% showing no long term drying effect beyond this point.

The results indicate that moisture is being redistributed to the OSB sheathing over the 2000 hours of the test. Some drying starts to occur at the top of the panel but the bottom of the panel remains above the 20% mark for the majority of the 2000 hours and does not dry to its original MC in the end. The hand held MC meter readings confirm that the sheathing ended the test in the 20%-36% range (Appendix 9).

7.3 Question 3 Drying Variations

Are some panels drying faster than others? What is the variation between the panels?

Overview of results from both phases:
The EDRA experiment was capable of discriminating among wall panel designs in terms of drying rates. Generally, in order of decreasing differences:

1. Panels with plywood sheathing dried faster (but also absorbed more initial moisture during panel wetting) than comparable panels with OSB sheathing.
2. Panels with cavities dried faster than comparable panels without cavities (see Section 10.4 for discussion).
3. Panels with top and bottom vented cavities dried faster than comparable panels with bottom only vented cavities (see Section 10.5 for discussion)
4. Panels with wood siding dried faster than comparable panels with stucco cladding in Phase 1 however this trend was reversed in Phase 2 with the simulated solar effect.
5. Panels with building paper or SBPO did not show any significant difference in drying rates.

7.3.1 Drying Variation Discussion

The test panels can be compared, by looking at the moisture loss in five ways:
a) total moisture loss over the period
b) moisture loss as a percent of total moisture gain
c) relative drying factors
d) effective permeance
e) change in hand held moisture meter readings

The variables which these measures assess are:

1. OSB sheathing vs. plywood sheathing
2. building paper vs. spun bonded polyolefin (SBPO)
3. stucco cladding vs. wood cladding
4. vented cavity vs. non vented (or 0 mm) cavity
5. 19 mm cavity vs. 10 mm cavity
6. cavity vented top and bottom vs. cavity vented bottom only

In this section we will look in detail at the differences between panels performance based on their material differences; OSB sheathing vs. Plywood sheathing, building paper vs. SBPO and stucco cladding vs. wood cladding.

The comparison of panels with differing cavity and venting arrangements are discussed in detail in Sections 10.4 and 10.5.

Total moisture loss from the panel over the test phase provides an indication of overall performance. However, panels which have absorbed a higher amount of moisture initially, may have a greater propensity to lose moisture, especially if the excess moisture is located in the sheathing. It is therefore more relevant to also compare panels using **moisture loss as a percent of total moisture gain**.

Relative drying factors are used as an evaluation tool where the comparison of a wall panel system to a reference wall panel system provides a measure for comparative performance within the test group. In this analysis we have chosen Panel 1 as our reference wall panel and defined the relative drying factor as:

$$\text{Relative drying factor} = R_n = \frac{\text{\% moisture loss Panel n}}{\text{\% moisture loss of Panel 1}}$$

In assessing drying variations we sought to identify which aspects of panel design resulted in a substantial drying advantage. By this method two similar panels with one feature different can be compared to assess the impact of the difference, (i.e. Panel 3 is compared to Panel 4, where the only difference is in the sheathing protection membrane).

Where the ratio of relative drying factors is:

$$\frac{R_3}{R_4} < 0.67 \quad \text{or} \quad \frac{R_3}{R_4} > 1.5$$

their relative performance difference is greater than 50%. This difference is considered substantial and indicates some performance advantage.

Effective permeance of a panel is used as an overall measure of performance. Since it is expressed in ng/Pa·sec·m2 is gives a rate per second and is independent of surface area, time and vapour pressure differences between the panels.

Hand held moisture readings were taken in the framing and sheathings (see figure 6) within 30 minutes prior to panel insertion in the chamber and within 30 minutes after panel removal from the chamber. The data appears in Table 2, 10 and 10B. These data have been summarized in Chart 1 for all 12 wall panels in both phases. These data represent only 2 points in time, the beginning and the end of the tests. Consequently conclusions cannot be drawn from these data about intermediate events. Based on oven dry tests of wood samples (see appendices 8 and 9) we can consider hand held readings in lumber and OSB to be accurate to within ±1% in the range of 15% to 25%, and ± 3% in the range or 8% to 15%. Readings above 25% are an indicator of relative moisture content. Overall performance of a panel is important, but it is equally important to assess performance of individual components, studs, plates and sheathing. Since the goal of designers is to produce a wall which dries in all parts, this experiment looked at the **change in hand held moisture meter readings** at various points in the test panels, from the start of the test to the end of the test. The information in Chart 1 provides a check on the performance of various components of the test wall panels.

It is possible to derive even further detailed analysis of the performance of wall panel components from the DAS data recorded in the DAS Charts provided in the report. While we have looked at these to verify our view of the handheld data we have chosen not to include a detailed description of these in this summary analysis of the data.

Which measure provides the best understanding of drying variations between the panels? By comparing the panels using all five measures we can form a more complete picture of overall performance, component performance and the magnitude of their differences.

7.3.2 Drying Variations: Phase 1 - Without solar

10.3.2.a) comparison by total moisture loss

In all cases we are using the total panel weight data. (This negates the effect of using the bare panel weights where moisture may have been absorbed in the insulation and removed with the insulation to obtain the bare panel weights.)

The ranked results are shown in Table 4. The average weight gain of the panels was 7756 g (17.1 pounds). Weight loss ranged from a low of 680 g (1.5 pounds) to a high of 2858 g (6.3 pounds).

All the plywood-sheathed panels dried faster than all the OSB-sheathed panels. The larger cavity OSB panels generally dried faster than the smaller cavity panels. The exception to this was panel 4. Panels with wood siding dried faster than the comparable stucco-clad panels.

After testing, Panels 7 and 12 had their top flashings removed for inspection of their cavities. The 10 mm cavity of Panel 7 was partially blocked, by stucco mortar pushing in the paper backing of the lath. The cavity of Panel 12 was 5 mm to 10 mm and should have been a nominal 10mm cavity as per the design.

10.3.2.b) Comparison by moisture loss as a percent of total moisture gain

The ranked results are shown in Table 5. All of the plywood-sheathed panels dried faster than the OSB-sheathed panels. Larger cavity panels with building paper dried faster than smaller cavity panels, no cavity panels and SBPO panels

10.3.2.c) Comparison by relative drying factors

Panel #1 which had one of the lowest moisture losses of the panels tested in Phase 1 was chosen as the reference panel (see Table 5 and Table 8).

Overall relative drying relationships:

The plywood-sheathed panels show a range of relative drying factors from 2.7 to 3.3, including 19, 10 and 0 mm cavities. Relative drying factors for OSB sheathing then drop down to two clusters, one with an average of 2.6 (which includes Panel 5) and the remainder lower at an average of 1.5. These are in a range which is 50% or less than the relative drying factors for plywood.

OSB Sheathing vs. Plywood Sheathing

Plywood-sheathed panels of similar cavity width, venting, cladding and sheathing membrane (bldg. paper) were 1.8 to 2.7 times the drying rates of their comparable OSB-sheathed panels. There was a marked difference between the panels with 0 Cavity #10 vs #1, where the plywood-sheathed panel had 2.7 times the rate of the OSB. Panels with 19mm cavity vented bottom only #11 dried 1.8 times the rate of the comparable OSB-sheathed panel #3. The differential between OSB with a 19mm cavity vented top and bottom #5 and plywood with a 10mm cavity vented top and bottom #12 shows the improved drying of the cavity assembly on OSB. Here the ratio of unit rates narrows to 1.1 in favour of plywood.

Building Paper vs. SBPO:

Panels 1, 3 and 5 with building paper were compared to Panels 2, 4 and 6 with SBPO. Each had stucco cladding and an equivalent arrangement of cavity width and venting. The ratio of unit drying factors show more than a 50% drying difference between the assemblies, however, the results are not consistent. With zero cavity the SBPO panel dried faster than the building paper panel, whereas with a 10 mm or 19 mm cavity the building paper panel, dried faster than the SBPO panel. It is possible that air movement in the cavity results in mass flow of moisture between the laps of the paper. The air barrier effect of the continuous sheet of SBPO precluded this drying mechanism and the SBPO could only pass moisture by diffusion.

Stucco Cladding vs. Wood Cladding:
Stucco-clad Panels 1 and 3 were compared to wood-clad Panels 8 and 9. In both cases the wood-clad panels experienced at or near 1.5 times the relative drying of the stucco-clad panels. The differences in relative drying are considered substantial. We know that wood siding has higher vapour permeability than stucco cladding. This difference would account for the drying improvement.

10.3.2.d) Comparison by effective permeance

Overall Effective Permeance results:
The effective permeance (e.p.) ranged from 241 to 1012 ng/Pa·sec·m2. This is a substantial difference in drying rates. The effective permeance of the panels are listed in Table 13.

OSB Sheathing vs. Plywood Sheathing:
The plywood-sheathed panels 10, 11 and 12 are compared to OSB-sheathed panels 1, 3 and 7. The e.p. of the plywood-sheathed panels were 2.4 to 3.5 times the e.p. of the OSB-sheathed panels.

Building Paper vs. SBPO:
Panels 1, 3 and 5 with building paper were compared to Panels 2, 4 and 6 with SBPO. Where there was a zero cavity the e.p. of the panel with building paper (#1) was lower than the SBPO panel (#3). Where there was a vented cavity the situation was reversed and the e.p. of the panels with building paper was higher. The difference was more pronounced in the comparison of Panel 5 to Panel 6. Here the panel with building paper had twice the e.p. of the panel with SBPO. Panel 5 would be expected to have more air flow in the cavity than Panel 3. It is possible that the building papers respond better to drying in a cavity where there is some air flow, while the response of the SBPO remains relatively unchanged .

Stucco Cladding vs. Wood Cladding:
Panels 1 and 3 with stucco cladding were compared to Panels 8 and 9 with channel cedar siding. Where there was a zero cavity the wood siding panel had 1.6 times the e.p. of the stucco-clad panel. Where the panels had a vented cavity there was no difference in their effective permeance.

10.3.2.e) Comparison by change in hand held moisture readings

Overall hand held meter results:
Typically the framing experienced a drop in the MC in the studs of 16% and in the upper bottom plate of 17%. The studs started at 28% and finished at 12%. The upper bottom plate of started at 31% and finished at 14%. The lower bottom plates appeared to be more isolated from the wetting and drying with an average start point of 25% and an average finish of 16% (see table 2). The OSB sheathing generally had lower MC at the end of the test than at the beginning. The plywood sheathing had the same or higher MC at the end of the test as at the beginning. Overall the sheathing drying did not follow the average drying trend of the framing and the sheathing finished the test averaging above 20% MC.

OSB Sheathing vs Plywood Sheathing.:
In each case of looking at comparable panels, the studs and plates dried to essentially the same moisture reading levels. However there were differences in the moisture levels in the sheathings. The OSB sheathing did not experience any significant drop in MC with start points averaging 25% and end points averaging 22%. The plywood sheathing had higher start points averaging 35% and end points averaging 37% (see table 10). While the plywood-sheathed panels showed the greatest weight loss over the experiment, they also showed higher MC in the sheathing at the end of the test in Phase 1.

Building Paper vs. SBPO:
The panels used for comparing building paper to SBPO were 1 vs. 2, 3 vs. 4, and 5 vs. 6. All used OSB sheathing. In these panels there were no substantial differences in the final MC of studs and plates. They started the test with MC in the studs and plates in the 25% to 35% range. They ended the test with MC in the studs and plates in the 10% to 15% range.

There were some differences in moisture loss in the sheathing. In Panels 2 and 4 (SBPO) the sheathing dried to a lower average MC than Panels 1& 3. They also had lower maximum moisture readings at the end of the test. However where the cavity was vented top and bottom, Panel 5 with building paper dried to a lower MC than panel 6 with SBPO. It also had lower maximum moisture readings at the end of the test. With no replicates in the test sets, the difference in performance is not significant. The data indicate overall trends and on a panel by panel basis there were no substantial differences in the drying rates as a result of the use of different sheathing protection membranes.

Stucco Cladding vs. Wood Cladding:
The panel with direct applied wood cladding had lower readings in the sheathing at the end of the test than the comparable stucco-clad panel. There was no substantial difference between the stucco or wood-clad panels with 19mm cavities vented at the bottom. The stucco-clad panels had slightly higher maximum moisture content in the sheathing at the end of the test, otherwise they performed equally.

7.3.3 Drying Variations: Phase 2 - With Solar

10.3.2.a) comparison by total moisture loss
In all cases we are using the total panel weight data.

The ranked results are shown in Table 4. The average weight gain of the panels was 7393 g (16.3 pounds). Weight loss ranged from a low of 997 g (2.2 pounds) to a high of 4309 g (9.5 pounds).

All the plywood-sheathed panels exceeded all the OSB-sheathed panels for both total moisture loss and % moisture loss. The larger cavity OSB panels generally outperformed the smaller cavity panels for total moisture loss. The exception to this was panel 7 (which had a partially blocked cavity). Wood clad panels with cavity dried faster than the comparable stucco panels.

10.3.2.b) Comparison by moisture loss as a % of total moisture gain
The ranked results are shown in Table 5. All of the plywood-sheathed panels dried faster than the OSB-sheathed panels. Larger cavity panels with building paper dried faster than larger cavity SBPO panels smaller cavity panels, and no-cavity panels.

10.3.2.c) Comparison by relative drying factors

Panel 1 was again chosen as the reference panel. In this case, it did not have the lowest moisture losses of the panels tested in Phase 2 (see Table 5 and Table 8).

Overall relative drying relationships:

The plywood panels with cavities were in the top group at 2.1 and 2.6 relative drying factor. The next group were in the 1.1 to 1.5 range. Here the plywood-sheathed panel with 0 cavity, had similar performance to the OSB-sheathed panels with cavities. The third group with 0 cavity and OSB sheathing, were at or below the relative drying factor of the reference wall panel.

OSB Sheathing vs. Plywood Sheathing

Plywood-sheathed panels of similar cavity width, venting, cladding and sheathing membrane (bldg. paper) demonstrated 1.5 to 3.1 times the drying rates of their comparable OSB-sheathed panels. There was a small difference between the conventional wall panels with 0 mm cavity Panel 10 vs. Panel 1, where the plywood-sheathed panel had 1.5 times the rate of the OSB. For panels with 19 mm cavity vented bottom only, the plywood-sheathed Panel 11, dried 2.4 times the rate of the OSB-sheathed Panel 3. The differential between OSB with a 19 mm cavity vented top and bottom Panel 5 and plywood with a 10 mm cavity vented top and bottom Panel 12 shows the improved drying of the cavity assembly on OSB with the wider cavity. Here the ratio of unit rates narrows to 1.7 in favour of plywood.

Building Paper vs. SBPO

Panels 1, 3 and 5 were compared to Panels 2, 4 and 6. Each had stucco cladding and an equivalent arrangement of cavity width and venting. The ratio of unit drying factors show little difference between the assemblies. With 0 cavity the paper outperformed the SBPO whereas with a cavity the SBPO slightly outperformed the paper. Given the differences in relative drying factors were not more than 1.5 times over 2000 hours the differences are not considered substantial.

Stucco Cladding vs. Wood Cladding

Stucco-clad Panels 1 and 3 were compared to wood-clad Panels 8 and 9. The stucco-clad panels were 0.7 and 1.3 times the relative drying of the wood-clad panels. Given the differences in relative drying were not more than 1.5 times over 2000 hours the differences are not considered substantial.

10.3.2.d) Comparison by effective permeance

Overall Effective Permeance results:

The effective permeance (e.p.) ranged from 415 to 1663 ng/Pa.sec.m2. This is a substantial difference in drying. The effective permeances of the panels are listed in Table 13.

OSB Sheathing vs. Plywood Sheathing:

The plywood-sheathed Panels 10, 11 and 12 are compared to OSB-sheathed Panels 1, 3 and 7. The e.p. of the plywood-sheathed panels were 1.6 to 3.5 times the e.p. of the OSB-sheathed panels. This result is similar to Phase 1.

Building Paper vs. SBPO:

Panels 1, 3 and 5 with building paper were compared to Panels 2, 4 and 6 with SBPO. Where there was a zero cavity the e.p. of the panel with building paper Panel 1 was slightly lower than the SBPO Panel 3. Where there was a vented cavity the result was inconsistent. With top and bottom venting the e.p. of the panels with building paper was higher. With bottom only venting the e.p. of the panel with SBPO was higher. The differences between all the panels in this comparison were not substantial. The solar effect would have caused heating in the cavity and increased air-flows are expected with top and bottom venting. This may have caused the building paper panel to provide faster drying than the SBPO panel with the top and bottom venting. In the case of the cavity vented at the bottom only, the SBPO panel had 1.5 times the e.p. of the building paper panel. In this case the air flow rate in the cavity would have been lower and the inherent higher permeability of the SBPO would have produced the drying difference.

Stucco Cladding vs. Wood Cladding:

Panels 1 and 3 with stucco cladding were compared to Panels 8 and 9 with channel cedar siding. Where there was a zero cavity the wood siding panel had 0.8 times the e.p. of the stucco-clad panel. Where there was a 19 mm cavity the wood siding panel had 0.9 times the e.p. of the stucco-clad panel. Essentially there was no substantial difference in their effective permeance depending on the cladding.

10.3.2.e) Comparison by change in hand held moisture readings

Hand held moisture readings were taken in the framing and sheathings (see figure 6) within 30 minutes prior to panel insertion in the chamber and within 30 minutes after panel removal from the chamber. The data appears in Tables 2, 10A and 10B. These data have been summarized in Chart 1 for all 12 wall panels in both phases. These data represent only 2 points in time, the beginning and the end of the test. Consequently conclusions cannot be drawn from these data about intermediate events.

Overall hand held meter results:

The framing experienced a typical drop in the MC in the studs of 25% from 37% to 11% and in the top plate of 22% from 36% to 14% (see Table 2). The OSB sheathing had an increase in average MC over the test, in all cases finishing in the 30% to 35% range. This was opposite to the trend in Phase 1 and indicates that the solar simulation effect changed the drying response of the wall panel system. The 0 mm cavity plywood-sheathed panel also experienced a rise in MC in the sheathing over the test. However, the plywood-sheathed panels with vented cavities experienced a substantial drop in average sheathing MC. Overall the sheathing MC did not drop to the same level as the framing MC, and finished the test substantially above the 20% MC level.

OSB Sheathing vs. Plywood Sheathing

Comparing plywood sheathing to OSB sheathing, in each case of looking at comparable panels the studs and plates dried to essentially the same moisture reading levels. The sheathings had a more varied result. At the end of the test vented panels with plywood sheathings averaging 29% MC were below the moisture levels of the unvented plywood and OSB sheathings averaging 41% and 34% MC respectively. The vented plywood dried, while the OSB sheathing MC rose over the test.

OSB Sheathing vs. Plywood Sheathing

In Panels 1 to 9 the OSB sheathing had MC start points averaging 23% and end points averaging 34%. In Panels 10 to 12 the plywood sheathing had higher start points averaging 36% and end points averaging 33%. (This average was skewed by Panel 10 at 42%.) Panel 11 reached an average of 27% and Panel 12 an average of 31% at the end of the test.) See Tables 2 & 10A. The plywood-sheathed panels had lower MC in the sheathing at the end of the test, than comparable OSB-sheathed panels.

Building Paper vs. SBPO

In looking at the Studs and Plates data, in terms of moisture loss & average moisture contents at the end of the test, there were no significant differences in moisture loss of one over the other in comparable panels.

In looking at the data from the OSB sheathing, there were no substantial differences in moisture loss of SBPO over building paper in comparable panels.

Stucco Cladding vs. Wood Cladding

The stucco-clad panels had lower average MC in the framing and the sheathing than the comparable wood-clad panels at the end of the test.

7.4 Question 4 Drainage Cavity Effect

Does the drainage cavity width affect drying? By how much?

Overview of results from both phases:
Generally panels with wider cavities dried faster than panels with narrow cavities. This trend was heightened in Phase 2 with the solar effect. Panel 7 with a 10 mm cavity showed no increase in drying rate from the solar effect. We know from post-test investigation that the cavity in Panel 7 was partially blocked by stucco mortar pushing in the paper backing on the lath.

7.4.1 Drainage Cavity Effect: Phase 1 Without Solar

No cavity (0 mm cavity) vs. Cavity Vented Bottom Only :

- Stucco Panels 1, 2 and 10 were compared to Stucco Panels 3, 4 and 11(see tables 3, 8 and 13)
- Wood-clad Panel 8 was compared to wood-clad Panel 9 (see tables 3, 8 and 13)

Panel 1 (0 mm cavity) vs. Panel 3 (19 mm cavity) both with building paper and OSB sheathing:

- There was a substantial difference in drying performance between these two panels
- The vented cavity Panel 3 had a +8% difference in total % weight loss over Panel 1.
- The relative drying ratio of Panel 3 to Panel 1 was 1.8.
- Panel 3's effective permeance was 1.3 times the e.p. of Panel 1.
- Panel 3 and Panel 1, had very similar average MC start and end points by handheld moisture readings in the framing. However, in the sheathing, Panel 1 experienced a rise in average MC over the test while Panel 3 experienced a decline in average MC over the test.

Panel 2 (0 mm cavity) vs. Panel 4 (19 mm cavity) both with SBPO:

- Panels 2 and 4, show no substantial improvement in drying rates with a vented cavity. It is not clear why Panel 4 performed differently from other vented panels. It is possible that SBPO does not perform similarly to paper facing a cavity.
- The vented cavity Panel 4 had a -5% difference in total % weight loss over Panel 2.
- The relative drying ratio of Panel 4 to Panel 2 was 0.6.
- Panel 4's effective permeance was identical to the e.p. of Panel 2.
- Panel 4 had handheld moisture readings for framing starting in the same range as Panel 2 (25% to 33%) and their end points both finished in the 10% to 15% MC range. However, in the sheathing, both Panel 2 and Panel 4 experienced a decline in average MC over the test.

Panel 10 (0 mm cavity) vs. Panel 11 (19 mm cavity) both with building paper and plywood sheathing:

- There was a substantial difference in drying performance between these two panels
- The vented cavity Panel 11 had a +6% difference in total % weight loss over Panel 10.
- The relative drying ratio of Panel 11 to Panel 10 was 1.2.
- Panel 11's effective permeance was 1.2 times the e.p. of Panel 10.
- At the start of the test, Panel 10 had slightly lower MC in the framing and 10% higher average MC in the sheathing than Panel 11. Both panels ended the test with average MC in the framing in the 15% range and with no substantial change in the average MC in their sheathing.

Panel 8 (0mm cavity) vs. Panel 9 (19mm cavity) both with wood siding with building paper

- There was a substantial difference in drying performance between these two panels with the vented cavity outperforming the unvented cavity in most aspects.
- The vented cavity Panel 9 had a +10% difference in total % weight loss over Panel 8.
- The relative drying ratio of Panel 9 to Panel 8 was 1.7.
- Panel 9's effective permeance however, was 0.8 times the e.p. of Panel 8.
- At the start of the test, Panel 9 had slightly higher MC in the framing and lower MC in the sheathing (as seen in the handheld moisture readings of Chart 1) than Panel 8. Both panels finished with the framing MC in the 10% to 15% range. Panel 8 experienced a drop in the average sheathing MC, from 26% to 20% while Panel 9 had no change in the sheathing, starting and finishing the test at an average sheathing MC of 20%. It is likely that the higher initial MC in the sheathing of Panel 8 contributed to its having a higher effective permeance than Panel 9.

No Cavity (0 mm cavity) vs. Cavity Vented Top and Bottom:

Stucco Panels 1, 2 and 10 were compared to Stucco Panels 5, 6, 7 and 12.

Panel 1 (0 mm cavity with paper) vs. Panel 5 (19 mm cavity vented top and bottom with paper):

- Panel 5 had a substantial improvement in drying performance over Panel 1.
- The top and bottom vented cavity Panel 5 had a +15% difference in total % weight loss over Panel 1.
- The relative drying ratio of Panel 5 to Panel 1 was 2.6.
- Panel 5's effective permeance was 2.9 times the e.p. of Panel 1.
- Panel 5's handheld moisture readings for framing had very similar start points MC as Panel 1. The framing of Panel 5 dried to a lower overall MC than the framing of panel 1. Comparing the average sheathing MC, Panel 1 experienced a rise in average MC over the test while Panel 5 experienced a slight decline in average MC over the test.

Panel 2 (0 mm cavity with SBPO) vs. Panel 6 (19 mm cavity vented top and bottom with SBPO):

- Panel 6 had no improvement in drying performance over Panel 2.
- The top and bottom vented cavity Panel 6 had the same % weight loss as Panel 2.
- The relative drying ratio of Panel 6 to Panel 2 was 0.9.
- Panel 6's effective permeance was 0.7 times the e.p. of Panel 2.
- At the start of the test, Panel 6 had slightly higher MC in the framing and lower MC in the sheathing (as seen in the handheld moisture readings of Chart 1) than Panel 2. Both panels finished with the framing MC in the 10% to 15% range. Panel 6 experienced no change in average sheathing MC, while Panel 2 had a drop in the average sheathing MC, 32% to 22% over the test. It is likely that the higher initial MC in the sheathing of Panel 2 resulted in it having a higher effective permeance than panel 6. Overall the panels exhibited no substantial difference in drying rates. This suggests that the cavity makes little difference to test panel drying in a non-solar condition, where the sheathing membrane is SBPO. Without replicates we cannot say if this difference is statistically significant.

- Panel 1 (0 mm cavity with paper) vs. Panel 7 (10 mm cavity vented top and bottom with paper):
- On inspection after the test it was found that the 10 mm cavity of Panel 7 was partially blocked with stucco mortar.
- Panel 7 had a marginal improvement in drying performance over Panel 1.
- The top and bottom vented cavity Panel 7 had a +5% difference in total % weight loss over Panel 1.
- The relative drying ratio of Panel 7 to Panel 1 was 1.5.
- Panel 7's effective permeance was 1.4 times the e.p. of Panel 1.
- Panel 7 and Panel 1, had very similar average MC start and end points by handheld moisture readings in the framing. The performance of their sheathing was nearly identical with both panels finishing the test with average MC 1% higher that they started.   This indicates that a very small cavity (< 10 mm) acts similarly to a 0 mm cavity.

Panel 10 (unvented with paper on plywood) vs. Panel 12 (10 mm vented T & B with paper on plywood):

- On inspection after the test it was found that the 10 mm cavity of Panel 7 was partially blocked with stucco mortar.
- Panel 12 had a marginal improvement in drying performance over Panel 10.
- The top and bottom vented cavity Panel 12 had a +2% difference in total % weight loss over Panel 10.
- The relative drying ratio of Panel 12 to Panel 10 was 1.1.
- Panel 12's effective permeance was 0.9 times the e.p. of Panel 10.
- Panel 12 and Panel 10, had very similar average MC start and end points by handheld moisture readings in the framing. The sheathing of panel 10 started the test with a +7% higher MC than the sheathing of Panel 12. Interestingly both panels finished the test with similar average MC in the sheathing. Panel 10 had no change in the sheathing MC, starting and finishing at 36% while Panel 12 started with an average sheathing MC of 30% and finished at 36%.   We conclude from this that a small cavity (< 10 mm) acts similarly to a 0 mm cavity, and that venting at the top and bottom did not substantially improve the performance of the panel.

Cavity Vented Bottom Only vs. Cavity Vented Top and Bottom:
Stucco-clad Panels 3 and 4 were compared to stucco-clad Panels 5 and 6.

Panel 3 (vented bottom only with paper) vs. Panel 5 (vented top and bottom with paper):

- Panel 5 had an improvement in drying performance over Panel 3.
- The top and bottom vented cavity Panel 5 had a +7% difference in total % weight loss over Panel 3.
- The relative drying ratio of Panel 5 to Panel 3 was 1.4.
- Panel 5's effective permeance was 2.2 times the e.p. of Panel 3.
- Panel 5's handheld moisture readings for framing and sheathing MC had very similar start and end points as Panel 3.

Panel 4 (vented bottom only with SBPO) vs. Panel 6 (vented top and bottom with SBPO):

- Panel 6 had an improvement in drying performance over Panel 4.
- The top and bottom vented cavity Panel 6 had a +5% difference in total % weight loss over Panel 4.
- The relative drying ratio of Panel 6 to Panel 4 was 1.5.
- Panel 6's effective permeance was 1.4 times the e.p. of Panel 4.

- At the start of the test, Panel 6 had slightly higher average MC in the framing and 5% higher average MC in the sheathing than Panel 4. Both panels finished with the framing MC in the 10% to 15% range. Both panels had final sheathing MC 1 to 3 % lower that their start points.

This suggests that in a non-solar test with either paper or SBPO on OSB, there is an improvement in performance where the panel is vented top and bottom over bottom only venting.

7.4.2 Drainage Cavity Effect: Phase 2 With Solar

No cavity (0 mm cavity) vs. Cavity Vented Bottom Only :
Stucco Panels 1, 2 and 10 were compared to Stucco Panels 3, 4 and 11(see tables 3, 8 and 13)

Panel 1 (0 mm cavity) vs. Panel 3 (19 mm cavity) both with building paper:

- There was a marginal difference in drying between these two panels. Both panels finished the test with higher MC in the sheathing than they started the test..
- The vented cavity Panel 3 had a +3% difference in total % weight loss over Panel 1.
- The relative drying ratio of Panel 3 to Panel 1 was 1.2.
- Panel 3's effective permeance was 0.8 times the e.p. of Panel 1.
- Panel 3 and Panel 1, had very similar average MC start and end points by handheld moisture readings in the framing and the sheathing. The interesting feature here is that both Panel 1 and Panel 3 experienced a rise in average MC in the sheathing over the test. They began the test with sheathing MC in the 25% range and finished the test with average sheathing MC in the 35% range.

Panel 2 (0 mm cavity) vs. Panel 4 (19 mm cavity) both with SBPO:

- Panel 4, shows an improvement in drying rates over Panel 2 with a vented cavity.
- The vented cavity Panel 4 had a +9% increase in total % weight loss over Panel 2.
- The relative drying ratio of Panel 4 to Panel 2 was 1.6.
- Panel 4's effective permeance was 1.3 times the e.p. of Panel 2.
- Panel 4 and Panel 2, had very similar average MC start and end points by handheld moisture readings in the framing and the sheathing. The interesting feature here, is that both Panel 4 and Panel 2 experienced a rise in average MC in the sheathing over the test. They began the test with sheathing MC in the 25% range and finished the test with average sheathing MC in the 35% range.

Panel 10 (0 mm cavity) vs. Panel 11 (19 mm cavity) both with building paper and plywood sheathing:

- There was a very substantial difference in drying performance between these two panels
- The vented cavity Panel 11 had a +24% difference in total % weight loss over Panel 10.
- The relative drying ratio of Panel 11 to Panel 10 was 1.9.
- Panel 11's effective permeance was 1.9 times the e.p. of Panel 10.
- At the start of the test, Panel 11 and Panel 10, had very similar average MC by handheld moisture readings in the framing and the sheathing. Both panels ended the test with average MC in the framing in the 15% range. However there was a substantial difference in their average sheathing MC at the end of the test. In Panel 10 the sheathing MC started in the 35% range and rose to over 40% by the end of the test. In Panel 11 the average sheathing MC started in the 40% range and dropped, to finish the test in the 26 % average MC range. This was the best sheathing performance of any panel in both phases of the experiment.

Panel 8 (0mm cavity) vs. Panel 9 (19mm cavity) both with wood siding with building paper

- There was a substantial difference in drying performance between these two panels with the vented cavity outperforming the unvented cavity in most aspects.
- The vented cavity Panel 9 had a +14% difference in total % weight loss over Panel 8.
- The relative drying ratio of Panel 9 to Panel 8 was 2.0.
- Panel 9's effective permeance was identical to the e.p. of Panel 8.
- Panel 9 and Panel 8, had very similar average MC start and end points by handheld moisture readings in the framing and the sheathing. The notable feature here, is that both Panel 9 and Panel 8 experienced a rise in average MC in the sheathing over the test. They began the test with sheathing MC in the 25% range and finished the test with average sheathing MC in the 35% range.

In summary, comparing no cavity (0 mm cavity) to cavity vented bottom only, the greatest increase in performance was with wood siding on OSB sheathing and stucco cladding on plywood sheathing. Where these panels had a vented cavity, their overall drying performances were twice the comparable 0 mm cavity panels. This is a marked difference from the Phase 1 tests. This suggests that the solar effect combined with a cavity improves drying with these panels.

No cavity (0 mm cavity) vs. Cavity Vented Top and Bottom:
Stucco Panels 1, 2 and 10 were compared to Stucco Panels 5, 6, 7 and 12.

Panel 1 (0 mm cavity with paper) vs. Panel 5 (19 mm cavity vented top and bottom with paper):

- Panel 5 had an improvement in drying performance over Panel 1.
- The top and bottom vented cavity Panel 5 had a +6% difference in total % weight loss over Panel 1.
- The relative drying ratio of Panel 5 to Panel 1 was 1.3.
- Panel 5's effective permeance was 1.4 times the e.p. of Panel 1.
- Panel 5 and Panel 1, had very similar average MC in the framing and the sheathing at the start and end of the test. Both Panel 5 and Panel 1 experienced a rise in average MC in the sheathing over the test. They began the test with sheathing MC in the 25% range and finished the test with average sheathing MC in the 35% range.

Panel 2 (0 mm cavity with SBPO) vs. Panel 6 (19 mm cavity vented top and bottom with SBPO):

- Panel 6 had a slight improvement in drying performance over Panel 2.
- The top and bottom vented cavity Panel 6 had an +8% increase in weight loss over Panel 2.
- The relative drying ratio of Panel 6 to Panel 2 was 1.7.
- Panel 6's effective permeance was 1.1 times the e.p. of Panel 2.
- Panel 6 and Panel 2, had very similar average MC in the framing and the sheathing at the start and end of the test. Both Panel 6 and Panel 2 experienced a rise in average MC in the sheathing over the test. They began the test with sheathing MC in the 25% range and finished the test with average sheathing MC in the 35% range.

Panel 1 (0 mm cavity with paper) vs. Panel 7 (10 mm cavity vented top and bottom with paper):

- On inspection after the test it was found that the 10 mm cavity of Panel 7 was partially blocked with stucco mortar.
- Panel 7 had a reduction in drying performance over Panel 1.
- The top and bottom vented cavity Panel 7 had a -7% difference in total % weight loss over Panel 1.
- The relative drying ratio of Panel 7 to Panel 1 was 0.7.
- Panel 7's effective permeance was 0.7 times the e.p. of Panel 1.

- Panel 7 and Panel 1, had very similar average MC in the framing and the sheathing at the start and end of the test. Both Panel 7 and Panel 1 experienced a rise in average MC in the sheathing over the test. They began the test with sheathing MC in the 25% range and finished the test with average sheathing MC in the 35% range. These test results indicate that a very small cavity (< 10 mm) acts similarly to a 0 mm cavity in both simulated solar and non simulated solar conditions.

Panel 10 (unvented with paper on plywood) vs. Panel 12 (10 mm vented T & B with paper on plywood):

- (The cavity of Panel 12 was inspected after the test and found to be close to the design depth of 10mm.)
- Panel 12 had an improvement in drying performance over Panel 10.
- The top and bottom vented cavity Panel 12 had a +14% difference in total % weight loss over Panel 10.
- The relative drying ratio of Panel 12 to Panel 10 was 1.5.
- Panel 12's effective permeance was 1.1 times the e.p. of Panel 10.
- Panel 12 and Panel 10, had similar average MC start and end points by handheld moisture readings in the framing. The sheathing of panel 10 started the test with a +3% higher MC than the sheathing of Panel 12. However there was a substantial difference in their average sheathing MC at the end of the test. In Panel 10 the sheathing MC started in the 35% range and rose to over 40% by the end of the test. In Panel 13 the average sheathing MC started with an average of 34% and dropped, to finish the test with an average of 31%. We conclude from this that venting top and bottom improved the drying of the small cavity (10mm) Panel 12 in simulated solar conditions .

The difference between unvented panels and panels vented top and bottom appears to be a substantial increase in drying in a solar condition where the sheathing is plywood. The drying rate increase between Panels 10 and 11 and between Panels 10 and 12, suggests that a 19 mm cavity vented top and bottom on plywood with building paper would have a relative drying factor ratio in excess of 2.0.

Cavity Vented Bottom Only vs. Cavity Vented Top and Bottom:

Stucco-clad Panels 3 and 4 were compared to stucco-clad Panels 5 and 6.

Panel 3 (vented bottom only with paper) vs. Panel 5 (vented top and bottom with paper):

- Panel 5 had a small improvement in drying performance over Panel 3.
- The top and bottom vented cavity Panel 5 had a +4% difference in total % weight loss over Panel 3.
- The relative drying ratio of Panel 5 to Panel 3 was 1.2.
- Panel 5's effective permeance was 1.2 times the e.p. of Panel 3.
- Both panels had similar average MC in framing and sheathing at the start and end points of the test. In both panels the sheathing experienced an increase in average MC over the test.

Panel 4 (vented bottom only with SBPO) vs. Panel 6 (vented top and bottom with SBPO):

- Panel 6 had no improvement in drying performance over Panel 4.
- The top and bottom vented cavity Panel 6 had a -5% difference in total % weight loss over Panel 4.
- The relative drying ratio of Panel 6 to Panel 4 was 1.0.
- Panel 6's effective permeance was 0.9 times the e.p. of Panel 4.
- Panel 6 and Panel 4 had similar average MC in framing and sheathing at the start and end points of the test. In both panels the sheathing experienced an increase in average MC over the test.

This leads to the conclusion that in a simulated solar test, with either paper or SBPO on OSB sheathing, there is no substantial improvement in performance where the wall panel is vented top and bottom over bottom only venting. This was contrary to our expectation that the air flow in the cavity out of the top vent would improve drying substantially. As the bottom only vented panels were not perfectly air tight at the top of the cavity, some small amount of air flow at this point would have been possible. It could be that the very small amount of air movement through the cavity in the bottom-only vented Panels 3 and 4 was sufficient to vent the panel. This implies that the 19mm top vent of the top and bottom vented panels was not fully utilized by the available air-flow in the cavity.

7.5 Question 5 Vent Area Effect

Does the vent area affect drying? By how much?

Overview of results from both phases:
There was no specific test for vent area variations in Group A. However, larger cavities and therefore larger vent areas vented at top and bottom were more effective than smaller cavities vented top and bottom only. This implies that a larger vent area may be beneficial under the given test conditions.

7.5.1 Vent Area Effect: Phase 1 Without Solar and Phase 2 With Solar:

10mm vent vs. 19 mm vent

- All vented panels had equivalent vent heights. The difference between the panels was in the width of the cavity. (See summary Table 4.) This would affect the vent areas to the extent that the entry area was restricted by the cavity width. The question then becomes is there a difference between the wider cavity and the narrower cavity.
- The plywood-sheathed Panels 11 and 12 showed that a wider cavity (and therefore a wider vent) did lose a higher % of original moisture (see Table 5). This effect was more pronounced in Phase 2, suggesting that the combination of a wider cavity and wider vent area enhances the effect of thermal pumping.

The OSB-sheathed Panels 5 and 7 showed that the wider cavity (19 mm) did lose a higher % of original moisture 24% vs. 14.4% than the narrower cavity. Since the cavity and therefore the vent area of Panel 7 was severely restricted by blockage the effect was magnified in Phase 2 where Panel 5 had twice the performance of Panel 7.

It is not possible to comment on vent area for SBPO as there were no 10 mm cavity SBPO panels.

From this limited comparison it is not possible to conclude that vent area has an effect on drying performance. Further tests with significant variations between vent areas for similar cavities would have to be undertaken to make any conclusions in this area.

7.6 Question 6 Lab Correlation to Computer Models

What is the correlation between the predicted moisture movement (by prior runs of computer model WALLDRY) within the framing lumber and the sheathing and the actual moisture movement?

It is not within the scope of this report use the data generated to validate mathematical models. The comparison to the HYGIRC model is not included in this report.

Overview of results from both phases: Generally, the predictions from the WALLDRY model were in reasonably good agreement with the results from the EDRA experiment. WALLDRY did not employ solar cycling as one of its test conditions.

In this report we will make a comparison of the results of EDRA relative to some of the 12 questions answered in the WALLDRY report. The questions are restated as follows:

1. What is the influence of the ventilation cavity depth and the ventilation gap dimensions - Decoupled Stucco
2. What is the influence of chamber RH on drying rates - Decoupled Stucco
3. What is the influence of chamber temperature on drying rates - Decoupled Stucco
4. What is the influence of chamber RH on the drying rates of walls with coupled stucco cladding? How much moisture leaves by diffusion compared to that by venting?
5. What difficulties will be experienced in separating actual moisture loss from the wood elements in the wall from redistribution of moisture during experiments on drying?
6. What are the moisture loss distributions in the walls, and the moisture gradients in different elements of the walls?
7. What are the moisture loss distributions in walls when the ventilation gap at the top is closed?
8. What effect does a simulated wind have on drying rates?
9. What is the difference in drying rates when plywood is used instead of OSB, using the properties implemented in WALLDRY?
10. What is the effect of using 2 x 6 framing instead of the usual 2 x 4 material?
11. What are the drying rates when the polyethylene vapour barrier is not installed?
12. What is the drying performance of the two reference walls, built using vinyl siding and wood siding subject to the same moisture load as used in this parametric study?

The WALLDRY study was able to test combinations of decoupled cladding vent size and cavity width, which EDRA could not test. This report cannot comment on questions 1, 2 and 3 dealing with decoupled stucco. This report can also not comment on questions 4, 8, 10 and 11; as these variables were not included in this experiment. On the remaining questions the following observations on comparisons are made.

WALLDRY Question #5 - What difficulties will be experienced in separating actual moisture loss from the wood elements in the wall from redistribution of moisture during experiments on drying?

The EDRA experiment traced stucco moisture content using removable stucco inserts for gravimetric, measurements.

Figure 6 of the WALLDRY report shows with coupled stucco cladding (as per EDRA), the effects of varying chamber RH. EDRA did not have varying RH conditions, therefore we cannot compare EDRA to the alternate scenarios. However, using the EDRA scenario for wall panel 5, after 1500 hours (62.5) days (with no solar effect) the panel had lost 1.81 kg 4.0 pounds. In WALLDRY (Figure 8) it lost 1.3 kg (2.8 pounds) in the comparable wall S19-12 with 70% RH chamber and 70%RH Stucco. The conclusion here is that the WALLDRY program is predicting only 72% of the total mass loss of the EDRA results for total drying where 19mm cavity widths and 12mm vent sizes are used.

Stucco changes:
Data on the change in weight of stucco samples in the test panels are presented in Table 9. They show that the stucco did gain weight and moisture as the test progressed. There was no drop in the stucco weight towards the end of the test. This implies that the drying process was continuing at 1500 hours and the stucco was still picking up moisture when the test was halted.   The estimated Equilibrium MC for the stucco at 70%RH at 5^{o}C is 5 to 7 % MC by weight. The stucco samples in Panel 5 were at 2.5% MC by weight at removal in phase 1.   This indicates they had not reached EMC. Transfer of moisture from the cavity to the stucco was ongoing after 1500 hours.

WALLDRY Question #6 - What are the moisture loss distributions in the walls, and the moisture gradients in different elements of the walls?

This is where the comparison of EDRA to WALLDRY becomes most complicated and perhaps most interesting. Here we are looking at the individual elements. Panel 5 of EDRA is compared to S19-12 of WALLDRY. Figures 8, 9, 10, and 11 of WALLDRY are referenced.

We will compare the results of WALLDRY Figure 8 to the Total Weight loss of Table 3, the hand held Delmhorst measurements of Chart 14-5. For a more complex comparison we will look at the individual data points for Panel 5 using C3, C6, and C9 as a proxy for the entire stud and B1, B2, and B3, as a proxy for the entire sheathing.

Total Drying:
WALLDRY Figure 8 Total Drying shows a total loss of 1300 gm after 1500 hours. EDRA shows 1800 gms over the same period. The difference here could be the 50% RH start point in the stucco. WALLDRY incorporates a lower permeability (higher diffusion resistivity WALLDRY Figure 2) for stucco at the lower RH.

Stud Drying:
WALLDRY Figure 8 Stud Drying shows the studs had lost 1.5 kg of a total of 2 kg or 75% of their total moisture loss after 1500 hours.   Chart A1-W5-1 shows that the studs had dried from an average of 30% MC to 12% MC after 1500 hours In the EDRA case this represented about 95% of the studs total drying. It indicates that the WALLDRY moisture transfer rate out of the studs may be too slow.

Comparison to points C1 through C9 Chart No. A1-W5-1
We can look at the individual MC points from EDRA for Panel 5 and draw some conclusions about whether WALLDRY simulated what happened on a point by point basis. Initial Drop and Redistribution Phase: First 500 hours

1. At the surface, the EDRA studs showed a steep drop in MC to rest at a steady low level within 500 hours. WALLDRY shows 50% stud moisture loss in the first 500 hours. This correlation is good.

2. At the core near the sheathing the EDRA studs had an initial rapid drop followed by a slow decline and achieved 50% of their total moisture drop in the first 500 hours. This compares well to WALLDRY.

3. At the core in the first 500 hours the EDRA studs had moisture level increase of 2 to 3%. Slow drying continued on from this state. This does not compare well to WALLDRY.

It is difficult to compare individual points from EDRA to the whole stud in WALLDRY on a direct basis. However in EDRA all points, except the bottom & top of the stud next to the sheathing, were below the 20% MC mark after 1500 hours. In WALLDRY, the stud, starting at 30% MC had lost 75% of its moisture load, corresponding to a resultant MC of 7.5% after 1500 hours. As a predictive tool of stud moisture content the simulation appears sufficiently accurate.

OSB Drying:
WALLDRY Figure 8 OSB Drying shows an initial moisture gain by the OSB for 1320 hours followed by drying. The EDRA data chart A1-W5-6 indicates a gain over the first 200 hours, followed by very slight drying over the next 1300 hours. This would agree well with the WALLDRY simulation.

(Note: The EDRA data points in the outside surface of the OSB are not considered reliable. Point A1 at 600mm shows very high resistance indicative of very low moisture or no reading. Point A2 at 50 mm from the bottom of the panel starts off the same, at very low moisture or no reading, and then indicates a rise of moisture from 8% to 12% over 1500 hours.)

Points B1, B2, B3 on the inside face of the OSB appeared more reliable. They indicate three different scenarios. At 1800mm, the moisture level stayed relatively constant around 13%. At 600 mm the moisture level dropped and stabilized around 9%. At B3, located 50mm level from the bottom of the panel, the OSB appears to gain moisture from a start point of 16% to a high of 22%. The B3 point data correlated closest to what was observed from the hand held MC measurements and from visual observation of the wall panels on removal from the chamber. B3 compares well with the WALLDRY simulated drying.

Stucco Drying:
WALLDRY Figure 8 Total Drying shows the stucco loads up with 300 grams of moisture after 200 hours and stays at that level for the duration of the simulation (3600 hrs). Table 9 shows the stucco samples achieving an average weight gain of 13.3 grams. The samples were .15 mm x .21 mm, in an overall panel area of 2.88 m^2. This represents a gain over the entire panel of 1210 grams. In this case the EDRA stucco has absorbed 4 times the predicted moisture of the WALLDRY simulation.

WALLDRY Figures 9, 10 and 11 Comparison to EDRA

Studs detailed comparison:
The data from hand held meter readings (Appendix 9) and DAS readings (Chart A1-W5-1) are relative to the core drying prediction of WALLDRY Figure 9. WALLDRY assumes a start point of 25% MC and predicts a level of 18% at 1500 hours. EDRA has a start point of average 30% and ends at average 12% at 1500 hours. The EDRA studs show a rapid initial drop, in the first 300 hours from the 30% range to the 15% range. This is closer to the predictions from WALLDRY for the outer shell. The much slower drying of EDRA studs next to the sheathing follows the inner core prediction of WALLDRY.

OSB Sheathing detailed comparison:

The location of B1, B2, B3 are relative to the inside face of the OSB for comparison to WALLDRY Figure 10. Since A1 and A2 were not reliable we cannot make a comparison to WALLDRY Figure 11.

In Figure 10, WALLDRY assumes a start point of 25% MC and predicts a level of 35% on the inside surface at 1500 hours. EDRA has a start point of 22% and ends at 21% at 1500 hours. (see Chart 1 Panel 5 and Appendix 9) WALLDRY predicts drying in the OSB starting around 1000 hours. The EDRA data show that drying has not begun in the OSB after 1500 hours. WALLDRY predicts an increase in MC from 25% to 37% over the first 500 hours. In EDRA, the only dramatic increase occurs at the bottom of the panel, in the right hand stud space. Otherwise, the rise in MC is slow and steady over the 1500 hours in the bottom of the panel whereas the top of the panel averages 14% over the last 1400 hours of the test. WALLDRY Figure 10 was not a good predictor of the MC level in the OSB after 100 hours, 500 hours or 1500 hours.

While the inner face data are not a good comparison , the outer layer Figure 11 data from WALLDRY would have been a good predictor of the MC observed in the OSB through the hand held measurements and the DAS trends over 1500 hours.

WALLDRY Question #7 - What are the moisture loss distributions in walls when the ventilation gap at the top is closed?

Here we are looking at the individual elements. Panel #3 of EDRA is compared to S19-12ct of WALLDRY. Figures 12, 13, 14, and 15 of WALLDRY are referenced.

We will compare the results of WALLDRY Figure 12 to the Total Weight loss of Table 3, the hand held Delmhorst measurements of Chart 14, Phase 1, Panel 3. For a more complex comparison we will look at the individual data points for Panel 3 using C3, C6, and C9 as a proxy for the entire stud and B1, B2, and B3, as a proxy for the entire sheathing.

Total Drying:

WALLDRY Figure 12 Total Drying shows a total loss of 750 g after 1500 hours. EDRA shows 1133 g over the same period. In WALLDRY the stucco gains 500 g after 1500 hours. In EDRA the stucco gains 1005 g over 1500 hours. The EDRA data show that up to 2033 g of moisture had moved out of the wood components of the panel and into either the chamber or the cladding vs 1250 g in WALLDRY.

Stud Drying:

WALLDRY Figure 12 Stud Drying shows the studs had lost 1.5 kg of a total of 1.9 kg or 79% of their total moisture loss after 1500 hours.   Chart A1-W3-1 shows that the studs had dried from an average of 30% MC to 12% MC after 1500 hours In the EDRA case this represented about 95% of the studs total drying. It indicates that the WALLDRY moisture transfer rate out of the studs may be too slow.

Comparison to points C1 through C9 Chart No. A1-W3-1

We can look at the individual MC points from EDRA for Panel 3 and draw some conclusions about whether WALLDRY simulated what happened on a point by point basis.

Initial Drop and Redistribution Phase: First 500 hours

1. At the surface the EDRA studs showed a steep drop in MC to rest at a steady low level within 500 hours. WALLDRY shows 50% stud moisture loss in the first 500 hours. This correlation is good.

2. At the core near the sheathing the EDRA studs had a small initial rapid drop of 2% to 5% followed by a slow decline and achieved 66% of their total moisture drop in the first 500 hours. WALLDRY predicts that after 500 hours core moisture levels will have increased and just begun to dry. WALLDRY predicts that after 500 hours the total moisture mass loss will be 50% and if the inner core and outer shell numbers are averaged the resultant 22% compares well to an EDRA prediction of 25%.

3. At the core in the first 500 hours the EDRA studs had moisture level decrease of from 0% to 12%. This does not compare well to WALLDRY which predicts a rise of 2 % followed by a decline of 5%. It is possible that the higher start points for the EDRA studs eliminated the rise in MC seen in WALLDRY.

Final drying phase to 1500 hours:

It is difficult to compare individual points from EDRA to the whole stud in WALLDRY on a direct basis. However in EDRA all points, except the bottom & top of the stud next to the sheathing, were below the 20% MC mark after 1500 hours. In WALLDRY, the stud, starting at 30% MC had lost 79% of its moisture load, corresponding to a resultant MC of 13% after 1500 hours. As a predictive tool of stud moisture content the simulation appears sufficiently accurate.

OSB Drying:

WALLDRY Figure 12 OSB Drying shows an initial moisture gain by the OSB for 500 hours followed by drying. The EDRA data from the hand held measurements Chart 1 Panel 3 indicate that overall the OSB started at 24% and finished at 23% MC. The detailed sensor Chart A1-W3-6 indicates a start point averaging 20% MC and drying to 15% over the 1500 hours. One of the sensors (3B3 at 600 mm on the inside face) showed a rise in MC from 20% to 25% over the test. The EDRA overall data do not agree well with the WALLDRY simulation in this case.

The EDRA data points in the outside surface of the OSB are not considered reliable. Point A1 at 600mm shows very high resistance indicative of very low moisture or no reading. Point A2 at 50 mm starts off the same, at very low moisture no reading, and then indicates a rise of moisture from 10% to 15% over 1500 hours.

Points B1, B2, B3 on the inside face of the OSB appeared more reliable. They indicate three different scenarios. At 1800mm and 600mm the moisture level dropped from 20% over the first 500 hours and then stayed relatively constant around 13%. At B3, 50 mm from the bottom of the panel, the moisture level rose steadily after the initial 100 hours and reaching 25% at the end of the test.. The B3 point data correlated closest to what was observed from the hand held MC measurements and from visual observation of the wall panels on removal from the chamber. B3 compares well with the WALLDRY simulated drying.

Stucco Drying:

WALLDRY Figure 12 Total Drying, shows the stucco loads up with 500 grams of moisture after 500 hours and stays at that level for the duration of the simulation (3600 hrs). Table 9 shows the stucco samples achieving an average weight gain of 12.6 grams. The samples were .15 mm x .21 mm, in an overall panel area of 2.88 m^2. This represents a gain over the entire panel of 1150. grams. In this case the EDRA stucco has absorbed 2.3 times the predicted moisture of the WALLDRY simulation.

WALLDRY Figures 13, 14 and 15 Comparison to EDRA

Studs detailed comparison:

The data from hand held meter readings (Appendix 9) and DAS readings (Chart A1-W3-1) are relative to the core drying prediction of WALLDRY Figure 13. WALLDRY assumes a start point of 25% MC and predicts a level of 18% at 1500 hours. EDRA has a start point of average 28% and ends at average 12% at 1500 hours. The difference in end points indicates that studs dried faster that predicted from 50 hours to 500 hours. As in the EDRA Panel 5 the core of the studs next to the sheathing retains moisture longer and drying is closer to the WALLDRY prediction for the inner core from Figure 13. After 500 hours both locations are close to 25% MC, by 1500 hours EDRA is at 20% MC and WALLDRY is at 15% MC.

OSB sheathing detailed comparison:

The location of B1, B2, B3 are relative to the inside face of the OSB for comparison to WALLDRY Figure 14. Since A1 and A2 were not reliable we cannot make a comparison to WALLDRY Figure 15.

In Figure 14, WALLDRY assumes a start point of 25% MC and predicts a level of 36% on the inside surface at 1500 hours. EDRA has a start point of 24% and ends at 22% at 1500 hours. (see Chart 1 Panel 5 and Appendix 9) WALLDRY predicts drying in the OSB starting around 1000 hours.

The EDRA DAS data show that drying has not begun in the OSB after 1500 hours. WALLDRY predicts an increase in MC from 25% to 38% over the first 500 hours. In EDRA, the only dramatic increase occurs at the bottom of the panel. MC % rises over the 1500 hours in the bottom 200 mm of the panel whereas the top 2200mm of the panel remains at a static MC% over the last 1400 hours of the test. WALLDRY Figure 14 was not a good predictor of the MC level in the OSB after 100 hours, 500 hours or 1500 hours.

While the inner face data are not a good comparison, the outer layer Figure 15 data from WALLDRY would have been a good predictor of the MC observed in the OSB through the hand held measurements and the DAS trends over 1500 hours.

WALLDRY Question #9 - What is the difference in drying rates when plywood is used instead of OSB, using the properties implemented in WALLDRY?

The WALLDRY report does not provide any Figures charting the stud and sheathing MC over the test period, therefore these comparisons cannot be made on a time weighted basis. In the WALLDRY simulation the plywood sheathing started off with a lower absolute MC than the OSB. In EDRA this was not the case, the plywood started off more than 10% higher than the OSB. The general conclusions of WALLDRY, were that the plywood-sheathed wall panels were drier at the end of the 5 month test that the equivalent OSB-sheathed panels. This relationship was seen in the EDRA data as well. The plywood-sheathed panels lost more weight (due to moisture loss), had a higher percentage weight loss (of moisture), but had higher final average MC than the equivalent OSB-sheathed panels.

In the WALLDRY simulation the plywood-sheathed wall had an apparent total drying rate of 59.6 grams /week. This would equate to 532 grams over 1500 hours. The equivalent EDRA Panel 11 had a weight loss over 1500 hours of 2630 grams. The WALLDRY prediction is not close to the EDRA data for total moisture loss.

WALLDRY Question #12 - What is the drying performance of the two reference walls, built using vinyl siding and wood siding subject to the same moisture load as used in this parametric study?

This EDRA experiment did not include any vinyl clad wall panels therefore no comparison to the vinyl cases of WALLDRY are possible.

The EDRA experiment included two cedar siding clad wall panels. WALLDRY Figure 26 is compared to the EDRA data for the 0 mm cavity Panel 8. WALLDRY Figures 27 to 31 are compared to EDRA data for the 19 mm cavity Panel 9.

In the WALLDRY simulation the 0 mm cavity wall loses a total of 1500 grams after 1500 hours. Panel 8 lost 997grams after 1500 hours. The simulation shows the OSB sheathing gaining moisture for the first 500 hours, then losing moisture for the next 1000 hours. The EDRA panel shows the OSB remains at a constant MC after an initial drop in the first 100 hours.

In the WALLDRY simulation of wood siding on strapping, the total loss after 1500 hours is 2500 grams. The EDRA Panel 9 lost 1630 grams over the same time period. The detailed predictions of stud MC show a start point of 25% and an average of 17% MC after 1500 hours. The EDRA panel started at 30 % and finished at 13 % after 1500 hours. The detailed prediction of OSB MC show a start point of 25% and an average of 16% MC after 1500 hours. The EDRA panel started at 20 % and finished at 20% after 1500 hours.

In the case of wood-clad walls the WALLDRY simulations are predicting greater moisture loss and lower moisture content levels than found in the EDRA experiment over the same time period.

7.7 Question 7 Calculated vs. Effective Permeance

How does the calculated permeance of the test wall panels compare to their effective permeance?

Overview of results from both phases:

The effective permeance (e.p.) is based on the total mass of moisture lost relative to the panel area and vapour pressure differential over the entire test period. The calculated permeance (c.p) is based on the sum of the known permeance values for the individual components of the wall panel assembly. In designing a high-performance drying wall, we are trying to produce a panel which has an effective permeance several times greater that its calculated permeance. The development of effective permeance numbers coming out of this experiment gives us a measuring tool for panels tested in subsequent experiments.

In Phase 1, the effective permeance was greater than the calculated permeance in 6 out of 12 of the panels. In Phase 2, the e.p. was greater in 11 out of 12 of the panels.

In Phase 1 the e.p. ranged from 0.6 to 2.2 times the c.p.
In Phase 2, the e.p. ranged from 1.0 to 3.6 times the c.p.

The plywood-sheathed panels had higher e.p. than OSB-sheathed panels. The difference between c.p. and e.p. was heightened in Phase 2 where the solar effect was present. Top and bottom vented large cavities showed the greatest e.p. gain from the solar effect. (It is interesting to note that Panel 7 ran contrary to the trend in Phase 2. After running the experiment we found that it had a blocked vent cavity. This confirms our conclusion that cavity width affects drying and the effective permeance number.)

Effective permeance is dependent on the formula [9] (5.11):

$$M_e = W/ (A\bullet q (p_1-p_2))$$

Where:

M_e= Effective Permeance ng/Pa·sec·m^2
W= mass of moisture vapour moving through the panel in nanograms
A= panel area in m^2
q = time in seconds
p_1= vapour pressure inside the stud space
p_2= vapour pressure inside the chamber

The moisture loss ranged from 680 g to 2850 g.
p_1 varied from stud space to stud space, from hour to hour, but for a simplified calculation the average temperature and RH from Sensors H1 and E1 was used for this comparison.
p_2 was relatively constant at 0.61 kPa

Over 1500 hours for the full panel size of 1.22m by 2.44m, this produces a range of effective permeance of 81 ng/Pa·sec·m^2 to 340 ng/Pa·sec·m^2 in Phase 1 and 78 ng/Pa·sec·m^2 to 399 ng/Pa·sec·m^2 in Phase 2.

The resultant effective permeances are shown in ranked order in Table 12.

The calculated permeances are based on the material properties as noted.

- Stucco 21mm at 70% RH 390 ng/Pa·sec·m^2 [8]
- Vent Cavity 19mm 9211 ng/Pa·sec·m^2 and 10mm 17,500 ng/Pa·sec·m^2 [9]
- Building paper one layer 30 minute at 60%RH 1080 ng/Pa·sec·m^2 [10] (note two layers used in calculation)
- SBPO (Tyvek) 1 layer at 60%RH 1500 ng/Pa·sec·m^2 [7]
- The Plywood and the OSB were monitored for MC throughout the test. To calculate the permeance of the sheathing we have used the average MC at the end of the test to estimate RH in the plywood and OSB. The high MC levels of the plywood average 36% correlate to RH of >96%. The lower MC levels of the OSB average 22% correlate to RH of 90%. [9]
- OSB 11.5 mm at 90% RH 372 ng/Pa·sec·m^2 [8]
- Plywood 12.5 mm at 100%RH 2376 ng/Pa·sec·m^2 [8]
- RSI 2.46 (R14) Batt Insulation 89mm at 60%RH 1910 ng/Pa·sec·m^2 [9]

The calculated permeance is based on the following formula [9] (5.14):

$$M_c = 1/R_c = 1/(R_1+R_2+\ldots R_n)$$

Where

$R = 1/M = R / F$
M_c= Permeance ng/Pa·sec·m^2
R= thickness of material in meters
F= permeability ng/ sec·m·Pa
R = resistance sec·m^2· Pa/ng

The calculated permeances for each panel are listed in Table 11

The effective permeance vs. the calculated permeance are listed in Table 13. The highest effective permeance was 1663 ng/Pa·sec·m^2 achieved by Panel 11 in Phase 2.

7.8 Question 8 Solar Effect on Drying

What is the effect of simulated solar radiation on wall panels?

The review of the data looked at the difference solar radiation made on the vented vs. unvented panels and whether simulated solar heating resulted in a difference in drying compared to no simulated solar heating. Specifically, did some panels dry faster or slower with solar? What might the implications of this be?

Overview of results from both phases:
The solar effect on drying is summarized as follows (data from Table 3):

1. Little or no effect on panels without cavities.
2. A 1.8 times increase in drying for Panel 11, a stucco-clad wall panel with plywood sheathing with 19 mm cavity vented at bottom only.
3. A 1.7 times increase in drying for Panel 12, a stucco-clad wall panel with plywood sheathing, with 10 mm cavity vented at top and bottom.
4. A 2.9 times improvement in Panel 4, a stucco-clad wall panel, with 19 mm cavity, with SBPO, with OSB sheathing vented bottom only.
5. A 1.9 times improvement in Panel 6, a stucco-clad wall panel, with 19 mm cavity, with SBPO, with OSB sheathing vented top and bottom.
6. Stucco-clad wall panels with 19 mm cavities with building paper and with OSB sheathing had an increase in drying with solar of 1.1 to 1.4.
7. Panel 1 with the conventional system of stucco directly on building paper had a 2.3 times increase in % moisture loss with solar.
8. There was no difference in wood-clad wall panels

A small amount of simulated solar radiation had a beneficial effect on the drying rate of stucco-clad wall panels with 19 mm cavities. The effect was greater in panels with SBPO sheathing membrane than with building paper.

8 Conclusions

- Panels with cavities dried faster than comparable panels without cavities.
- Panels with wider cavities dried faster than panels with narrow cavities.
- Panels with top and bottom vented cavities dried faster than comparable panels with bottom only vented cavities.
- The practical lower limit for a stucco-cladding cavity width in the field is 19mm.
- Panels with plywood sheathing dried faster (but also absorbed more initial moisture during panel wetting) than comparable panels with OSB.
- Panels with wood siding dried faster than comparable panels with stucco cladding without solar effect however this trend was reversed with solar effect.
- There were no substantial differences in drying rates between panels with building paper and panels with SBPO.
- Many areas of the framing dried relatively to below 19% MC in under 100 hours.
- The area of the framing next to the sheathing did not dry to below 19% in either Phase 1 or Phase 2, possibly due in part to the presence of strapping over the sheathing in the case of panels with cavities.
- The sheathing components of the panels stayed above 22% MC for the entire test in both phases.
- The sheathing and framing at the bottom of the panel dried more slowly than the other parts of the panel, possibly due to the presence of impervious flashing.
- Generally, the predictions from the WALLDRY model were in reasonably good agreement with the results from the EDRA experiment, however, the EDRA panels lost more overall moisture mass than was predicted by WALLDRY.
- The simulated solar regime resulted in:
  Little or no effect on panels without cavities.
  An increase in the difference between panels' effective permeance and calculated permeance.
  Panels with bottom venting performing similarly to panels with top and bottom venting indicating sufficient air flow in the cavities to eliminate the need for large areas of top venting.
- The fastest drying panel with solar effect had an effective permeance of 1663 ng/Pa·sec·m2, a "benchmark" on panel performance for future tests.

9 Recommendations

The 12 test wall panels of Group A are the first test assemblies in this program. Initially it was envisioned that 40 wall types would be tested. Group A consisted primarily of stucco-clad wall panels. Other cladding systems including vinyl, EIFS, masonry and concrete board should also be tested.

We have seen from Group A that the test panels dried to below 19% MC, in some areas and remained above 19% in other areas. We should test the following assemblies to determine if improvements can be made to the areas of the test walls which stayed above 19%.

1. Sheathing with 2, 75 mm holes at the bottom of each stud space and 50 mm above the bottom plates.
2. Stucco on 19 mm cavity vented top and bottom, on building paper on plywood sheathing.
3. Rim joist assembly with wall section above and below:

   a. with cross cavity flashing
   b. without cross cavity flashing
4. Stucco on 19 mm cavity vented at the bottom only with cavity strapping not located over the studs.
5. Stucco on 38 mm cavity vented:
   a. at bottom only
   b. at top and bottom

Once the drying characteristics of the proceeding assemblies are better understood it may be advisable to go beyond these basic details and test more complex assemblies incorporating windows and doors, with headers and cripples.

We have seen from these tests, that some parts of a test wall loaded with moisture to 30% MC can dry to below 19% in less than 100 hours. Further testing should be undertaken to determine if it is possible for all parts of the building envelope to achieve rapid drying. This testing should include alternate locations for impermeable metal flashings and the testing of vapour permeable flashings adjacent to large concentrations of wood such as rim joists and headers.

Drying is a feasible moisture management mechanisms and should be promoted in the Best Practice Guides.

Further improvements to wall design are needed to achieve rapid drying in all parts of the wall.

Table 1: Group A - 12 Test Panels Specifications

	Venting Location					
R14 Insul			Bottom Only	Bottom Only	Top & Bottom	Top & Bottom
Venting %	0%	0%	0.8%	0.8%	0.8% & 0.8%	0.8% & 0.8%
Cavity Size mm	Bldg Paper	SBPO	Bldg Paper	SBPO	Bldg Paper	SBPO
0	1. Stucco on OSB	2. Stucco on OSB				
10					7. Stucco on OSB	
19			3. Stucco on OSB	4. Stucco on OSB	5. Stucco on OSB	6. Stucco on OSB
0	8. Wood on OSB					
19			9. Wood on OSB			
0	10. Stucco on Ply					
10					12. Stucco on Ply	
19			11. Stucco on Ply			

Table 2: Hand held Moisture Reading Summary Group A Phase 1 & Phase 2

MC % Average of Readings All Wall Panels
Before Installation and After Testing
Handheld Delmhorst RDM-1set for SPF @ 21C

Group A - Phase 1

	All Walls Average		All Walls Median	
	Before	After	Before	After
Studs	28.5	12.2	28.1	12.2
A	30.5	12.5	29.3	12.7
D	26.4	11.9	26.8	11.8
Plates	28.5	14.6	28.7	14.8
A	31.3	13.7	31.3	13.8
C	25.7	15.5	26.2	15.7
Sheathing	27.8	27.7	26.9	28.8
OSB	24.6	22.1	24.3	21.0
Plywood	31.0	33.4	29.6	36.5

Group A - Phase 2

	All Walls Average		All Walls Median	
	Before	After	Before	After
Studs	36.7	11.4	36.3	11.6
A	39.5	11.6	39.1	11.8
D	34.0	11.2	33.5	11.3
Plates	36.2	14.4	36.2	14.3
A	37.5	13.8	38.1	13.6
C	34.8	15.1	34.3	14.9
Sheathing	29.8	33.6	30.0	32.5
OSB	23.0	34.0	23.0	34.1
Plywood	36.7	33.1	37.1	30.9

Table 3: Group A - Phase 1 & 2: Pre and Post Test Wall Panel Weights

Phase 1 - no solar

Wall No	Bare Dry Weight (pounds)	Total Wet Weight (pounds)	Water Gained (pounds)	Removal Weight (pounds)	Total Water Loss [1] (pounds)	Bare panel Loss [2] (pounds)	Total % weight Loss [3]	Net % weight Loss [4]
1	375.2	438.6	16.0	437.1	1.5	1.9	9.3	11.9
2	413.4	479.2	15.8	476.9	2.3	2.1	14.4	13.3
3	436.6	501.5	14.6	499.0	2.5	2.1	17.0	14.4
4	416.4	479.2	15.8	477.7	1.5	1.9	9.4	12.0
5	437.4	501.0	16.6	497.0	4.0	3.9	24.0	23.5
6	439.4	503.2	17.5	500.7	2.5	3.0	14.1	17.1
7	403.7	465.1	15.9	462.8	2.3	3.3	14.4	20.8
8	161.1	224.6	15.3	222.4	2.2	2.6	14.2	17.0
9	171.4	233.4	14.9	229.8	3.6	3.3	24.1	22.1
10	385	452.4	19.7	447.5	4.9	4.8	24.8	24.4
11	430	499.3	19.1	493.5	5.8	5.8	30.3	30.4
12	425.5	498.0	23.7	491.7	6.3	6.5	26.5	27.4

Phase 2 - with solar

Wall No	Bare Dry Weight	Total Wet Weight	Water Gained	Removal Weight	Total Water Loss [1]	Bare panel Loss [2]	Total % weight Loss [3]	Net % weight Loss [4]
1	378.6	442.2	15.7	438.9	3.3	2.8	21.0	17.8
2	416.1	482.3	16.1	479.4	2.9	2.6	18.0	16.1
3	440.1	506.2	16.0	502.4	3.8	3.5	23.8	21.9
4	421.1	485.0	17.1	480.4	4.6	5.0	26.9	29.2
5	441.8	504.9	15.5	500.7	4.2	4.2	27.1	27.1
6	443.9	509.5	18.2	504.7	4.8	4.4	26.4	24.2
7	407.7	469.9	15.5	467.7	2.2	3.0	14.2	19.4
8	164.1	227.1	15.4	224.7	2.4	3.6	15.6	23.4
9	174.6	238.0	16.1	233.2	4.8	5.0	29.8	31.1
10	389	453.5	16.0	448.6	4.9	4.3	30.6	26.9
11	434	504.5	17.6	495.0	9.5	9.0	54.0	51.1
12	428.9	495.7	16.8	488.3	7.4	7.2	44.0	42.9

1. Fully assembled panel weight prior to testing less fully assembled panel weight after testing.
2. Bare panel weight with insulation, poly and interior finished removed, weight prior to testing less weight after testing.
3. Total % weight loss = total water loss / water gained * 100.
4. Net % weight loss =Bare panel loss / water gained * 100.

Table 4: Group A - Phase 1 & 2: All Panels - Sorted by Total Weight Loss

Phase 1 - no solar

Wall No	Sheathing	Membrane	Cavity	Venting	Siding	Total Weight Loss (lbs)
12	Plywood	Paper	10	T&B	Stucco	6.3
11	Plywood	Paper	19	B	Stucco	5.8
10	Plywood	Paper	0	0	Stucco	4.9
5	OSB	Paper	19	T&B	Stucco	4.0
9	OSB	Paper	19	B	Wood	3.6
3	OSB	Paper	19	B	Stucco	2.5
6	OSB	SBPO	19	T&B	Stucco	2.5
7	OSB	Paper	10	T&B	Stucco	2.3
2	OSB	SBPO	0	0	Stucco	2.3
8	OSB	Paper	0	0	Wood	2.2
4	OSB	SBPO	19	B	Stucco	1.5
1	OSB	Paper	0	0	Stucco	1.5

Phase 2 - with solar

Wall No	Sheathing	Membrane	Cavity	Venting	Siding	Total Weight Loss (lbs)
11	Plywood	Paper	19	B	Stucco	9.5
12	Plywood	Paper	10	T&B	Stucco	7.4
10	Plywood	Paper	0	0	Stucco	4.9
6	OSB	SBPO	19	T&B	Stucco	4.8
9	OSB	Paper	19	B	Wood	4.8
4	OSB	SBPO	19	B	Stucco	4.6
5	OSB	Paper	19	T&B	Stucco	4.2
3	OSB	Paper	19	B	Stucco	3.8
1	OSB	Paper	0	0	Stucco	3.3
2	OSB	SBPO	0	0	Stucco	2.9
8	OSB	Paper	0	0	Wood	2.4
7	OSB	Paper	10	T&B	Stucco	2.2

Table 5: Group A - Phase 1 & 2: All Panels - Sorted by % Weight Loss [1]

Phase 1 - no solar

Wall No	Sheathing	Membrane	Cavity	Venting	Siding	Weight Loss % [1]	Relative Drying Factors [2]
11	Plywood	Paper	19	B	Stucco	30.3	3.3
12	Plywood	Paper	10	T&B	Stucco	26.5	2.9
10	Plywood	Paper	0	0	Stucco	24.8	2.7
9	OSB	Paper	19	B	Wood	24.1	2.6
5	OSB	Paper	19	T&B	Stucco	24.0	2.6
3	OSB	Paper	19	B	Stucco	17.0	1.8
2	OSB	SBPO	0	0	Stucco	14.4	1.6
7	OSB	Paper	10	T&B	Stucco	14.4	1.5
8	OSB	Paper	0	0	Wood	14.2	1.5
6	OSB	SBPO	19	T&B	Stucco	14.1	1.5
4	OSB	SBPO	19	B	Stucco	9.4	1.0
1	OSB	Paper	0	0	Stucco	9.3	1.0

Phase 2 - with solar

Wall No	Sheathing	Membrane	Cavity	Venting	Siding	Weight Loss % [1]	Relative Drying Factors [2]
11	Plywood	Paper	19	B	Stucco	54.0	2.6
12	Plywood	Paper	10	T&B	Stucco	44.0	2.1
10	Plywood	Paper	0	0	Stucco	30.6	1.5
9	OSB	Paper	19	B	Wood	29.8	1.4
5	OSB	Paper	19	T&B	Stucco	27.1	1.3
4	OSB	SBPO	19	B	Stucco	26.9	1.3
6	OSB	SBPO	19	T&B	Stucco	26.4	1.3
3	OSB	Paper	19	B	Stucco	23.8	1.1
1	OSB	Paper	0	0	Stucco	21.0	1
2	OSB	SBPO	0	0	Stucco	18.0	.9
8	OSB	Paper	0	0	Wood	15.6	.7
7	OSB	Paper	10	T&B	Stucco	14.2	.7

1 - see definition 3 ***Table 3***
2 - Relative Drying Factor = weight Loss % wall n / weight loss % wall 1

Table 6: Group A - Phase 1 & 2: OSB & Stucco Wall Panels - Sorted by Total Weight Loss

Phase 1 - no solar

Wall No	Sheathing	Membrane	Cavity	Venting	Siding	Total Weight Loss (lbs)	Relative Drying Factors [1]
5	OSB	Paper	19	T&B	Stucco	4.0	2.6
3	OSB	Paper	19	B	Stucco	2.5	1.8
6	OSB	SBPO	19	T&B	Stucco	2.5	1.5
7	OSB	Paper	10	T&B	Stucco	2.3	1.5
2	OSB	SBPO	0	0	Stucco	2.3	1.6
4	OSB	SBPO	19	B	Stucco	1.5	1.0
1	OSB	Paper	0	0	Stucco	1.5	1.0

Phase 2 - with solar

Wall No	Sheathing	Membrane	Cavity	Venting	Siding	Total Weight Loss (lbs)	Relative Drying Factors [1]
6	OSB	SBPO	19	T&B	Stucco	4.8	1.3
4	OSB	SBPO	19	B	Stucco	4.6	1.3
5	OSB	Paper	19	T&B	Stucco	4.2	1.3
3	OSB	Paper	19	B	Stucco	3.8	1.1
1	OSB	Paper	0	0	Stucco	3.3	1.0
2	OSB	SBPO	0	0	Stucco	2.9	0.9
7	OSB	Paper	10	T&B	Stucco	2.2	0.7

1 - Relative Drying Factor = weight Loss % wall n / weight loss % wall 1

Table 7: Group A - Phase 1 & 2: OSB & Stucco Wall Panels - Sorted by % Weight Loss [1]

Phase 1 - no solar

Wall No	Sheathing	Membrane	Cavity	Venting	Siding	Weight Loss % [1]	Relative Drying Factors [2]
5	OSB	Paper	19	T&B	Stucco	24.0	2.6
3	OSB	Paper	19	B	Stucco	17.0	1.8
2	OSB	SBPO	0	0	Stucco	14.4	1.6
7	OSB	Paper	10	T&B	Stucco	14.4	1.5
6	OSB	SBPO	19	T&B	Stucco	14.1	1.5
4	OSB	SBPO	19	B	Stucco	9.4	1.0
1	OSB	Paper	0	0	Stucco	9.3	1.0

Phase 2 - with solar

Wall No	Sheathing	Membrane	Cavity	Venting	Siding	Weight Loss % [1]	Relative Drying Factors [2]
5	OSB	Paper	19	T&B	Stucco	27.1	1.3
4	OSB	SBPO	19	B	Stucco	26.9	1.3
6	OSB	SBPO	19	T&B	Stucco	26.4	1.3
3	OSB	Paper	19	B	Stucco	23.8	1.1
1	OSB	Paper	0	0	Stucco	21.0	1.0
2	OSB	SBPO	0	0	Stucco	18.0	0.9
7	OSB	Paper	10	T&B	Stucco	14.2	0.7

1 - See definition 3 ***Table 3***.
2 - See definition 2 ***Table 5.***

Table 8: *Material & Systems Comparison by Relative Drying Factors*

Phase 1 - no solar

Wall Panel Type	Panel # A	Relative Drying Factor	Panel # B	Relative Drying Factor	Relative Drying Factor Ratio B/A
A. OSB Sheathing vs. B. Plywood Sheathing	1	1	10	2.7	2.7
	3	1.8	11	3.3	1.8
	7	1.5	12	2.9	1.9
A. Building Paper vs B. SBPO Membrane	1	1	2	1.6	1.6
	3	1.8	4	1	0.6
	5	2.6	6	1.5	0.6
A. Stucco Cladding vs B. Wood Cladding	1	1	8	1.5	1.5
	3	1.8	9	2.6	1.4
A. No Cavity vs. B. Bottom Vent Cavity	1	1	3	1.8	1.8
	2	1.6	4	1	0.6
	10	2.7	11	3.3	1.2
	8	1.5	9	2.6	1.7
A. No Cavity vs B. Top & Bottom Vent Cavity	1	1	5	2.6	2.6
	1	1	7	1.5	1.5
	2	1.6	6	1.5	0.9
	10	2.7	12	2.9	1.1
A. Bottom Vent vs B. Top & Bottom Vent Cavity	3	1.8	5	2.6	1.4
	4	1.0	6	1.5	1.5

Phase 2 - with solar

Wall Panel Type	Panel # A	Relative Drying Factor	Panel # B	Relative Drying Factor	Relative Drying Factor Ratio B/A
A. OSB sheathing vs B. Plywood Sheathing	1	1	10	1.5	1.5
	3	1.2	11	2.9	2.4
	7	0.7	12	2.2	3.1
A. Building Paper vs B. SBPO Membrane	1	1	2	0.9	0.9
	3	1.2	4	1.4	1.2
	5	1.3	6	1.5	1.2
A. Stucco Cladding vs B. Wood Cladding	1	1	8	0.7	0.7
	3	1.2	9	1.5	1.3
A. No Cavity vs B. Bottom Vent Cavity	1	1	3	1.2	1.2
	2	0.9	4	1.4	1.6
	10	1.5	11	2.9	1.9
	8	0.7	9	1.4	2.0
A. No Cavity vs B. Top & Bottom Vent Cavity	1	1	5	1.3	1.3
	1	1	7	0.7	0.7
	2	0.9	6	1.5	1.7
	10	1.5	12	2.2	1.5
A. Bottom Vent vs B. Top & Bottom Vent Cavity	3	1.1	5	1.3	1.2
	4	1.3	6	1.3	1

Table 9: Stucco Sample Weights & MC% Group A - Phase 1 & Phase 2

Stucco Sample Weights Group A - Phase I - March 6 to May 12, 2000

Panel Sample	Initial Wet Weight grams	In Test Weight March 16	In Test Weight March 30	In Test Weight April 19	In Test Weight May 4	Oven Dry Weight
1-1	1314	1318.8	1320.6	1322.9	1323.8	1300.4
1-2	1289	1297	1299.2	1301.6	1302.7	1279.5
1-3	1345	1352.6	1355	1357.6	1358.6	1334.7
3-1	1170	1178	1179.7	1181.5	1182.1	1165.1
3-2	1184	1191.4	1193	1194.8	1195.5	1177.2
3-3	1299	1308.6	1310.6	1312.5	1313.2	1292.8
5-1	1257	1264.6	1266.3	1268.1	1269	1237.5
5-2	1353	1361.6	1364	1366.6	1367.6	1334.6
5-3	1266	1273.8	1275.8	1278.3	1279.3	1249.2

Stucco Sample Weights Group A - Phase 2 - July 27 to October 27, 2000

Panel Sample	Initial Wet Weight grams	In Test Weight Sept 21	In Test Weight Oct 6	In Test Weight Oct 18	In Test Weight Oct 25	Oven Dry Weight
1-1	1314	1327	1327.7	1328.4	1328.6	1300.4
1-2	1289	1306.1	1306.5	1306.9	1307.3	1279.5
1-3	1345	1362.3	1363	1363.8	1364.1	1334.7
3-1	1170	1185.1	1185.4	1185.7	1185.9	1165.1
3-2	1184	1200.9	1200.6	1201	1201.3	1177.2
3-3	1299	1313	1317.5	1317.9	1318.3	1292.8
5-1	1257	1271.1	1271.5	1271.9	1272.2	1237.5
5-2	1353	1370.6	1371.1	1371.6	1371.9	1334.6
5-3	1266	1283.7	1284.5	1285.1	1285.6	1249.2

Stucco Sample MC Percent Group A - Phase I - March 6 to May 12, 2000

Panel Sample	Initial Wet %	In Test % March 16	In Test % March 30	In Test % April 19	In Test % May 4	Oven Dry %
1-1	1.05%	1.41%	1.55%	1.7%	1.80%	1300.4
1-2	0.74%	1.37%	1.54%	1.7%	1.81%	1279.5
1-3	0.77%	1.34%	1.52%	1.7%	1.79%	1334.7
3-1	0.42%	1.11%	1.25%	1.4%	1.46%	1165.1
3-2	0.58%	1.21%	1.34%	1.5%	1.55%	1177.2
3-3	0.48%	1.22%	1.38%	1.5%	1.58%	1292.8
5-1	1.58%	2.19%	2.33%	2.5%	2.55%	1237.5
5-2	1.38%	2.02%	2.20%	2.4%	2.47%	1334.6
5-3	1.34%	1.97%	2.13%	2.3%	2.41%	1249.2

Stucco Sample Weights Group A - Phase 2 - July 27 to October 27, 2000

Panel Sample	Initial Wet Weight grams	In Test Weight Sept 21	In Test Weight Oct 6	In Test Weight Oct 18	In Test Weight Oct 25	Oven Dry Weight
1-1	1.05%	2.05%	2.10%	2.15%	2.17%	1300.4
1-2	0.74%	2.08%	2.11%	2.14%	2.17%	1279.5
1-3	0.77%	2.07%	2.12%	2.18%	2.20%	1334.7
3-1	0.42%	1.72%	1.74%	1.77%	1.79%	1165.1
3-2	0.58%	2.01%	1.99%	2.02%	2.05%	1177.2
3-3	0.48%	1.56%	1.91%	1.94%	1.97%	1292.8
5-1	1.58%	2.72%	2.75%	2.78%	2.80%	1237.5
5-2	1.38%	2.70%	2.73%	2.77%	2.79%	1334.6
5-3	1.34%	2.76%	2.83%	2.87%	2.91%	1249.2

Table 10A: Moisture Readings in Wall Panels at Installation & Removal

Wall #	Stud A Before	Stud A After	Stud MC Change	Sheathing Before	Sheathing After	Sheathing Change	Panel Weight Loss g	Panel % Weight Loss
Group A Phase I	MC % from Delmhorst RDM-1 set SPF @ 21C							
OSB-sheathed walls:								
1	29	13	-16	25	26	1	681	9
2	39	13	-26	32	22	-10	1044	14
3	29	12	-17	24	22	-2	1135	17
4	32	12	-20	22	18	-4	681	9
5	31	12	-19	22	21	-1	1816	24
6	28	12	-16	29	28	-1	1135	14
7	29	13	-16	21	21	0	1044	14
8	29	13	-16	27	20	-7	999	14
9	34	13	-21	20	19	-1	1634	24
Average	**31**	**13**	**-19**	**25**	**22**	**-3**	**1130**	**16**
Plywoood sheathed walls:								
10	28	13	-15	37	37	0	2225	25
11	30	12	-18	27	27	0	2633	30
12	28	13	-15	30	37	7	2860	27
Average	**29**	**13**	**-16**	**31**	**34**	**2**	**2573**	**27**
Average all walls phase 1	**31**	**13**	**-18**	**26**	**25**	**-2**	**1491**	**19**
Group A Phase 2								
OSB-sheathed walls:								
1	39	12	-27	24	33	9	1498	21
2	48	12	-36	25	33	8	1317	18
3	39	12	-27	23	36	13	1725	24
4	40	12	-28	23	34	11	2088	27
5	40	12	-28	22	35	13	1907	27
6	41	12	-29	25	35	10	2179	26
7	38	12	-26	21	31	10	999	14
8	43	12	-31	21	36	15	1090	16
9	39	12	-27	22	34	12	2179	30
Average	**41**	**12**	**-29**	**23**	**34**	**11**	**1665**	**23**
Plywoood sheathed walls:								
10	36	11	-25	37	42	5	2225	31
11	38	11	-27	39	27	-12	4313	54
12	35	11	-24	34	31	-3	3360	44
Average	**36**	**11**	**-25**	**37**	**33**	**-3**	**3299**	**43**
Average all walls phase 2	**40**	**12**	**-28**	**26**	**34**	**8**	**2073**	**28**

Table 10 - B : Group A Phase 1 - Hand held Moisture Readings Before Installation & After Removal From Chamber

Stud/Plate/sheathing Average Handheld Delmhorst RDM-1 Set for SPF @ 21oC

	Wall #	1	Wall #	2	Wall #	3	Wall #	4	Wall #	5	Wall #	6	Wall #	7	Wall #	8	Wall #	9	Wall #	10	Wall #	11	Wall #	12
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Studs																								
A	29.1	12.9	38.5	12.7	28.6	12.1	31.7	12.4	31.4	11.8	27.8	12.4	29.2	12.6	29.4	12.7	34.5	12.7	28.5	12.9	30.1	11.6	27.8	12.8
D	26.8	11.4	23.5	11.8	28.3	11.8	30.4	12.4	27.8	11.6	26.5	11.9	27.8	11.5	23.9	12.0	27.9	13.0	23.1	11.8	26.8	11.7	24.5	12.1
Plates																								
A	31.5	13.7	26.3	13.1	31.3	14.4	30.8	14.2	31.3	12.5	37.7	13.9	28.6	13.8	31.2	14.8	33.3	12.3	27.9	13.0	31.5	14.8	34.4	14.2
C	30.4	16.6	28.3	15.6	27.4	15.3	23.6	14.1	23.1	12.3	27.2	15.7	22.4	16.0	26.0	14.9	25.0	15.3	21.6	17.1	27.3	16.7	26.4	16.3
Sheathing																								
OSB	25.0	26.5	31.5	22.5	24.3	22.5	21.6	18.2	22.1	21.0	29.0	28.3	20.6	21.0	27.3	19.8	19.7	19.2						
Plywood																			37.0	36.5	26.6	26.5	29.6	37.1

Readings After Removal From Chamber

	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Studs	9.6	16.2	9.6	15.1	9.6	14.9	10.1	15.5	9.3	14.2	10	14.8	9.7	14.7	10	14.7	9.7	15.3	9.7	15.5	9.5	13.5	11	14.6
Plates	10.2	18.1	11.3	17.3	11.8	17.4	12.3	15.9	9.7	15	10.1	18.2	11	17.9	12.1	18.2	9.7	16.7	9.7	18.2	11.1	18.4	12.1	16.8
Sheathing																								
OSB	15.8	50.5	15.3	29.7	12.9	52.6	13.3	24.4	12.2	36.6	15.3	52.5	13	30.8	8.8	31.9	12.4	27.3						
Plywood																			30.2	44.3	22.9	34.1	32	46.5

Table 10 - B : Group A Phase 2 - Hand held Moisture Readings Before Installation & After Removal From Chamber

Stud/Plate/sheathing Average				Handheld Delmhorst RDM-1						Set for SPF @ 21oC														
	Wall #	1	Wall #	2	Wall #	3	Wall #	4	Wall #	5	Wall #	6	Wall #	7	Wall #	8	Wall #	9	Wall #	10	Wall #	11	Wall #	12
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Studs																								
A	39.2	12.1	47.7	12.0	38.7	11.6	39.8	11.8	40.2	12.0	40.7	11.7	37.5	12.0	42.6	11.8	38.9	12.1	36.0	11.0	37.6	10.9	35.2	10.8
D	35.3	11.0	33.7	11.4	36.8	11.3	41.5	11.6	29.6	11.3	32.5	11.2	31.9	11.5	34.6	11.6	40.0	12.1	28.9	10.8	29.2	10.7	33.3	10.0
Plates																								
A	39.7	13.4	31.9	13.6	38.0	13.5	36.5	14.1	40.4	13.4	42.1	14.5	38.4	13.9	38.2	14.4	35.3	13.7	34.5	13.5	36.7	15.0	38.1	12.7
C	30.3	14.8	32.0	14.2	36.4	13.8	41.7	16.0	34.6	14.5	29.9	13.9	29.2	16.5	28.0	16.6	39.1	15.8	34.0	16.1	36.1	13.8	46.8	15.0
Sheathing																								
OSB	24.3	33.2	24.8	32.9	23.0	36.0	23.3	34.1	22.1	35.0	24.9	34.9	21.3	30.9	20.9	35.5	22.1	34.0						
Plywood																			37.1	41.6	39.0	26.9	34.0	30.9
Readings After Removal From Chamber																								
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Studs	9.5	14.3	10	14.2	9.7	14.1	9.7	14.3	9.4	14.2	9.5	13.5	9.8	14.2	9.6	13.7	9.8	14.6	9.2	13.9	9.1	12.9	8.6	13.2
Plates	10.7	16.4	11.7	15.9	11.3	15.8	11.6	18.6	11.2	16.3	11.8	17.8	11.6	18.8	12.2	19.1	11.3	18.4	11.3	18.3	11.8	17.3	10.2	17
Sheathing																								
OSB	22.5	50.5	25.1	54	23.1	58.6	22.7	60	19.8	60	21.6	56.5	20.3	53.3	23.5	60	19.9	59.2						
Plywood																			30.7	60	20.6	32	21	38.8

Table 11: Calculated Permeance Analysis

Group A - Phase I and Phase 2

Calculated Permeance Analysis

Panel #	Stucco 21mm thick	Paper backed lath	Wood cedar siding 19mm thick	19mm Cavity	10mm cavity	SBPO	note: 2 layers required 1 layer 30 min. Bldg Ppr. @60%	OSB 11.5mm @ 90% RH	Plywood 12.5mm @ 100% RH	Batt Insulation 89mm	Panel permeance ng/Pa.s.m2	Panel #	Total Calculated Permeance
Units	ng/Pa.s.m2	ng/Pa.s.m2	ng/Pa.s.m2	ng/Pa.s.m2	ng/Pa.s.m2	ng/Pa.s.m2	ng/Pa.s.m2	ng/Pa.s.m2	ng/Pa.s.m2	ng/Pa.s.m2			Phase 1 & 2
M or u	M	M	M	M	M	M	M	M	M	M			
1	390.48						1080	372		1910	131	1	390
2	390.48					1500		372		1910	155	2	462
3	390.48	1080		9211			1080	372		1910	123	3	363
4	390.48	1080		9211		1500		372		1910	134	4	395
5	390.48	1080		9211			1080	372		1910	115	5	338
6	390.48	1080		9211		1500		372		1910	134	6	392
7	390.48	1080			17500		1080	372		1910	116	7	340
8			236				1080	372		1910	108	8	320
9			236	9211			1080	372		1910	106	9	314
10	390.48						1080		2376	1910	187	10	556
11	390.48	1080		9211			1080		2376	1910	156	11	462
12	390.48	1080			17500		1080		2376	1910	158	12	462
reference	[1]		[3]	[2]	[2]	[3]	[2]	[1]	[1]	[2]			

[1] NRC IRC Kumaran unpublished data May 1999

[2] Building Science for a Cold Climate Table 5.5 and 5.6 Hutcheon & Handegord, 1983

[3] Drying of Walls with Ventilated Stucco cladding as Parametric Analysis, pp 16-17 and Appendix C, CMHC Onysko 1999

Table 12: Effective Permeance of Test Wall Panels, Including Average Vapour Pressures

Group A - Phase I

Effective Permeance Analysis 1500 hours test

Wall Panels ranked from highest to lowest effective permeance

						P2				P1			
Panel #	Weight loss lbs	Weight loss grams	Ave Temp Chamber	Sat. Vapour pressure kPa	Ave. RH Chamber	Vapour pressure Chamber kPa	Ave Temp Stud Spa.	Sat. Vapour pressure kPa	Ave RH Stud Spa.	Vapour Pressure Stud Space kPa	P1 - P2 kPa	Effective Permeance ng/(sec m^2Pa)	Total Effective Permeance
11	5.8	2622	5	0.8719	70	0.61033	16	1.817	60	1.0902	0.47987	**340**	1012
10	4.9	2214	5	0.8719	70	0.61033	16	1.817	60	1.0902	0.47987	**287**	854
12	6.3	2849	5	0.8719	70	0.61033	16	1.817	70	1.2719	0.66157	**268**	798
5	4.0	1807	5	0.8719	70	0.61033	16	1.817	60	1.0902	0.47987	**234**	697
2	2.3	1032	5	0.8719	70	0.61033	16	1.817	56	1.01752	0.40719	**158**	469
8	2.2	986	5	0.8719	70	0.61033	16	1.817	60	1.0902	0.47987	**128**	381
6	2.5	1123	5	0.8719	70	0.61033	16	1.817	67	1.21739	0.60706	**115**	342
7	2.3	1036	5	0.8719	70	0.61033	16	1.817	65	1.18105	0.57072	**113**	336
3	2.5	1125	5	0.8719	70	0.61033	16	1.817	70	1.2719	0.66157	**106**	315
9	3.6	1625	5	0.8719	70	0.61033	16	1.817	87	1.58079	0.97046	**104**	310
4	1.5	675	5	0.8719	70	0.61033	16	1.817	62	1.12654	0.51621	**81**	242
1	1.5	673	5	0.8719	70	0.61033	16	1.817	62	1.12654	0.51621	**81**	241

Group A - Phase 2

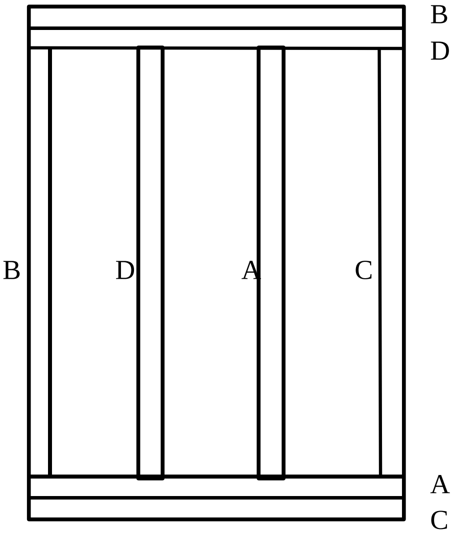
Effective Permeance Analysis 2100 hours test

Wall Panels ranked from highest to lowest effective permeance

						P2				P1			
Panel #	Weight loss lbs	Weight loss grams	Ave Temp Chamber	Sat. Vapour pressure kPa	Ave. RH Chamber	Vapour pressure Chamber kPa	Ave Temp Stud Spa.	Sat. Vapour pressure kPa	Ave RH Stud Spa.	Vapour Pressure Stud Space kPa	P1 - P2 kPa	Effective Permeance ng/(sec m^2 Pa)	Total Effective Permeance
11	9.5	4309	5	0.8719	70	0.61033	16	1.817	60	1.0902	0.47987	**399**	1188
12	7.4	3357	5	0.8719	70	0.61033	16	1.817	70	1.2719	0.66157	**225**	671
10	4.9	2223	5	0.8719	70	0.61033	16	1.817	60	1.0902	0.47987	**206**	613
4	4.6	2087	5	0.8719	70	0.61033	16	1.817	62	1.12654	0.51621	**180**	535
5	4.2	1905	5	0.8719	70	0.61033	16	1.817	60	1.0902	0.47987	**176**	525
6	4.8	2177	5	0.8719	70	0.61033	16	1.817	67	1.21739	0.60706	**159**	474
2	2.9	1315	5	0.8719	70	0.61033	16	1.817	56	1.01752	0.40719	**144**	427
1	3.3	1497	5	0.8719	70	0.61033	16	1.817	62	1.12654	0.51621	**129**	384
3	3.8	1724	5	0.8719	70	0.61033	16	1.817	70	1.2719	0.66157	**116**	345
8	2.4	1089	5	0.8719	70	0.61033	16	1.817	60	1.0902	0.47987	**101**	300
9	4.8	2177	5	0.8719	70	0.61033	16	1.817	87	1.58079	0.97046	**100**	297
7	2.2	998	5	0.8719	70	0.61033	16	1.817	65	1.18105	0.57072	**78**	231

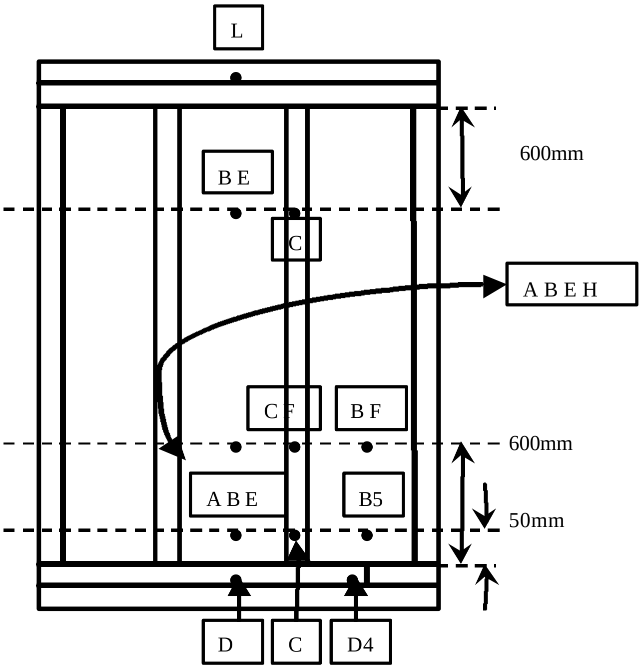
Table 13: Calculated Permeance vs Effective Permeance ng/Pa·sec·m^2

Panel #	**Total Calculated Permeance**	**Total Effective Permeance Over 1500 hrs**	**Total Effective Permeance Over 2000 hrs**
	Phase 1 & 2	Phase 1	Phase 2
1	390	241	537
2	462	469	598
3	363	315	482
4	395	242	749
5	338	697	735
6	392	342	664
7	340	336	324
8	320	381	420
9	314	310	415
10	556	854	858
11	462	1012	1663
12	462	798	940



	Max. Drying	Min. Drying
Max. Wetting	A	B
Min. Wetting	C	D

Figure 1: Distribution of lumber types (in terms of wetting and drying) in each panel



"A" - sheathing surface WMC vent cavity

"B" - sheathing surface WMC stud cavity

"C" - stud WMC's

"D" - Plate WMC's

"E" - Temperature

"F" - WMC for strapping / Claddings

"H" - Relative humidity

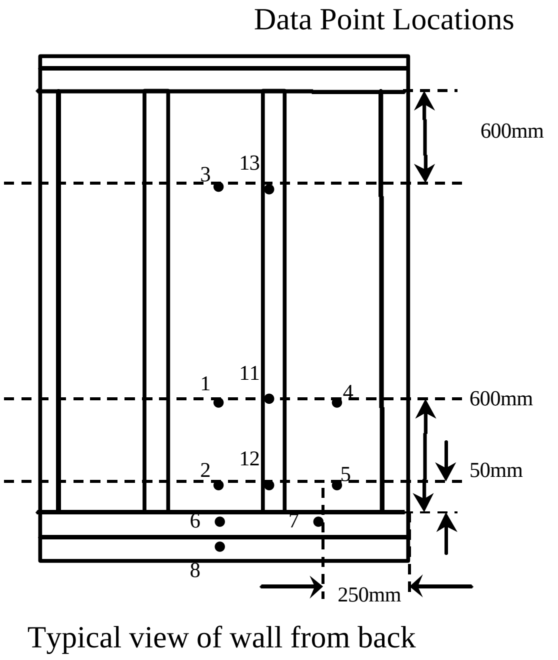
"L" - Loadcells

"P" - Pressure readings

Typical Wall view from back

Figure 2: Typical wall panel locations and detail for test points

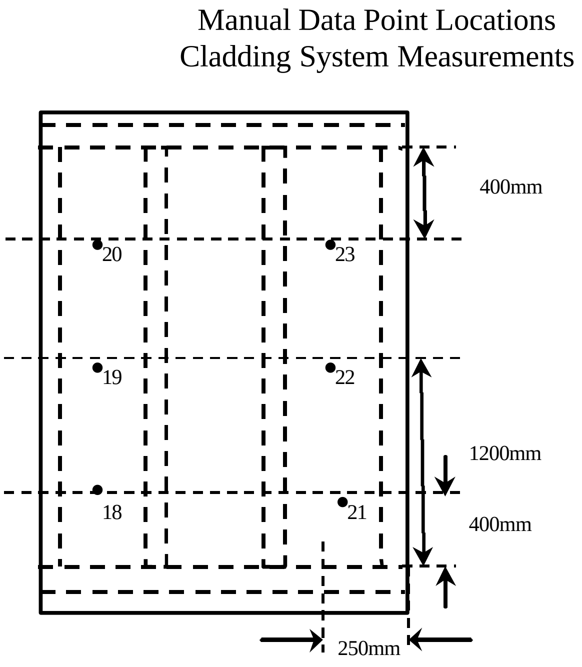
(for detailed locations of sensors see Appendix 2 and Appendix 7)



Detail description

- The numbers on the panel indicate the locations where data collection is taking place
- These numbers are referred to in the panel instrumentation tables as the data point locations

Figure 3: Data point locations - typical view of wall panel from back



Detail description

- The numbers on the panel indicate the locations where manual data collection on cladding moisture is taking place
- These numbers are referred to in the panel instrumentation tables as the data point locations

Figure 4: Data point locations - typical view of wall panel from front

North

Wall Panel No	9	8	7	12	11	10
Bay Number	7	8	9	10	11	12
Bay Number	1	2	3	4	5	6
Wall Panel No	1	5	3	4	2	6

South

Figure 5: Group A - 12 Test Panels - Test Wall Panels Locations in Chamber

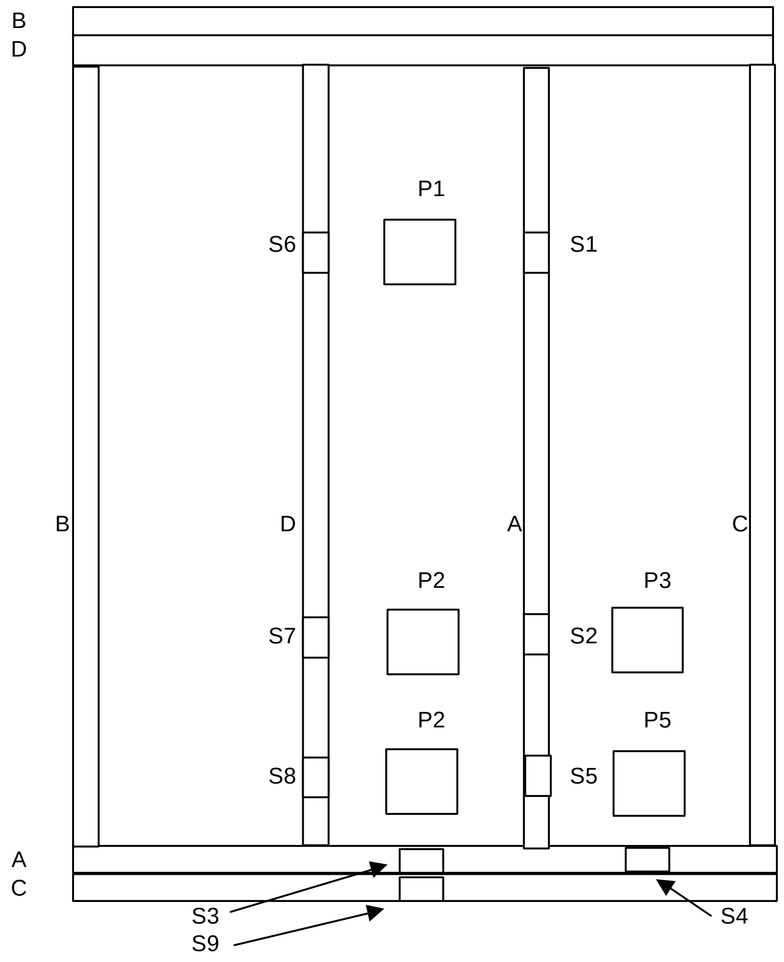


Figure 6: Hand Held Moisture Meter Readings Locations

(see Appendix 9 for detailed data.)

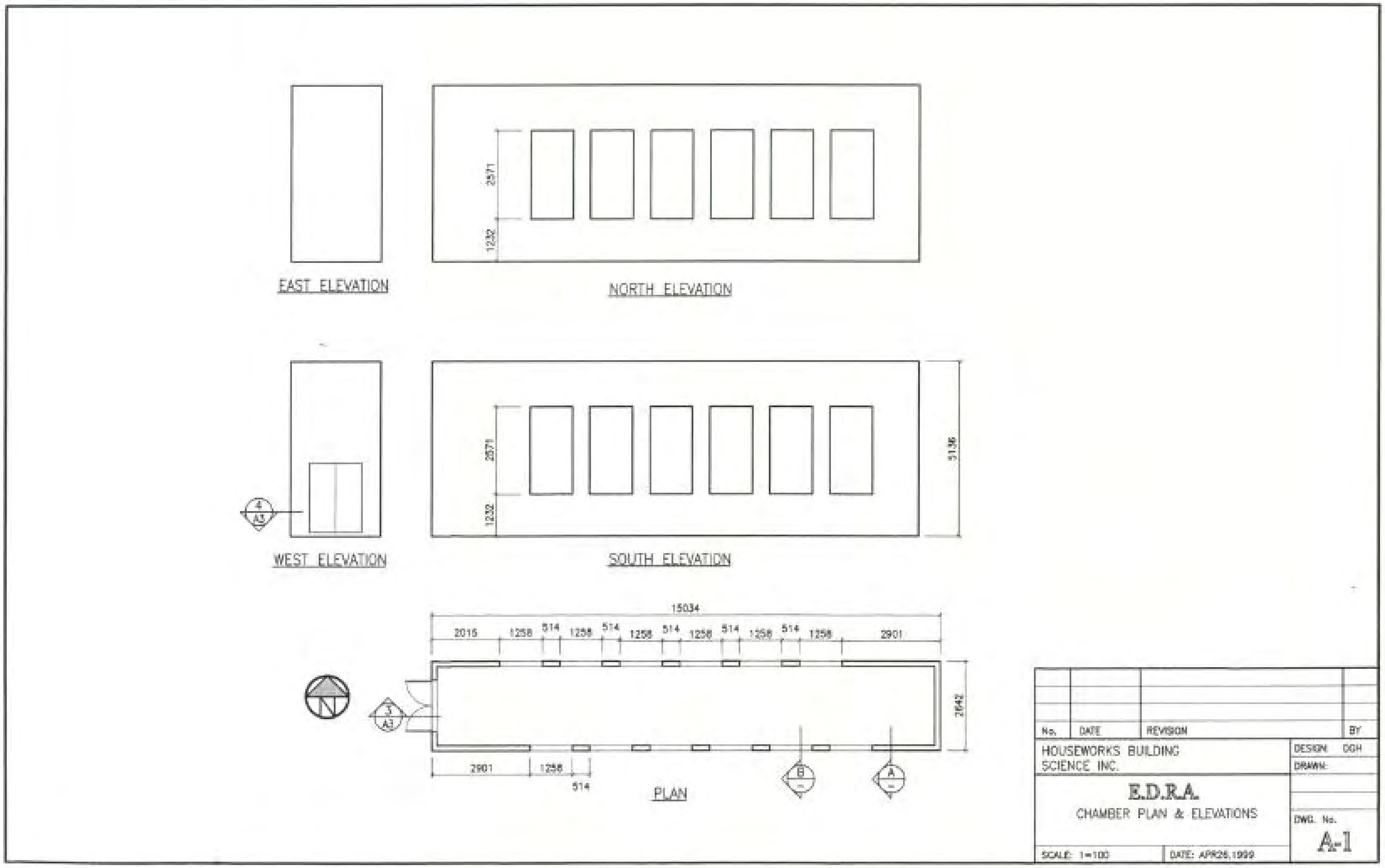


Figure 7: Chamber Plan & Elevations

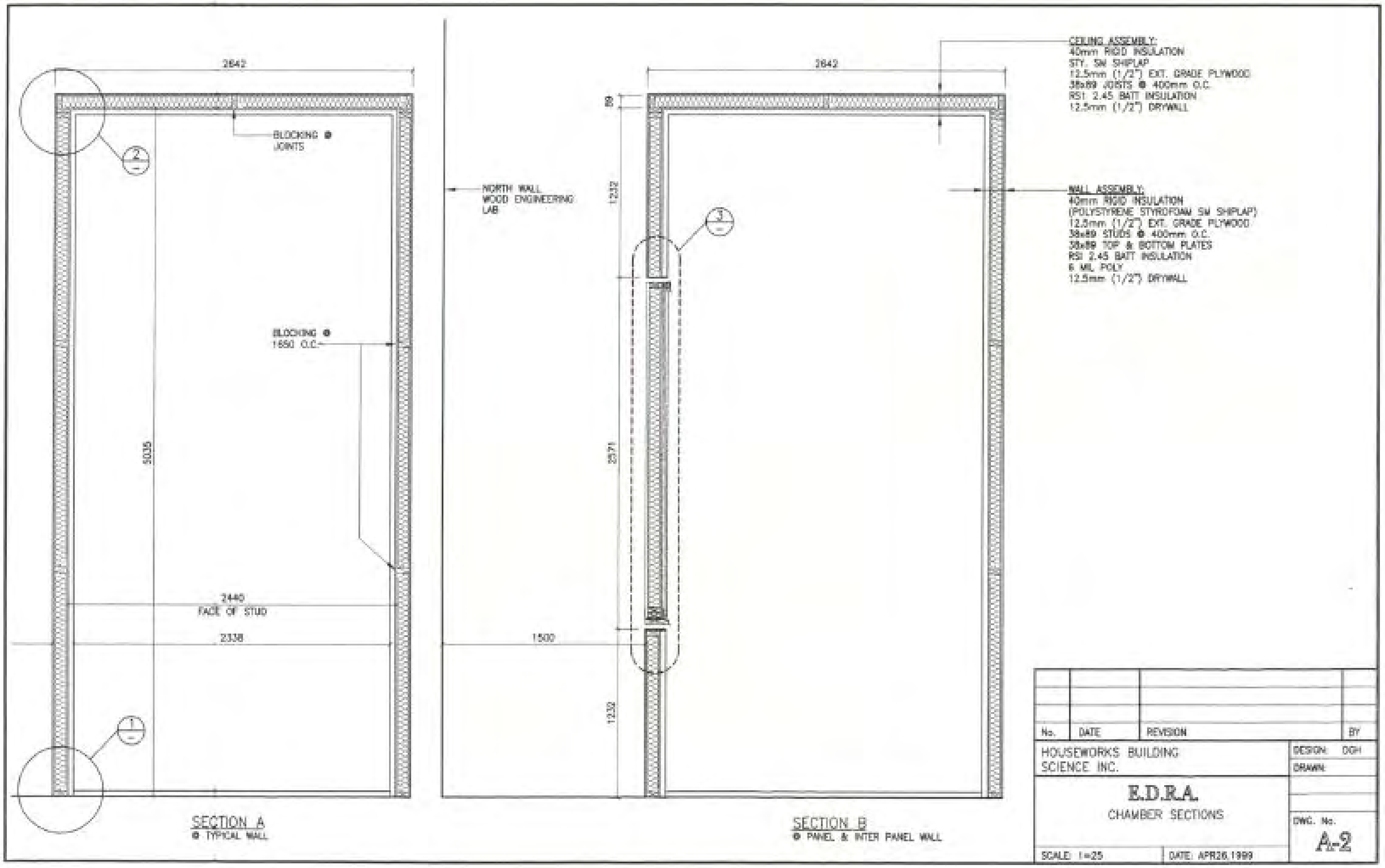


Figure 8: Chamber Sections

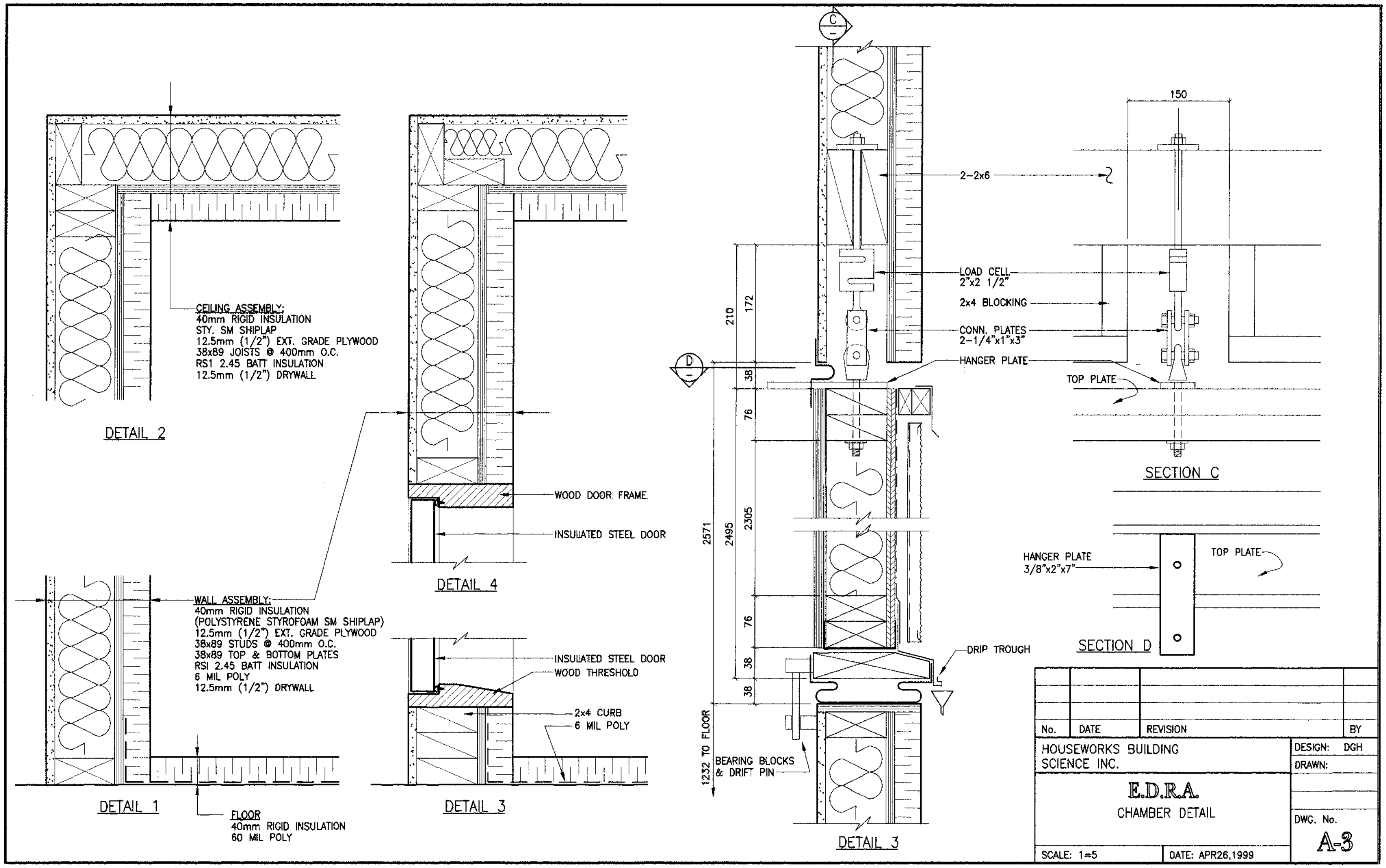


Figure 9: Chamber Details

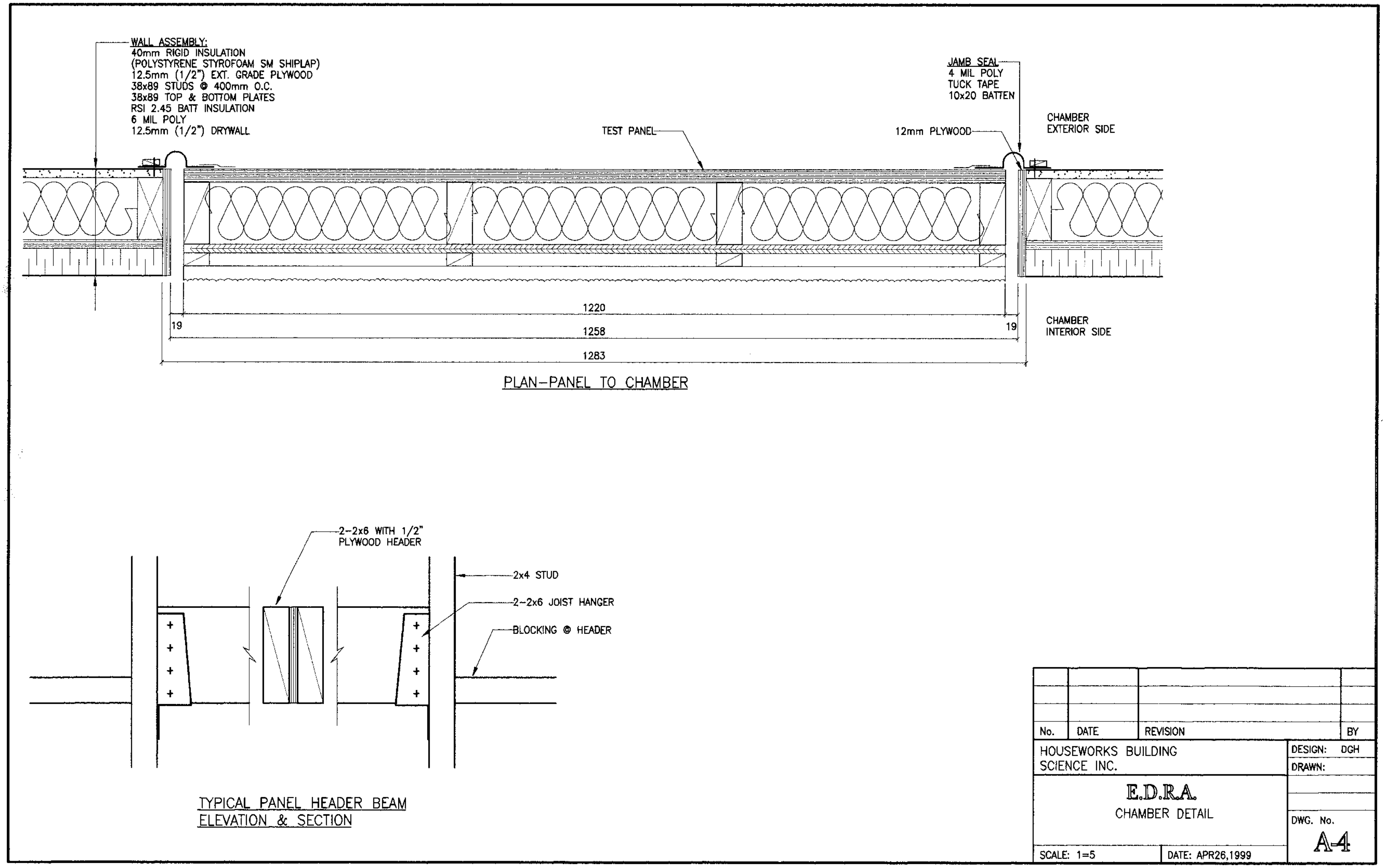
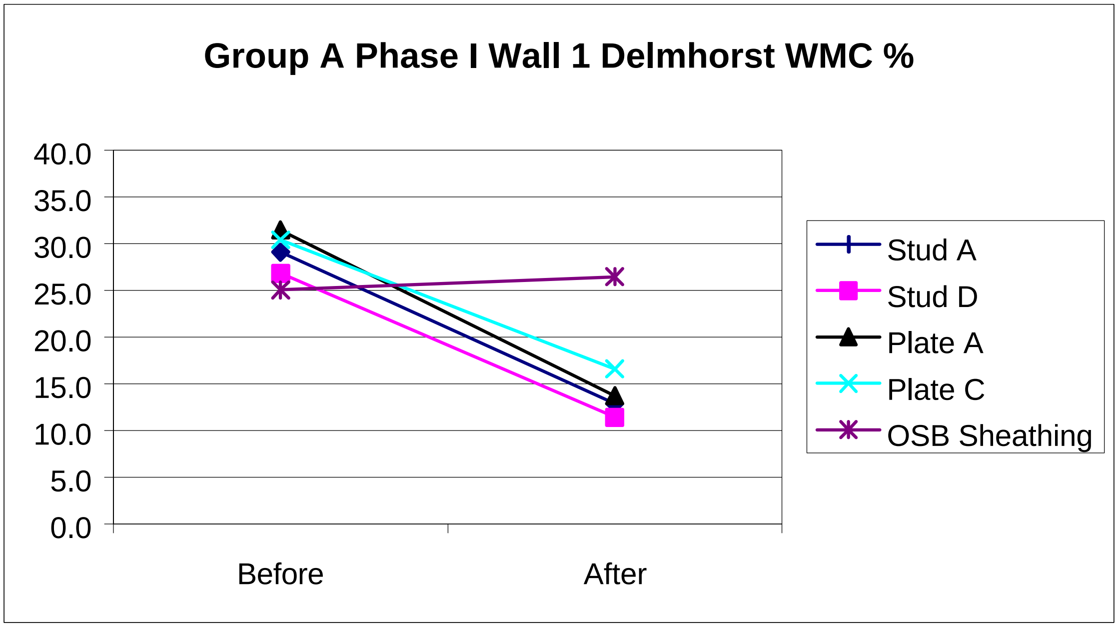
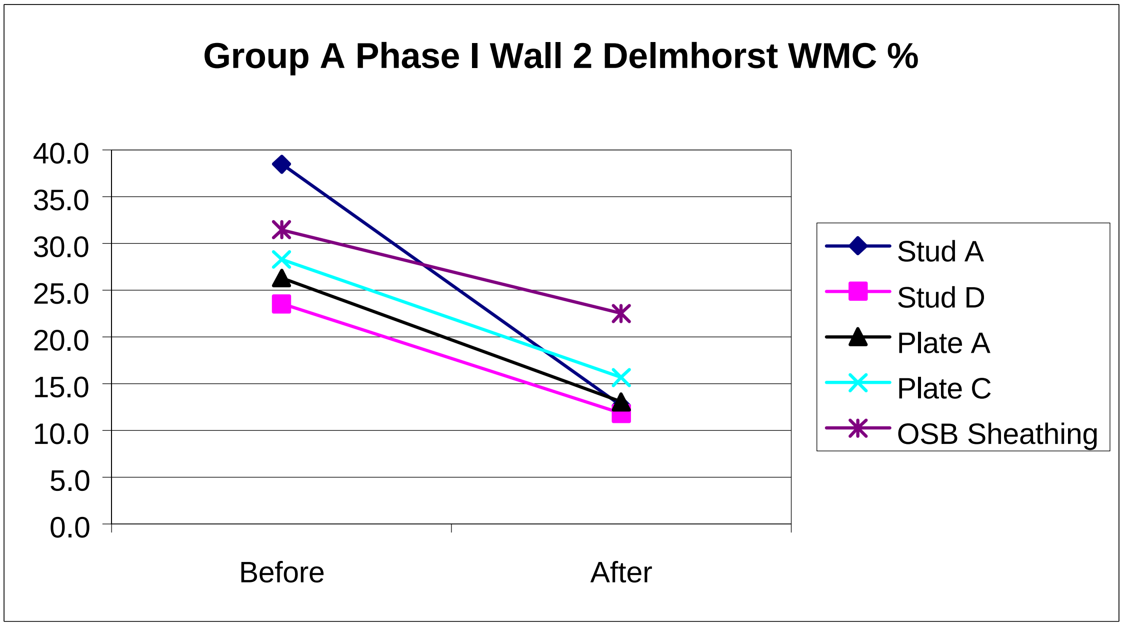
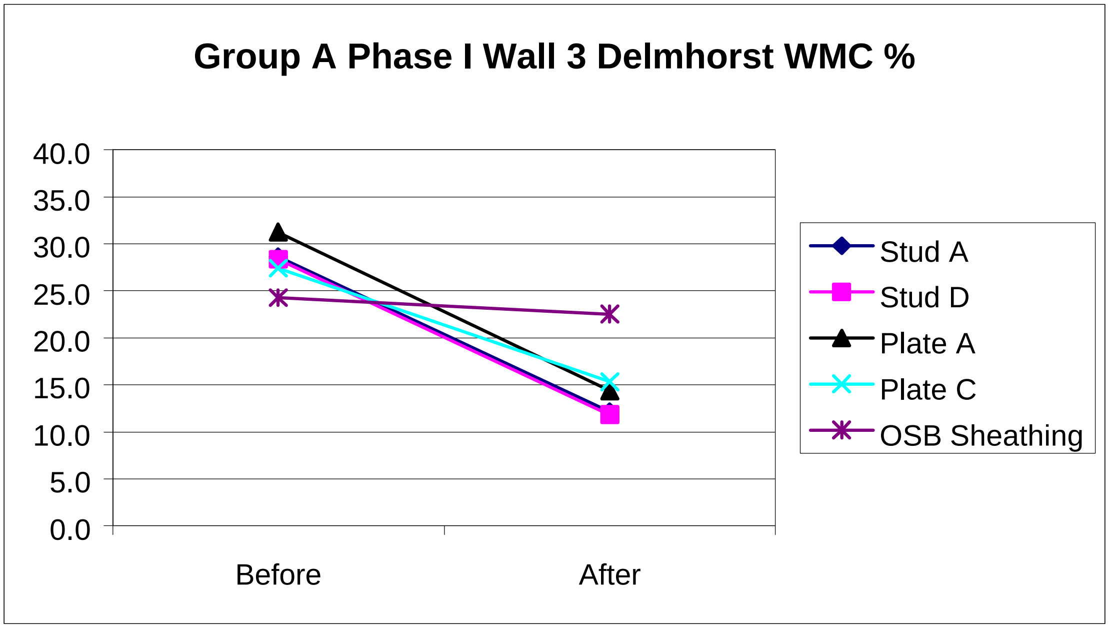


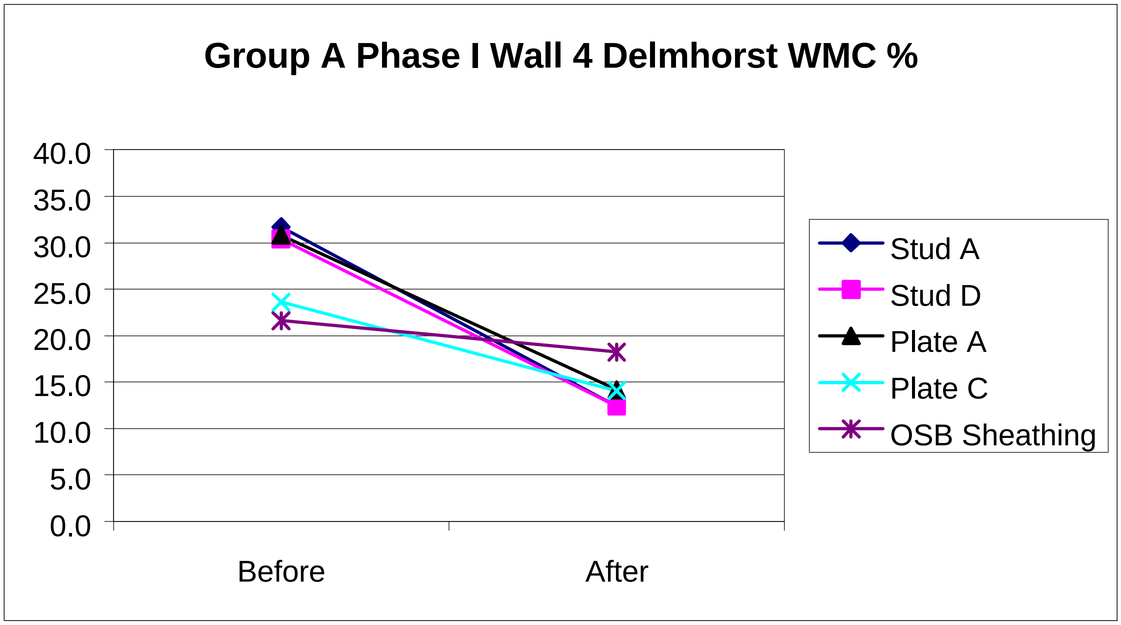
Figure 10: Chamber Details

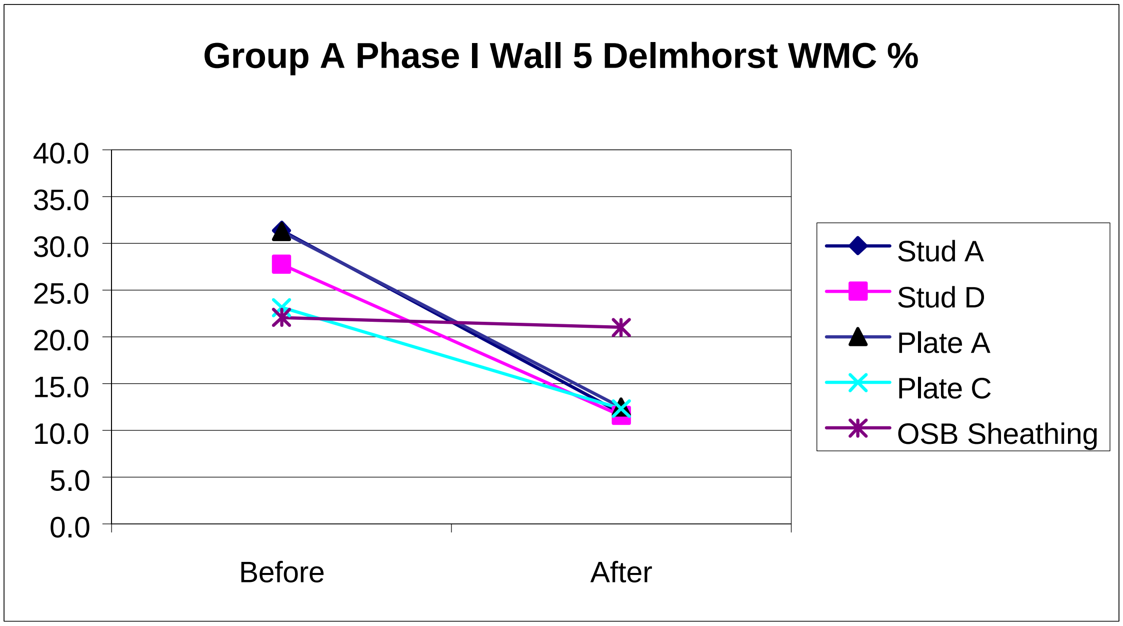
Chart 1: Group A Phase 1 & 2 Moisture Contents by Hand Held Meter Before & After Test






Group A Phase I Wall 3 Delmhorst WMC %
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase I Wall 4 Delmhorst WMC %
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase I Wall 5 Delmhorst WMC %
40.0
35.0
30.0
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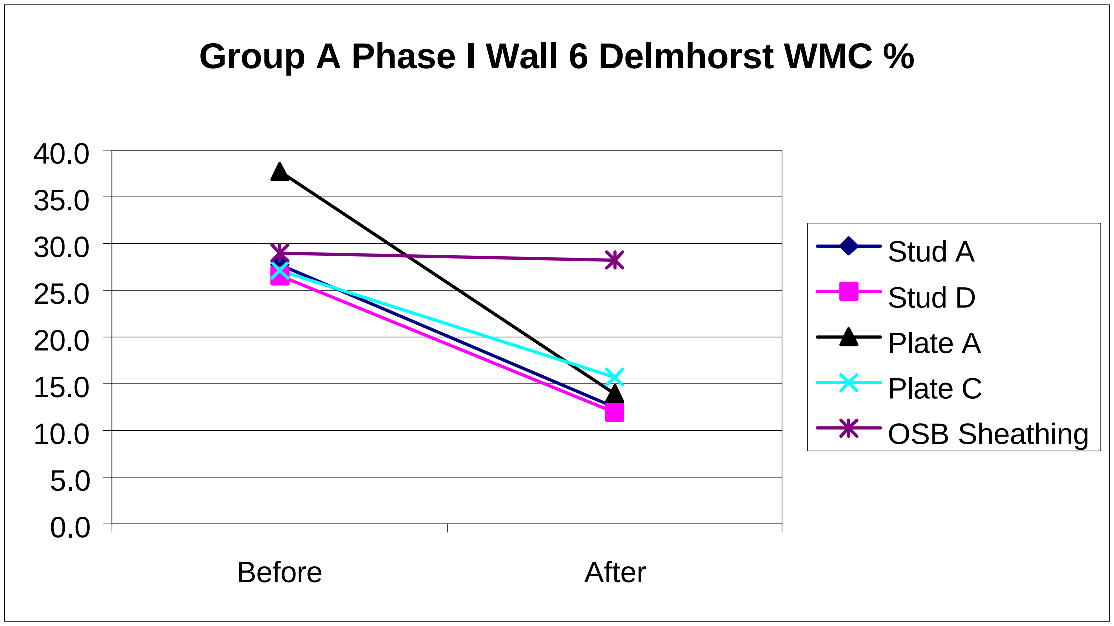
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase I Wall 6 Delmhorst WMC %
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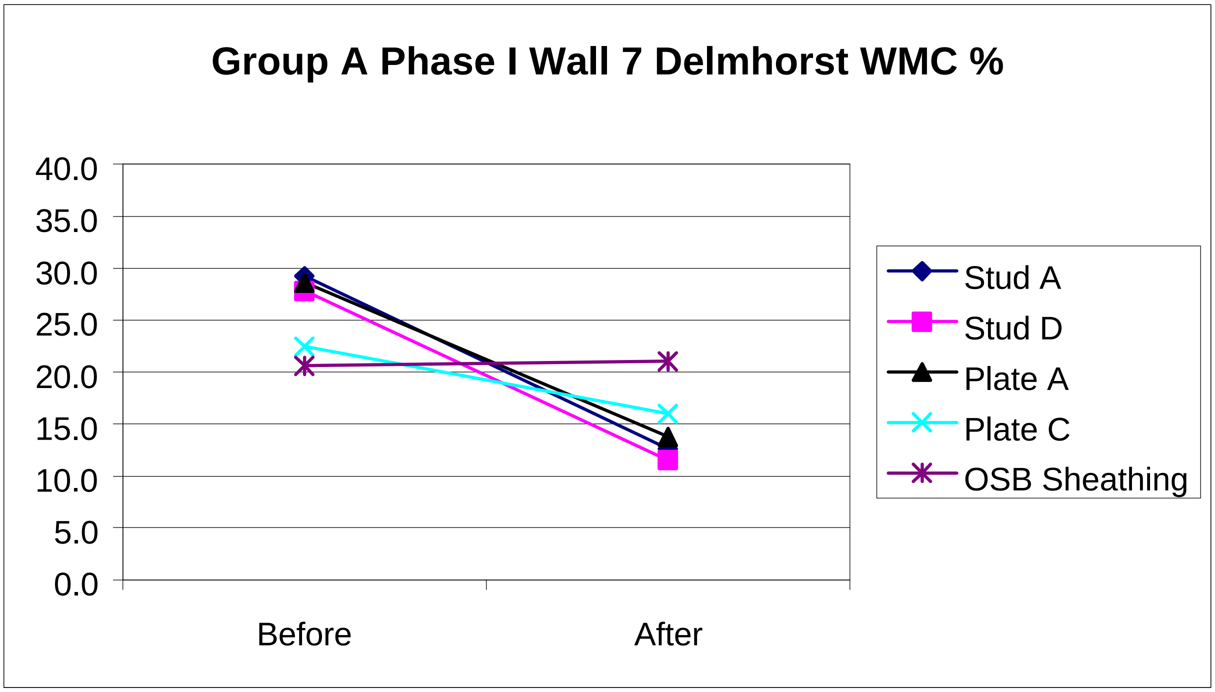
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase I Wall 7 Delmhorst WMC %
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30.0
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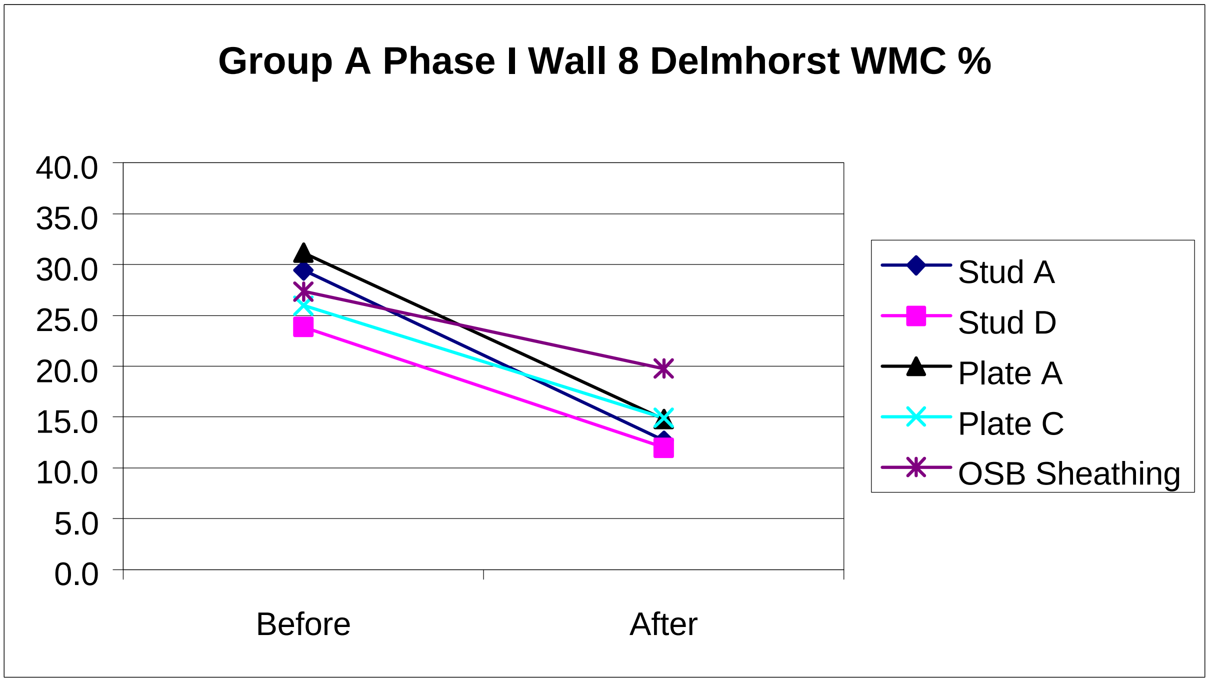
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase I Wall 8 Delmhorst WMC %
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35.0
30.0
25.0
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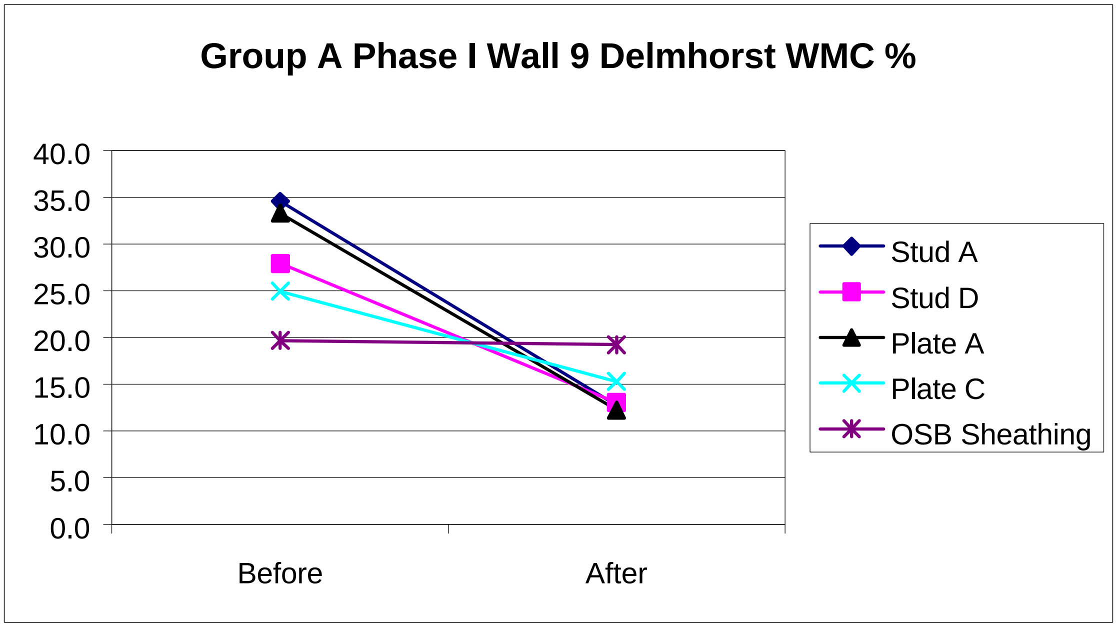
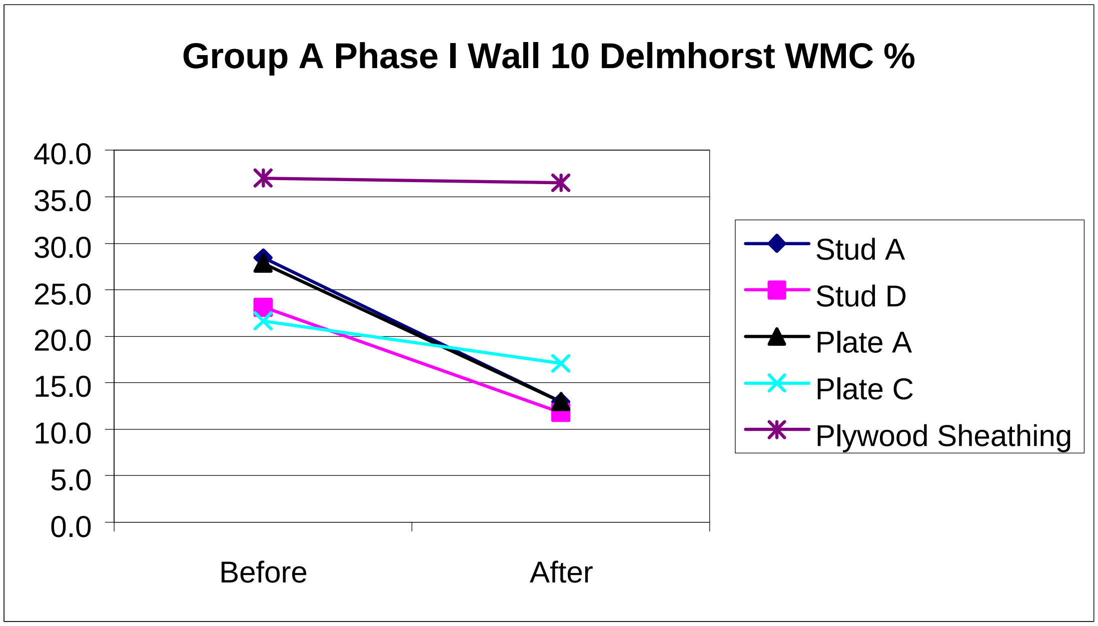
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase I Wall 9 Delmhorst WMC %
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase I Wall 10 Delmhorst WMC %
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35.0
30.0
25.0
20.0
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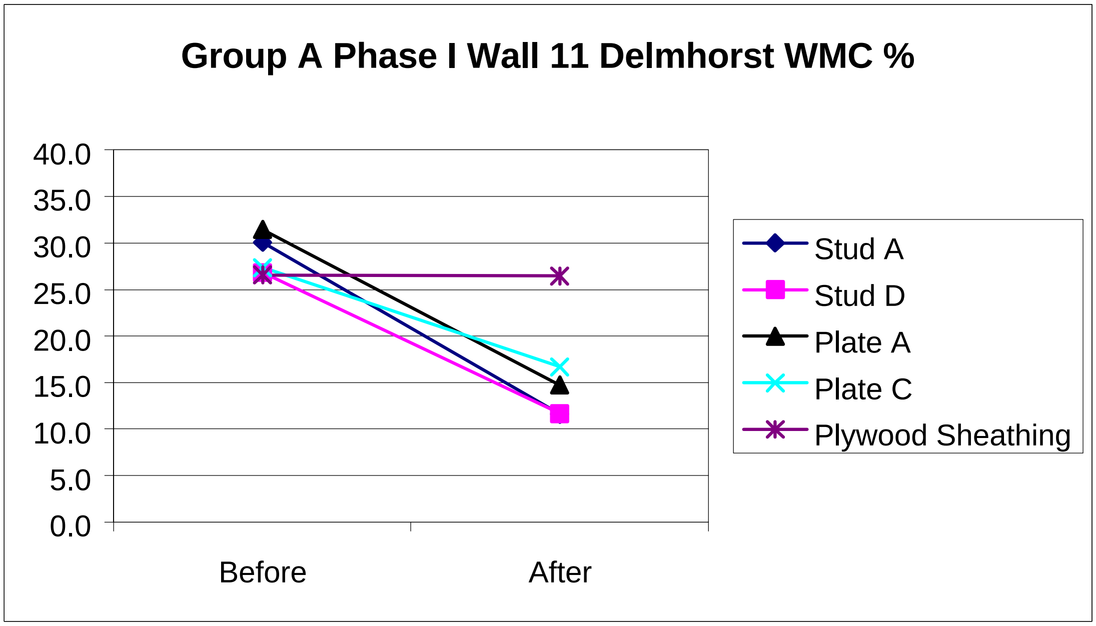
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
Plywood Sheathing


Group A Phase I Wall 11 Delmhorst WMC %
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35.0
30.0
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10.0
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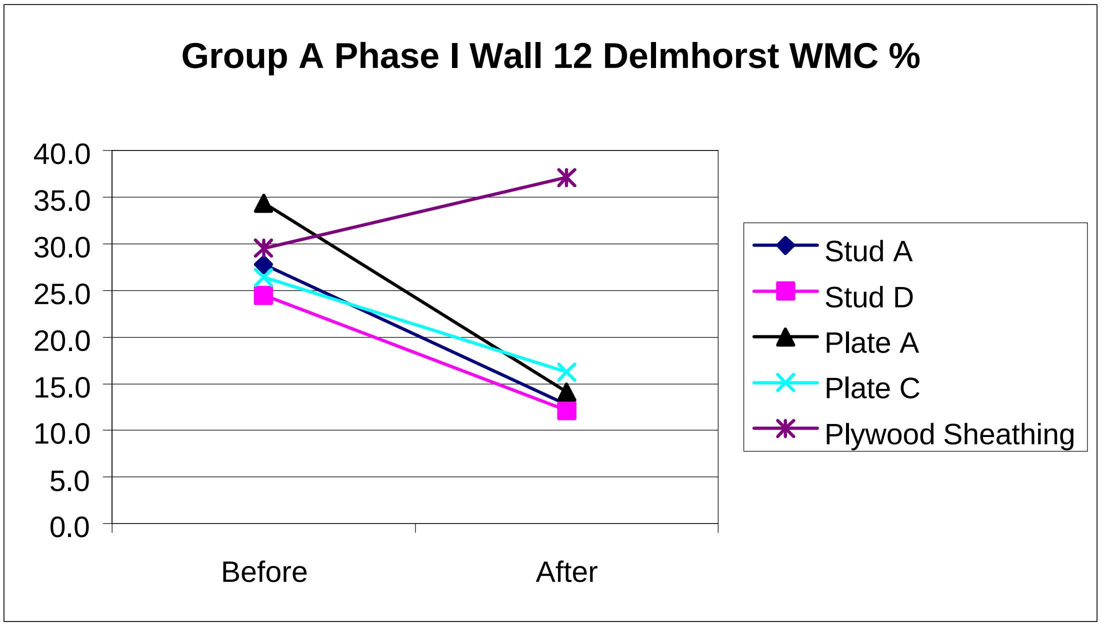
Before
After
Stud A
Stud D
Plate A
Plate C
Plywood Sheathing


Group A Phase I Wall 12 Delmhorst WMC %
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30.0
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5.0
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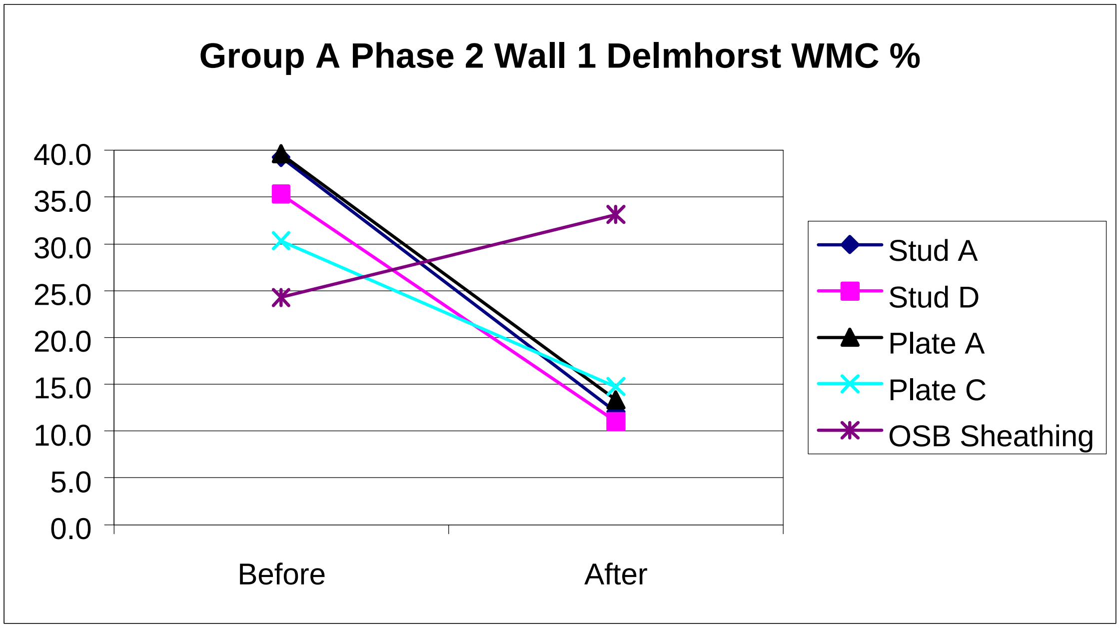
Before
After
Stud A
Stud D
Plate A
Plate C
Plywood Sheathing


Group A Phase 2 Wall 1 Delmhorst WMC %
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30.0
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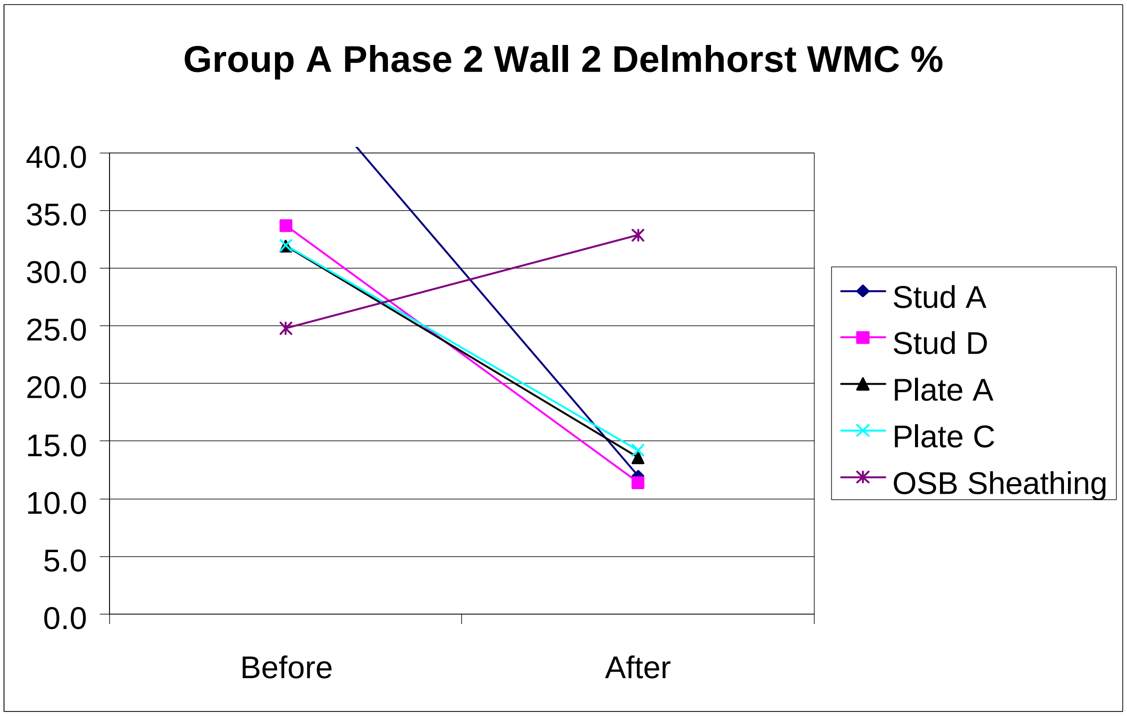
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase 2 Wall 2 Delmhorst WMC %
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5.0
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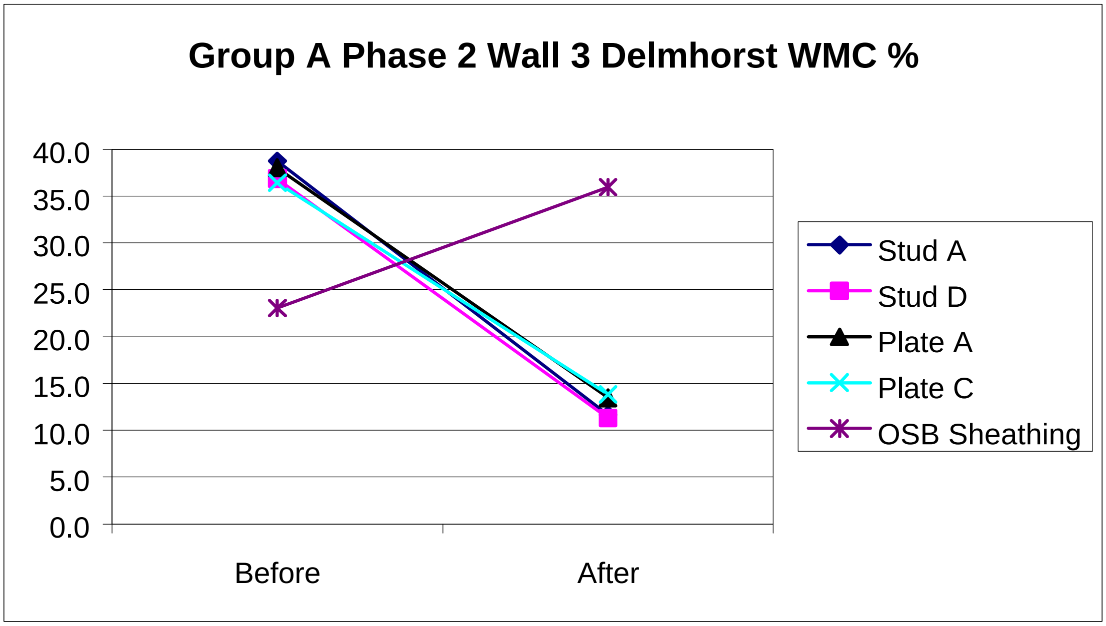
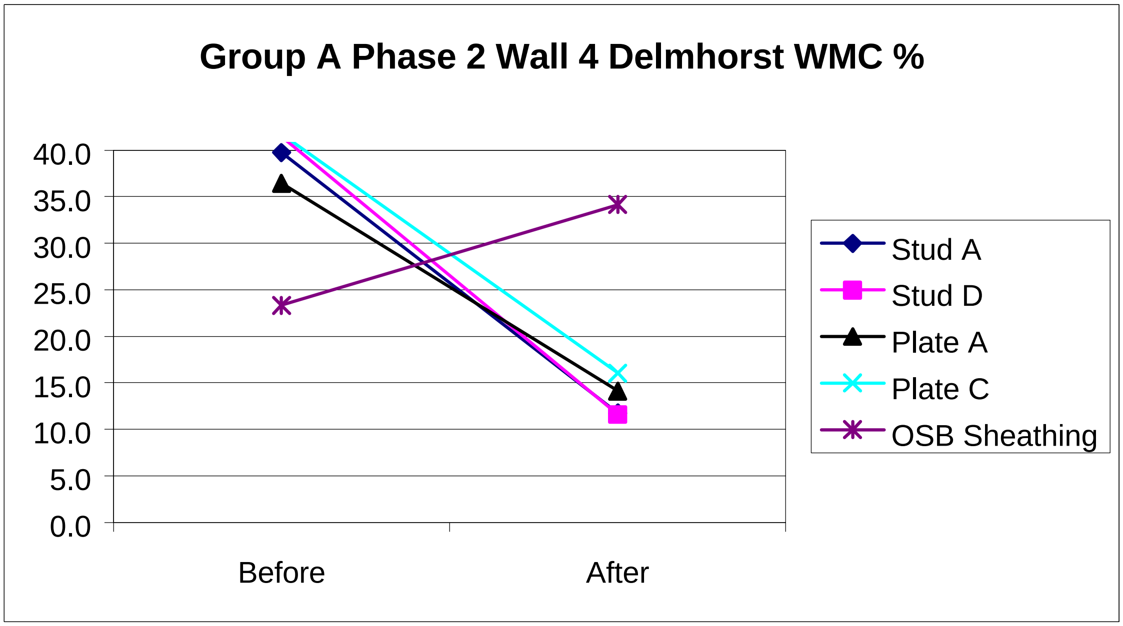
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase 2 Wall 3 Delmhorst WMC %
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase 2 Wall 4 Delmhorst WMC %
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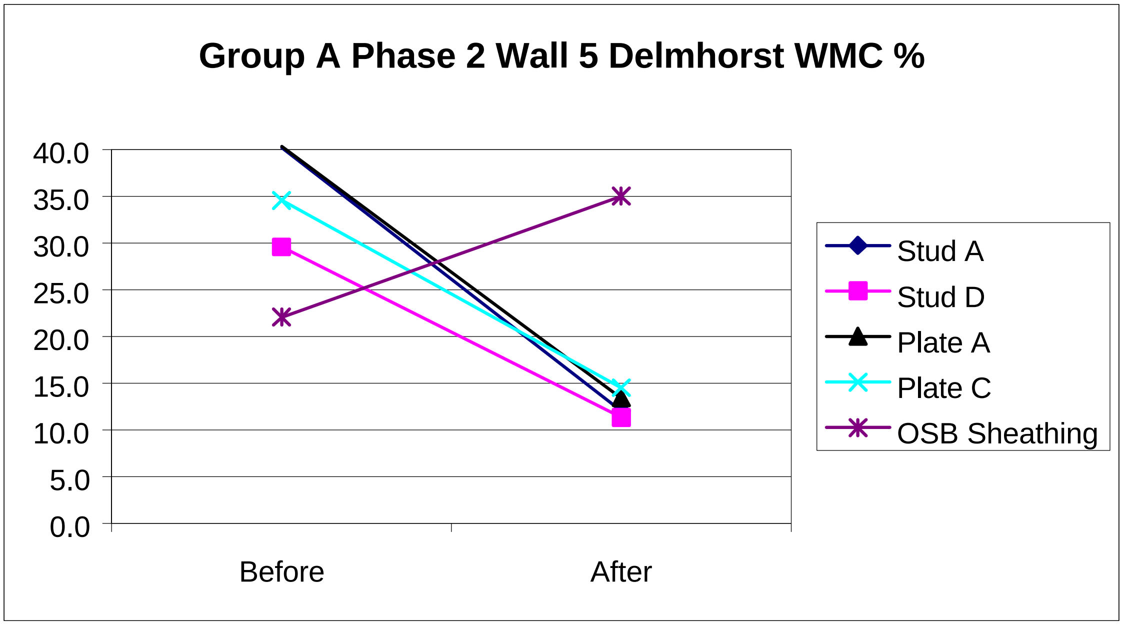
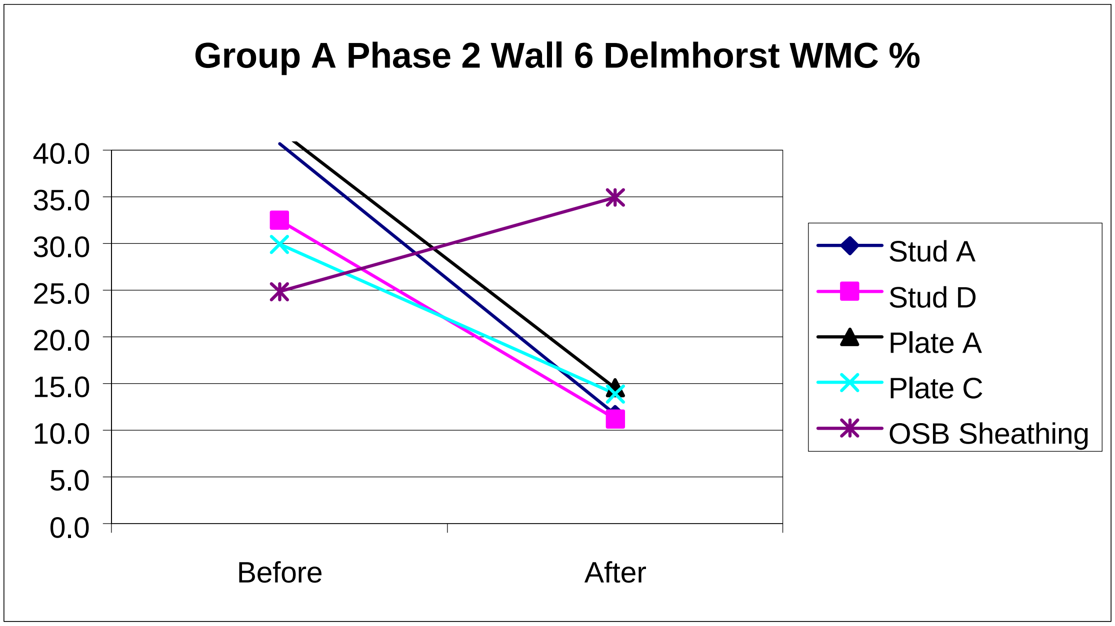
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase 2 Wall 5 Delmhorst WMC %
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase 2 Wall 6 Delmhorst WMC %
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30.0
25.0
20.0
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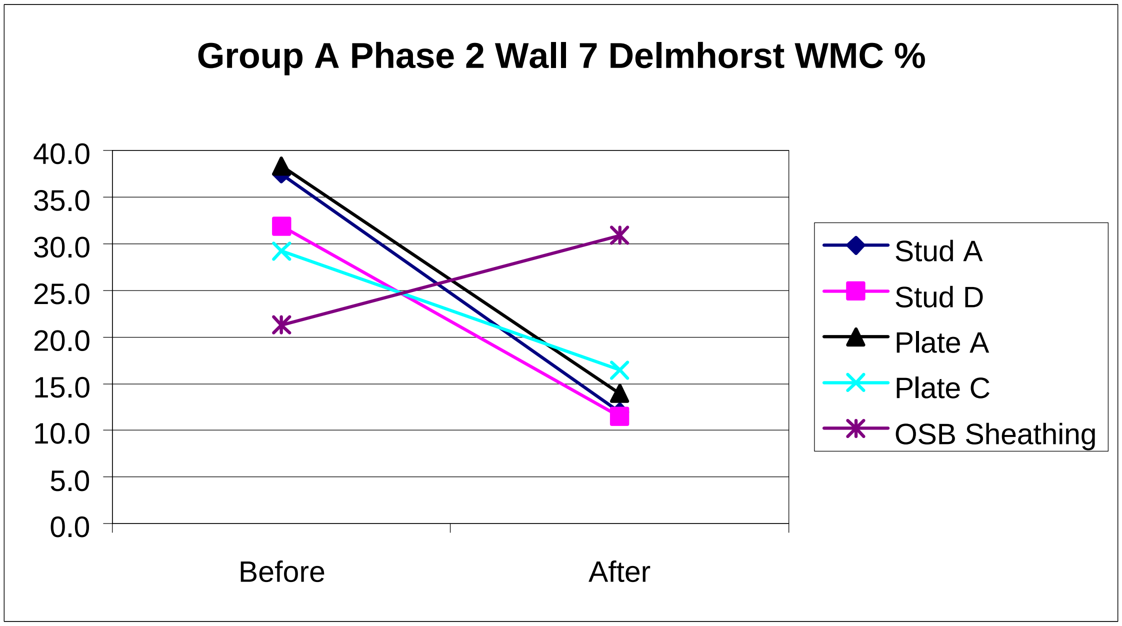
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase 2 Wall 7 Delmhorst WMC %
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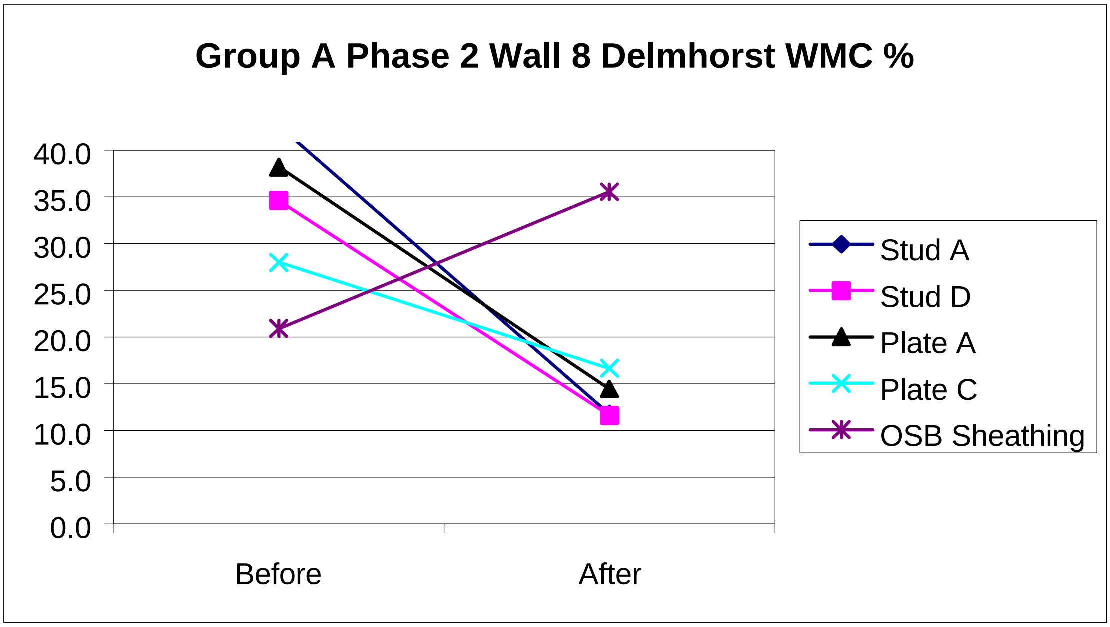
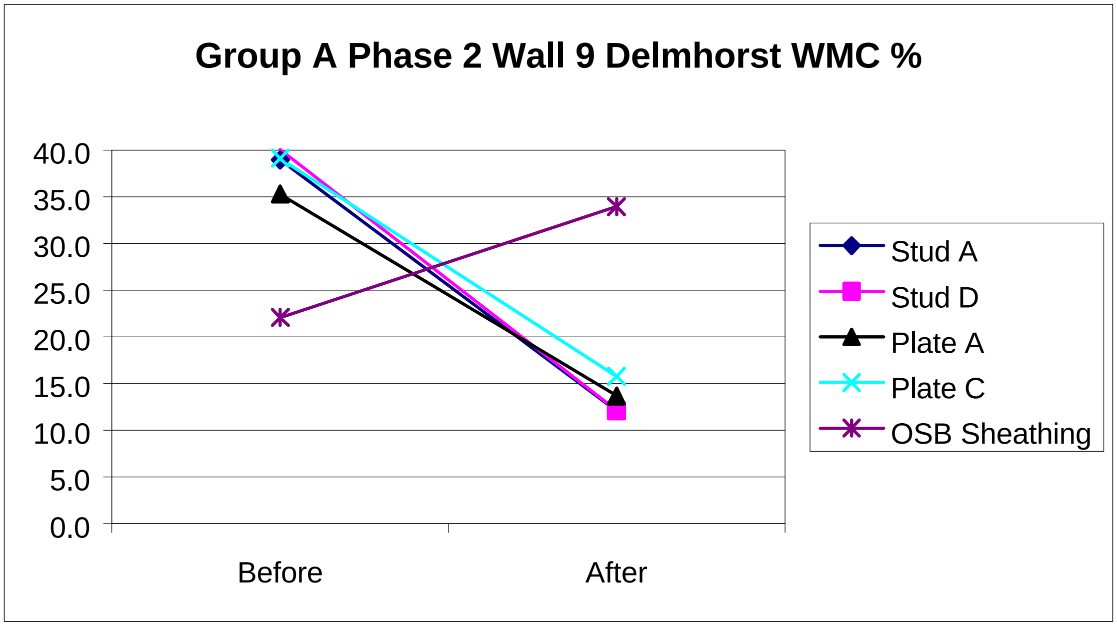
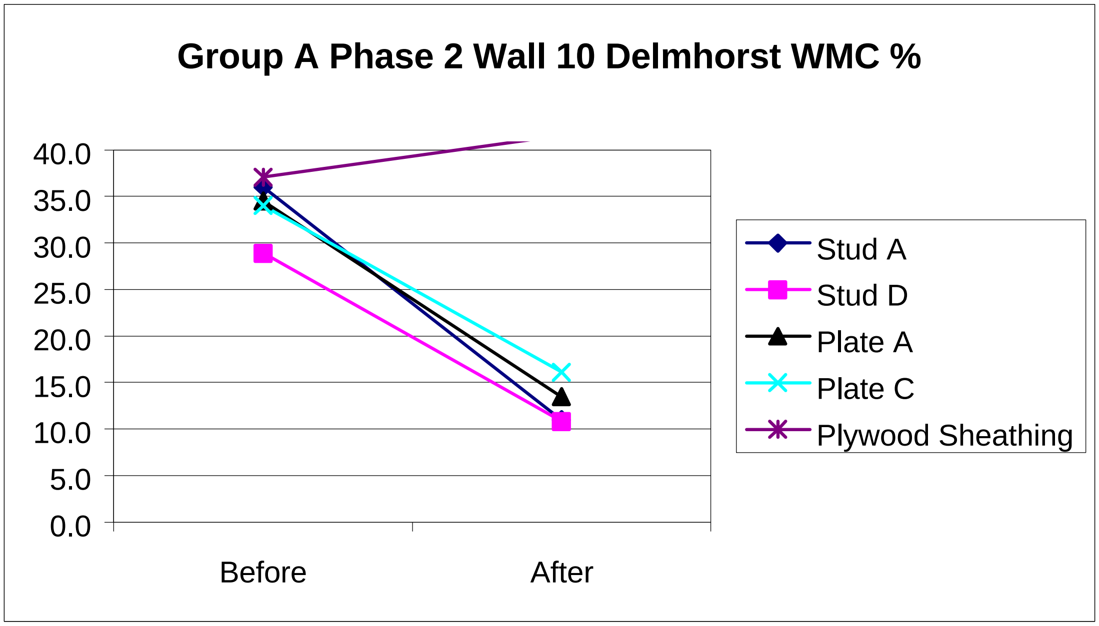
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase 2 Wall 8 Delmhorst WMC %
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing


Group A Phase 2 Wall 9 Delmhorst WMC %
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
OSB Sheathing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40.0
35.0
30.0
25.0
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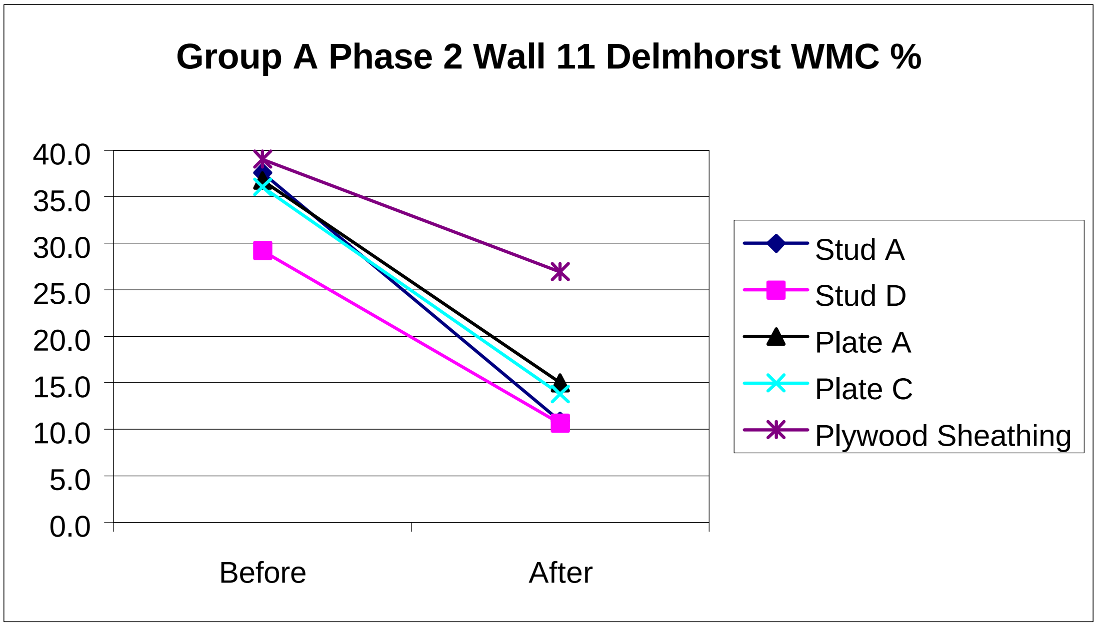
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
Plywood Sheathing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35.0
30.0
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5.0
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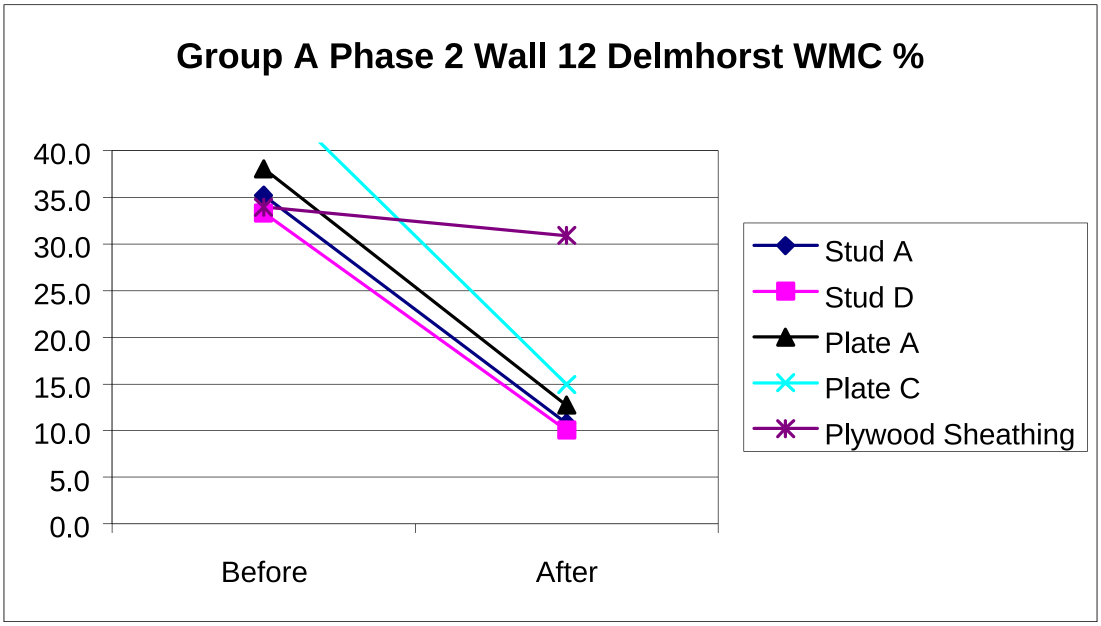
Before
After
Stud A
Stud D
Plate A
Plate C
Plywood Sheathing


Group A Phase 2 Wall 12 Delmhorst WMC %
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35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Before
After
Stud A
Stud D
Plate A
Plate C
Plywood Sheathing

DAS Charts 1: DAS Charts Group A Phase 1 & 2

Comparative Charts - All Walls Phase 1

Chart A1 –1: Group A – Phase 1: All Walls MC% Stud A Surface Top
Chart A1 –2: Group A – Phase 1: All Walls MC% Stud A Surface Lower
Chart A1 –3: Group A – Phase 1: All Walls MC% Stud A Surface Bottom
Chart A1 –4: Group A – Phase 1: All Walls MC% Stud A Core Top
Chart A1 –5: Group A – Phase 1: All Walls MC% Stud A Core Lower
Chart A1 –6: Group A – Phase 1: All Walls MC% Stud A Core Bottom
Chart A1 –7: Group A – Phase 1: All Walls MC% Stud A at Sheathing Top
Chart A1 –8: Group A – Phase 1: All Walls MC% Stud A at Sheathing Lower
Chart A1 –9: Group A – Phase 1: All Walls MC% Stud A at Sheathing Bottom
Chart A1 –10: Group A – Phase 1: All Walls MC% Plate Surface
Chart A1 –11: Group A – Phase 1: All Walls MC% Plate Core
Chart A1 –12: Group A – Phase 1: All Walls MC% Plate Core
Chart A1 –13: Group A – Phase 1: All Walls MC% Plate @ Cut
Chart A1 –14: Group A – Phase 1: All Walls MC% Sheathing
Chart A1 –15: Group A – Phase 1: All Walls MC% Sheathing
Chart A1 –16: Group A – Phase 1: All Walls MC% Sheathing
Chart A1 –17: Group A – Phase 1: All Walls MC% Sheathing
Chart A1 –18: Group A – Phase 1: All Walls MC% Sheathing
Chart A1 –19: Group A – Phase 1: All Walls MC% Sheathing
Chart A1 –20: Group A – Phase 1: All Walls MC% Sheathing
Chart A1 –21: Group A – Phase 1: All Walls RH% Stud Space
Chart A1 –22: Group A – Phase 1: All Walls RH% Cavity
Chart A1 –23: Group A – Phase 1: All Walls Temp C Stud Space
Chart A1 –24: Group A – Phase 1: All Walls Temp C Inside Sheathing
Chart A1 –25: Group A – Phase 1: All Walls Temp C Inside Sheathing
Chart A1 –26: Group A – Phase 1: All Walls Temp C Inside Sheathing
Chart A1 –27: Group A – Phase 1: All Walls Temp C Centre of Cladding
Chart A1 –28: Group A – Phase 1: All Walls Temp C Centre of Cavity
Chart A1 –29: Group A – Phase 1: All Walls Temp C Exterior Face of Sheathing
Chart A1 –30: Group A – Phase 1: All Walls Weight Loss (1bs)

Comparative Charts - All Walls Phase 2

Individual Wall Charts Phase 1

Chart A1 –W1-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W1-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W1-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W1-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W1-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W1-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W2-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W2-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W2-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W2-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W2-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W2-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W3-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W3-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W3-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W3-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W3-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W3-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W4-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W4-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W4-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W4-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W4-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W4-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W5-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W5-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W5-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W5-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W5-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W5-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W6-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W6-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W6-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W6-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W6-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W6-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W7-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W7-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W7-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W7-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W7-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W7-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W8-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W8-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W8-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W8-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W8-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W8-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W9-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W9-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W9-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W9-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W9-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W9-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W10-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W10-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W10-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W10-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W10-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W10-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W11-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W11-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W11-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W11-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W11-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W11-6: Group A – Phase 1: Wall 5 MC % Sheathing

Chart A1 –W12-1: Group A – Phase 1: Wall 5 MC% Stud A All Points
Chart A1 –W12-2: Group A – Phase 1: Wall 5 MC% Stud A Surface
Chart A1 –W12-3: Group A – Phase 1: Wall 5 MC% Stud A Core
Chart A1 –W12-4: Group A – Phase 1: Wall 5 MC Stud A Sheathing
Chart A1 –W12-5: Group A – Phase 1: Wall 5 MC % Plates
Chart A1 –W12-6: Group A – Phase 1: Wall 5 MC % Sheathing

Individual Wall Charts Phase 2

Chart A2 –W1-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W1-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W1-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W1-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W1-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W1-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W2-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W2-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W2-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W2-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W2-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W2-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W3-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W3-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W3-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W3-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W3-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W3-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W4-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W4-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W4-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W4-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W4-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W4-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W5-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W5-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W5-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W5-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W5-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W5-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W6-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W6-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W6-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W6-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W6-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W6-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W7-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W7-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W7-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W7-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W7-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W7-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W8-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W8-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W8-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W8-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W8-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W8-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W9-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W9-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W9-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W9-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W9-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W9-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W10-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W10-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W10-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W10-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W10-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W10-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W11-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W11-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W11-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W11-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W11-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W11-6: Group A – Phase 2: Wall 5 MC % Sheathing

Chart A2 –W12-1: Group A – Phase 2: Wall 5 MC% Stud A All Points
Chart A2 –W12-2: Group A – Phase 2: Wall 5 MC% Stud A Surface
Chart A2 –W12-3: Group A – Phase 2: Wall 5 MC% Stud A Core
Chart A2 –W12-4: Group A – Phase 2: Wall 5 MC Stud A Sheathing
Chart A2 –W12-5: Group A – Phase 2: Wall 5 MC % Plates
Chart A2 –W12-6: Group A – Phase 2: Wall 5 MC % Sheathing